Tasneef

هيئة الإمارات للتصنيف
Emirates Classification Society

Rules for the Classification of Offshore Units Operating in the Caspian Sea and Similar Areas

Effective from 1 January 2023

Part B

Hull and Stability

+971 2 6922333 +971 2 4454333 info@tasneef.ae 111155, Abu Dhabi, UAE

GENERAL CONDITIONS

Definitions:

"*Administration*" means the Government of the State whose flag the Ship is entitled to fly or under whose authority the Ship is authorised to operate in the specific case.

"IACS" means the International Association of Classification Societies.

"*Interested Party*" means the party, other than the Society, having an interest in or responsibility for the Ship, product, plant or system subject to classification or certification (such as the owner of the Ship and his representatives, the ship builder, the engine builder or the supplier of parts to be tested) who requests the Services or on whose behalf the Services are requested.

"*Owner*" means the registered owner, the ship owner, the manager or any other party with the responsibility, legally or contractually, to keep the ship seaworthy or in service, having particular regard to the provisions relating to the maintenance of class laid down in Part A, Chapter 2 of the Rules for the Classification of Ships or in the corresponding rules indicated in the specific Rules.

"Rules" in these General Conditions means the documents below issued by the Society:

- (i) Rules for the Classification of Ships or other special units;
- (ii) Complementary Rules containing the requirements for product, plant, system and other certification or containing the requirements for the assignment of additional class notations;
- (iii) Rules for the application of statutory rules, containing the rules to perform the duties delegated by Administrations;
- (iv) Guides to carry out particular activities connected with Services;
- (v) Any other technical document, as for example rule variations or interpretations.

"*Services*" means the activities described in Article 1 below, rendered by the Society upon request made by or on behalf of the Interested Party.

"Ship" means ships, boats, craft and other special units, as for example offshore structures, floating units and underwater craft.

"*Society*" or *"TASNEEF"* means Tasneef and/or all the companies in the Tasneef Group which provide the Services.

"*Surveyor*" means technical staff acting on behalf of the Society in performing the Services.

Article 1

1.1. The purpose of the Society is, among others, the classification and certification of ships and the certification of their parts and components. In particular, the Society:
- (i) sets forth and develops Rules;
- (ii) publishes the Register of Ships;
- (iii) issues certificates, statements and reports based on its survey activities.

1.2. The Society also takes part in the implementation of national and international rules and standards as delegated by various Governments.

1.3. The Society carries out technical assistance activities on request and provides special services outside the scope of classification, which are regulated by these general conditions, unless expressly excluded in the particular contract.

Article 2

2.1. The Rules developed by the Society reflect the level of its technical knowledge at the time they are published. Therefore, the Society, although committed also through its research and development services to continuous updating of the Rules, does not guarantee the Rules meet state-of-the-art science and technology at the time of publication or that they meet the Society's or others' subsequent technical developments.

2.2. The Interested Party is required to know the Rules on the basis of which the Services are provided. With particular reference to Classification Services, special attention is to be given to the Rules concerning class suspension, withdrawal and reinstatement. In case of doubt or inaccuracy, the Interested Party is to promptly contact the Society for clarification.
The Rules for Classification of Ships are published on the Society's website: www.tasneef.ae.

2.3. The Society exercises due care and skill:
- (i) in the selection of its Surveyors
- (ii) in the performance of its Services, taking into account the level of its technical knowledge at the time the Services are performed.

2.4. Surveys conducted by the Society include, but are not limited to, visual inspection and non-destructive testing. Unless otherwise required, surveys are conducted through sampling techniques and do not consist of comprehensive verification or monitoring of the Ship or of the items subject to certification. The surveys and checks made by the Society on board ship do not necessarily require the constant and continuous presence of the Surveyor. The Society may also commission laboratory testing, underwater inspection and other checks carried out by and under the responsibility of qualified service suppliers. Survey practices and procedures are selected by the Society based on its experience and knowledge and according to generally accepted technical standards in the sector.

Article 3

3.1. The class assigned to a Ship, like the reports, statements, certificates or any other document or information issued by the Society, reflects the opinion of the Society concerning compliance, at the time the Service is provided, of the Ship or product subject to certification, with the applicable Rules (given the intended use and within the relevant time frame).
The Society is under no obligation to make statements or provide information about elements or facts which are not part of the specific scope of the Service requested by the Interested Party or on its behalf.

3.2. No report, statement, notation on a plan, review, Certificate of Classification, document or information issued or given as part of the Services provided by the Society shall have any legal effect or implication other than a representation that, on the basis of the checks made by the Society, the Ship, structure, materials, equipment, machinery or any other item covered by such document or information meet the Rules. Any such document is issued solely for the use of the Society, its committees and clients or other duly authorised bodies and for no other purpose. Therefore, the Society cannot be held liable for any act made or document issued by other parties on the basis of the statements or information given by the Society. The validity, application, meaning and interpretation of a Certificate of Classification, or any other document or information issued by the Society in connection with its Services, is governed by the Rules of the Society, which is the sole subject entitled to make such interpretation. Any disagreement on technical matters between the Interested Party and the Surveyor in the carrying out of his functions shall be raised in writing as soon as possible with the Society, which will settle any divergence of opinion or dispute.

3.3. The classification of a Ship, or the issuance of a certificate or other document connected with classification or certification and in general with the performance of Services by the Society shall have the validity conferred upon it by the Rules of the Society at the time of the assignment of class or issuance of the certificate; in no case shall it amount to a statement or warranty of seaworthiness, structural integrity, quality or fitness for a particular purpose or service of any Ship, structur e, material, equipment or machinery inspected or tested by the Society.

3.4. Any document issued by the Society in relation to its activities reflects the condition of the Ship or the subject of certifi cation or other activity at the time of the check.

3.5. The Rules, surveys and activities performed by the Society, reports, certificates and other documents issued by the Society are in no way intended to replace the duties and responsibilities of other parties such as Governments, designers, ship builders, manufacturers, repairers, suppliers, contractors or sub-contractors, Owners, operators, charterers, underwriters, sellers or intended buyers of a Ship or other product or system surveyed.

These documents and activities do not relieve such parties from any fulfilment, warranty, responsibility, duty or obligation (also of a contractual nature) expressed or implied or in any case incumbent on them, nor do they confer on such parties any right, claim or cause of action against the Society. With particular regard to the duties of the ship Owner, the Services undertaken by the Society do not relieve the Owner of his duty to ensure proper maintenance of the Ship and ensure seaworthiness at all times. Likewise, t he Rules, surveys performed, reports, certificates and other documents issued by the Society are intended neither to guarantee the buyers of the Ship, its components or any other surveyed or certified item, nor to relieve the seller of the duties arising out of the law or the contract, regarding the quality, commercial value or characteristics of the item which is the subject of transaction.

In no case, therefore, shall the Society assume the obligations incumbent upon the above-mentioned parties, even when it is consulted in connection with matters not covered by its Rules or other documents.

In consideration of the above, the Interested Party undertakes to relieve and hold harmless the Society from any third party claim, as well as from any liability in relation to the latter concerning the Services rendered.

Insofar as they are not expressly provided for in these General Conditions, the duties and responsibilities of the Owner and Interested Parties with respect to the services rendered by the Society are described in the Rules applicable to the specific Service rendered.

Article 4

4.1. Any request for the Society's Services shall be submitted in writing and signed by or on behalf of the Interested Party. Such a request will be considered irrevocable as soon as received by the Society and shall entail acceptance by the applicant of all relevant requirements of the Rules, including these General Conditions. Upon acceptance of the written request by the Society, a contract between the Society and the Interested Party is entered into, which is regulated by the present General Conditions.

4.2. In consideration of the Services rendered by the Society, the Interested Party and the person requesting the service shall be jointly liable for the payment of the relevant fees, even if the service is not concluded for any cause not pertaining to the Society. In the latter case, the Society shall not be held liable for non-fulfilment or partial fulfilment of the Services requested. In the event of late payment, interest at the legal current rate increased by 1.5% may be demanded.

4.3. The contract for the classification of a Ship or for other Services may be terminated and any certificates revoked at the request of one of the parties, subject to at least 30 days' notice to be given in writing. Failure to pay, even in part, the fees due for Services carried out by the Society will entitle the Society to immediately terminate the contract and suspend the Services.

For every termination of the contract, the fees for the activities performed until the time of the termination shall be owed to the Society as well as the expenses incurred in view of activities already programmed; this is without prejudice to the right to compensation due to the Society as a consequence of the termination.

With particular reference to Ship classification and certification, unless decided otherwise by the Society, termination of the contract implies that the assignment of class to a Ship is withheld or, if already assigned, that it is suspended or withdrawn; any st atutory certificates issued by the Society will be withdrawn in those cases where provided for by agreements between the Society and the flag State.

Article 5

5.1. In providing the Services, as well as other correlated information or advice, the Society, its Surveyors, servants or agents operate with due diligence for the proper execution of the activity. However, considering the nature of the activities performed (see art. 2.4), it is not possible to guarantee absolute accuracy, correctness and completeness of any information or advice supplied. Express and implied warranties are specifically disclaimed.

Therefore, except as provided for in paragraph 5.2 below, and also in the case of activities carried out by delegation of Governments, neither the Society nor any of its Surveyors will be liable for any loss, damage or expense of whatever nature sustained by any person, in tort or in contract, derived from carrying out the Services.

5.2. Notwithstanding the provisions in paragraph 5.1 above, should any user of the Society's Services prove that he has suffered a loss or damage due to any negligent act or omission of the Society, its Surveyors, servants or agents, then the Society will pay compensation to such person for his proved loss, up to, but not exceeding, five times the amount of the fees charged for the specific services, information or opinions from which the loss or damage derives or, if no fee has been charged, a maximum of AED5,000 (Arab Emirates Dirhams Five Thousand only). Where the fees charged are related to a number of Services, the amount of the fees will be apportioned for the purpose of the calculation of the maximum compensation, by reference to the estimated time involved in the performance of the Service from which the damage or loss derives. Any liability for indirect or consequential loss, damage or expense is specifically excluded. In any case, irrespective of the amount of the fees charged, the maximum damages payable by the Society will not be more than AED5,000,000 (Arab Emirates Dirhams Five Millions only). Payment of compensation under this paragraph will not entail any admission of responsibility and/or liability by the Society and will be made without prejudice to the disclaimer clause contained in paragraph 5.1 above.

5.3. Any claim for loss or damage of whatever nature by virtue of the provisions set forth herein shall be made to the Society in writing, within the shorter of the following periods: (i) THREE (3) MONTHS from the date on which the Services were performed, or (ii) THREE (3) MONTHS from the date on which the damage was discovered. Failure to comply with the above deadline will constitute an absolute bar to the pursuit of such a claim against the Society.

Article 6

6.1. These General Conditions shall be governed by and construed in accordance with United Arab Emirates (UAE) law, and any dispute arising from or in connection with the Rules or with the Services of the Society, including any issues concerning responsibility, liability or limitations of liability of the Society, shall be determined in accordance with UAE law. The courts of the Dubai International Financial Centre (DIFC) shall have exclusive jurisdiction in relation to any claim or dispute which may arise out of or in connection with the Rules or with the Services of the Society.

6.2. However,

(i) In cases where neither the claim nor any counterclaim exceeds the sum of AED300,000 (Arab Emirates Dirhams Three Hundred Thousand) the dispute shall be referred to the jurisdiction of the DIFC Small Claims Tribunal; and

(ii) for disputes concerning non-payment of the fees and/or expenses due to the Society for services, the Society shall have the right to submit any claim to the jurisdiction of the Courts of the place where the registered or operating office of the Interested Party or of the applicant who requested the Service is located.

In the case of actions taken against the Society by a third party before a public Court, the Society shall also have the righ t to summon the Interested Party or the subject who requested the Service before that Court, in order to be relieved and held harmless according to art. 3.5 above.

Article 7

7.1. All plans, specifications, documents and information provided by, issued by, or made known to the Society, in connection with the performance of its Services, will be treated as confidential and will not be made available to any other party other than the Owner without authorisation of the Interested Party, except as provided for or required by any applicable international, European or domestic legislation, Charter or other IACS resolutions, or order from a competent authority. Information about the status and validity of class and statutory certificates, including transfers, changes, suspensions, withdrawals of class, recommendations/conditions of cl ass, operating conditions or restrictions issued against classed ships and other related information, as may be required, may be published on the website or released by other means, without the prior consent of the Interested Party.

Information about the status and validity of other certificates and statements may also be published on the website or released by other means, without the prior consent of the Interested Party.

7.2. Notwithstanding the general duty of confidentiality owed by the Society to its clients in clause 7.1 above, the Society's c lients hereby accept that the Society may participate in the IACS Early Warning System which requires each Classification Society to provide other involved Classification Societies with relevant technical information on serious hull structural and engineering systems failures, as defined in the IACS Early Warning System (but not including any drawings relating to the ship which may be the specific propert y of another party), to enable such useful information to be shared and used to facilitate the proper working of the IACS Early Warning System. The Society will provide its clients with written details of such information sent to the involved Classification Societies.

7.3. In the event of transfer of class, addition of a second class or withdrawal from a double/dual class, the Interested Party undertakes to provide or to permit the Society to provide the other Classification Society with all building plans and drawings, certificat es, documents and information relevant to the classed unit, including its history file, as the other Classification Society may require for the purpose of classification in compliance with the applicable legislation and relative IACS Procedure. It is the Owner's duty t o ensure that, whenever required, the consent of the builder is obtained with regard to the provision of plans and drawings to the new Society, either by way of appropriate stipulation in the building contract or by other agreement.

In the event that the ownership of the ship, product or system subject to certification is transferred to a new subject, the latter shall have the right to access all pertinent drawings, specifications, documents or information issued by the Society or which has come to the knowledge of the Society while carrying out its Services, even if related to a period prior to transfer of ownership.

Article 8

8.1. Should any part of these General Conditions be declared invalid, this will not affect the validity of the remaining provisions.

RULES FOR THE CLASSIFICATION OF
OFFSHORE UNITS OPERATING IN THE CASPIAN SEA
AND SIMILAR AREAS

Part B
Hull and Stability

Chapters **1 2 3 4 5 6 7 8 9 10 11 12**

CHAPTER 1
GENERAL

Section 3 Documentation to be Submitted

Section 4 Calculation Programs

CHAPTER 2
GENERAL ARRANGEMENT DESIGN

Section 1 Subdivision Arrangement

Section 2 Compartment Arrangement

Section 3 Access Arrangement

CHAPTER 3
STABILITY

Section 1 General

Section 2 Intact Stability

Appendix 1 Inclining Test and Lightweight Check

Appendix 2 Trim and Stability Booklet

CHAPTER 4
STRUCTURE DESIGN PRINCIPLES

Section 4 Bottom Structure

Section 7 Bulkhead Structure

CHAPTER 5
DESIGN LOADS

Section 3 Ship Motions and Accelerations

Section 4 Load Cases

Section 5 Sea Pressures

Section 6 Internal Pressures and Forces

Appendix 1 Inertial Pressure for Typical Tank Arrangement

CHAPTER 6
HULL GIRDER STRENGTH

Section 3 Ultimate Strength Check

Appendix 1 Hull Girder Ultimate Strength

CHAPTER 7
HULL SCANTLINGS

Section 1 Plating

Section 2 Ordinary Stiffeners

Section 3 Primary Supporting Members

Section 4 Fatigue Check of Structural Details

Appendix 1 Analyses based on Three Dimensional Models

Appendix 2 Analyses of Primary Supporting Members Subjected to Wheeled Loads

Appendix 3 Analyses based on Complete Ship Models

CHAPTER 8
SHIPS LESS THAN 90 M IN LENGTH

Section 1 Design Loads

Section 2 Hull Girder Strength

Section 3 Plating

Section 4 Ordinary Stiffeners

Section 5 Primary Supporting Members

CHAPTER 9
OTHER STRUCTURES

Section 1 Fore Part

Section 2 Aft Part

Section 3 Machinery Space

Section 4 Superstructures and Deckhouses

Section 5 Bow Doors and Inner Doors

Section 6 Side Doors and Stern Doors

Section 7 Hatch Covers

CHAPTER 10
HULL OUTFITTING

Section 1 Rudders

Appendix 1 Criteria for Direct Calculation of Rudder Loads

CHAPTER 11
CORROSION PROTECTION AND LOADING INFORMATION

Section 1 Protection of Hull Metallic Structures

Section 2 Loading Manual and Loading Instruments

CHAPTER 12
CONSTRUCTION AND TESTING

Section 1 Welding and Weld Connections

Section 2 Special Structural Details

Section 3 Testing

Appendix 1 Reference Sheets for Special Structural Details

Part B
Hull and Stability

Chapter 1
GENERAL

SECTION 1 APPLICATION

1 General

1.1 Structural requirements

1.1.1

Part B contains the requirements for determination of the minimum hull scantlings, applicable to all types of seagoing monohull displacement ships of normal form, speed and proportions, made in welded steel construction, except for oil tankers, for which the requirements in the "Common Structural Rules for Double Hull Tankers" apply. These requirements are to be integrated with those specified in Part E, for any individual ship type, and in Part F, as applicable, depending on the additional class notations assigned to the ships.

For ships with the notation **oil tanker ESP CSR,** the above-mentioned Common Structural Rules apply as appropriate with the addition of the following requirements:

- Sec 4 - as regards the calculation programs
- Ch 3, Sec 1, Ch 3, Sec 2, Ch 3, App 1 and Ch 3, App 2 - for the requirements concerning Intact Stability
- Ch 9, Sec 4 - for the requirements concerning superstructures and deckhouses
- Ch 10, App 1 - for the requirements concerning rudders.

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

1.1.3 Ships whose hull materials are different than those given in [1.1.2] and ships with novel features or unusual hull design are to be individually considered by the Society, on the basis of the principles and criteria adopted in the Rules.

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

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

1.2 Limits of application to lifting appliances

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

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

2 Rule application

2.1 Ship parts

2.1.1 General

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

- fore part
- central part
- aft part.

2.1.2 Fore part

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

- the fore peak structures
- the stems.

In addition, it includes:

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

2.1.3 Central part

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

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

2.1.4 Aft part

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

2.2 Rules applicable to various ship parts

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

2.3 Rules applicable to other ship items

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

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

<table>
<tr><th rowspan="2">Part</th><th colspan="2">Applicable Chapters and Sections</th></tr>
<tr><th>General</th><th>Specific</th></tr>
<tr><td>Fore part</td><td rowspan="4">Chapter 1
Chapter 2
Chapter 3
Chapter 4
Chapter 9 (1),
excluding:
• Ch 9, Sec 1
• Ch 9, Sec 2
Chapter 11
Chapter 12</td><td>Ch 9, Sec 1</td></tr>
<tr><td>Central part
L ≥ 90 m</td><td>Chapter 5
Chapter 6
Chapter 7</td></tr>
<tr><td>Central part
L < 90 m</td><td>Chapter 8</td></tr>
<tr><td>Aft part</td><td>Ch 9, Sec 2</td></tr>
<tr><td colspan="3">(1) See also [2.3].</td></tr>
</table>

3 Rounding off of scantlings

3.1

3.1.1 Plate thicknesses

Thicknesses as calculated in accordance with the rule requirements are to be rounded off to the nearest half-millimetre.

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%.

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

Item	Applicable Chapter and Section
Machinery space	Ch 9, Sec 3
Superstructures and deckhouses	Ch 9, Sec 4
Bow doors and inner doors	Ch 9, Sec 5
Side shell doors and stern doors	Ch 9, Sec 6
Hatch covers	Ch 9, Sec 7
Movable decks and inner ramp External ramps	Ch 9, Sec 8
Rudders	Ch 10, Sec 1
Other hull outfitting	Ch 10, Sec 2 Ch 10, Sec 3 Ch 10, Sec 4

SECTION 2 SYMBOLS AND DEFINITIONS

1 Units

1.1

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

2 Symbols

2.1

2.1.1

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

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

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

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

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

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

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

Δ : Moulded displacement, in tonnes, at draught T, in sea water (density ρ = 1,025 t/m³)

C_B : Total block coefficient

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

3 Definitions

3.1 Rule length

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

3.1.2 In ships without rudder stock (e.g. ships fitted with azimuth thrusters), the rule length L is to be taken equal to 97% of the extreme length on the summer load waterline.

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

3.2 Freeboard length

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

Table 1 : Units

Designation	Usual symbol	Units
Ship's dimensions	See [2]	m
Hull girder section modulus	Z	m³
Density	ρ	t/m³
Concentrated loads	P	kN
Linearly distributed loads	q	kN/m
Surface distributed loads (pressures)	p	kN/m²
Thicknesses	t	mm
Span of ordinary stiffeners and primary supporting members	ℓ	m
Spacing of ordinary stiffeners and primary supporting members	s	m
Bending moment	M	kN.m
Shear force	Q	kN
Stresses	σ, τ	N/mm²
Section modulus of ordinary stiffeners and primary supporting members	w	cm³
Sectional area of ordinary stiffeners and primary supporting members	A	cm²

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

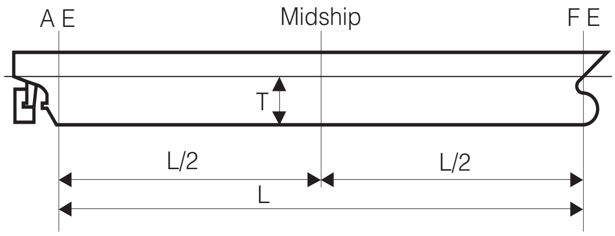
3.2.3 In ship design with a rake of keel, the waterline on which this length is measured is to be parallel to the designed waterline.

3.3 Ends of rule length L and midship

3.3.1 Fore end

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

Figure 1 : Ends and midship



3.3.2 Aft end

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

3.3.3 Midship

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

3.4 Moulded breadth

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

3.5 Depth

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

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

3.6 Moulded draught

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

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

3.7 Lightweight

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

3.8 Deadweight

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

3.9 Freeboard deck

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

3.10 Superstructure

3.10.1 General

A superstructure is a decked structure connected to the freeboard deck, extending from side to side of the ship or with the side plating not being inboard of the shell plating more than 0,04 B.

3.10.2 Enclosed and open superstructure

A superstructure may be:

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

3.11 Raised quarterdeck

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

3.12 Deckhouse

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

3.13 Trunk

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

3.14 Standard height of superstructure

3.14.1 The standard height of superstructure is defined in Tab 2.

Table 2 : Standard height of superstructure

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

3.15 Type A and Type B ships

3.15.1 Type A ship

A Type A ship is one which:

- is designed to carry only liquid cargoes in bulk;
- has a high integrity of the exposed deck with only small access openings to cargo compartments, closed by watertight gasketed covers of steel or equivalent material; and
- has low permeability of loaded cargo compartments.

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

3.15.2 Type B ship

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

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

3.15.3 Type B-60 ship

A Type B-60 ship is any Type B ship of over 100 metres in length which, fulfilling the requirements reported in Regulation 27 of Part 3, Annex I, Chapter III of the International Convention on Load Lines, 1966 and Protocol of 1988, as amended, is assigned with a value of tabular freeboard which can be reduced up to 60 per cent of the difference between the "B" and "A" tabular values for the appropriate ship lengths.

3.15.4 Type B-100 ships

A Type B-100 ship is any Type B ship of over 100 metres in length which, fulfilling the requirements reported in Regulation 27 of Part 3, Annex I, Chapter III of the International Convention on Load Lines, 1966 and Protocol of 1988, as amended, is assigned with a value of tabular freeboard which can be reduced up to 100 per cent of the difference between the "B" and "A" tabular values for the appropriate ship lengths.

3.16 Positions 1 and 2

3.16.1 Position 1

Position 1 includes:

- exposed freeboard and raised quarter decks,
- exposed superstructure decks situated forward of 0,25 L_{LL} from the perpendicular, at the forward side of the stem, to the waterline at 85% of the least moulded depth measured from the top of the keel.

3.16.2 Position 2

Position 2 includes:

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

4 Reference co-ordinate system

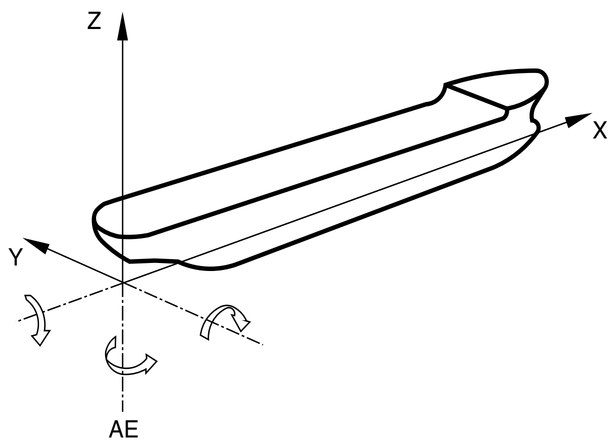
4.1

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

- Origin: at the intersection among the longitudinal plane of symmetry of ship, the aft end of L and the baseline
- X axis: longitudinal axis, positive forwards
- Y axis: transverse axis, positive towards portside
- Z axis: vertical axis, positive upwards.

4.1.2 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 ships

1.1 Ships built under the Society's supervision

1.1.1 Plans and documents to be submitted for approval

The plans and documents to be submitted to the Society for approval are listed in Tab 1. This list is intended as guidance for the complete set of information to be submitted, rather than an actual list of titles.

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

Structural plans are to show details of connections of the various parts and, in general, are to specify the materials used, including their manufacturing processes, welded procedures and heat treatments. See also Ch 12, Sec 1, [1.6].

1.1.2 Plans and documents to be submitted for information

In addition to those in [1.1.1], the following plans and documents are to be submitted to the Society for information:

- general arrangement
- capacity plan, indicating the volume and position of the centre of gravity of all compartments and tanks
- lines plan
- hydrostatic curves
- lightweight distribution
- towing and mooring arrangement plan, containing the information specified in Ch 10, Sec 4, [3.1]
- list of dangerous goods intended to be carried, if any.

In addition, when direct calculation analyses are carried out by the Designer according to the rule requirements, they are to be submitted to the Society.

1.1.3 Number of copies

The number of copies to be submitted for each plan or document is to be agreed with the Society on a case by case basis depending on the specific conditions under which plan approval and supervision during construction are organised. However, it is generally equal to:

- 3 for plans and documents submitted for approval
- 2 for plans and documents submitted for information.

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

1.2.1 Plans and documents to be submitted for approval

The plans required by the Government Regulations concerned are to be submitted to the Society for approval, in addition to those in [1.1]. Such plans are in general to comprise:

- arrangement of lifesaving appliances and relevant embarking and launching devices (davits and winches)
- arrangement of compasses
- arrangement of navigation lights
- order transmission
- loading and unloading arrangement to be included in the ILO Register
- forced ventilation in cargo spaces intended for the carriage of vehicles, dangerous goods in bulk or packaged form, etc.
- cargo securing manual, where required
- bridge visibility plan.

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

2.1 General

2.1.1 Depending on the service notation and, possibly, the additional class notation (see Pt A, Ch 1, Sec 2) assigned to the ship, other plans or documents may be required to be submitted to the Society, in addition to those in [1.1]. They are listed in [2.2] and [2.3] for the service notations and additional class notations which require this additional documentation.

However, the additional documentation relevant to a service notation or an additional class notation may be required also for ships to which it is not assigned, when this is deemed necessary by the Society on the basis, inter alia, of the ship service, the structural arrangements, the type of cargo carried and its containment.

2.2 Service notations

2.2.1 The plans or documents to be submitted to the Society are listed in Tab 2.

2.3 Additional class notations

2.3.1 The plans or documents to be submitted to the Society are listed in Tab 3.

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

Plan or document	Containing also information on
Midship section Transverse sections Shell expansion Decks and profiles Double bottom Pillar arrangements Framing plan Deep tank and ballast tank bulkheads, wash bulkheads	Class characteristics Main dimensions Minimum ballast draught Frame spacing Contractual service speed Density of cargoes Design loads on decks and double bottom Steel grades Location and height of air vent outlets of various compartments Corrosion protection Openings in decks and shell and relevant compensations Boundaries of flat areas in bottom and sides Details of structural reinforcements and/or discontinuities Bilge keel with details of connections to hull structures
Loading manual and loading instruments	See Ch 11, Sec 2, [3]
Watertight subdivision bulkheads Watertight tunnels	Openings and their closing appliances, if any
Fore part structure	Location and height of air vent outlets of various compartments
Transverse thruster, if any, general arrangement, tunnel structure, connections of thruster with tunnel and hull structures	
Aft part structure	Location and height of air vent outlets of various compartments
Machinery space structures Foundations of propulsion machinery and boilers	Type, power and r.p.m. of propulsion machinery Mass and centre of gravity of machinery and boilers
Superstructures and deckhouses Machinery space casing	Extension and mechanical properties of the aluminium alloy used (where applicable)
Bow doors, stern doors and inner doors, if any, side doors and other openings in the side shell	Closing appliances Electrical diagrams of power control and position indication circuits for bow doors, stern doors, side doors, inner doors, television system and alarm systems for ingress of water
Hatch covers, if any	Design loads on hatch covers Sealing and securing arrangements, type and position of locking bolts Distance of hatch covers from the summer load waterline and from the fore end
Movable decks and ramps, if any	
Windows and side scuttles, arrangements and details	
Scuppers and sanitary discharges	
Bulwarks and freeing ports	Arrangement and dimensions of bulwarks and freeing ports on the freeboard deck and superstructure deck
Rudder and rudder horn **(1)**	Maximum ahead service speed
Sternframe or sternpost, sterntube Propeller shaft boss and brackets **(1)**	

(1) Where other steering or propulsion systems are adopted (e.g. steering nozzles or azimuth propulsion systems), the plans showing the relevant arrangement and structural scantlings are to be submitted. For azimuth propulsion systems, see Ch 10, Sec 1, [11].

Plan or document	Containing also information on
Derricks and cargo gear Cargo lift structures	Design loads (forces and moments) Connections to the hull structures
Sea chests, stabiliser recesses, etc.	
Hawse pipes	
Plan of outer doors and hatchways	
Plan of manholes	
Plan of access to and escape from spaces	
Plan of ventilation	Use of spaces
Plan of tank testing	Testing procedures for the various compartments Height of pipes for testing
Plan of watertight doors and scheme of relevant manoeuvring devices	Manoeuvring devices Electrical diagrams of power control and position indication circuits
Freeboard calculations	
Stability documentation	See Ch 3, Sec 1, [2.1]
Calculations relevant to intact stability	
Equipment number calculation	Geometrical elements for calculation List of equipment Construction and breaking load of steel wires Material, construction, breaking load and relevant elongation of synthetic ropes
Helicopter deck, if any	General arrangement Main structure Characteristics of helicopters: maximum mass, distance between axles of wheels or skids, print area of wheels or skids, rotor diameter
Emergency towing arrangement	See Ch 10, Sec 4, [4.3]

(1) Where other steering or propulsion systems are adopted (e.g. steering nozzles or azimuth propulsion systems), the plans showing the relevant arrangement and structural scantlings are to be submitted. For azimuth propulsion systems, see Ch 10, Sec 1, [11].

Table 2 : Plans and documents to be submitted depending on service notations

Service notations	Plans or documents
oil tanker ESP **FLS tanker**	Arrangement of pressure/vacuum valves in cargo tanks Cargo temperatures
Tanker	Cargo temperatures
dredger	Transverse sections through hoppers, wells, pump rooms and dredging machinery spaces Structural arrangement of hoppers and supporting structures Closing arrangements, if any Connection of dredging machinery with the hull structure
hopper dredger **hopper unit**	Transverse sections through hoppers, wells, pump rooms and dredging machinery spaces Structural arrangement of hoppers and supporting structures including: • location, mass, fore and aft extent of the movable dredging equipment, for each loading condition • calculations of the horizontal forces acting on the suction pipe and on the gallows Closing arrangements, if any Connection of dredging machinery with the hull structure

Service notations	Plans or documents
split hopper dredger **split hopper unit**	Transverse sections through hoppers, wells, pump rooms and dredging machinery spaces Structural arrangement of hoppers and supporting structures, including: • location, mass, fore and aft extent of the movable dredging equipment, for each loading condition • calculations of the horizontal forces acting on the suction pipe and on the gallows Closing arrangements, if any Connection of dredging machinery with the hull structure Superstructure hinges and connections to the ship's structure, including mass and location of the superstructure centre of gravity Structure of hydraulic jack spaces Deck hinges, including location of centre of buoyancy and of centre of gravity of each half-hull, mass of equipped half-hull, half mass of spoil or water, supplies for each half-hull and mass of superstructures supported by each half-hull Hydraulic jacks and connections to ship's structure including operating pressure and maximum pressure of the hydraulic jacks (cylinder and rod sides) and corresponding forces Longitudinal chocks of bottom and deck Transverse chocks Hydraulic installation of jacks, with explanatory note
tug **salvage tug** **tug escort**	Structural arrangement of the winch and its remote control of the quick-release device for opening under load Structural arrangement of the hook and its remote control of the quick-release device for opening under load Connection of the towing system (winch and hook) with the hull structures
tug, **salvage tug**, **tug escort** with additional service feature **barge combined** **barge** with additional service feature **tug combined**	Structural arrangement of the fore part of the tug, showing details of reinforcements in way of the connecting point Structural arrangement of the aft part of the barge, showing details of reinforcements in way of the connecting point Details of the connection system
supply vessel	General plan showing the location of storage and cargo tanks with adjacent cofferdams and indicating the nature and density of cargoes intended to be carried Plan of gas-dangerous spaces Connection of the cargo tanks with the hull structure Stowage of deck cargoes and lashing arrangement with location of lashing points and indication of design loads Structural reinforcements in way of load transmitting elements, such as winches, rollers, lifting appliances
supply vessel with additional service feature **anchor handling** or **anchor handling stab**	General arrangement of the fittings and equipment for anchor handling operations Structural drawings of the guides/rollers used for anchor handling operations Structural drawings of hull supporting structures in way of guides/rollers used for anchor handling operations Only for ships with service feature **anchor handling stab**: stability operational manual for anchor handling operations, as detailed in Pt E, Ch 4, Sec 2, [3.4.3]
oil recovery ship	General plan showing the location of tanks intended for the retention of oily residues and systems for their treatment Plan of the system for treatment of oily residues and specification of all relevant apparatuses Supporting structures of the system for treatment of oily residues Operating manual

Table 3 : Plans and documents to be submitted depending on additional class notations

Additional class notation	Plans or documents
DMS	See Pt F, Ch 10, Sec 9, [1.2]
ICE CLASS IA SUPER **ICE CLASS IA** **ICE CLASS IB** **ICE CLASS IC** **ICE CLASS ID**	The plans relevant to shell expansion and fore and aft part structures are to define (see Pt F, Ch 6, Sec 1, [2.2]) the maximum draught LWL, the minimum draught BWL (both draughts at midship, fore and aft ends), and the borderlines of fore, midship and aft regions defined in Pt F, Ch 6, Sec 2, [1.2]
MON-HULL	See Pt F, Ch 3, Sec 1, [1.2]
POLAR CLASS PC1 **POLAR CLASS PC2** **POLAR CLASS PC3** **POLAR CLASS PC4** **POLAR CLASS PC5** **POLAR CLASS PC6** **POLAR CLASS PC7**	The plans relevant to shell expansion and fore and aft part structures are to define the maximum draught at UIWL, the minimum draught at LIWL (both draughts at midship, fore and aft ends), and the borderlines of hull areas in longitudinal and vertical directions as indicated in Pt F, Ch 7, Sec 2, [1.1] as well as the other items required for the structural checks as per Pt F, Ch 7, Sec 2, [4] and Pt F, Ch 7, Sec 2, [6].
SPM	See Pt F, Ch 10, Sec 3, [2]

SECTION 4 CALCULATION PROGRAMS

1 Program for the Rule based scantling

1.1 General

1.1.1 Computer programs dealing with rule checking are available. The Society may be contacted in order to have information on these programs and associated hardware and operating system requirements.

1.2 LEONARDO HULL

1.2.1 The LEONARDO HULL program performs the rule scantling check of plating and ordinary stiffeners at any transverse section along the ship's hull, primary supporting members and associated shell plating in various hull portions.

1.2.2 In particular, LEONARDO HULL makes it possible to:

- calculate the transverse section geometric properties
- carry out the hull girder strength checks, including ultimate strength
- carry out all the rule strength checks of:
  - strakes
  - longitudinal and transverse ordinary stiffeners
  - strakes and ordinary stiffeners of transverse bulkheads.
- verification and finite element analysis of hull structure, including automatic generation of part of the finite element model and load case generation. Scantling criteria verification, in accordance with the Rules, are automatically performed.

1.2.3 LEONARDO HULL also calculates the steel renewal thicknesses based on rule scantlings and permits the reassessment of ships in service.

1.3 BULK

1.3.1 The BULK program is designed to assess, according to the IACS Unified Requirements adopted in the Rules, the structural strength of transverse corrugated bulkheads and double bottoms of new and existing bulk carriers to which these requirements apply.

Part B
Hull and Stability

Chapter 2
GENERAL ARRANGEMENT DESIGN

Symbols used in chapter 2

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

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

SECTION 1 SUBDIVISION ARRANGEMENT

1 Number and arrangement of transverse watertight bulkheads

1.1 Number of watertight bulkheads

1.1.1 General

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

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

1.1.2 Additional bulkheads

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

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

Table 1 : Number of bulkheads

Length (m)	Number of bulkheads for ships with aft machinery **(1)**	Number of bulkheads for other ships
$L < 65$	3	4
$65 \le L < 85$	4	5
$85 \le L < 105$	4	5
$105 \le L < 120$	5	6
$120 \le L < 145$	6	7
$145 \le L < 165$	7	8
$165 \le L < 190$	8	9
$L \ge 190$	to be defined on a case by case basis	
(1) After peak bulkhead and aft machinery bulkhead are the same.		

2 Collision bulkhead

2.1 Arrangement of collision bulkhead

2.1.1

A collision bulkhead is to be fitted which is to be watertight up to the freeboard deck. This bulkhead is to be located at a distance from the forward perpendicular FPLL of not less than 0,05 L_{LL} or 10 m, whichever is the less, and not more than 0,08 or 0,05 L_{LL} + 3 m, whichever is the greater.

2.1.2

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

- at the midlength of such extension, or
- at a distance 0,015 L_{LL} forward of the forward perpendicular, or
- at a distance 3 metres forward of the forward perpendicular; whichever gives the smallest measurement.

2.1.3

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

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

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

2.1.5

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

The extension is to be so arranged as to preclude the possibility of the bow door causing damage to it in the case of damage to, or detachment of, a bow door.

2.1.6

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

Ramps not meeting the above requirements are to be disregarded as an extension of the collision bulkhead.

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

3 After peak, machinery space bulkheads and stern tubes

3.1

3.1.1 General

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

3.1.2 Sterntubes

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

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

4 Number and arrangement of tank bulkheads

4.1 Bulkheads in ships intended for the carriage of liquid cargoes

4.1.1 The number and location of transverse and longitudinal watertight bulkheads in ships intended for the carriage of liquid cargoes (tankers and similar) are to comply with the subdivision requirements to which the ship is subject.

5 Height of transverse watertight bulkheads

5.1

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

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

6 Openings in watertight bulkheads and decks

6.1 General

6.1.1 The number of openings in watertight subdivisions is to be kept to a minimum compatible with the design and proper working of the ship. Where penetrations of watertight bulkheads and internal decks are necessary for access, piping, ventilation, electrical cables, etc., arrangements are to be made to maintain the watertight integrity. The Society may permit relaxation in the watertightness of openings above the freeboard deck, provided that it is demonstrated that any progressive flooding can be easily controlled and that the safety of the ship is not impaired.

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

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

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

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

6.2 Openings in the watertight bulkheads below the freeboard deck

6.2.1 Openings used while at sea

Doors provided to ensure the watertight integrity of internal openings which are used while at sea are to be sliding watertight doors capable of being remotely closed from the bridge and are also to be operable locally from each side of the bulkhead. Indicators are to be provided at the control position showing whether the doors are open or closed, and an audible alarm is to be provided at the door closure. The power, control and indicators are to be operable in the event of main power failure. Particular attention is to be paid to minimise the effect of control system failure. Each power-operated sliding watertight door is to be provided with an individual hand-operated mechanism. The possibility of opening and closing the door by hand at the door itself from both sides is to be assured.

Table 2 : Doors

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

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

6.2.2 Openings normally closed at sea

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

6.2.3 Doors or ramps in large cargo spaces

Watertight doors or ramps of satisfactory construction may be fitted to internally subdivide large cargo spaces, provided that the Society is satisfied that such doors or ramps are essential. These doors or ramps may be hinged, rolling or sliding doors or ramps, but are not to be remotely controlled. Such doors are to be closed before the voyage commences and are to be kept closed during navigation. Should any of the doors or ramps be accessible during the voyage, they are to be fitted with a device which prevents unauthorised opening.

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

6.2.4 Openings permanently kept closed at sea

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

6.3 Openings in the bulkheads above the freeboard deck

6.3.1 General

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

6.3.2 Doors used while at sea

The doors used while at sea are to be sliding doors capable of being remotely closed from the bridge and are also to be operable locally from each side of the bulkhead. Indicators are to be provided at the control position showing whether the doors are open or closed, and an audible alarm is to be provided at the door closure. The power, control and indicators are to be operable in the event of main power failure. Particular attention is to be paid to minimise the effect of control system failure. Each power-operated sliding watertight door is to be provided with an individual hand-operated mechanism. It should be possible to open and close the door by hand at the door itself from both sides.

6.3.3 Doors normally closed at sea

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

6.3.4 Openings kept permanently closed at sea

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

SECTION 2 COMPARTMENT ARRANGEMENT

1 Definitions

1.1 Cofferdam

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

1.2 Machinery spaces of category A

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

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

2 Cofferdams

2.1 Cofferdam arrangement

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

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

- the thickness of common boundary plates of adjacent tanks is increased, with respect to the thickness obtained according to Ch 7, Sec 1, by 2 mm in the case of tanks carrying fresh water or boiler feed water, and by 1 mm in all other cases
- the sum of the throats of the weld fillets at the edges of these plates is not less than the thickness of the plates themselves
- the structural test is carried out with a head increased by 1 m with respect to Ch 12, Sec 3, [2].

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

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

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

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

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

3 Double bottoms

3.1 General

3.1.1 Double bottom

a) A double bottom shall be fitted extending from the collision bulkhead to the afterpeak bulkhead, as far as this is practicable and compatible with the design and proper working of the ship.

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

$h = B / 20$

However, in no case is the value of h to be less than 760 mm, and need not be taken as more than 2,000 mm.

c) Small wells constructed in the double bottom in connection with drainage arrangements of holds, etc., shall not extend downward more than necessary. A well extending to the outer bottom is, however, permitted at the after end of the shaft tunnel. Other wells (e.g., for lubricating oil under main engines) may be permitted by the Society if satisfied that the arrangements give protection equivalent to that afforded by a double bottom complying with this regulation. In no case shall the vertical distance from the bottom of such a well to a plane coinciding with the keel line be less than 500 mm.

d) A double bottom need not be fitted in way of watertight tanks, including dry tanks of moderate size, provided the safety of the ship is not impaired in the event of bottom or side damage.

e) Any part of a cargo ship that is not fitted with a double bottom in accordance with paragraphs a) and d) shall be capable of withstanding bottom damages, as specified in paragraph h), in that part of the ship.

f) In the case of unusual bottom arrangements in a cargo ship, it shall be demonstrated that the ship is capable of withstanding bottom damages as specified in paragraph g).

g) Compliance with paragraphs e) or f) is to be achieved by demonstrating that s_i, when calculated in accordance with Reg. II-1 of SOLAS Convention, is not less than 1 for all service conditions when subject to a bottom damage assumed at any position along the ship's bottom and with an extent specified in item 2) below for the affected part of the ship:

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

   2) Assumed extent of damage shall be as follows Tab 1.

   3) If any damage of a lesser extent than the maximum damage specified in item 2) would result in a more severe condition, such damage should be considered.

For ships not subject to SOLAS Convention the requirements of this item [3.1.1] will be specially considered by the Society in each single case.

3.1.2 Special requirements for tankers are specified in Part E.

Table 1

	For 0,3 L from the forward perpendicular of the ship	Any other part of the ship
Longitudinal extent	1/3 $L^{2/3}$ or 14.5 m, whichever is less	1/3 $L^{2/3}$ or 14.5 m, whichever is less
Transverse extent	B/6 or 10 m, whichever is less	B/6 or 5 m, whichever is less
Vertical extent, measured from the keel line	B/20 or 2 m, whichever is less	B/20 or 2 m, whichever is less

4 Compartments forward of the collision bulkhead

4.1 General

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

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

5 Minimum bow height

5.1 Application

5.1.1 This item [5] applies to ships subject to the International Load Line Convention 1966, as amended.

5.2 General

5.2.1

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

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

where:

F_b : calculated minimum bow height, in mm

T_1 : draught at 85% of the least moulded depth D_1, in m

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

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

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

C_b : block coefficient:

$$C_b = \frac{\nabla}{L_{LL} B T_1}$$

: volume of the moulded displacement, excluding appendages, in m^3, at draught T_1

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

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

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

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

5.2.2 Where the bow height required in item [5.2.1] is obtained by sheer, the sheer is to extend for at least 15% of the length of the ship measured from the forward perpendicular. Where it is obtained by fitting a superstructure, such superstructure is to extend from the stem to a point at least 0,07L abaft the forward perpendicular, and is to be enclosed as defined Ch 9, Sec 4.

5.2.3 Ships which, to suit exceptional operational requirements, cannot meet the requirements in [5.2.1] and [5.2.2] are considered by the Society on a case-by-case basis.

5.2.4 The sheer of the forecastle deck may be taken into account, even if the length of the forecastle is less than 0,15L, but greater than 0,07L, provided that the forecastle height is not less than one half of the standard height of superstructure between 0,07L and the forward perpendicular.

5.2.5 Where the forecastle height is less than one half of the standard height of superstructure, the credited bow height may be determined as follows (hf in Fig 1 and Fig 2 is one half of the standard height of superstructure):

a) Where the freeboard deck has sheer extending from abaft 0,15L, by a parabolic curve having its origin at 0,15L abaft the forward perpendicular at a height equal to the midship depth of the ship, extended through the point of intersection of forecastle bulkhead and deck, and up to a point at the forward perpendicular not higher than the level of the forecastle deck (as illustrated in Fig 1). However, if the value of the height denoted h_t in Fig 1 is smaller than the value of the height denoted h_b then h_t may be replaced by h_b in the available bow height, where:

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

Z_b : as defined in Fig 1

Z_t : as defined in Fig 1

b) Where the freeboard deck has sheer extending for less than 0,15L or has no sheer, by a line from the forecastle deck at side at 0,07L extended parallel to the base line to the forward perpendicular (as illustrated in Fig 2).

5.2.6 All ships assigned a type 'B' freeboard are to have additional reserve buoyancy in the fore end. Within the range of 0,15L abaft the forward perpendicular, the sum of the projected area between the summer load waterline and the deck at side (A1 and A2 in Fig 3) and the projected area of an enclosed superstructure, if fitted, (A3 in Fig 3) is not to be less than:

[0.15Fmin + 4(LLL/3 + 10)] LLL/1000, in m2,

where:

F_0 : is the tabular freeboard, in mm, taken from the International Convention Load Line in force, table 28.2, corrected for regulation 27(9) or 27(10), as applicable

F_{min} : coefficient, to be taken equal to:

$F_{min} = (F_0\ f_1) + f_2$

f_1 : is the correction for block coefficient given in the International Convention Load Line in force, regulation 30, and

f_2 : is the correction for depth, in mm, given in the International Convention Load Line in force, regulation 31.

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

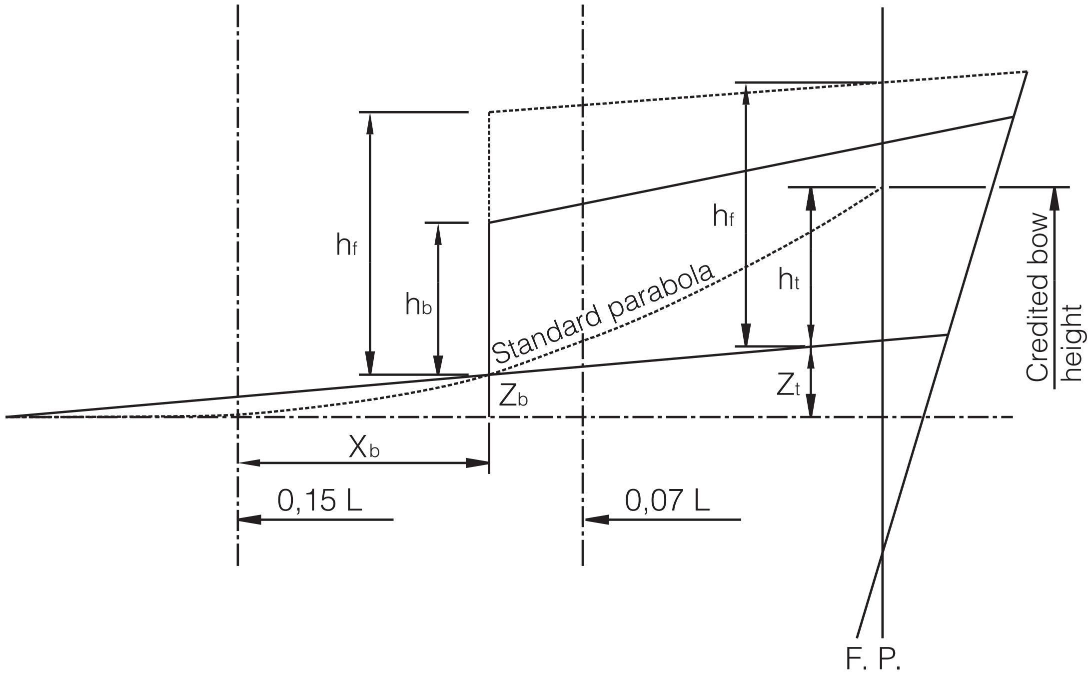


Figure 2 : Credited bow height where the freeboard deck has sheer extending for less than 0,15L

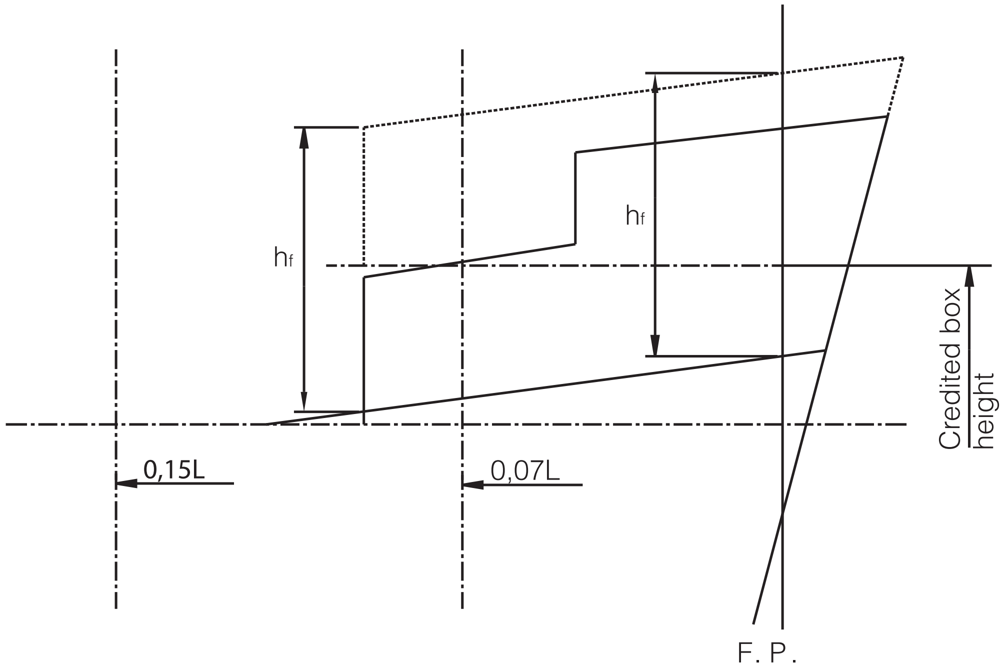
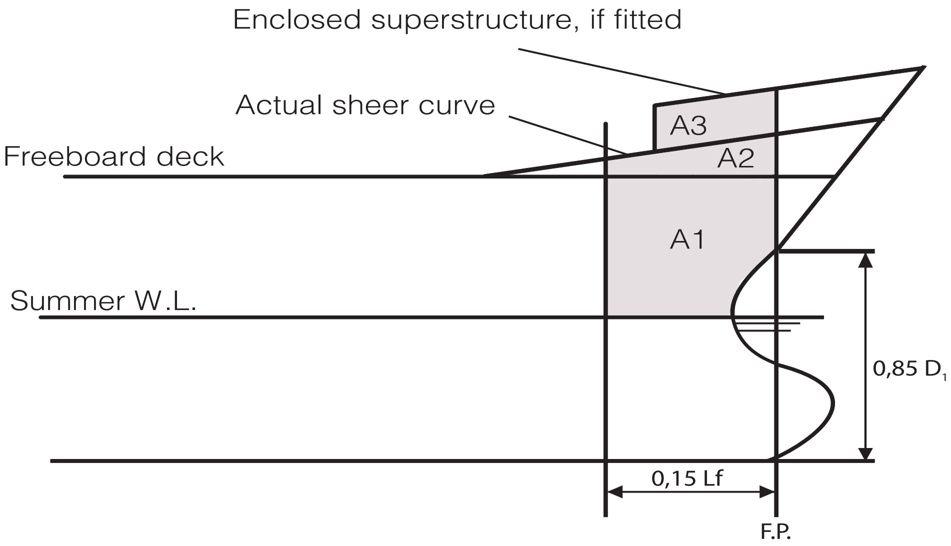


Figure 3 : Areas A1, A2 and A3



6 Shaft tunnels

6.1 General

6.1.1

Shaft tunnels are to be watertight.

See also Ch 2, Sec 3, [4].

7 Watertight ventilators and trunks

7.1 General

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

8 Fuel oil tanks

8.1 General

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

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

Where fuel oil tanks, other than double bottom tanks, are necessarily located adjacent to or within machinery spaces of category A, at least one of their vertical sides is to be contiguous to the machinery space boundaries, they are preferably to have a common boundary with the double bottom tanks and the area of the tank boundary common with the machinery spaces is to be kept to a minimum.

Where such tanks are situated within the boundaries of machinery spaces of category A, they may not contain fuel oil having a flashpoint of less than 60°C.

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

Precautions are to be taken to prevent any oil that may escape under pressure from any pump, filter or heater from coming into contact with heated surfaces.

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

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

SECTION 3 ACCESS ARRANGEMENT

1 General

1.1

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

2 Double bottom

2.1 Inner bottom manholes

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

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

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

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

2.2 Floor and girder manholes

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

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

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

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

3 Large cargo holds, large tanks and large water ballast tanks

3.1 General

3.1.1 Tanks in double bottom and in double side are generally not to be considered as large water ballast tanks.

3.2 Access to tanks

3.2.1 Tanks with a length equal or greater than 35 m

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

3.2.2 Tanks with a length less than 35 m

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

3.2.3 Dimensions of access hatchways

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

3.2.4 Tanks subdivided by wash bulkheads

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

3.3 Access within tanks

3.3.1 Wash bulkheads in tanks

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

3.3.2 Passage on the tank bottom

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

3.3.3 Passageways in the tanks

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

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

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

3.3.4 Manholes

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

3.3.5 Guard rails

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

3.4 Construction of ladders

3.4.1 General

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

3.4.2 Construction

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

3.4.3 Corrosive effect of the cargo

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

3.4.4 Width of ladders

The width of ladders between stringers is not to be less than 400 mm.

3.4.5 Treads

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

3.4.6 Sloping ladders

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

4 Shaft tunnels

4.1 General

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

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

5 Access to steering gear compartment

5.1

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

5.1.2 Suitable arrangements to ensure working access to steering gear machinery and controls are to be provided.

These arrangements are to include handrails and gratings or other non-slip surfaces to ensure suitable working conditions in the event of hydraulic fluid leakage.

Part B
Hull and Stability

Chapter 3
STABILITY

SECTION 1 GENERAL

1 General

1.1 Application

1.1.1 General

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

1.1.2 Ships less than 24 m in length

The Rules also apply to ships less than 24 m in length. In this case, the requirements concerned may be partially omitted subject to the agreement of the Society.

1.1.3 Approval of the Administration

When the Administration of the State whose flag the ship is entitled to fly has issued specific rules covering stability, the Society may accept such rules for classification purposes in lieu of those given in this Chapter.

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

In cases of application of the above requirements an appropriate entry is made in the classification files of the ship.

2 Definitions

2.1 General

2.1.1 For the purpose of this Chapter 3 the definitions given in the International Code on Intact Stability, 2008 (IMO Resolution MSC.267(85)) apply. The definitions in [2.2] to [2.7] are given for ease of reference.

2.2 Length of ship

2.2.1 The length is to be taken as 96% of the total length on a waterline at 85% of the least moulded depth measured from the top of the keel, or as the length from the foreside of the stem to the axis of the rudder stock on the waterline, if that is greater. In ships designed with a rake of keel, the waterline on which this length is measured is to be parallel to the designed waterline.

2.3 Moulded breadth

2.3.1 The moulded breadth is the maximum breadth of the ship measured amidships to the moulded line of the frame in a ship with a metal shell and to the outer surface of the hull in a ship with a shell of any other material.

2.4 Moulded depth

2.4.1 The moulded depth is the vertical distance measured from the top of the keel to the top of the freeboard deck beam at side. In wood and composite ships, the distance is measured from the lower edge of the keel rabbet. Where the form at the lower part of the midship section is of a hollow character, or where thick garboards are fitted, the distance is measured from the point where the line of the flat of the bottom continued inwards cuts the side of the keel. In ships having rounded gunwales, the moulded depth is to be measured to the point of intersection of the moulded lines of the deck and side shell plating, the lines extending as though the gunwale were of angular design. Where the freeboard deck is stepped and the raised part of the deck extends over the point at which the moulded depth is to be determined, the moulded depth is to be measured to a line of reference extending from the lower part of the deck along a line parallel with the raised part.

2.5 Timber

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

2.6 Timber deck cargo

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

2.7 Timber load line

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

3 Examination procedure

3.1 Documents to be submitted

3.1.1 List of documents

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

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

a) Inclining test report for the ship, as required in [3.2] or:
   - where the stability data is based on a sister ship, the inclining test report of that sister ship along with the lightship measurement report for the ship in question; or
   - where lightship particulars are determined by methods other than inclining of the ship or its sister, the lightship measurement report of the ship along with a summary of the method used to determine those particulars as indicated in [3.2.4].

b) trim and stability booklet, as required in Sec 2, [1.1.1]

c) and, as applicable:
   - loading computer documentation, as required in Sec 2, [1.1.2] and in Pt F, Ch 10, Sec 9, [2.1.2].

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

3.1.2 Provisional documentation

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

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

3.1.3 Final documentation

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

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

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

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

3.2 Inclining test/lightweight check

3.2.1 Definitions

a) Lightship

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

b) Inclining test

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

c) Lightweight check

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

3.2.2 General

Any ship for which a stability investigation is requested in order to comply with class requirements is to be initially subject to an inclining test permitting the evaluation of the position of the lightship centre of gravity so that the stability data can be determined.

The inclining test or lightweight check (see [3.2.4]) 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.

For cargo ships having length less than 24 metres, irrespective of their navigation, at the discretion of the Society, instead of the inclining test one or more practical stability test(s) relevant to the most severe conditions foreseen in real service may be carried out.

In such cases a report is to be prepared relevant to the tested loading conditions containing restrictions in the loading conditions and/or in ballasting, if any, which, duly approved by the Society, is to replace the prescribed stability booklet.

3.2.3 Inclining test

The inclining test is required in the following cases:

- Any new cargo ship having length of 24 m and upwards, after its completion, except for the cases specified in [3.2.4]
- Any ship, if deemed necessary by the Society, where any alterations are made so as to materially affect the stability.

3.2.4 Lightweight check

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

a) an individual cargo ship, 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 prototype ship. The lightweight check is to be carried out upon the ship's completion. 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 prototype. Whenever, in comparison with the data derived from the prototype, a deviation from the lightship displacement exceeding 1% for ships of 160 m or more in length, or 2% for ships of 50 m or less in length, or as determined by linear interpolation for intermediate lengths, or a deviation from the lightship longitudinal centre of gravity exceeding 0,5% of L_s is found, the ship is to be inclined.

b) special types of ship, not subject to SOLAS Convention, provided that the vertical centre of gravity is considered at the level of the deck.

c) special types of ship, not subject to SOLAS Convention, provided that:
   - a detailed list of weights and the positions of their centres of gravity is submitted
   - a lightweight check is carried out, showing accordance between the estimated values and those determined
   - adequate stability is demonstrated in all the loading conditions reported in the trim and stability booklet.

3.2.5 Detailed procedure

A detailed procedure for conducting an inclining test is included in App 1. For the lightweight check, the same procedure applies except as provided for in App 1, [1.1.8].

SECTION 2 INTACT STABILITY

1 General

1.1 Information for the Master

1.1.1 Stability booklet

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

If a stability instrument is used as a supplement to the stability booklet for the purpose of determining compliance with the relevant stability criteria such instrument is to be subject to approval by the Society (see Ch 11, Sec 2, [4.5]).

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

Stability data and associated plans are to be drawn up in the working language of the ship and any other language the Administration the flag of which the ship is entitled to fly may require.

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

If curves or tables of minimum operational metacentric height (GM) or maximum centre of gravity (VCG) are used to ensure compliance with the relevant intact stability criteria those limiting curves are to extend over the full range of operational trims, unless the Society agrees that trim effects are not significant. When curves or tables of minimum operational metacentric height (GM) or maximum centre of gravity (VCG) versus draught covering the operational trims are not available, the Master is to verify that the operating condition does not deviate from a studied loading condition, or verify by calculation that the stability criteria are satisfied for this loading condition taking into account trim effects.

1.1.2 Loading instrument

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

A simple and straightforward instruction manual is to be provided.

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

The procedure to be followed, as well as the list of technical details to be sent in order to obtain loading instrument approval, are given in Ch 11, Sec 2, [4].

1.1.3 Operating booklets for certain ships

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

1.2 Permanent ballast

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

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

1.3 Still waters

1.3.1 Still waters are, generally, sheets of water within a mile of the shore, distinguished by a wind scale not higher than 2 Beaufort, light breeze 4-6 knots, sea scale 2 (slight sea), mean height of waves 0,10-0,50 m.

2 Design criteria

2.1 General intact stability criteria

2.1.1 General

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

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

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

For ships of length less than 24 m, except passenger ships, and ships of any length classed to sail in still waters, instead of the stability criteria specified in *[2.1.2]*, *[2.1.3]* and *[2.1.4]*, only the criterion mentioned in *[2.1.5]* b) is to be complied with.

Where anti-rolling devices are installed in a ship, the Society is to be satisfied that the criteria can be maintained when the devices are in operation and that failure of the power supply or the failure of the device(s) will not result in the vessel being unable to meet the relevant provisions of this Chapter.

2.1.2 GZ curve area

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

Note 1: θ_f is an angle of heel at which openings in the hull, superstructures or deckhouses which cannot be closed weathertight submerge. In applying this criterion, small openings through which progressive flooding cannot take place need not be considered as open.

2.1.3 Minimum righting lever

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

2.1.4 Angle of maximum righting lever

The maximum righting lever is to occur at an angle of heel not less than 25°. If this is not practicable, alternative criteria, based on an equivalent level of safety, may be applied subject to the approval of the Society.

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

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

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

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

2.1.5 Initial metacentric height

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

b) For ships of length less than 24 m, except passenger ships, and ships of any lenght classed to sail in still waters, the initial metacentric height GMo is not to be less than 0,35 m, except in the lightship condition.

2.1.6 Elements affecting stability

A number of influences such as icing of topsides, water trapped on deck, etc., adversely affect stability and are to be taken into account, so far as is deemed necessary by the Society.

2.1.7 Elements reducing stability

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

3 Weather criterion

3.1 Assumptions

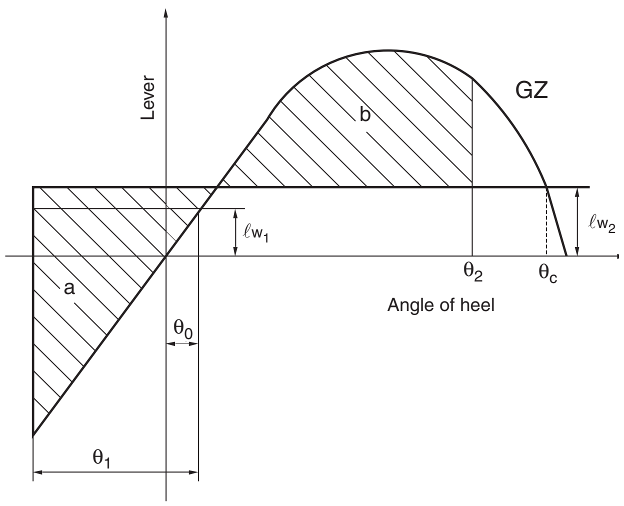
3.1.1

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

- the ship is subjected to a steady wind pressure acting perpendicular to the ship's centreline which results in a steady wind heeling lever (ℓ_{w1});
- from the resultant angle of equilibrium (θ_0), the ship is assumed to roll owing to wave action to an angle of roll (θ_1) to windward. The angle of heel under action of steady wind (θ_0) is not to exceed 16° or 80% of the angle of deck edge immersion, whichever is less;
- the ship is then subjected to a gust wind pressure which results in a gust wind heeling lever (ℓ_{w2});
- under these circumstances, area b is to be equal to or greater than area a, as indicated in Fig 1, where the angles in Fig 1 are defined as follows:
  - θ_0 : Angle of heel, in degrees, under action of steady wind
  - θ_1 : Angle of roll, in degrees, to windward due to wave action, calculated according to [3.1.4]
  - θ_2 : Angle of downflooding (θ_f) in degrees, or 50° or θ_c , whichever is less

  where:
    - θ_f : Angle of heel in degrees, at which openings in the hull, superstructures or deckhouses which cannot be closed weathertight immerse. In applying this criterion, small openings through which progressive flooding cannot take place need not be considered as open;
    - θ_c : Angle in degrees, of second intercept between wind heeling lever ℓ_{w2} and GZ curves

Figure 1 : Severe wind and rolling



a: area above the GZ curve and below ℓ_{w2}, between θ_R and the intersection of ℓ_{w2} with the GZ curve

b: area above the heeling lever ℓ_{w2} and below the GZ curve, between the intersection of ℓ_{w2} with the GZ curve and ℓ_2.

3.1.2 Heeling levers

The wind heeling levers ℓ_{w1} and ℓ_{w2}, in m, referred to in [3.1.1], are constant values at all angles of inclination and are to be calculated as follows:

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

and

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

where:

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

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

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

Δ : Displacement, in t;

g : gravitational acceleration of 9,81 m/s².

3.1.3 Alternative criteria

Alternative means for determining the wind heeling lever (ℓ_{w1}) may be accepted, to the satisfaction of the Society, as equivalent to the calculation in [3.1.2]. When such alternative tests are carried out, reference is to be to MSC/Circ. 1200 "Interim Guidelines for alternative assessment of the weather criterion". The wind velocity used in the tests is to be 26 m/s in full scale with uniform velocity profile. The value of wind velocity used for ships engaged in restricted services may be reduced to the satisfaction of the Society.

3.1.4 Angles of rool

The angle of roll θ_1, in degrees, (see Note 1) referred to in [3.1.1] is to be calculated as follows:

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

where:

X_1 : Coefficient defined in Tab 1

X_2 : Coefficient defined in Tab 2

k : Coefficient:
- k = 1,0 for a round-bilged ship having no bilge or bar keels
- k = 0,7 for a ship having sharp bilge
- k = as shown in Tab 3 for a ship having bilge keels, a bar keel or both.

$$r = 0{,}73 + 0{,}6(OG)/d$$

with:

OG : KG - d

KG : Height of centre of gravity above baseline, in m

d : Mean moulded draught of the ship, in m

s : Factor defined in Tab 4, where T is the ship roll natural period, in s. In absence of sufficient information, the following formula can be used:

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

where:

$$C = 0{,}373 + 0{,}023\left(\frac{B}{d}\right) - 0{,}043\left(\frac{L_{Wl}}{100}\right)$$

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

$L_{w\ell}$: Length of the ship at the waterline, in m

b : Moulded breadth of ship, in m

d : Mean moulded draught of the ship, in m

C_b : Block coefficient

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

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

Note 1: The angle of roll for ships with anti-rolling devices is to be determined without taking into account the operation of these devices unless the Society is satisfied with the proof that the devices are effective even with sudden shutdown of their supplied power.

Table 1 : Values of coefficient X_1

B/d	X_1
≤ 2,4	1,00
2,5	0,98
2,6	0,96
2,7	0,95
2,8	0,93
2,9	0,91
3,0	0,90
3,1	0,88
3,2	0,86
3,4	0,82
≥ 3,5	0,80

Table 2 : Values of coefficient X_2

C_B	X_2
≤ 0,45	0,75
0,50	0,82
0,55	0,89
0,60	0,95
0,65	0,97
≥ 0,70	1,00

Table 3 : Values of coefficient k

$\frac{A_K \times 100}{L_{wl} \times B}$	k
0,0	1,00
1,0	0,98
1,5	0,95
2,0	0,88
2,5	0,79
3,0	0,74
3,5	0,72
≥ 4,0	0,70

Table 4 : Values of factor s

T	s
≤ 6	0,100
7	0,098
8	0,093
12	0,065
14	0,053
16	0,044
18	0,038
≥ 20	0,035

3.1.5 Application criteria

Tables and formulae above are based on data from ships having:

- B/d smaller than 3,5
- (KG/d-1) between -0,3 and 0,5
- T smaller than 20 s.

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

4 Effects of free surfaces of liquids in tanks

4.1 General

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

4.2 Consideration of free surface effects

4.2.1 Free surface effects are to be considered whenever the filling level in a tank is less than 98% of full condition. Free surface effects need not be considered where a tank is nominally full, i.e. filling level is 98% or above. However, nominally full cargo tanks are to be corrected for free surface effects at 98% filling level. In doing so, the correction to initial metacentric height is to be based on the inertia moment of liquid surface at 5° of heeling angle divided by displacement, and the correction to righting lever is to be in general on the basis of real shifting moment of cargo liquids.

4.2.2 Free surface effects for small tanks may be ignored under the condition in [4.8.1].

(Intermediate values in these tables are to be obtained by linear interpolation)

4.3 Categories of tanks

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

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

4.4 Consumable liquids

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

4.5 Water ballast tanks

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

4.6 Liquid transfer operations

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

Note 1: A sufficient number of loading conditions representing the initial, intermediate and final stages of the filling or discharge operation using the free surface correction at the filling level in each tank at the considered stage may be evaluated to fulfil this recommendation.

4.7 GM_0 and GZ curve corrections

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

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

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

- Correction based on the actual moment of fluid transfer for each angle of heel calculated;
- Correction based on the moment of inertia, calculated at 0 degrees angle of heel, modified at each angle of heel calculated.

Corrections may be calculated according to the categories indicated in [4.2.1].

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

4.8 Small tanks

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

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

where:

M_{fs} : Free surface moment, in mt

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

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

4.9 Remainder of liquid

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

5 Cargo ships carrying timber deck cargoes

5.1 Application

5.1.1 The provisions given hereunder apply to all ships of 24 m in length and over engaged in the carriage of timber deck cargoes. Ships that are provided with and make use of their timber load line are also to comply with the requirements of regulations 41 to 45 of the International Load Line Convention 1966, as amended.

5.2 Stability criteria

5.2.1 For ships loaded with timber deck cargoes and provided that the cargo extends longitudinally between superstructures (where there is no limiting superstructure at the after end, the timber deck cargo is to extend at least to the after end of the aftermost hatchway) and transversely for the full beam of ship after due allowance for a rounded gunwale not exceeding 4% of the breadth of the ship and/or securing the supporting uprights and which remains securely fixed at large angles of heel, the Society may apply the criteria given in [5.2.2] to [5.2.5], which substitute those given in [2.1.2], [2.1.3], [2.1.4] and [2.1.5] and in [3].

5.2.2 The area under the righting lever curve (GZ curve) is to be not less than 0.08 m.rad up to θ = 40° or the angle of flooding if this angle is less than 40°.

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

5.2.4 At all times during a voyage, the metacentric height GM0 is to be not less than 0,1 m taking into account the absorption of water by the deck cargo and/or ice accretion on the exposed surfaces. (Details regarding ice accretion are given in [6]).

5.2.5 When determining the ability of the ship to withstand the combined effect of beam wind and rolling according to [3], the 16° limiting angle of heel under action of steady wind is to be complied with, but the additional criterion of 80% of the angle of deck edge immersion may be ignored.

5.3 Stability booklet

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

5.3.2 The Society may deem it necessary that the Master be given information setting out the changes in deck cargo from that shown in the loading conditions, when the permeability of the deck cargo is significantly different from 25% (see [5.4.1]).

5.3.3 Conditions are to be shown indicating the maximum permissible amount of deck cargo having regard to the lightest stowage rate likely to be met in service.

5.4 Calculation of the stability curve

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

5.5 Loading conditions to be considered

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

5.6 Assumptions for calculating loading conditions

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

- the amount of cargo and ballast is to correspond to the worst service condition in which all the relevant stability criteria reported in [2.1.2], [2.1.3], [2.1.4] and [2.1.5], or the optional criteria given in [5.2], are met.
- In the arrival condition, it is to be assumed that the weight of the deck cargo has increased by 10% due to water absorption.

5.6.2 The stability of the ship at all times, including during the process of loading and unloading timber deck cargo, is to be positive and in compliance with the stability criteria of [5.2]. It is to be calculated having regard to:

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

5.6.3 Excessive initial stability is to be avoided as it will result in rapid and violent motion in heavy seas which will impose large sliding and racking forces on the cargo causing high stresses on the lashings. Unless otherwise stated in the stability booklet, the metacentric height is generally not to exceed 3% of the breadth in order to prevent excessive acceleration in rolling provided that the relevant stability criteria given in [5.2] are satisfied.

5.7 Stowage of timber deck cargoes

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

6 Icing

6.1 General

6.1.1 Ice formation is a complicated process which depends upon meteorological conditions, condition of loading and behaviour of the ship in stormy weather as well as on the size and location of superstructures and rigging. The most common cause of ice formation is the deposit of water droplets on the ship's structure. These droplets come from spray driven from wave crests and from ship-generated spray.

6.1.2 Ice formation may also occur in conditions of snowfall, sea fog including arctic sea smoke, a drastic fall in ambient temperature, as well as from the freezing of drops of rain on impact with the ship's structure.

6.1.3 Ice formation may sometimes be caused or accentuated by water shipped on board and retained on deck.

6.1.4 Intensive ice formation generally occurs on stem, bulwark and bulwark rail, front walls of superstructures and deckhouses, hawse holes, anchors, deck gear, forecastle deck and upper deck, freeing ports, aerials, stays, shrouds, masts and spars.

6.1.5 The most dangerous areas as far as ice formation is concerned are the sub-Arctic regions.

6.1.6 The most intensive ice formation takes place when wind and sea come from ahead. In beam and quartering winds, ice accumulates quicker on the windward side of the ship, thus leading to a constant list which can be extremely dangerous.

6.1.7 Listed below are meteorological conditions causing the most common type of ice formation due to spraying of a ship.

a) Slow accumulations of ice take place:
   - at ambient temperature from -1°C to -3°C and any wind force
   - at ambient temperature -4°C and lower and wind force from 0 to 9 m/s
   - under the conditions of precipitation, fog or sea mist followed by a drastic fall of the ambient temperature.

b) At ambient temperature of -4°C to -8°C and wind force 10-15 m/s, rapid accumulation of ice takes place. Under these conditions the intensity of ice accumulation can reach three times the amount normally accumulated in a).

c) Very fast accumulation of ice takes place:
   - at ambient temperature of -4°C and lower and wind forces of 16 m/s and over
   - at ambient temperature -9°C and lower and wind force 10 to 15 m/s.

6.2 Icing accumulation consequences

6.2.1 Ice formation adversely affects the seaworthiness of the ship as ice formation leads to:

- an increase in the weight of the ship due to accumulation of ice on the ship's surfaces which may cause the reduction of freeboard and buoyancy
- a rise of the ship's centre of gravity due to the high location of ice on the ship's structures with corresponding reduction in the level of stability
- an increase of windage area due to ice formation on the upper parts of the ship and hence an increase in the heeling moment due to the action of the wind
- the development of a constant list due to uneven distribution of ice across the breadth of the ship
- impairment of the manoeuvrability and reduction of the speed of the ship.

6.3 Application

6.3.1 For any ship operating in areas where ice accretion is likely to occur, adversely affecting a ship's stability, icing allowances are to be included in the analysis of conditions of loading.

6.3.2 The Society is concerned to take icing into account and may apply national standards where environmental conditions warrant higher standards than those specified in the following regulations.

6.4 Ships carrying timber deck cargoes

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

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

6.5 Calculation assumptions

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

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

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

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

6.6 Guidance relating to ice accretion

6.6.1 The following icing areas are to be considered:

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

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

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

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

e) south of latitude 60°S.

6.6.2 For ships operating where ice accretion may be expected:

- within the areas defined in a), c), d) and e) of [6.6.1] known to having icing conditions significantly different from those described in [6.5], ice accretion requirements of one half to twice the required allowance may be applied;
- within the area defined in b), where ice accretion in excess of twice the allowance required by [6.5] may be expected, more severe requirements than those given in [6.5] may be applied.

APPENDIX 1 INCLINING TEST AND LIGHTWEIGHT CHECK

1 Inclining test and lightweight check

1.1 General

1.1.1 General conditions of the ship

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

- the weather conditions are to be favourable
- the ship is to be moored in a quiet, sheltered area free from extraneous forces, such as to allow unrestricted heeling. The ship is to be positioned in order to minimise the effects of possible wind, stream and tide
- the ship is to be upright however, with inclining weights in the initial position, up to 0,5° of list is acceptable. The actual trim and deflection of keel, if practical, are to be considered in the hydrostatic data. In order to avoid excessive errors caused by significant changes in the water plane area during heeling, hydrostatic data for the actual trim and the maximum anticipated heeling angles are to be checked beforehand and the trim is to be taken not more than 1% of the length between perpendiculars. Otherwise, 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 to be suspended and crew or personnel not directly involved in the inclining test are to leave the ship
- the ship is to be as complete as possible at the time of the test. The number of weights to be removed, added or shifted is to be limited to a minimum. Temporary material, tool boxes, staging, sand, debris, etc., on board is to be reduced to an absolute minimum.

1.1.2 Inclining weights

The total weight used is preferably to be sufficient to provide a minimum inclination of one degree and a maximum of four degrees of heel to each side. The Society may, however, accept a smaller inclination angle for large ships provided that the requirement on pendulum deflection or U-tube difference in height specified in [1.1.4] is complied with. Test weights are to be compact and of such a configuration that the VCG (vertical centre of gravity) of the weights can be accurately determined. Each weight is to be marked with an identification number and its mass. Re-certification of the test weights is to be carried out prior to the incline. A crane of sufficient capacity and reach, or some other means, is to be available during the inclining test to shift weights on the deck in an expeditious and safe manner. Water ballast is generally not acceptable as inclining weight.

1.1.3 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. As a minimal prerequisite for acceptability, the following conditions are to be required:

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

1.1.4 Pendulums

The use of three pendulums is recommended but a minimum of two are to be used to allow identification of bad readings at any one pendulum station. However, for ships of a length equal to or less than 30 m, only one pendulum can be accepted. They are each to be located in an area protected from the wind. The pendulums are to be long enough to give a measured deflection, to each side of upright, of at least 10 cm.

To ensure recordings from individual instruments are kept separate, it is suggested that the pendulums should be physically located as far apart as practical.

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

1.1.5 Means of communications

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

1.1.6 Documentation

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

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

1.1.7 Determination of the displacement

The Society’s Surveyor is to carry out all the operations necessary for the accurate evaluation of the displacement of the ship 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 ship's lines drawing or outboard profile to ensure that all readings are consistent and together define the correct waterline. The resulting plot is to yield either a straight line or a waterline which is either hogged or sagged. If inconsistent readings are obtained, the freeboards/draughts are to be retaken
- the specific gravity of the sea water is to be determined. Samples are to be taken from a sufficient depth of the water to ensure a true representation of the sea water and not merely surface water, which could contain fresh water from run off of rain. A hydrometer is to be placed in a water sample and the specific gravity read and recorded. For large ships, it is recommended that samples of the sea water be taken forward, midship and aft, and the readings averaged. For small ships, one sample taken from midship is sufficient. The temperature of the water is to be taken and the measured specific gravity corrected for deviation from the standard, if necessary. A correction to water specific gravity is not necessary if the specific gravity is determined at the inclining experiment site. Correction is necessary if specific gravity is measured when the sample temperature differs from the temperature at the time of the inclining (e.g., if the check of specific gravity is performed at the office). Where the value of the average calculated specific gravity is different from that reported in the hydrostatic curves, adequate corrections are to be made to the displacement curve
- all double bottoms, as well as all tanks and compartments which can contain liquids, are to be checked, paying particular attention to air pockets which may accumulate due to the ship’s trim and the position of air pipes, and also taking into account the provisions of [1.1.1]
- it is to be checked that the bilge is dry, and an evaluation of the liquids which cannot be pumped, remaining in the pipes, boilers, condenser, etc., is to be carried out
- the entire ship is to be surveyed in order to identify all items which need to be added, removed or relocated to bring the ship to the lightship condition. Each item is to be clearly identified by weight and location of the centre of gravity
- the possible solid permanent ballast is to be clearly identified and listed in the report.

1.1.8 The incline

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

Table 1 : Weight shift procedure

No. of Weights or Weight Groups				
Weight shifts	Four		Six	
	PS	SB	PS	SB
No. 0	2, 4	1, 3	2, 4, 6	1, 3, 5
No. 1	4	1, 2, 3	4, 6	1, 2, 3, 5
No. 2		1, 2, 3, 4		1, 2, 3, 4, 5, 6
No. 3	1	2, 3, 4	6	1, 2, 3, 4, 5
No. 4	1, 3	2, 4	2, 4, 6	1, 3, 5
No. 5	1, 2, 3,	4	1, 2, 3, 4, 6	5
No. 6	1, 2, 3, 4		1, 2, 3, 4, 5, 6	
No. 7	2, 3, 4	1	1, 2, 4, 6	3, 5
No. 8	2, 4	1, 3	2, 4, 6	1, 3, 5

PS and SB denotes port and starboard sides of ship respectively.
The underlined numbers indicate the last weight groups shifted.

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

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

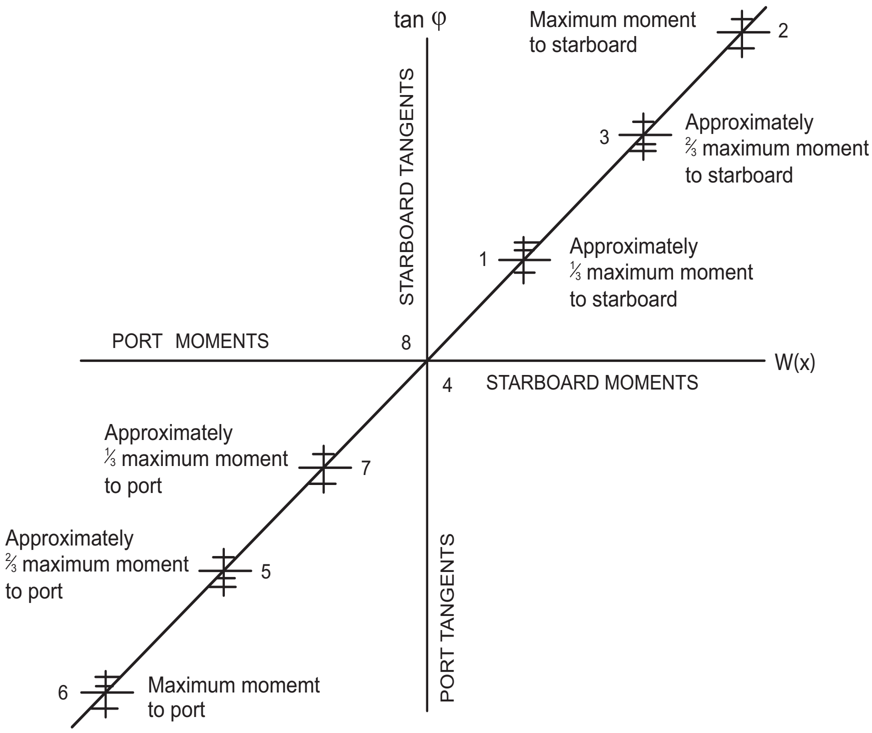
After each weight movement, the distance the weight was moved (centre to centre) is to be measured and the heeling moment calculated by multiplying the distance by the amount of weight moved. The tangent is calculated for each pendulum by dividing the deflection by the length of the pendulum. The resultant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

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

During the reading, no movements of personnel are allowed.

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

Figure 1 : Graph of resultant tangents



The plotting of all the readings for each of the pendulums during the inclining experiment aids in the discovery of bad readings. Since the ratio tangent/moment should be constant, the plotted line should be straight. Deviations from a straight line are an indication that there were other moments acting on the ship during the inclining. These other moments are to be identified, the cause corrected, and the weight movements repeated until a straight line is achieved. Fig 2 to Fig 5 illustrate examples of how to detect some of these other moments during the inclining, and a recommended solution for each case. For simplicity, only the average of the readings is shown on the inclining plots.

Figure 2 : Excessive free liquids (re-check all tanks and voids and pump out as necessary; re-do all weight movements and re-check freeboard and draught readings

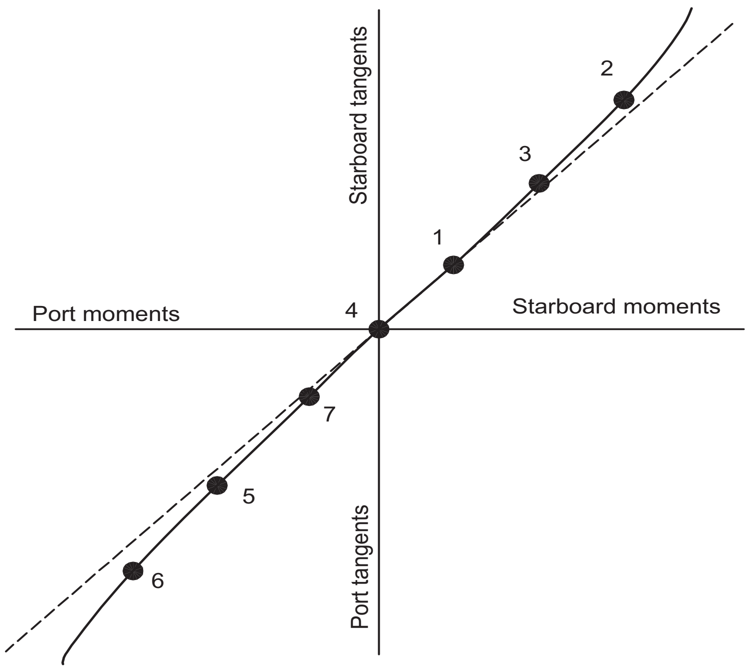


Figure 3 : Ship touching bottom or restrained by mooring lines (take water soundings and check lines: re-do weight movements 2 and 3)

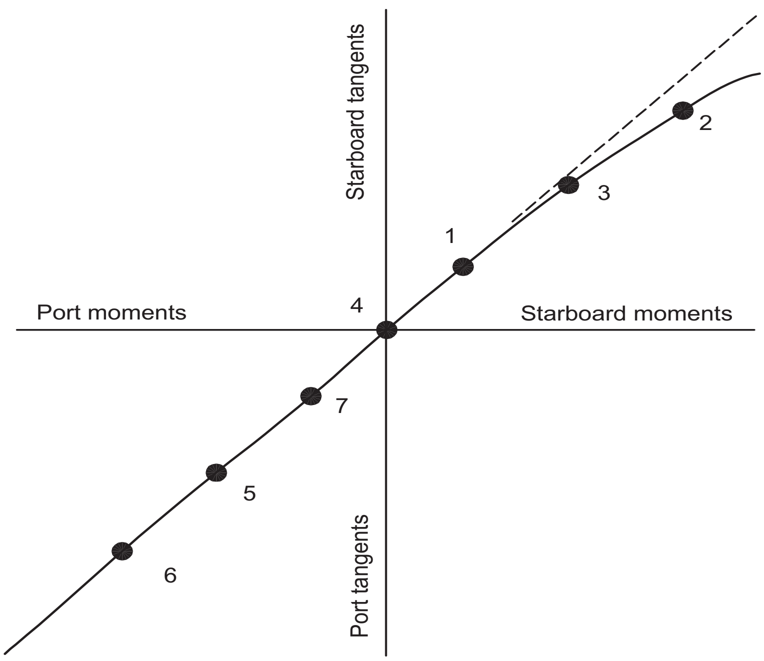


Figure 4 : Steady wind from port side came up after initial zero point taken (plot acceptable)

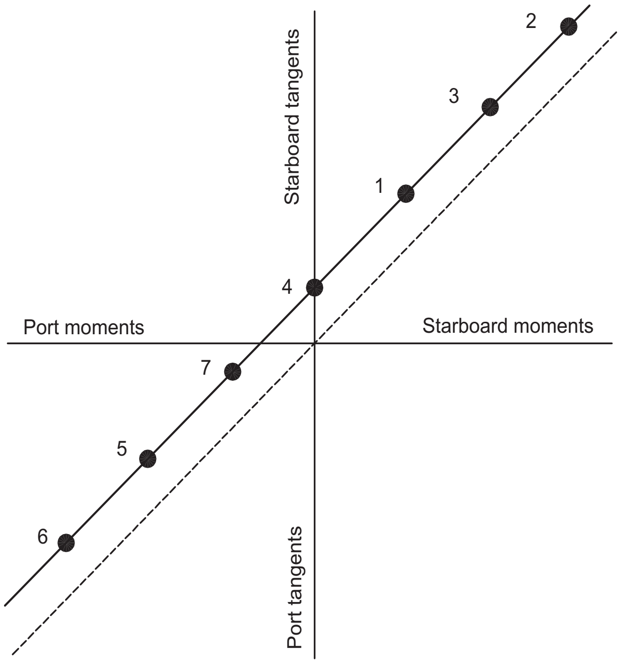
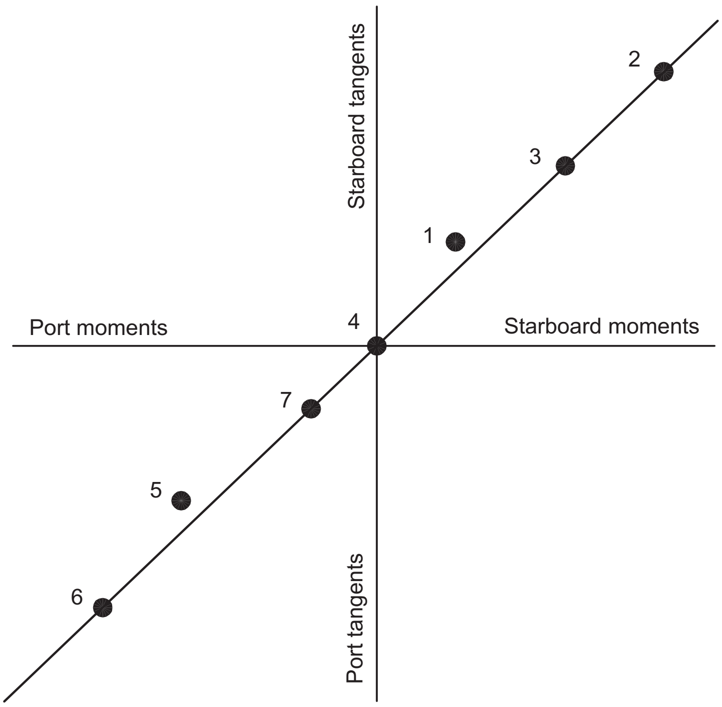


Figure 5 : Gusty wind from port side (re-do weight movements 1 and 5)



APPENDIX 2 TRIM AND STABILITY BOOKLET

1 Trim and stability booklet

1.1 Information to be included in the trim and stability booklet

1.1.1 General

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

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

1.1.2 List of information

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

- a general description of the ship, including:
  - the ship's name and the Society classification number
  - the ship type and service notation
  - the class notations
  - the yard, the hull number and the year of delivery
  - the Flag, the port of registry, the international call sign and the IMO number
  - the moulded dimensions
  - the draught corresponding to the assigned summer load line, the draught corresponding to the assigned summer timber load line and the draught corresponding to the tropical load line, if applicable
  - the displacement corresponding to the above-mentioned draughts
- clear instructions on the use of the booklet
- general arrangement and capacity plans indicating the assigned use of compartments and spaces (cargo, passenger, stores, accommodation, etc.)
- a sketch indicating the position of the draught marks referred to the ship's perpendiculars
- hydrostatic curves or tables corresponding to the design trim, and, if significant trim angles are foreseen during the normal operation of the ship, curves or tables corresponding to such range of trim are to be introduced. A clear reference relevant to the sea density, in t/m^3, is to be included as well as the draught measure (from keel or underkeel).
- cross curves (or tables) of stability calculated on a free trimming basis, for the ranges of displacement and trim anticipated in normal operating conditions, with indication of the volumes which have been considered in the computation of these curves
- tank sounding tables or curves showing capacities, centres of gravity, and free surface data for each tank
- lightship data from the inclining test, as indicated in Sec 1, [3.2], including lightship displacement, centre of gravity co-ordinates, place and date of the inclining test, as well as the Society approval details specified in the inclining test report. It is suggested that a copy of the approved test report be included.

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

1.2 Loading conditions

1.2.1 General

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

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

Additional loading conditions are required depending on the ship type and kind of cargo carried as specified in the following paragraphs, such loading cases being considered as a minimum requirement. Therefore, further loading cases may be included when deemed necessary or useful.

When a tropical freeboard is to be assigned to the ship, the corresponding loading conditions are also to be included.

1.2.2 Ships carrying cargo on deck

In addition to the loading conditions indicated in [1.2.1] to [1.2.13], in the case of cargo carried on deck the following cases are to be considered:

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

1.2.3 Oil tankers and FLS tankers

All the intended cargo loading conditions are to be included in the trim and stability booklet for examination within the scope of Pt E, Ch 1, Sec 3, [1].

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

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

  When it is impossible to have segregations, these conditions are to be replaced by loading conditions with the same specific gravity and with slack cargo tanks.
- same loading condition as above, but with 10% stores and consumables
- For oil tankers having segregated ballast tanks as defined in Pt E, Ch 1, Sec 1, [1.3.13, the lightship condition with segregated ballast only is also to be included in the trim and stability booklet for examination.

1.2.4 Dredgers

For ships with one of the service notations **dredger**, **hopper dredger**, **hopper unit**, **split hopper dredger** and **split hopper unit**, the following loading conditions are to be considered:

a) Dredging unit in lightship condition

b) Dredging unit in ballast in the departure condition without dredged materials and with the dredging devices suitably lashed, with full stores and fuel

c) Dredging unit in ballast in the arrival condition, without dredged materials and with the dredging devices suitably lashed, with 10% stores and fuel remaining

d) Dredging unit in working condition with full stores and fuel, wells with homogeneous full loading of dredged spoil up to the overflow pipes or, where the latter are not fitted, up to the top of the hatchway and with draught corresponding to the summer freeboard

e) Dredging unit as per item d) but with only 10% of stores and fuel

f) Dredging unit in working condition with full stores and fuel, with wells with homogeneous partial loading of dredged spoil having mass density equal to 2,2 t/m^3 and with draught corresponding to the summer freeboard

g) Dredging unit as per item f) but with only 10% of stores and fuel.

1.2.5 Tugs and fire-fighting ships

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

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

1.2.6 Supply vessels

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

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

1.3 Stability curve calculation

1.3.1 General

Hydrostatic and stability curves are normally prepared for the trim range of operating loading conditions taking into account the change in trim due to heel (free trim hydrostatic calculation).

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

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

Enclosed superstructures complying with Ch 1, Sec 2, [3.10] may be taken into account.

Additional tiers of similarly enclosed superstructures may also be taken into account, except for ships of length less than 20 m, for which only the first tier of enclosed superstructures may be taken into account and, in the event of doors on both sides of a deckhouse, access from the top is not required.

As guidance, windows (pane and frame) that are considered without deadlights in additional tiers above the second tier if considered buoyant are to be designed with strength to sustain a safety margin of at least 30% with regard to the required strength of the surrounding structure.

Deckhouses on the freeboard deck may be taken into account, provided that they comply with the conditions for enclosed superstructures laid down in Ch 1, Sec 2, [3.12].

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

Deckhouses, the doors of which do not comply with the requirements of Ch 9, Sec 4, [1.5.4], are not to be taken into account; however, any deck openings inside the deckhouse are regarded as closed where their means of closure comply with the requirements of Ch 9, Sec 7, [7.3].

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

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

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

1.3.3 Angle of flooding

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

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

Part B
Hull and Stability

Chapter 4
STRUCTURE DESIGN PRINCIPLES

SECTION 1 MATERIALS

1 General

1.1 Characteristics of materials

1.1.1 The characteristics of the materials to be used in the construction of ships are to comply with the applicable requirements of Part D.

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 Part D.

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 Part D. In particular:

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

2 Steels for hull structure

2.1 Application

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

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

2.1.3 When steels with a minimum guaranteed yield stress R_{eH} other than 235 N/mm^2 are used on a ship, hull scantlings are to be determined by taking into account the material factor k defined in [2.3].

2.1.4 Characteristics of steels with specified through thickness properties are given in Pt D, Ch 2, Sec 1, [9].

2.2 Information to be kept on board

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

2.2.2 It is also recommended that a plan is kept on board indicating the hull structures built in normal strength steel of grades D or E.

Table 1 : Mechanical properties of hull steels

Steel grades	Minimum yield stress R_{eH}, in N/mm^2	Ultimate minimum tensile strength R_m, in N/mm^2
A-B-D-E t ≤ 100mm	235	400 - 520
AH32-DH32-EH32 t ≤ 100mm FH32 t ≤ 50mm	315	440 - 590
AH36-DH36-EH36 t ≤ 100mm FH36 t ≤ 50mm	355	490 - 620
AH40-DH40-EH40 FH40 t ≤ 50mm	390	510 - 650
Note 1: Reference in Part D: Pt D, Ch 2, Sec 1, [2]		

2.3 Material factor k

2.3.1 General

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

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

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

Table 2 : Material factor k

R_{eH}, in N/mm^2	k
235	1
315	0,78
355	0,72
390	0,68

2.4 Grades of steel

2.4.1 Materials in the various strength members are not to be of lower grade than those corresponding to the material classes and grades specified in Tab 3 to Tab 6. General requirements are given in Tab 3, while additional minimum requirements for ships with length exceeding 150 m and 250 m are given in Tab 4 and Tab 5.

2.4.2 The material grade requirements for hull members of each class depending on the thickness are defined in Tab 6.

Table 3 : Material Classes and Grades for ships in general

Structural member category	Material class/grade
SECONDARY: • Longitudinal bulkhead strakes, other than that belonging to the Primary category • Deck plating exposed to weather, other than that belonging to the Primary or Special category • Side plating	• Class I within 0,4L amidships • Grade A/AH outside 0,4L amidships
PRIMARY: • Bottom plating, including keel plate • Strength deck plating, excluding that belonging to the Special category • Continuous longitudinal members above strength deck, excluding hatch coamings • Uppermost strake in longitudinal bulkhead • Vertical strake (hatch side girder) and uppermost sloped strake in top wing tank	• Class II within 0,4L amidships • Grade A/AH outside 0,4L amidships
SPECIAL: • Sheerstrake at strength deck **(1)** • Stringer plate in strength deck **(1)** • Deck strake at longitudinal bulkhead, excluding deck plating in way of inner-skin bulkhead of double hull ships **(1)**	• Class III within 0,4L amidships • Class II outside 0,4L amidships • Class I outside 0,6L amidships
• Strength deck plating at outboard corners of cargo hatch openings in container carriers and other ships with similar hatch opening configurations	• Class III within 0,4L amidships • Class II outside 0,4L amidships • Class I outside 0,6L amidships • Min. Class III within cargo region
• Strength deck plating at corners of cargo hatch openings in bulk carriers and other ships with similar hatch opening configurations	• Class III within 0,6L amidships • Class II within rest of cargo region
• Bilge strake in ships with double bottom over the full breadth and length less than 150 m **(1)**	• Class II within 0,6L amidships • Class I outside 0,6L amidships
• Bilge strake in other ships **(1)**	• Class III within 0,4L amidships • Class II outside 0,4L amidships • Class I outside 0,6L amidships
• Longitudinal hatch coamings of length greater than 0,15L • End brackets and deck house transition of longitudinal cargo hatch coamings	• Class III within 0,4L amidships • Class II outside 0,4L amidships • Class I outside 0,6L amidships • Not to be less than Grade D/DH
(1) Single strakes required to be of Class III within 0,4L amidships are to have breadths not less than 800+5L (mm), but need not be greater than 1800 (mm), unless limited by the geometry of the ship's design.	

Table 4 : Minimum Material Grades for ships with length exceeding 150 m and single strength deck

Structural member category	Material grade
Longitudinal strength members of strength deck plating	Grade B/AH within 0,4L amidships
Continuous longitudinal strength members above strength deck	Grade B/AH within 0,4L amidships
Single side strakes for ships without inner continuous longitudinal bulkhead(s) between bottom and the strength deck	Grade B/AH within cargo region

Table 5 : Minimum Material Grades for ships with length exceeding 250 m

Structural member category	Material grade
Sheerstrake at strength deck **(1)**	Grade E/EH within 0,4L amidships
Stringer plate in strength deck **(1)**	Grade E/EH within 0,4L amidships
Bilge strake **(1)**	Grade D/DH within 0,4L amidships
(1) Single strakes required to be of Grade E/EH and within 0,4L amidships are to have breadths not less than 800+5L (mm), but need not be greater than 1800 (mm), unless limited by the geometry of the ship's design.	

Table 6 : Material grade requirements for classes I, II and III

Class	I		II		III	
Gross thickness, in mm	NSS	HSS	NSS	HSS	NSS	HSS
t ≤ 15	A	AH	A	AH	A	AH
15 < t ≤ 20	A	AH	A	AH	B	AH
20 < t ≤ 25	A	AH	B	AH	D	DH
25 < t ≤ 30	A	AH	D	DH	D	DH
30 < t ≤ 35	B	AH	D	DH	E	EH
35 < t ≤ 40	B	AH	D	DH	E	EH
40 < t ≤ 50	D	DH	E	EH	E	EH
Note 1:“NSS” and “HSS” mean, respectively: “Normal Strength Steel” and “Higher Strength Steel”.						

2.4.3 For strength members not mentioned in Tab 3 to Tab 5, 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 Sec 2, [1].

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

2.4.6 In specific cases, such as [2.4.7], with regard to stress distribution along the hull girder, the classes required within 0,4L amidships may be extended beyond that zone, on a case by case basis.

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

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

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

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

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

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

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

2.4.12 For certain uses, grade B steel with controlled toughness at 0°C may be required for plates of gross thickness less than 25 mm.

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

2.5 Grades of steel for structures exposed to low air temperatures

2.5.1 For ships intended to operate in areas with low air temperatures (-20°C or below), e.g. regular service during winter seasons to Arctic or Antarctic waters, the materials in exposed structures are to be selected based on the design temperature t_D, to be taken as defined in [2.5.2].

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

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

Average : Average during one day and night

Lowest : Lowest during one year

Fig 1 illustrates the temperature definition.

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

Figure 1 : Commonly used definitions of temperatures

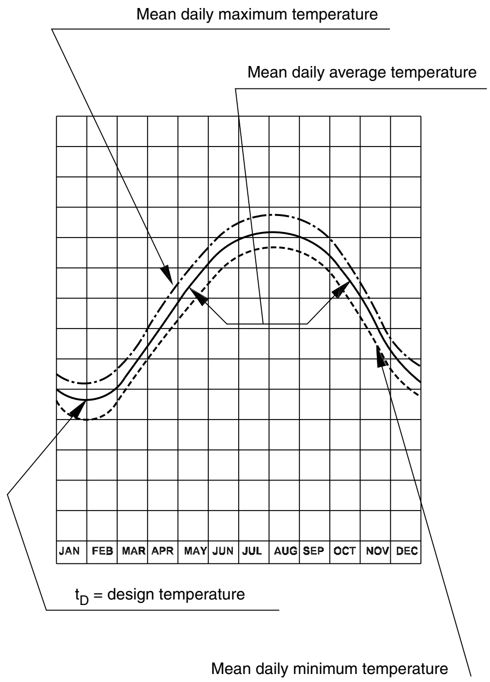


Table 7 : Application of material classes and grades for structures exposed to low air temperatures

Structural member category	Material class	
	Within 0,4L amidships	Outside 0,4L amidships
SECONDARY: Deck plating exposed to weather (in general) Side plating above T_B **(1)** Transverse bulkheads above T_B **(1)**	I	I
PRIMARY: Strength deck plating **(2)** Continuous longitudinal members above strength deck (excluding longitudinal hatch coamings of ships equal to or greater than 90 m in length) Longitudinal bulkhead above T_B **(1)** Topside tank bulkhead above T_B **(1)**	II	I
SPECIAL: Sheer strake at strength deck **(3)** Stringer plate in strength deck **(3)** Deck strake at longitudinal bulkhead **(4)** Continuous longitudinal hatch coamings of ships equal to or greater than 90 m in length **(5)**	III	II

(1) T_B is the draught in light ballast condition, defined in Ch 5, Sec 1, [2.4.3].
(2) Plating at corners of large hatch openings to be considered on a case by case basis.
Class III or grade E/EH to be applied in positions where high local stresses may occur.
(3) To be not less than grade E/EH within 0,4 L amidships in ships with length exceeding 250 m.
(4) In ships with breadth exceeding 70 metres at least three deck strakes to be class III.
(5) To be not less than grade D/DH.
Note 1: Plating materials for sternframes, rudder horns, rudders and shaft brackets are to be of grades not lower than those corresponding to the material classes in [2.4].

2.5.3 For the purpose of the selection of steel grades to be used for the structural members above the lowest ballast waterline and exposed to air, the latter are divided into categories (SECONDARY, PRIMARY and SPECIAL), as indicated in Tab 7.

Tab 7 also specifies the classes (I, II and III) of the materials to be used for the various categories of structural members.

For non-exposed structures and structures below the lowest ballast waterline, see [2.4].

2.5.4 Materials may not be of a lower grade than that indicated in Tab 8 to Tab 10 depending on the material class, structural member gross thickness and design temperature t_D.

For design temperatures $t_D < -55°C$, materials will be specially considered by the Society on a case by case basis.

2.5.5 Single strakes required to be of class III or of grade E/EH of FH are to have breadths not less than (800+5L) mm, but not necessarily greater than 1800 mm.

2.6 Grades of steel within refrigerated spaces

2.6.1 For structural members within or adjacent to refrigerated spaces, when the design temperatures is below 0°C, the materials are to be of grade not lower than those indicated in Tab 11, depending on the design temperature, the structural member gross thickness and its category (as defined in Tab 3).

2.6.2 Unless a temperature gradient calculation is carried out to assess the design temperature and the steel grade in the structural members of the refrigerated spaces, the temperatures to be assumed are specified below:

- temperature of the space on the uninsulated side, for plating insulated on one side only, either with uninsulated stiffening members (i.e. fitted on the uninsulated side of plating) or with insulated stiffening members (i.e. fitted on the insulated side of plating)
- mean value of temperatures in the adjacent spaces, for plating insulated on both sides, with insulated stiffening members, when the temperature difference between the adjacent spaces is generally not greater than 10 °C (when the temperature difference between the adjacent spaces is greater than 10°C, the temperature value is established by the Society on a case by case basis)
- in the case of non-refrigerated spaces adjacent to refrigerated spaces, the temperature in the non-refrigerated spaces is to be conventionally taken equal to 0°C.

2.6.3 Situations other than those mentioned in [2.6.1] and [2.6.2] or special arrangements will be considered by the Society on a case by case basis.

2.6.4 Irrespective of the provisions of [2.6.1], [2.6.2] and Tab 11, steel having grades lower than those required in [2.4], Tab 3 to Tab 6, in relation to the class and gross thickness of the structural member considered, may not be used.

Table 8 : Material grade requirements for class I at low temperatures

Gross thickness, in mm	-20°C / -25°C		-26°C / -35°C		-36°C / -45°C		-46°C / -55°C	
	NSS	HSS	NSS	HSS	NSS	HSS	NSS	HSS
t ≤ 10	A	AH	B	AH	D	DH	D	DH
10 < t ≤ 15	B	AH	D	DH	D	DH	D	DH
15 < t ≤ 20	B	AH	D	DH	D	DH	E	EH
20 < t ≤ 25	D	DH	D	DH	D	DH	E	EH
25 < t ≤ 30	D	DH	D	DH	E	EH	E	EH
30 < t ≤ 35	D	DH	D	DH	E	EH	E	EH
35 < t ≤ 45	D	DH	E	EH	E	EH	ϕ	FH
45 < t ≤ 50	E	EH	E	EH	ϕ	FH	ϕ	FH

Note 1:"NSS" and "HSS" mean, respectively, "Normal Strength Steel" and "Higher Strength Steel".
Note 2:"ϕ" = not applicable.

Table 9 : Material grade requirements for class II at low temperatures

Gross thickness, in mm	-20°C / -25°C		-26°C / -35°C		-36°C / -45°C		-46°C / -55°C	
	NSS	HSS	NSS	HSS	NSS	HSS	NSS	HSS
t ≤ 10	B	AH	D	DH	D	DH	E	EH
10 < t ≤ 20	D	DH	D	DH	E	EH	E	EH
20 < t ≤ 30	D	DH	E	EH	E	EH	ϕ	FH
30 < t ≤ 40	E	EH	E	EH	ϕ	FH	ϕ	FH
40 < t ≤ 45	E	EH	ϕ	FH	ϕ	FH	ϕ	ϕ
45 < t ≤ 50	E	EH	ϕ	FH	ϕ	FH	ϕ	ϕ

Note 1:“NSS” and “HSS” mean, respectively, “Normal Strength Steel” and “Higher Strength Steel”.
Note 2:“ϕ” = not applicable.

Table 10 : Material grade requirements for class III at low temperatures

Gross thickness, in mm	-20°C / -25°C		-26°C / -35°C		-36°C / -45°C		-46°C / -55°C	
	NSS	HSS	NSS	HSS	NSS	HSS	NSS	HSS
t ≤ 10	D	DH	D	DH	E	EH	E	EH
10 < t ≤ 20	D	DH	E	EH	E	EH	ϕ	FH
20 < t ≤ 25	E	EH	E	EH	ϕ	FH	ϕ	FH
25 < t ≤ 30	E	EH	E	EH	ϕ	FH	ϕ	FH
30 < t ≤ 35	E	EH	ϕ	FH	ϕ	FH	ϕ	ϕ
35 < t ≤ 40	E	EH	ϕ	FH	ϕ	FH	ϕ	ϕ
40 < t ≤ 50	ϕ	FH	ϕ	FH	ϕ	ϕ	ϕ	ϕ

Note 1:“NSS” and “HSS” mean, respectively, “Normal Strength Steel” and “Higher Strength Steel”.
Note 2:“ϕ” = not applicable.

Table 11 : Material grade requirements for members within or adjacent to refrigerated spaces

Design temperature, in °C	Gross thickness, in mm	Structural member category	
		Secondary	Primary or Special
$-10 \le t_D < 0$	t ≤ 20	B / AH	B / AH
	20 < t ≤ 25	B / AH	D / DH
	t > 25	D / DH	E / EH
$-25 \le t_D < -10$	t ≤ 15	B / AH	D / DH
	15 < t ≤ 25	D / DH	E / EH
	t > 25	E / EH	E / EH
$-40 \le t_D < -25$	t ≤ 25	D / DH	E / EH
	t > 25	E / EH	E / EH

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

3 Steels for forging and casting

3.1 General

3.1.1 Mechanical and chemical properties of steels for forging and casting to be used for structural members are to comply with the applicable requirements of Part D.

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

3.1.3 The steels used are to be tested in accordance with the applicable requirements of Part D.

3.2 Steels for forging

3.2.1 For the purpose of testing, which is to be carried out in accordance with the applicable requirements of Part D, the above steels for forging are assigned to class 1 (see Pt D, Ch 2, Sec 3, [1.2]).

In such case, compliance with the requirements of Pt D, Ch 2, Sec 1, relevant to the quality and testing of rolled parts accepted in lieu of forged parts, may be required.

3.3 Steels for casting

3.3.1 Cast parts intended for stems, sternframes, rudders, parts of steering gear and deck machinery in general may be made of C and C-Mn weldable steels of quality 1, having tensile strength R_m = 400 N/mm^2 or 440 N/mm^2, in accordance with the applicable requirements of Pt D, Ch 2, Sec 4.

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

3.3.2 For the purpose of testing, which is to be carried out in accordance with Pt D, Ch 2, Sec 4, [1.11], the above steels for casting are assigned to class 1 irrespective of their quality.

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

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

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

4 Aluminium alloy structures

4.1 General

4.1.1 The characteristics of aluminium alloys are to comply with the requirements of Pt D, Ch 3, Sec 2.

Series 5000 aluminium-magnesium alloys or series 6000 aluminium-magnesium-silicon alloys are generally to be used (see Pt D, Ch 3, Sec 2, [2]).

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

4.2 Extruded plating

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

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

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

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

4.3 Influence of welding on mechanical characteristics

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

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

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

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

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

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

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

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

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

4.4 Material factor k

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

$$k = \frac{235}{\eta R_{p0,2}}$$

where:

η : Joint coefficient for the welded assembly, corresponding to the aluminium alloy considered, given in Tab 12

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

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

5 Other materials and products

5.1 General

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

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

5.1.3 Materials used in welding processes are to comply with the applicable requirements of Part D.

5.2 Iron cast parts

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

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

Table 12 : Joint coefficient for aluminium alloys

Aluminium alloy	η
Alloys without work-hardening treatment (series 5000 in annealed condition 0 or annealed flattened condition H111)	1
Alloys hardened by work hardening (series 5000 other than condition 0 or H111)	$R'_{p0,2}/R_{p0,2}$
Alloys hardened by heat treatment (series 6000) **(1)**	$R'_{p0,2}/R_{p0,2}$

(1) When no information is available, coefficient η is to be taken equal to the metallurgical efficiency coefficient β defined in Tab 13.

Note 1:

$R'_{p0,2}$: Minimum guaranteed yield stress, in N/mm², of material in welded condition (see [4.3]).

(1) When no information is available, coefficient η is to be taken equal to the metallurgical efficiency coefficient β defined in Tab 13.

Note 1:

$R'_{p0,2}$: Minimum guaranteed yield stress, in N/mm², of material in welded condition (see [4.3]).

Table 13 : Aluminium alloys
Metallurgical efficiency coefficient β

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

SECTION 2 NET SCANTLING APPROACH

Symbols

t_N : Net thickness, in mm, of plating, including that which constitutes primary supporting members

w_N : Net section modulus, in cm^3, of ordinary stiffeners

w_G : Gross section modulus, in cm^3, of ordinary stiffeners.

1 Application criteria

1.1 General

1.1.1 The scantlings obtained by applying the criteria specified in Part B are net scantlings, i.e. those which provide the strength characteristics required to sustain the loads, excluding any addition for corrosion. Exceptions are:

- the scantlings obtained from the yielding checks of the hull girder in Ch 6, Sec 2
- the scantlings of doors in Ch 9, Sec 5 and Ch 9, Sec 6
- the scantlings of rudder structures and hull appendages in Chapter 10,

which are gross scantlings, i.e. they include additions for corrosion.

1.1.2 The required strength characteristics are:

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

1.1.3 The ship is to be built at least with the gross scantlings obtained by adding the corrosion additions, specified in Tab 2, to the net scantlings.

2 Net strength characteristic calculation

2.1 Designer's proposal based on gross scantlings

2.1.1 General criteria

If the Designer provides the gross scantlings of each structural element, the structural checks are to be carried out on the basis of the net strength characteristics, derived as specified in [2.1.2] to [2.1.6].

2.1.2 Plating

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

2.1.3 Ordinary stiffeners

The net transverse section is to be obtained by deducting t_C from the gross thickness of the elements which constitute the stiffener profile. For bulb profiles, an equivalent angle profile, as specified in Sec 3, [3.1.2], may be considered.

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

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

where α and β are the coefficients defined in Tab 1.

Table 1 : Coefficients α and β

Type of ordinary stiffeners	α	β
Flat bars	0,035	2,8
Flanged profiles	0,060	14,0
Bulb profiles: $w_G \leq 200$ cm^3 $w_G > 200$ cm^3	 0,070 0,035	 0,4 7,4

2.1.4 Primary supporting members analysed through an isolated beam structural model

The net transverse section is to be obtained by deducting t_C from the gross thickness of the elements which constitute the primary supporting members.

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

2.1.5 Primary supporting members analysed through a three dimensional model or a complete ship model

The net thickness of the structure elements represented in the model is to be obtained by deducting $0,5t_c$ from the gross thickness.

2.1.6 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].

It is to be checked whether:

$$Z_{NA} \geq 0,9 Z_{GD}$$

where:

Z_{NA} : Net midship section modulus, in m^3, calculated on the basis of the net scantlings obtained considering the corrosion additions t_C according to [2.1.2] to [2.1.4]

Z_{GD} : Gross midship section modulus, in m³, calculated on the basis of the gross scantlings proposed by the Designer.

Where the above condition is not satisfied, the hull girder normal and shear stresses, to be used for the checks of plating, ordinary stiffeners and primary supporting members analysed through an isolated beam structural model, are to be obtained by dividing by 0,9 those obtained by considering the hull girder transverse sections with their gross scantlings.

2.2 Designer's proposal based on net scantlings

2.2.1 Net strength characteristics and corrosion additions

If the Designer provides the net scantlings of each structural element, the structural checks are to be carried out on the basis of the proposed net strength characteristics.

The Designer is also to provide the corrosion additions or the gross scantlings of each structural element. The proposed corrosion additions are to be not less than the values specified in [3].

2.2.2 Hull girder net strength characteristic calculation

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

It is to be checked whether:

$$Z_{NAD} \geq 0{,}9 Z_{GD}$$

where:

Z_{NAD} : Net midship section modulus, in m³, calculated on the basis of the net scantlings proposed by the Designer

Z_{GD} : Gross midship section modulus, in m³, calculated on the basis of the gross scantlings proposed by the Designer.

Where the above condition is not satisfied, the hull girder normal and shear stresses, to be used for the checks of plating, ordinary stiffeners and primary supporting members analysed through an isolated beam structural model, are to be obtained by dividing by 0,9 those obtained by considering the hull girder transverse sections with their gross scantlings.

Table 2 : Corrosion additions t_c , in mm, for one side exposure

Compartment type		General (1)	Special cases
Ballast tank (2)		1,00	1,25 in upper zone (5)
Cargo tank and fuel oil tank (3)	Plating of horizontal surfaces	0,75	1,00 in upper zone (5)
	Plating of non-horizontal surfaces	0,50	1,00 in upper zone (5)
	Ordinary stiffeners	0,75	1,00 in upper zone (5)
Dry bulk cargo hold (4)	General	1,00	
	Inner bottom plating Side plating for single hull ship Inner side plating for double hull ship Sloping stool plate of hopper tanks and lower stool Transverse bulkhead plating	1,75	
	Frames	1,00	1,50 in lower zone (6)
Hopper well of dredging ships		2,00	
Accommodation space		0,00	
Compartments other than those mentioned above Outside sea and air		0,50	

(1) General: corrosion additions t_c are applicable to all members of the considered item with possible exceptions given for upper and lower zones.
(2) Ballast tank: does not include cargo oil tanks which may carry ballast according to Regulation 13 of MARPOL 73/78.
(3) For ships with the service notation **tanker**, the corrosion addition t_C may be taken equal to 0 for cargo tanks covered with a protective coating.
(4) Dry bulk cargo hold: includes holds, intended for the carriage of dry bulk cargoes, which may carry oil or water ballast.
(5) Upper zone: area within 1,5 m below the top of the tank or the hold. This is not to be applied to tanks in the double bottom.
(6) Lower zone: area within 3 m above the bottom of the tank or the hold.

3 Corrosion additions

3.1 Values of corrosion additions

3.1.1 General

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

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

3.1.2 Corrosion additions for steel other than stainless steel

In general, the corrosion addition to be considered for plating forming the boundary between two compartments of different types is the sum of the values specified in Tab 2 for one side exposure to each compartment.

For an internal member within a given compartment, or for plating forming the boundary between two compartments of the same type, the corrosion addition to be considered is twice the value specified in Tab 2 for one side exposure to that compartment.

When, according to Tab 2, a structural element is affected by more than one value of corrosion additions (e.g. a side frame in a dry bulk cargo hold extending above the lower zone), the scantling criteria are generally to be applied considering the value of corrosion addition applicable at the lowest point of the element.

3.1.3 Corrosion additions for stainless steel

For structural members made of stainless steel, the corrosion addition t_c is to be taken equal to 0.

3.1.4 Corrosion additions for non-alloyed steel clad with stainless steel

For plates made of non-alloyed steel clad with stainless steel, the corrosion addition t_c is to be taken equal to 0 only for the plate side clad with stainless steel.

3.1.5 Corrosion additions for aluminium alloys

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

SECTION 3 STRENGTH PRINCIPLES

Symbols

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

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

ℓ : Span, in m, of an ordinary stiffener or a primary supporting member, as the case may be, measured between the supporting members (see Fig 2 to Fig 5)

ℓ_b : Length, in m, of brackets (see Fig 4 and Fig 5)

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

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

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

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

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

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

I : Net moment of inertia, in cm⁴, of an ordinary stiffener or a primary supporting member, as the case may be, without attached plating, around its neutral axis parallel to the plating (see Fig 4 and Fig 5)

I_B : Net 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 (see Fig 4 and Fig 5).

1 General principles

1.1 Structural continuity

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

1.1.2 Attention is to be paid to the structural continuity:

- in way of changes in the framing system
- at the connections of primary or ordinary stiffeners
- in way of the ends of the fore and aft parts (see Ch 9, Sec 1 and Ch 9, Sec 2) and machinery space (see Ch 9, Sec 3)
- in way of ends of superstructures (see Ch 9, Sec 4).

1.1.3 Longitudinal members contributing to the hull girder longitudinal strength, according to Ch 6, Sec 1, [2], are to extend continuously for a sufficient distance towards the ends of the ship.

Ordinary stiffeners contributing to the hull girder longitudinal strength are generally to be continuous when crossing primary supporting members. Otherwise, the detail of connections is considered by the Society on a case by case basis.

Longitudinals of the bottom, bilge, sheerstrake, deck, upper and lower longitudinal bulkhead and inner side strakes, as well as the latter strakes themselves, the lower strake of the centreline bottom girder and the upper strake of the centreline deck girder, where fitted, are to be continuous through the transverse bulkheads of the cargo area and cofferdams. Alternative solutions may be examined by the Society on a case by case basis, provided they are equally effective.

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

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

Where necessary, the shape of openings is to be specially designed to reduce the stress concentration factors.

Openings are to be generally well rounded with smooth edges.

1.1.6 Primary supporting members are to be arranged in such a way that they ensure adequate continuity of strength. Abrupt changes in height or in cross-section are to be avoided.

1.2 Connections with higher strength steel

1.2.1 The vertical extent of higher strength steel is to comply with the requirements of Ch 6, Sec 2, [4.5].

1.2.2 When a higher strength steel is adopted at deck, members not contributing to the longitudinal strength and welded to the strength deck (e.g. hatch coamings, strengthening of deck openings) are also generally to be made of the same higher strength steel.

1.3 Connections between steel and aluminium

1.3.1 Any direct contact between steel and aluminium alloy is to be avoided (e.g. by means of zinc or cadmium plating of the steel parts and application of a suitable coating on the corresponding light alloy parts).

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

1.3.3 The use of transition joints made of aluminium/steel-clad plates or profiles is considered by the Society on a case by case basis (see Pt D, Ch 3, Sec 2, [4]).

2 Plating

2.1 Insert plates and doublers

2.1.1 A local increase in plating thickness is generally to be achieved through insert plates. Local doublers, which are normally only allowed for temporary repair, may however be accepted by the Society on a case by case basis.

In any case, doublers and insert plates are to be made of materials of a quality at least equal to that of the plates on which they are welded.

2.1.2 Doublers having width, in mm, greater than:

- 20 times their thickness, for thicknesses equal to or less than 15 mm
- 25 times their thickness, for thicknesses greater than 15 mm

are to be fitted with slot welds, to be effected according to Ch 12, Sec 1, [2.6].

2.1.3 When doublers fitted on the outer shell and strength deck within 0,6L amidships are accepted by the Society, their width and thickness are to be such that slot welds are not necessary according to the requirements in [2.1.2]. Outside this area, the possibility of fitting doublers requiring slot welds will be considered by the Society on a case by case basis.

3 Ordinary stiffeners

3.1 General

3.1.1 Stiffener not perpendicular to the attached plating

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

$$w = w_0 \sin\alpha$$

where:

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

α : Angle between the stiffener web and the attached plating.

3.1.2 Bulb section: equivalent angle profile

A bulb section may be taken as equivalent to an angle profile.

The dimensions of the equivalent angle profile are to be obtained, in mm, from the following formulae:

$$h_w = h'_w - \frac{h'_w}{9,2} + 2$$

$$t_w = t'_w$$

$$b_f = \alpha\left[t'_w + \frac{h'_w}{6,7} - 2\right]$$

$$t_f = \frac{h'_w}{9,2} - 2$$

where:

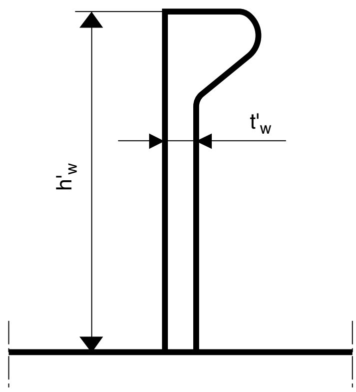
h'_w, t'_w : Height and net thickness of the bulb section, in mm, as shown in Fig 1

α : Coefficient equal to:

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

$$1 \quad \text{for } h'_w > 120$$

Figure 1 : Dimensions of a bulb section



3.2 Span of ordinary stiffeners

3.2.1 General

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

Figure 2 : Ordinary stiffener without brackets

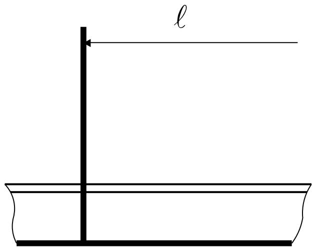


Figure 3 : Ordinary stiffener with a stiffener at one end

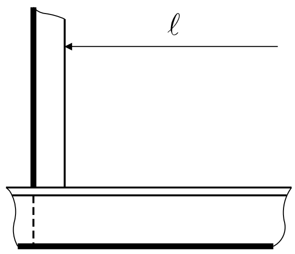


Figure 4 : Ordinary stiffener with end bracket

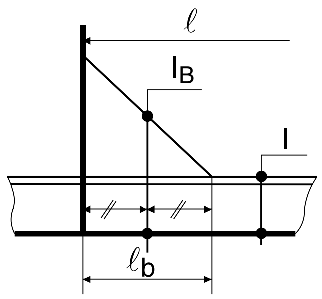
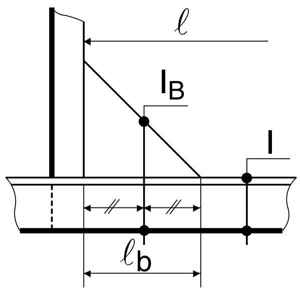


Figure 5 : Ordinary stiffener with a bracket and a stiffener at one end



3.2.2 Open floors

The span ℓ of transverse ordinary stiffeners constituting an open floor is to be taken as the greater of $1,4\ell_1$ and $0,7\ell_2$, where ℓ_1 and ℓ_2 are the spans defined in Fig 6.

3.3 Width of attached plating

3.3.1 Yielding check

The width of the attached plating to be considered for the yielding check of ordinary stiffeners is to be obtained, in m, from the following formulae:

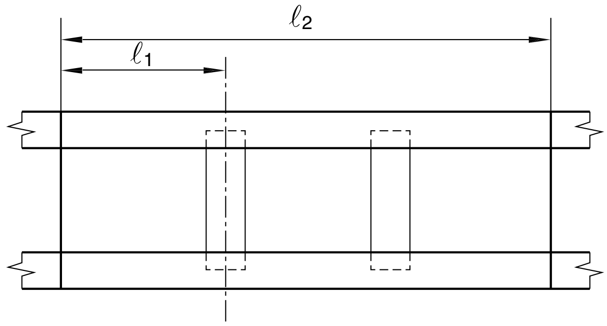
- where the plating extends on both sides of the ordinary stiffener:

  $b_P = s$

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

  $b_P = 0,5s$.

Figure 6 : Span of ordinary stiffeners in the case of open floors



3.3.2 Buckling check and ultimate strength check

The attached plating to be considered for the buckling and ultimate strength check of ordinary stiffeners is defined in Ch 7, Sec 2, [4.1] and Ch 7, Sec 2, [5.2], respectively.

3.4 Geometric properties

3.4.1 Built section

The geometric properties of built sections as shown in Fig 7 may be calculated as indicated in the following formulae. These formulae are applicable provided that:

$A_a \geq t_f b_f$

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

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

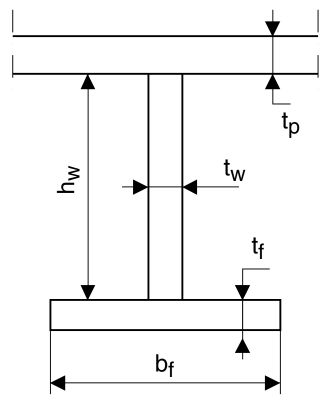
where:

A_a : Net sectional area, in mm², of the attached plating.

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

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

Figure 7 : Dimensions of a built section



The net section modulus of a built section with attached plating is to be obtained, in cm³, from the following formula:

$$w = \frac{h_w t_f b_f}{1000} + \frac{t_W h_W^2}{6000}\left(1 + \frac{A_a - t_f b_f}{A_a + \frac{t_W h_W}{2}}\right)$$

The distance from face plate to neutral axis is to be obtained, in cm, from the following formula:

$$v = \frac{h_W(A_a + 0,5 t_W h_W)}{10(A_a + t_f b_f + t_W h_W)}$$

The net moment of inertia of a built section with attached plating is to be obtained, in cm⁴, from the following formula:

I = w v

3.4.2 Corrugations

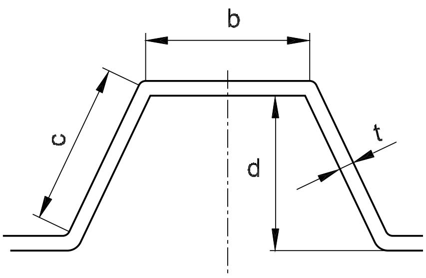
Unless otherwise specified, the net section modulus of a corrugation is to be obtained, in cm³, from the following formula:

$$w = \frac{td}{6}(3b + c)10^{-3}$$

where:

- t : Net thickness of the plating of the corrugation, in mm
- d, b, c : Dimensions of the corrugation, in mm, shown in Fig 8.

Figure 8 : Dimensions of a corrugation



At the corrugation ends, where the web continuity is not ensured (e.g. where the corrugation webs are not supported by local brackets) the net section modulus of the corrugation is to be obtained, in cm³, from the following formula:

$$w = 0,5\ btd10^{-3}$$

A more precise calculation of the net section modulus may be carried out taking into account the effectiveness of corrugation webs. In general, the corrugation webs may be considered 30% effective.

3.5 End connections

3.5.1 Where ordinary stiffeners are continuous through primary supporting members, they are to be connected to the web plating so as to ensure proper transmission of loads, e.g. by means of one of the connection details shown in Fig 9 to Fig 12.

Connection details other than those shown in Fig 9 to Fig 12 may be considered by the Society on a case by case basis. In some cases, the Society may require the details to be supported by direct calculations submitted for review.

Figure 9 : End connection of ordinary stiffener Without collar plate

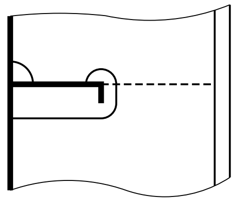


Figure 10 : End connection of ordinary stiffener Collar plate

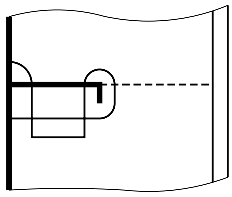


Figure 11 : End connection of ordinary stiffener One large collar plate

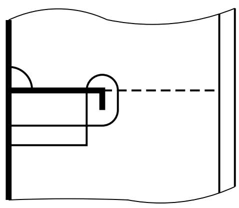
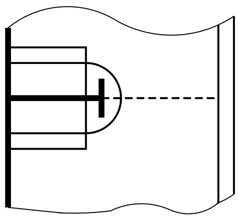


Figure 12 : End connection of ordinary stiffener Two large collar plates

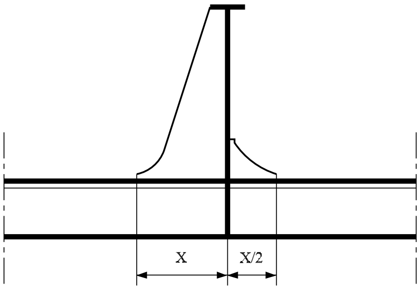


3.5.2 Where ordinary stiffeners are cut at primary supporting members, brackets are to be fitted to ensure the structural continuity. Their net section modulus and their net sectional area are to be not less than those of the ordinary stiffeners.

The net thickness of brackets is to be not less than that of ordinary stiffeners. Brackets with net thickness, in mm, less than $15L_b$, where L_b is the length, in m, of the free edge of the end bracket, are to be flanged or stiffened by a welded face plate. The net sectional area, in cm², of the flanged edge or face plate is to be at least equal to $10L_b$.

3.5.3 Where necessary, the Society may require backing brackets to be fitted, as shown in Fig 13, in order to improve the fatigue strength of the connection (see also [4.7.4]).

Figure 13 : End connection of ordinary stiffener Backing bracket



4 Primary supporting members

4.1 Span of primary supporting members

4.1.1 The span of primary supporting members is to be determined in accordance with [3.2].

4.2 Width of attached plating

4.2.1 General

The width of the attached plating to be considered for the yielding check of primary supporting members analysed through beam structural models is to be obtained, in m, from the following formulae:

- where the plating extends on both sides of the primary supporting member:

  $b_P = \min (s; 0,2\ell)$

- where the plating extends on one side of the primary supporting member (i.e. primary supporting members bounding openings):

  $b_P = 0,5 \min (s; 0,2\ell)$

4.2.2 Corrugated bulkheads

The width of attached plating of corrugated bulkhead primary supporting members is to be determined as follows:

- when primary supporting members are parallel to the corrugations and are welded to the corrugation flanges, the width of the attached plating is to be calculated in accordance with [4.2.1] and is to be taken not greater than the corrugation flange width
- when primary supporting members are perpendicular to the corrugations, the width of the attached plating is to be taken equal to the width of the primary supporting member face plate.

4.3 Geometric properties

4.3.1 Standard roll sections

The geometric properties of primary supporting members made of standard roll sections may be determined in accordance with [3.4.1].

4.3.2 Built sections

The geometric properties of primary supporting members made of built sections (including primary supporting members of double skin structures, such as double bottom floors and girders) are generally determined in accordance with [3.4.1].

Additional requirements relevant to the net shear sectional area are provided in [4.3.3].

4.3.3 Net shear sectional area in the case of web large openings

Where large openings are fitted in the web of primary supporting members (e.g. where a pipe tunnel is fitted in the double bottom, see Fig 14), their influence is to be taken into account by assigning an equivalent net shear sectional area to the primary supporting member.

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

$$A_{Sh} = \frac{A_{Sh1}}{1 + \dfrac{0,0032\,\ell^2 A_{Sh1}}{I_1}} + \frac{A_{Sh2}}{1 + \dfrac{0,0032\,\ell^2 A_{Sh2}}{I_2}}$$

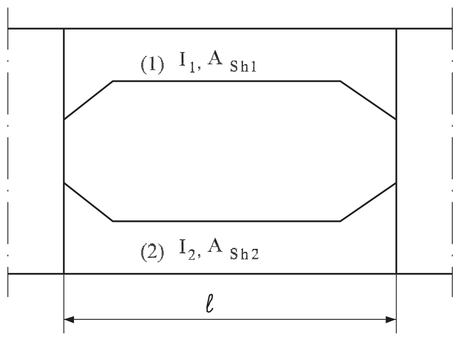
where (see Fig 14):

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

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

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

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



4.4 Bracketed end connections

4.4.1 Arm lengths of end brackets are to be equal, as far as practicable.

With the exception of primary supporting members of transversely framed single sides (see Sec 5, [3.2]), the height of end brackets is to be not less than that of the primary supporting member.

4.4.2 The net thickness of the end bracket web is generally to be not less than that of the primary supporting member web.

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

4.4.4 The width, in mm, of the face plate of end brackets is to be not less than $50(L_b+1)$, where L_b is the length, in m, of the free edge of the end bracket.

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

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

As guidance, the following prescriptions may be applied:

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

4.4.6 In addition to the above requirements, the net scantlings of end brackets are to comply with the applicable requirements given in Sec 4 to Sec 7.

4.5 Bracketless end connections

4.5.1 In the case of bracketless crossing between primary supporting members (see Fig 15), the net thickness of the common part of the web is to be not less than the value obtained, in mm, from the following formula:

$$t = 15,75\frac{w}{\Omega}$$

where:

- w : the lesser of w_1 and $w_{2,MAX}$
- w_1 : gross section modulus, in cm^3, of member 1
- $w_{2,MAX}$: the greater value, in cm^3, of the gross section moduli of members 2 and 3
- Ω : Area, in cm^2, of the common part of members 1, 2 and 3.

In the absence of one of members 2 and 3 shown in Fig 15, the value of the relevant gross section modulus is to be taken equal to zero.

4.5.2 In no case may the net thickness calculated according to [4.5.1] be less than the smallest web net thickness of the members forming the crossing.

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

4.6 Cut-outs and holes

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

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

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

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

Figure 15 : Bracketless end connections of primary supporting members

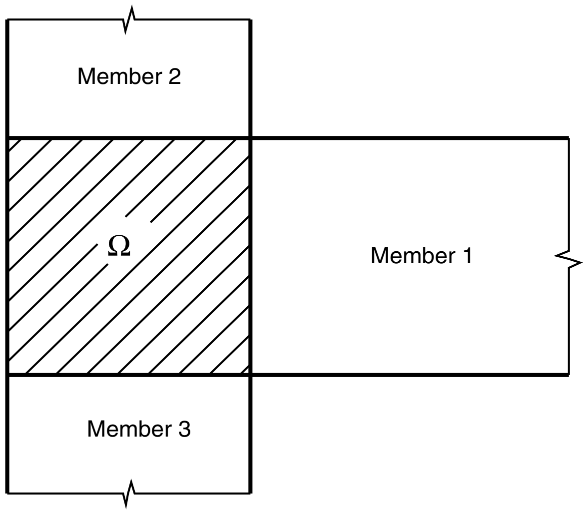
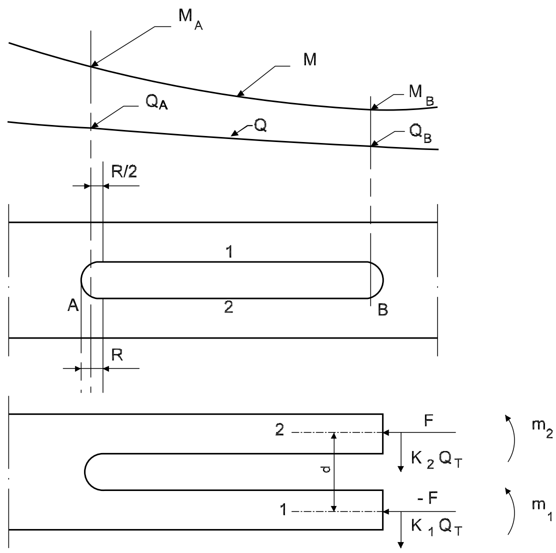


Figure 16 : Large openings in primary supporting members - Secondary stresses



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

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

4.6.5 In the case of large openings as shown in Fig 16, the secondary stresses in primary supporting members are to be considered for the reinforcement of the openings.

The secondary stresses may be calculated in accordance with the following procedure.

Members (1) and (2) are subjected to the following forces, moments and stresses:

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

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

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

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

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

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

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

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

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

where:

- M_A, M_B : Bending moments, in kN.m, in sections A and B of the primary supporting member
- m_1, m_2 : Bending moments, in kN.m, in (1) and (2)
- d : Distance, in m, between the neutral axes of (1) and (2)
- σ_{F1}, σ_{F2} : Axial stresses, in N/mm^2, in (1) and (2)
- σ_{m1}, σ_{m2} : Bending stresses, in N/mm^2, 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/mm^2, in (1) and (2)
- w_1, w_2 : Net section moduli, in cm^3, of (1) and (2)
- S_1, S_2 : Net sectional areas, in cm^2, of (1) and (2)
- S_{w1}, S_{w2} : Net sectional areas, in cm^2, of webs in (1) and (2)
- I_1, I_2 : Net moments of inertia, in cm^4, of (1) and (2) with attached plating

$$K_1 = \frac{I_1}{I_1 + I_2}$$

$$K_2 = \frac{I_2}{I_1 + I_2}$$

The combined stress σ_C calculated at the ends of members (1) and (2) is to be obtained from the following formula:

$$\sigma_c = \sqrt{(\sigma_F + \sigma_m)^2 + 3\tau^2}$$

The combined stress σ_C is to comply with the checking criteria in Ch 7, Sec 3, [3.6] or Ch 7, Sec 3, [4.3], 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 17 to Fig 19:

- continuous face plate (solution 1): see Fig 17
- straight face plate (solution 2): see Fig 18
- compensation of the opening (solution 3): see Fig 19
- combination of the above solutions.

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

Figure 17 : Stiffening of large openings in primary supporting members - Solution 1

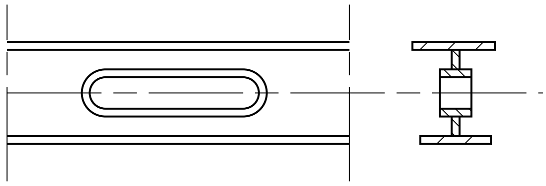


Figure 18 : Stiffening of large openings in primary supporting members - Solution 2

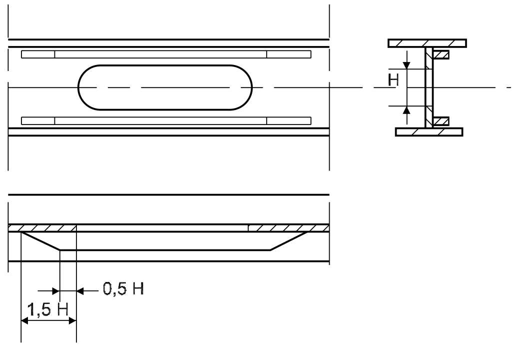
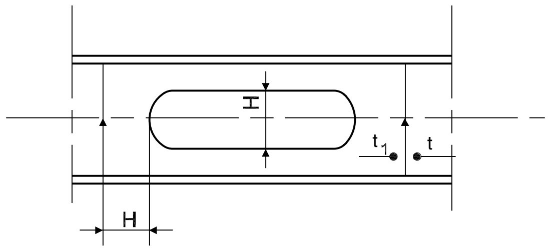


Figure 19 : Stiffening of large openings in primary supporting members - Solution 3

Inserted plate



4.7 Stiffening arrangement

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

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

4.7.2 Where primary supporting member web stiffeners are welded to ordinary stiffener face plates, their net sectional area at the web stiffener mid-height is to be not less than the value obtained, in cm^2, from the following formula:

$$A = 0{,}1 k_1(\gamma_{S2} p_S + \gamma_{W2} p_W) s \ell$$

where:

- k_1 : Coefficient depending on the web connection with the ordinary stiffener, to be taken as:
  - k_1 = 0,3 for connections without collar plate (see Fig 9)
  - k_1 = 0,225 for connections with a collar plate (see Fig 10)
  - k_1 = 0,2 for connections with one or two large collar plates (see Fig 11 and Fig 12)

p_S, p_W : Still water and wave pressure, respectively, in kN/m², acting on the ordinary stiffener, defined in Ch 7, Sec 2, [3.3.2] or Ch 8, Sec 4, [3.3.2]

γ_{S2}, γ_{W2} : Partial safety factors, defined in Ch 7, Sec 2, Tab 1 or Ch 8, Sec 4, Tab 1 for yielding check (general).

4.7.3 The net section modulus of web stiffeners of non-watertight primary supporting members is to be not less than the value obtained, in cm³, from the following formula:

$$w = 2{,}5 s^2 t S_s^2$$

where:

s : Length, in m, of web stiffeners

t : Web net thickness, in mm, of the primary supporting member

S_s : Spacing, in m, of web stiffeners.

Moreover, web stiffeners located in areas subject to compression stresses are to be checked for buckling in accordance with Ch 7, Sec 2, [4].

4.7.4 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
- at the toe of end brackets
- at rounded face plates
- in way of cross ties
- in way of concentrated loads.

Where the width of the symmetrical face plate is greater than 400 mm, backing brackets are to be fitted in way of the tripping brackets.

4.7.5 In general, the width of the primary supporting member face plate is to be not less than one tenth of the depth of the web, where tripping brackets are spaced as specified in [4.7.4].

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

$$d = 0{,}38 b$$

$$d = 0{,}85 b \sqrt{\frac{s_t}{t}}$$

where:

b : Height, in m, of tripping brackets, shown in Fig 20

s_t : Spacing, in m, of tripping brackets

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

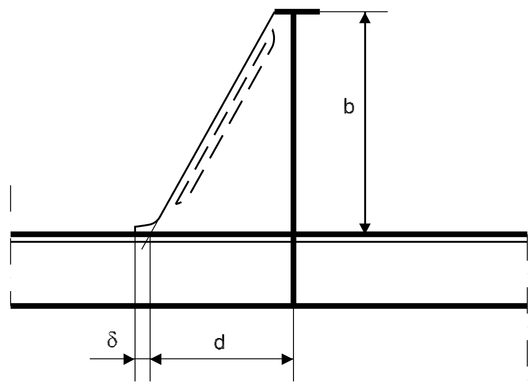
It is recommended that the bracket toe should be designed as shown in Fig 20.

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

The net sectional area, in cm², of the flanged edge or the face plate is to be not less than $10L_b$, where L_b is the length, in m, of the free edge of the bracket.

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

Figure 20 : Primary supporting member: web stiffener in way of ordinary stiffener



SECTION 4 BOTTOM STRUCTURE

1 General

1.1 Application

1.1.1 The requirements of this Section apply to longitudinally or transversely framed single and double bottom structures.

1.2 General arrangement

1.2.1 In ships greater than 120 m in length, the bottom is, in general, to be longitudinally framed.

1.2.2 The bottom is to be checked by the Designer to ascertain that it withstands the loads resulting from the dry-docking of the ship.

1.2.3 The bottom is to be locally stiffened where concentrated loads are envisaged.

1.2.4 Girders or floors are to be fitted under each line of pillars, when deemed necessary by the Society on the basis of the loads carried by the pillars.

1.2.5 Adequate tapering is to be provided between double bottom and adjacent single bottom structures. Similarly, adequate continuity is to be provided in the case of height variation in the double bottom. Where such a height variation occurs within 0,6 L amidships, the inner bottom is generally to be maintained continuous by means of inclined plating.

1.2.6 Provision is to be made for the free passage of water from all parts of the bottom to the suctions, taking into account the pumping rate required.

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

1.3 Keel

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

$$b = 0,8 + 0,5\frac{L}{100}$$

1.4 Drainage and openings for air passage

1.4.1 Holes are to be cut into floors and girders to ensure the free passage of air and liquids from all parts of the double bottom.

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

2 Longitudinally framed single bottom

2.1 General

2.1.1 Single bottom ships are to be fitted with a centre girder formed by a vertical continuous or intercostal web plate and a horizontal face plate continuous over the floors.

Intercostal web plates are to be aligned and welded to floors.

2.1.2 In general, girders are to be fitted spaced not more than 2,5 m apart and formed by a vertical intercostal web plate and a horizontal face plate continuous over the floors.

Intercostal web plates are to be aligned and welded to floors.

2.1.3 Centre and side girders are to be extended as far aft and forward as practicable.

2.1.4 Where side girders are fitted in lieu of the centre girder, the scarfing is to be adequately extended and additional stiffening of the centre bottom may be required.

2.1.5 Longitudinal girders are to be fitted in way of each line of pillars.

2.1.6 Floors are to be made with a welded face plate between the collision bulkhead and 0,25L from the fore end.

2.2 Floors

2.2.1 In general, the floor spacing is to be not greater than 5 frame spacings.

2.3 Longitudinal ordinary stiffeners

2.3.1 Longitudinal ordinary stiffeners are generally to be continuous when crossing primary members.

3 Transversely framed single bottom

3.1 General

3.1.1 The requirements in [2.1] apply also to transversely framed single bottoms.

3.2 Floors

3.2.1 Floors are to be fitted at every frame.

3.2.2 The height, in m, of floors at the centreline is to be not less than B/16. In the case of ships with considerable rise of floor, this height may be required to be increased so as to assure a satisfactory connection to the frames.

4 Longitudinally framed double bottom

4.1 General

4.1.1 The centre girder is to be continuous and extended over the full length of ship and the spacing of adjacent longitudinal girders is generally to be not greater than 6,5 m.

4.2 Double bottom height

4.2.1 The double bottom height is to be sufficient to ensure access to all parts and, in way of the centre girder, is to be not less than the greater value obtained, in m, from the following formulae:

$$h_{DB} = 3\frac{B+T+10}{100}$$

$$h_{DB} = 0,7$$

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

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

4.2.3 In ships without a flat bottom, the height of double bottom specified in [4.2.1] may be required to be adequately increased such as to ensure sufficient access to the areas towards the sides.

4.3 Floors

4.3.1 The spacing of plate floors, in m, is generally to be not greater than 0,05L or 3,8 m, whichever is the lesser.

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

4.3.2 Plate floors are generally to be provided with stiffeners in way of longitudinal ordinary stiffeners.

4.3.3 Where the double bottom height exceeds 0,9 m, watertight floors are to be fitted with stiffeners having a net section modulus not less than that required for tank bulkhead vertical stiffeners.

4.4 Bottom and inner bottom longitudinal ordinary stiffeners

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

4.5 Brackets to centreline girder and margin plate

4.5.1 In general, intermediate brackets are to be fitted connecting either the margin plate or the centre girder to the nearest bottom and inner bottom ordinary stiffeners.

4.5.2 Such brackets are to be stiffened at the edge with a flange having a width not less than 1/10 of the local double bottom height.

If necessary, the Society may require a welded flat bar to be arranged in lieu of the flange.

4.5.3 Where the side shell is transversely stiffened, margin plate brackets are to be fitted at every frame.

4.6 Duct keel

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

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

4.7 Bilge wells

4.7.1 Bilge wells arranged in the double bottom are to be limited in depth and formed by steel plates having a net thickness not less than the greater of that required for watertight floors and that required for the inner bottom.

4.7.2 In ships subject to subdivision requirements, such bilge wells are to be fitted so that the distance of their bottom from the shell plating is not less than 460 mm.

4.7.3 Where there is no margin plate, well arrangement is considered by the Society on a case by case basis.

5 Transversely framed double bottom

5.1 General

5.1.1 The requirements in [4.1], [4.2], [4.5], [4.6] and [4.7] apply also to transversely framed double bottoms.

5.2 Floors

5.2.1 Plate floors are to be fitted at every frame forward of 0,75L from the aft end.

Plate floors are also to be fitted:

- in way of transverse watertight bulkheads
- in way of double bottom steps.

Elsewhere, plate floors may be arranged at a distance not exceeding 3 m.

5.2.2 In general, plate floors are to be continuous between the centre girder and the margin plate.

5.2.3 Open floors are to be fitted in way of intermediate frames.

5.2.4 Where the double bottom height exceeds 0,9 m, plate floors are to be fitted with vertical stiffeners spaced not more than 1,5 m apart.

These stiffeners may consist of flat bars with a width equal to one tenth of the floor depth and a net thickness, in mm, not less than $0,8L^{0,5}$.

5.3 Girders

5.3.1 Side girders are to be arranged in such a way that their distance to adjacent girders or margin plate does not generally exceed 4,5 m.

5.3.2 Where the double bottom height exceeds 0,9 m, longitudinal girders are to be fitted with vertical stiffeners spaced not more than 1,5 m apart.

These stiffeners may consist of flat bars with a width equal to one tenth of the girder height and a net thickness, in mm, not less than $0{,}8L^{0{,}5}$.

5.3.3 In way of open floors, side girders are to be provided with stiffeners having a web height which is generally to be not less than 150 mm.

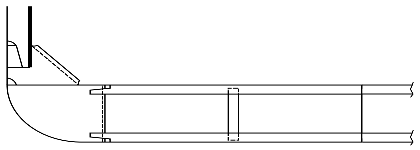
5.4 Open floors

5.4.1 At each frame between plate floors, open floors are to be arranged consisting of a frame connected to the bottom plating and a reverse frame connected to the inner bottom plating (See Fig 1).

5.4.2 Open floors are to be attached to the centreline girder and to the margin plate by means of flanged brackets having a width of flange not less than 1/10 of the local double bottom height.

5.4.3 Where frames and reverse frames are interrupted in way of girders, double brackets are to be fitted.

Figure 1 : Open floor



6 Bilge keel

6.1 Arrangement, scantlings and connections

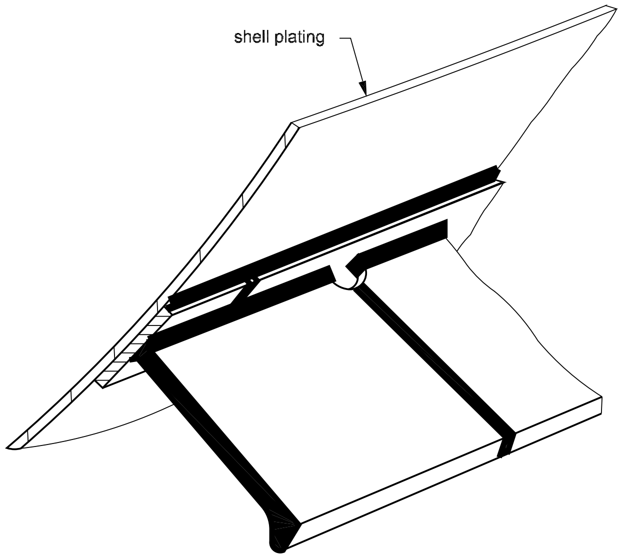
6.1.1 Arrangement

Bilge keels may not be welded directly on the shell plating. An intermediate flat, or doubler, is required on the shell plating.

The ends of the bilge keel are to be sniped at an angle of 15° or rounded with large radius. They are to be located in way of a transverse bilge stiffener. The ends of the intermediate flat are to be sniped at an angle of 15°.

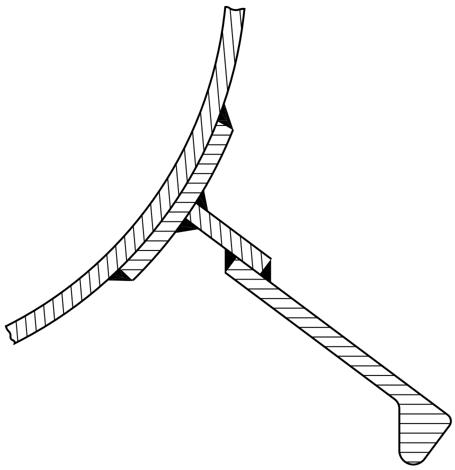
The arrangement shown in Fig 2 is recommended.

Figure 2 : Bilge keel arrangement



The arrangement shown in Fig 3 may also be accepted.

Figure 3 : Bilge keel arrangement



6.1.2 Materials

The bilge keel and the intermediate flat are to be made of steel with the same yield stress and grade as that of the bilge strake.

6.1.3 Scantlings

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

6.1.4 Welding

Welding of bilge keel and intermediate plate connections is to be in accordance with Ch 12, Sec 1, [3.2].

SECTION 5 SIDE STRUCTURE

1 General

1.1 Application

1.1.1 The requirements of this Section apply to longitudinally or transversely framed single and double side structures.

1.1.2 The transversely framed side structures are built with transverse frames possibly supported by side girders (see [5.3.1]).

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

1.2 General arrangement

1.2.1 Unless otherwise specified, side girders are to be fitted aft of the collision bulkhead up to 0,2L aft of the fore end, in line with fore peak girders.

1.2.2 Side vertical primary supporting members are to be fitted in way of hatch end beams.

1.3 Sheerstrake

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

$$b = 0{,}715 + 0{,}425\frac{L}{100}$$

However, the sheerstrake is also to comply with the requirements in Sec 1, [2.5.5].

1.3.2 The sheerstrake may be either welded to the stringer plate or rounded. If it is rounded, the radius, in mm, is to be not less than $17t_S$, where t_S is the net thickness, in mm, of the sheerstrake.

1.3.3 The upper edge of the welded sheerstrake is to be rounded and free of notches.

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

Plans showing details of this transition are to be submitted for approval to the Society.

2 Longitudinally framed single side

2.1 Longitudinal ordinary stiffeners

2.1.1 Longitudinal ordinary stiffeners are generally to be continuous when crossing primary members.

2.2 Primary supporting members

2.2.1 In general, the side vertical primary supporting member spacing may not exceed 5 frame spacings.

2.2.2 In general, the side vertical primary supporting members are to be bracketed to the double bottom transverse floors.

3 Transversely framed single side

3.1 Frames

3.1.1 Transverse frames are to be fitted at every frame.

3.1.2 Frames are generally to be continuous when crossing primary members.

Otherwise, the detail of the connection is to be examined by the Society on a case by case basis.

3.1.3 In general, the net section modulus of ‘tween deck frames is to be not less than that required for frames located immediately above.

3.2 Primary supporting members

3.2.1 In 'tweendecks of more than 4 m in height, side girders or side vertical primary supporting members or both may be required by the Society.

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

The width of the flanged edge or face plate is to be not less than 22t, where t is the web net thickness, in mm, of the girder.

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

4 Longitudinally framed double side

4.1 General

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

In particular, scarfing of the inner side is to be ensured beyond the cargo hold region.

4.1.2 Knuckles of the inner side are to be adequately stiffened by longitudinal stiffeners. Equivalent arrangement may be considered by the Society on a case by case basis.

4.2 Primary supporting members

4.2.1 The height of side vertical primary supporting members may be gradually tapered from bottom to deck. The maximum acceptable taper, however, is 8 cm per metre.

4.2.2 Side vertical primary supporting members supported by a strut and two diagonals converging on the former are to be considered by the Society on a case by case basis.

5 Transversely framed double side

5.1 General

5.1.1 The requirements in [4.1] also apply to transversely framed double side.

5.1.2 Transverse frames may be connected to the vertical ordinary stiffeners of the inner side by means of struts.

Struts are generally to be connected to transverse frames and vertical ordinary stiffeners of the inner side by means of vertical brackets.

5.2 Frames

5.2.1 Transverse frames are to be fitted at every frame.

5.3 Primary supporting members

5.3.1 Unless otherwise specified, transverse frames are to be supported by side girders if $D \geq 6$ m.

These girders are to be supported by side vertical primary supporting members spaced no more than 3,8 m apart.

5.3.2 In the case of ships having $4,5 < D < 6$ m, side vertical primary supporting members are to be fitted, in general not more than 5 frame spacings apart.

6 Frame connections

6.1 General

6.1.1 End connections of frames are to be bracketed.

6.1.2 'Tweendeck frames are to be bracketed at the top and welded or bracketed at the bottom to the deck.

In the case of bulb profiles, a bracket may be required to be fitted at bottom.

6.1.3 Brackets are normally connected to frames by lap welds. The length of overlap is to be not less than the depth of frames.

6.2 Upper brackets of frames

6.2.1 The arm length of upper brackets connecting frames to deck beams is to be not less than the value obtained, in mm, from the following formula:

$$d = \varphi \sqrt{\frac{w + 30}{t}}$$

where:

φ : coefficient equal to:

- for unflanged brackets:

  $\varphi = 48$

- for flanged brackets:

  $\varphi = 43,5$

w : required net section modulus of the stiffener, in cm^3, given in [6.2.2] and [6.2.3] and depending on the type of connection,

t : bracket net thickness, in mm.

6.2.2 For connections of perpendicular stiffeners located in the same plane (see Fig 1) or connections of stiffeners located in perpendicular planes (see Fig 2), the required net section modulus is to be taken equal to:

$w = w_2$ if $w_2 \leq w_1$

$w = w_1$ if $w_2 > w_1$

where w_1 and w_2 are the required net section moduli of stiffeners, as shown in Fig 1 and Fig 2.

Figure 1 : Connections of perpendicular stiffeners in the same plane

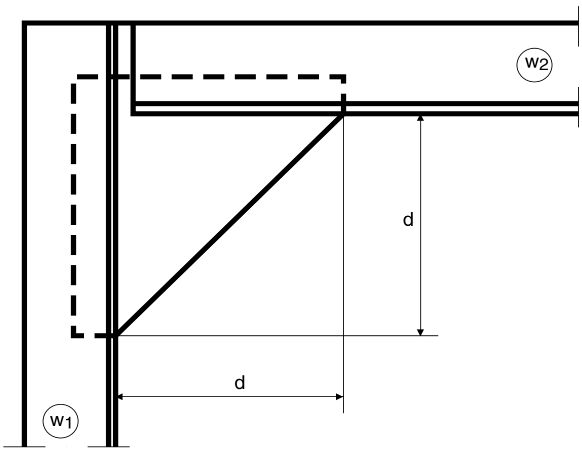
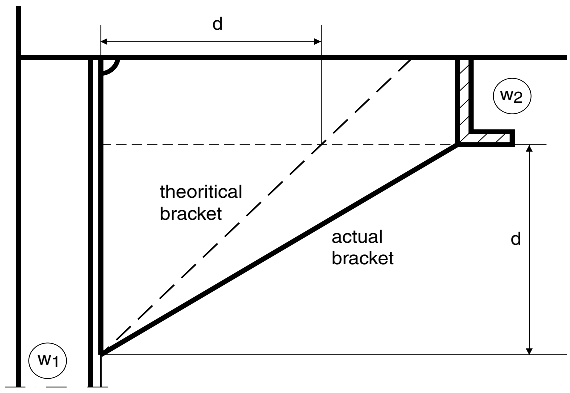


Figure 2 : Connections of stiffeners located in perpendicular planes



6.2.3 For connections of frames to deck beams (see Fig 3), the required net section modulus is to be taken equal to:

- for bracket "A":

  $w_A = w_1$ if $w_2 \le w_1$

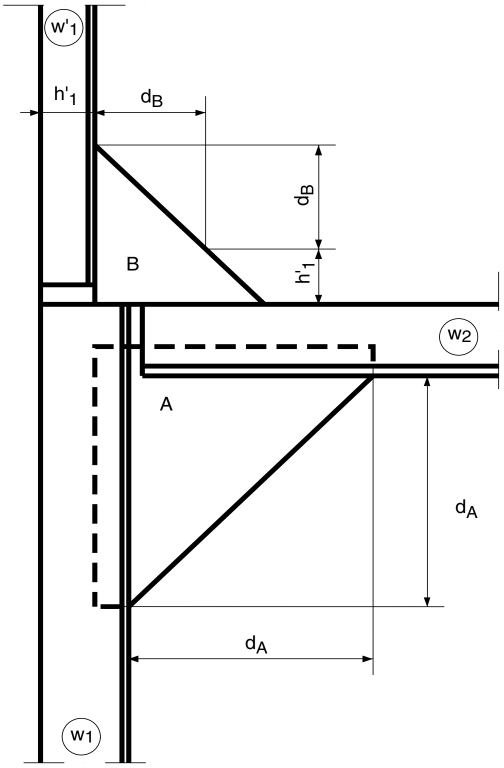
  $w_A = w_2$ if $w_2 > w_1$

- for bracket "B":

  $w_B = w'_1$ need not be greater than w_1

where w_1 , w'_1 and w_2 are the required net section moduli of stiffeners, as shown in Fig 3.

Figure 3 : Connections of frames to deck beams



6.3 Lower brackets of frames

6.3.1 In general, frames are to be bracketed to the inner bottom or to the face plate of floors as shown in Fig 4.

6.3.2 The arm lengths d_1 and d_2 of lower brackets of frames are to be not less than the value obtained, in mm, from the following formula:

$$d = \varphi\sqrt{\frac{w+30}{t}}$$

where:

φ : coefficient equal to:
- for unflanged brackets:
  $\varphi = 50$
- for flanged brackets:
  $\varphi = 45$

w : required net section modulus of the frame, in cm^3,

t : Bracket net thickness, in mm.

6.3.3 Where the bracket net thickness, in mm, is less than $15L_b$, where L_b is the length, in m, of the bracket free edge, the free edge of the bracket is to be flanged or stiffened by a welded face plate.

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

7 Openings in the shell plating

7.1 Position of openings

7.1.1 Openings in the shell plating are to be located at a vertical distance from the decks at side not less than:

- two times the opening diameter, in case of circular opening
- the opening minor axis, in case of elliptical openings.

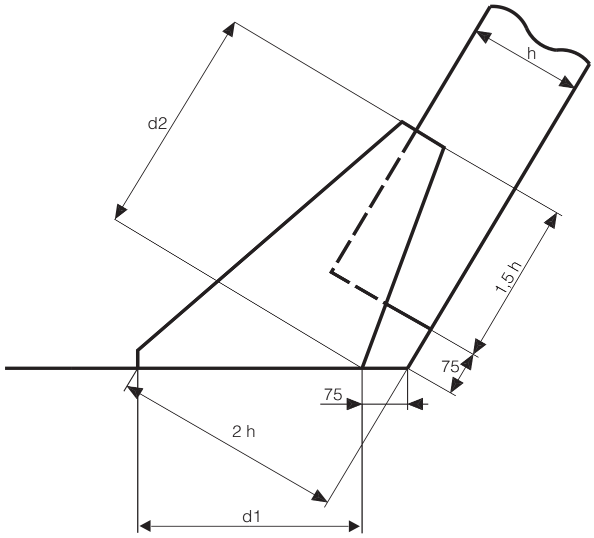
See also Sec 6, Fig 1.

7.2 Local strengthening

7.2.1 Openings in the ship sides, e.g. for cargo ports, are to be well rounded at the corners and located well clear of superstructure ends or any openings in the deck areas at sides of hatchways.

7.2.2 Openings for sea intakes are to be well rounded at the corners and, within 0,6 L amidships, located outside the bilge strakes. Where arrangements are such that sea intakes are unavoidably located in the curved zone of the bilge strakes, such openings are to be elliptical with the major axis in the longitudinal direction. Openings for stabiliser fins are considered by the Society on a case by case basis. The thickness of sea chests is generally to be that of the local shell plating, but in no case less than 12 mm.

Figure 4 : Lower brackets of main frames



7.2.3 Openings in [7.2.1] and [7.2.2] and, when deemed necessary by the Society, other openings of considerable size are to be adequately compensated by means of insert plates of increased thickness or doublers sufficiently extended in length. Such compensation is to be partial or total depending on the stresses occurring in the area of the openings.

Circular openings on the sheerstrake need not be compensated where their diameter does not exceed 20% of the sheerstrake minimum width, defined in [1.3], or 380 mm, whichever is the lesser, and where they are located away from openings on deck at the side of hatchways or superstructure ends.

SECTION 6 DECK STRUCTURE

1 General

1.1 Application

1.1.1 The requirements of this Section apply to longitudinally or transversely framed deck structures.

1.2 General arrangement

1.2.1 The deck supporting structure consists of ordinary stiffeners (beams or longitudinals), longitudinally or transversely arranged, supported by primary supporting members which may be sustained by pillars.

1.2.2 Where beams are fitted in a hatched deck, these are to be effectively supported by at least two longitudinal girders located in way of hatch side girders to which they are to be connected by brackets and/or clips.

1.2.3 In ships greater than 120 m in length, the zones outside the line of openings of the strength deck and other decks contributing to longitudinal strength are, in general, to be longitudinally framed.

Where a transverse framing type is adopted for such ships, it is considered by the Society on a case by case basis.

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

- stepped strength decks
- changes in the framing system.

Details of structural arrangements are to be submitted for review to the Society.

1.2.5 Where applicable, deck transverses of reinforced scantlings are to be aligned with floors.

1.2.6 Inside the line of openings, a transverse structure is generally to be adopted for cross-deck structures, beams are to be adequately supported by girders and, in ships greater than 120 m in length, extend up to the second longitudinal from the hatch side girders toward the bulwark.

Where this is impracticable, intercostal stiffeners are to be fitted between the hatch side girder and the second longitudinal.

Other structural arrangements may be accepted, subject to their strength verification. In particular, their buckling strength against the transverse compression loads is to be checked. Where needed, deck transverses may be required to be fitted.

1.2.7 Deck supporting structures under deck machinery, cranes and king posts are to be adequately stiffened.

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

1.2.9 Special arrangements, such as girders supported by cantilevers, are considered by the Society on a case by case basis.

1.2.10 Where devices for vehicle lashing arrangements and/or corner fittings for containers are directly attached to deck plating, provision is to be made for the fitting of suitable additional reinforcements of the sizes required by the load carried.

1.2.11 Stiffeners are also to be fitted in way of the ends and corners of deck houses and partial superstructures.

1.3 Construction of watertight decks

1.3.1 Watertight decks are to be of the same strength as watertight bulkheads at corresponding levels. The means used for making them watertight, and the arrangements adopted for closing openings in them, are to be to the satisfaction of the Society.

1.4 Stringer plate

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

$$b = 0{,}35 + 0{,}5\frac{L}{100}$$

However, the stringer plate is also to comply with the requirements in Sec 1, [2.5.5].

1.4.2 Stringer plates of lower decks not extending over the full ship's length are to be gradually tapered or overlapped by adequately sized brackets.

2 Longitudinally framed deck

2.1 General

2.1.1 Deck longitudinals are to be continuous, as far as practicable, in way of deck transverses and transverse bulkheads.

Other arrangements may be considered, provided adequate continuity of longitudinal strength is ensured.

2.1.2 In general, the spacing of deck transverses is not to exceed 5 frame spacings.

2.2 Longitudinal ordinary stiffeners

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

2.2.2 Frame brackets, in ships with transversely framed sides, are generally to have their horizontal arm extended to the adjacent longitudinal ordinary stiffener.

3 Transversely framed deck

3.1 General

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

4 Pillars

4.1 General

4.1.1 Pillars are to be fitted, as far as practicable, in the same vertical line.

4.1.2 In general, pillars are to be fitted below winches, cranes, windlasses and steering gear, in the engine room and at the corners of deckhouses.

4.1.3 In tanks, solid or open section pillars are generally to be fitted. Pillars located in spaces intended for products which may produce explosive gases are to be of open section type.

4.1.4 Tight or non-tight bulkheads may be considered as pillars, provided that their arrangement complies with Sec 7, [4].

4.2 Connections

4.2.1 Heads and heels of pillars are to be attached to the surrounding structure by means of brackets, insert plates so that the loads are well distributed.

Insert plates may be replaced by doubling plates, except in the case of pillars which may also work under tension such as those in tanks.

In general, the net thickness of doubling plates is to be not less than 1,5 times the net thickness of the pillar.

4.2.2 Pillars are to be attached at their heads and heels by continuous welding.

4.2.3 Pillars are to be connected to the inner bottom at the intersection of girders and floors.

4.2.4 Where pillars connected to the inner bottom are not located in way of intersections of floors and girders, partial floors or girders or equivalent structures suitable to support the pillars are to be arranged.

4.2.5 Manholes may not be cut in the girders and floors below the heels of pillars.

4.2.6 Where pillars are fitted in tanks, head and heel brackets may be required if tensile stresses are expected.

4.2.7 Where side pillars are not fitted in way of hatch ends, vertical stiffeners of bulkheads supporting hatch side girders or hatch end beams are to be bracketed at their ends.

5 Hatch supporting structures

5.1 General

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

In general, hatched end beams and deck transverses are to be in line with bottom and side transverse structures, so as to form a reinforced ring.

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

5.1.3 The details of connection of deck transverses to longitudinal girders and web frames are to be submitted to the Society for approval.

6 Openings in the strength deck

6.1 Position of openings and local strengthening

6.1.1 Openings in the strength deck are to be kept to a minimum and spaced as far apart from one another and from breaks of effective superstructures as practicable. Openings are generally to be cut outside the hatched areas; in particular, they are to be cut as far as practicable from hatchway corners.

The dashed areas in Fig 1 are those where openings are generally to be avoided. The meaning of the symbols in Fig 1 is as follows:

c, e : Longitudinal and transverse dimensions of hatched area:

$c = 0,07\ \ell + 0,10\ b$ without being less than 0,25 b,

$e = 0,25\ (B - b)$

a : Transverse dimension of openings

g : Transverse dimension of the area where openings are generally to be avoided in way of the connection between deck and side (as shown in Fig 1), deck and longitudinal bulkheads, deck and large deck girders:

- in the case of circular openings:

  $g = 2\ a$

- in the case of elliptical openings:

  $g = a$

6.1.2 No compensation is required where the openings are:

- circular of less than 350 mm in diameter and at a distance from any other opening in compliance with Fig 2
- elliptical with the major axis in the longitudinal direction and the ratio of the major to minor axis not less than 2.

Figure 1 : Position of openings in the strength deck

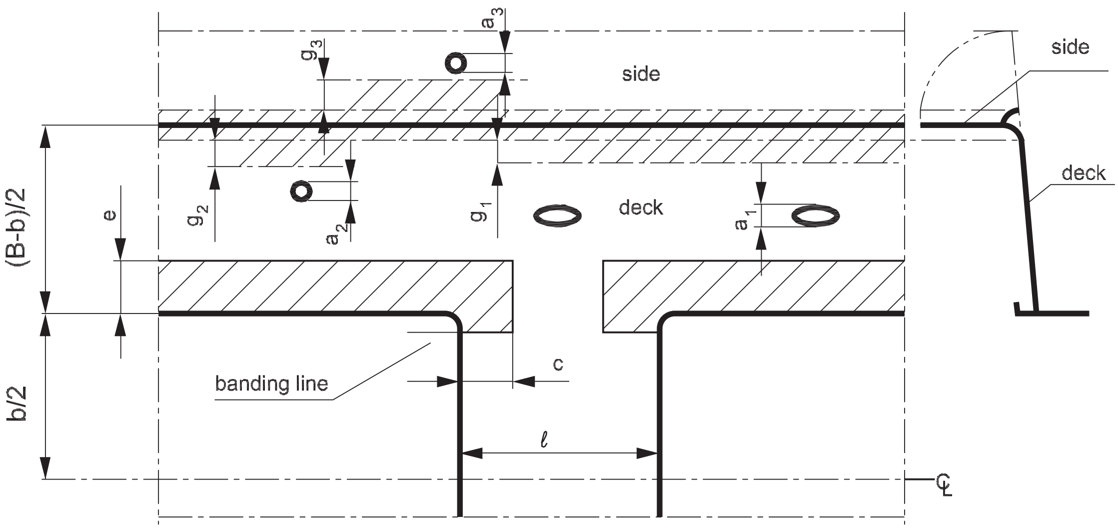
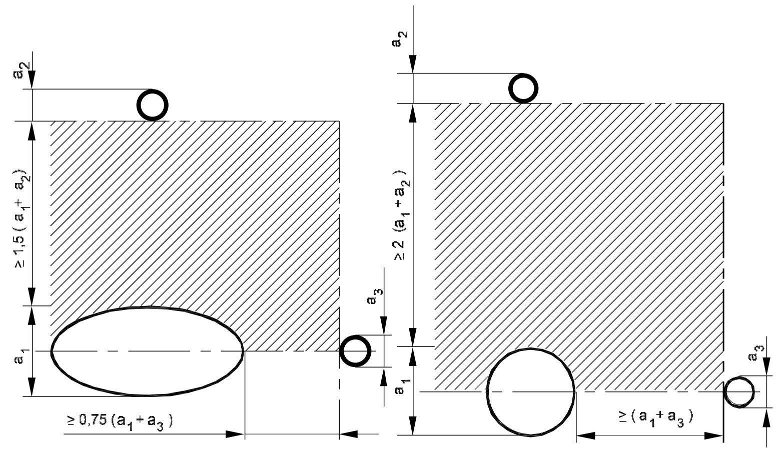


Figure 2 : Circular openings in the strength deck



6.2 Corners of hatchways

6.2.1 For hatchways located within the cargo area, insert plates, whose thickness is to be determined according to [6.2.3], are generally to be fitted in way of corners where the plating cut-out has a circular profile.

The radius of circular corners is to be not less than:

- 5% of the hatch width, where a continuous longitudinal deck girder is fitted below the hatch coaming
- 8% of the hatch width, where no continuous longitudinal deck girder is fitted below the hatch coaming.

Corner radiusing, in the case of the arrangement of two or more hatchways athwartship, is considered by the Society on a case by case basis.

6.2.2 For hatchways located in the positions specified in [6.2.1], insert plates are, in general, not required in way of corners where the plating cut-out has an elliptical or parabolic profile and the half axes of elliptical openings, or the half lengths of the parabolic arch, are not less than:

- 1/20 of the hatchway width or 600 mm, whichever is the lesser, in the transverse direction
- twice the transverse dimension, in the fore and aft direction.

6.2.3 Where insert plates are required, their thickness is obtained, in mm, from the following formula:

$$t_{INS} = \left(0,8 + 0,4\frac{\ell}{b}\right)t$$

without being taken less than t or greater than 1,6t

where:

ℓ : Width, in m, in way of the corner considered, of the cross deck strip between two consecutive hatchways, measured in the longitudinal direction (see Fig 1)

b : Width, in m, of the hatchway considered, measured in the transverse direction (see Fig 1)

t : Actual thickness, in mm, of the deck at the side of the hatchways.

For the extreme corners of end hatchways, the thickness of insert plates is to be 60% greater than the actual thickness of the adjacent deck plating. A lower thickness may be accepted by the Society on the basis of calculations showing that stresses at hatch corners are lower than pemissible values.

6.2.4 Where insert plates are required, the arrangement shown in Sheet 10.1 of Ch 12, App 1 is to be complied with.

6.2.5 For hatchways located in positions other than those in [6.2.1], a reduction in the thickness of the insert plates in way of corners may be considered by the Society on a case by case basis.

7 Openings in decks other than the strength deck

7.1 General

7.1.1 The requirements for such openings are similar to those in [6.1] for the strength deck. However, circular openings need not to be compensated.

7.1.2 Corners of hatchway openings are to be rounded, as specified in [6.2] for the strength deck; insert plates may be omitted, however, when deemed acceptable by the Society.

SECTION 7 BULKHEAD STRUCTURE

1 General

1.1 Application

1.1.1 The requirements of this Section apply to longitudinal or transverse bulkhead structures which may be plane or corrugated.

1.1.2 Bulkheads may be horizontally or vertically stiffened.

Horizontally framed bulkheads consist of horizontal ordinary stiffeners supported by vertical primary supporting members.

Vertically framed bulkheads consist of vertical ordinary stiffeners which may be supported by horizontal girders.

1.2 General arrangement

1.2.1 The number and location of watertight bulkheads are to be in accordance with the relevant requirements given in Ch 2, Sec 1.

1.2.2 For ships greater than 180 m in length, longitudinal corrugated bulkheads are to have horizontal corrugations and the upper and lower strakes of longitudinal corrugated bulkheads are to be plane up to a distance of at least 0,1D from deck and bottom.

Transverse corrugated bulkheads having horizontal corrugations are to be fitted with vertical primary supporting members of number and size sufficient to ensure the required vertical stiffness of the bulkhead.

1.2.3 Where an inner bottom terminates on a bulkhead, the lowest strake of the bulkhead forming the watertight floor of the double bottom is to extend at least 300 mm above the inner bottom.

1.2.4 Longitudinal bulkheads are to terminate at transverse bulkheads and are to be effectively tapered to the adjoining structure at the ends and adequately extended in the machinery space, where applicable.

1.2.5 Where the longitudinal watertight bulkheads contribute to longitudinal strength, the plating thickness is to be uniform for a distance of at least 0,1D from the deck and bottom.

1.2.6 The structural continuity of the bulkhead vertical and horizontal primary supporting members with the surrounding supporting structures is to be carefully ensured.

1.2.7 The height of vertical primary supporting members of longitudinal bulkheads may be gradually tapered from bottom to deck. The maximum acceptable taper, however, is 8 cm per metre.

1.3 Watertight bulkheads of trunks, tunnels, etc.

1.3.1 Watertight trunks, tunnels, duct keels and ventilators are to be of the same strength as watertight bulkheads at corresponding levels. The means used for making them watertight, and the arrangements adopted for closing openings in them, are to be to the satisfaction of the Society.

1.4 Openings in watertight bulkheads

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

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

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

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

1.5 Watertight doors

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

1.5.2 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.

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

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

1.5.4 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 Plane bulkheads

2.1 General

2.1.1 Where a bulkhead does not extend up to the uppermost continuous deck (such as the after peak bulkhead), suitable strengthening is to be provided in the extension of the bulkhead.

2.1.2 Bulkheads are to be stiffened in way of deck girders.

2.1.3 The stiffener webs of hopper and topside tank watertight bulkheads are generally to be aligned with the webs of inner hull longitudinal stiffeners.

2.1.4 Plate floors are to be fitted in the double bottom in way of plane transverse bulkheads.

2.1.5 A doubling plate of the same net thickness as the bulkhead plating is to be fitted on the after peak bulkhead in way of the sterntube, unless the net thickness of the bulkhead plating is increased by at least 60%.

2.2 End connections of ordinary stiffeners

2.2.1 In general, end connections of ordinary stiffeners are to be bracketed (see [2.3]). However, stiffeners of watertight bulkheads in upper 'tweendecks may be sniped, provided the scantlings of such stiffeners are modified accordingly.

2.2.2 Where hull lines do not enable compliance with the requirements of [2.2.1], sniped ends may be accepted, provided the scantlings of stiffeners are modified accordingly.

2.2.3 Where sniped ordinary stiffeners are fitted, the snipe angle is to be not greater than 30° and their ends are to be extended, as far as practicable, to the boundary of the bulkhead.

2.3 Bracketed ordinary stiffeners

2.3.1 Where bracketed ordinary stiffeners are fitted, the arm lengths of end brackets of ordinary stiffeners, as shown in Fig 1 and Fig 2, are to be not less than the following values, in mm:

- for arm length a:
  - brackets of horizontal stiffeners and bottom bracket of vertical stiffeners:

    $a = 100\ell$
  - upper bracket of vertical stiffeners:

    $a = 80\ell$
- for arm length b, the greater of:

$$b = 80\sqrt{\frac{w + 20}{t}}$$

$$b = \alpha\frac{ps\ell}{t}$$

where:

ℓ : Span, in m, of the stiffener measured between supports

w : Net section modulus, in cm³, of the stiffener

t : Net thickness, in mm, of the bracket

p : Design pressure, in kN/m², calculated at mid-span

α : Coefficient equal to:

$\alpha = 4,9$ for tank bulkheads

$\alpha = 3,6$ for watertight bulkheads.

Figure 1 : Bracket at upper end of ordinary stiffener on plane bulkhead

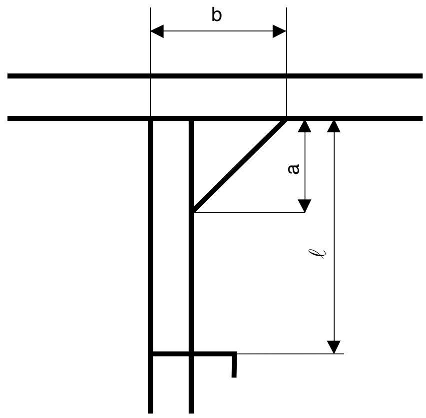
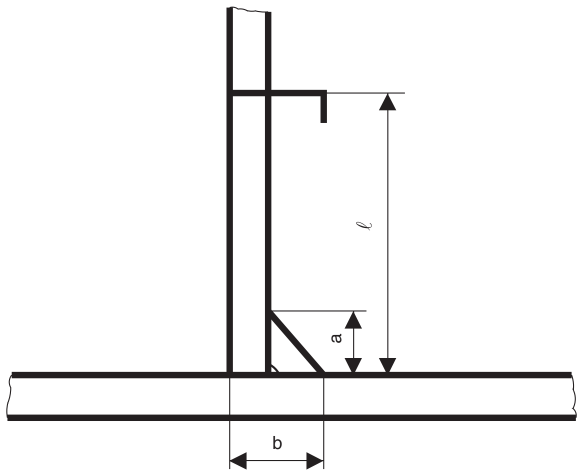


Figure 2 : Bracket at lower end of ordinary stiffener on plane bulkhead



2.3.2 The connection between the stiffener and the bracket is to be such that the net section modulus of the connection is not less than that of the stiffener.

3 Corrugated bulkheads

3.1 General

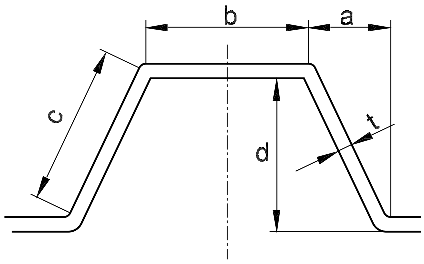
3.1.1 The main dimensions a, b, c and d of corrugated bulkheads are defined in Fig 3.

3.1.2 Unless otherwise specified, the following requirement is to be complied with:

$a \leq 1,2d$

Moreover, in some cases, the Society may prescribe an upper limit for the ratio b/t.

Figure 3 : Corrugated bulkhead



3.1.3 In general, the bending internal radius is to be not less than the following values, in mm:

- for normal strength steel:

  $R_i = 2,5\ t$
- for high tensile steel:

  $R_i = 3,0\ t$

where t is the net thickness, in mm, of the corrugated plate.

3.1.4 When 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.

Moreover, when the gross thickness of the bulkhead plating is greater than 20 mm, the Society may require the use of steel grade E or EH.

3.1.5 In general, where girders or vertical primary supporting members are fitted on corrugated bulkheads, they are to be arranged symmetrically.

3.2 Structural arrangement

3.2.1 The strength continuity of corrugated bulkheads is to be ensured at ends of corrugations.

3.2.2 Where corrugated bulkheads are cut in way of primary members, attention is to be paid to ensure correct alignment of corrugations on each side of the primary member.

3.2.3 In general, where vertically corrugated transverse bulkheads are welded on the inner bottom, plate floors are to be fitted in way of the flanges of corrugations.

However, other arrangements ensuring adequate structural continuity may be accepted by the Society.

3.2.4 In general, where vertically corrugated longitudinal bulkheads are welded on the inner bottom, girders are to be fitted in way of the flanges of corrugations.

However, other arrangements ensuring adequate structural continuity may be accepted by the Society.

3.2.5 In general, the upper and lower parts of horizontally corrugated bulkheads are to be flat over a depth equal to 0,1D.

3.2.6 Where stools are fitted at the lower part of transverse bulkheads, the net thickness of adjacent plate floors is to be not less than that of the stool plating.

3.3 Bulkhead stool

3.3.1 In general, plate diaphragms or web frames are to be fitted in bottom stools in way of the double bottom longitudinal girders or plate floors, as the case may be.

3.3.2 Brackets or deep webs are to be fitted to connect the upper stool to the deck transverses or hatch end beams, as the case may be.

3.3.3 The continuity of the corrugated bulkhead with the stool plating is to be adequately ensured. In particular, the upper strake of the lower stool is to be of the same net thickness and yield stress as those of the lower strake of the bulkhead.

4 Non-tight bulkheads

4.1 Non-tight bulkheads not acting as pillars

4.1.1 Non-tight bulkheads not acting as pillars are to be provided with vertical stiffeners with a maximum spacing equal to:

- 0,9 m, for transverse bulkheads
- two frame spacings, with a maximum of 1,5 m, for longitudinal bulkheads.

4.2 Non-tight bulkheads acting as pillars

4.2.1 Non-tight bulkheads acting as pillars are to be provided with vertical stiffeners with a maximum spacing equal to:

- two frame spacings, when the frame spacing does not exceed 0,75 m,
- one frame spacing, when the frame spacing is greater than 0,75 m.

4.2.2 Each vertical stiffener, in association with a width of plating equal to 35 times the plating net thickness, is to comply with the applicable requirements for pillars in Ch 7, Sec 3, the load supported being determined in accordance with the same requirements.

4.2.3 In the case of non-tight bulkheads supporting longitudinally framed decks, vertical girders are to be provided in way of deck transverses.

5 Wash bulkheads

5.1 General

5.1.1 The requirements in [5.2] apply to transverse and longitudinal wash bulkheads whose main purpose is to reduce the liquid motions in partly filled tanks.

5.2 Openings

5.2.1 The total area of openings in a transverse wash bulkhead is generally to be between 10% and 30% of the total bulkhead area.

In the upper, central and lower portions of the bulkhead (the depth of each portion being 1/3 of the bulkhead height), the areas of openings, expressed as percentages of the corresponding areas of these portions, are to be within the limits given in Tab 1.

5.2.2 In any case, the distribution of openings is to fulfil the strength requirements specified in [4.2].

5.2.3 In general, openings may not be cut within 0,15D from bottom and from deck.

Table 1 : Areas of openings in transverse wash bulkheads

Bulkhead portion	Lower limit	Upper limit
Upper	10 %	15 %
Central	10 %	50 %
Lower	2 %	10 %

Part B
Hull and Stability

Chapter 5
DESIGN LOADS

Symbols used in chapter 5

n, n_1 : Navigation coefficients, defined in Pt B, Ch 5, Sec 1, [2.6],

F : Froude's number:

$$F = 0{,}164\frac{V}{\sqrt{L}}$$

V : Maximum ahead service speed, in knots,

T_1 : Draught, in m, defined in Pt B, Ch 5, Sec 1, [2.4.3] or Pt B, Ch 5, Sec 1, [2.5.3], as the case may be,

g : Gravity acceleration, in m/s^2:

$g = 9{,}81\ m/s^2$,

x, y, z : X, Y and Z co-ordinates, in m, of the calculation point with respect to the reference co-ordinate system defined in Pt B, Ch 1, Sec 2, [4].

SECTION 1 GENERAL

1 Definitions

1.1 Still water loads

1.1.1 Still water loads are those acting on the ship at rest in calm water.

1.2 Wave loads

1.2.1 Wave loads are those due to wave pressures and ship motions, which can be assumed to have the same period of the inducing waves.

1.3 Dynamic loads

1.3.1 Dynamic loads are those that have a duration much shorter than the period of the inducing waves.

1.4 Local loads

1.4.1 Local loads are pressures and forces which are directly applied to the individual structural members: plating panels, ordinary stiffeners and primary supporting members.

- Still water local loads are constituted by the hydrostatic external sea pressures and the static pressures and forces induced by the weights carried in the ship spaces.
- Wave local loads are constituted by the external sea pressures due to waves and the inertial pressures and forces induced by the ship accelerations applied to the weights carried in the ship spaces.
- Dynamic local loads are constituted by the impact and sloshing pressures.

1.4.2 For the structures which constitute the boundary of spaces not intended to carry liquids and which do not belong to the outer shell, the still water and wave pressures in flooding conditions are also to be considered.

1.5 Hull girder loads

1.5.1 Hull girder loads are (still water, wave and dynamic) forces and moments which result as effects of local loads acting on the ship as a whole and considered as a girder.

1.6 Loading condition

1.6.1 A loading condition is a distribution of weights carried in the ship spaces arranged for their storage.

1.7 Load case

1.7.1 A load case is a state of the ship structures subjected to a combination of hull girder and local loads.

2 Application criteria

2.1 Fields of application

2.1.1 Requirements applicable to all types of ships

The still water, wave induced and dynamic loads defined in this Chapter are to be used for the determination of the hull girder strength and structural scantlings in the central part (see Ch 1, Sec 1) of ships equal to or greater than 90 m in length, according to the requirements in Chapter 6 and Chapter 7.

The design loads to be used for the determination of the hull girder strength and structural scantlings in the central part (see Ch 1, Sec 1) of ships less than 90 m in length are specified in Chapter 8.

2.1.2 Requirements applicable to specific ship types

The design loads applicable to specific ship types are to be defined in accordance with the requirements in Part E.

2.1.3 Load direct calculation

As an alternative to the formulae in Sec 2 and Sec 3, the Society may accept the values of wave induced loads and dynamic loads derived from direct calculations, when justified on the basis of the ship's characteristics and intended service. The calculations are to be submitted to the Society for approval.

2.2 Hull girder loads

2.2.1 The still water, wave and dynamic hull girder loads to be used for the determination of:

- the hull girder strength, according to the requirements of Chapter 6, and
- the structural scantling of plating, ordinary stiffeners and primary supporting members contributing to the hull girder strength, in combination with the local loads given in Sec 5 and Sec 6, according to the requirements in Chapter 7,

are specified in 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 Sec 4.

Dynamic loads are to be taken into account and calculated according to the criteria specified in Sec 5 and Sec 6.

2.3.2 Ship motions and accelerations

The wave local loads are to be calculated on the basis of the reference values of ship motions and accelerations specified in Sec 3.

2.3.3 Calculation and application of local loads

The criteria for calculating:

- still water local loads
- wave local loads on the basis of the reference values of ship motions and accelerations

are specified in Sec 5 for sea pressures and in Sec 6 for internal pressures and forces.

2.3.4 Flooding conditions

The still water and wave pressures in flooding conditions are specified in Sec 6, [9]. The pressures in flooding conditions applicable to specific ship types are to be defined in accordance with the requirements in Part E.

2.4 Load definition criteria to be adopted in structural analyses based on plate or isolated beam structural models

2.4.1 Application

The requirements of this sub-article apply for the definition of local loads to be used in the scantling checks of:

- plating, according to Ch 7, Sec 1
- ordinary stiffeners, according to Ch 7, Sec 2
- primary supporting members for which a three dimensional structural model is not required, according to Ch 7, Sec 3, [3].

2.4.2 Cargo and ballast distributions

When calculating the local loads for the structural scantling of an element which separates two adjacent compartments, the latter may not be considered simultaneously loaded. The local loads to be used are those obtained considering the two compartments individually loaded.

For elements of the outer shell, the local loads are to be calculated considering separately:

- the still water and wave external sea pressures, considered as acting alone without any counteraction from the ship interior
- the still water and wave differential pressures (internal pressure minus external sea pressure) considering the compartment adjacent to the outer shell as being loaded.

2.4.3 Draught associated with each cargo and ballast distribution

Local loads are to be calculated on the basis of the ship's draught T_1 corresponding to the cargo or ballast distribution considered according to the criteria in [2.4.2]. The ship draught is to be taken as the distance measured vertically on the hull transverse section at the middle of the length L, from the moulded base line to the waterline in:

- full load condition, when:
  - one or more cargo compartments (e.g. oil tank, dry cargo hold, vehicle space, passenger space) are considered as being loaded and the ballast tanks are considered as being empty
  - the still water and wave external pressures are considered as acting alone without any counteraction from the ship's interior
- light ballast condition, when one or more ballast tanks are considered as being loaded and the cargo compartments are considered as being empty. In the absence of more precise information, the ship's draught in light ballast condition may be obtained, in m, from the following formulae:
  - $T_B = 0{,}03L \leq 7{,}5$ m in general
  - $T_B = 2 + 0{,}02L$ for ships with the service notation **oil tanker ESP**.

2.5 Load definition criteria to be adopted in structural analyses based on three dimensional structural models

2.5.1 Application

The requirements of this sub-article apply for the definition of local loads to be used in the scantling checks of primary supporting members for which a three dimensional structural model is required, according to Ch 7, Sec 3, [4].

2.5.2 Loading conditions

For all ship types for which analyses based on three dimensional models are required according to Ch 7, Sec 3, [4], the most severe loading conditions for the structural elements under investigation are to be considered. These loading conditions are to be selected among those envisaged in the ship loading manual.

Further criteria applicable to specific ship types are specified in Part E.

2.5.3 Draught associated with each loading condition

Local loads are to be calculated on the basis of the ship's draught T_1 corresponding to the loading condition considered according to the criteria in [2.5.2].

2.6 Navigation coefficients

2.6.1 The navigation coefficients, which appear in the formulae of this Chapter for the definition of wave hull girder and local loads, are:

- $n = 0{,}90$
- $n_1 = 0{,}95$.

SECTION 2 HULL GIRDER LOADS

Symbols

For symbols not defined in this Section, refer to the list at the beginning of this Chapter.

C : Wave parameter:

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

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

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

1 General

1.1 Application

1.1.1 The requirements of this Section apply to ships having the following characteristics:

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

Ships not having one or more of these characteristics, ships intended for the carriage of heated cargoes and ships of unusual type or design will be considered by the Society on a case by case basis.

1.2 Sign conventions of vertical bending moments and shear forces

1.2.1 The sign conventions of bending moments and shear forces at any ship transverse section are as shown in Fig 1, namely:

- the vertical bending moment M is positive when it induces tensile stresses in the strength deck (hogging bending moment); it is negative in the opposite case (sagging bending moment)
- the vertical shear force Q is positive in the case of downward resulting forces preceding and upward resulting forces following the ship transverse section under consideration; it is negative in the opposite case.

2 Still water loads

2.1 General

2.1.1 Still water load calculation

For all ships, the longitudinal distributions of still water bending moment and shear force are to be calculated, for each of the loading conditions in [2.1.2], on the basis of realistic data related to the amount of cargo, ballast, fuel, lubricating oil and fresh water. Except for docking condition afloat, departure and arrival conditions are to be considered.

Where the amount and disposition of consumables at any intermediate stage of the voyage are considered more severe, calculations for such intermediate conditions are to be performed in addition to those for departure and arrival conditions. Also, where any ballasting and/or deballasting is intended during the voyage, calculations of the intermediate condition just before and just after ballasting and/or deballasting any ballast tank are to be considered and where approved included in the loading manual for guidance.

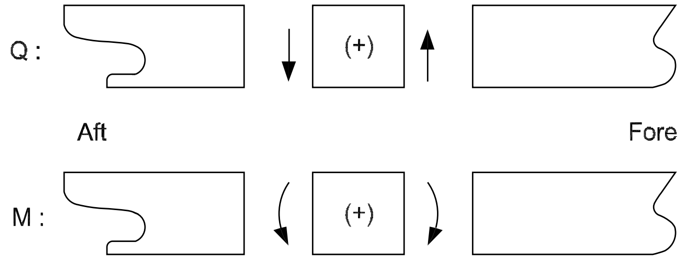
The actual hull lines and lightweight distribution are to be taken into account in the calculations. The lightweight distribution may be replaced, if the actual values are not available, by a statistical distribution of weights accepted by the Society.

The designer is to supply the data necessary to verify the calculations of still water loads.

2.1.2 Loading conditions

Still water loads are to be calculated for all the design loading conditions (cargo and ballast) subdivided into departure and arrival conditions, on which the approval of hull structural scantlings is based.

Figure 1 : Sign conventions for shear forces Q and bending moments M



For all ships, the following loading conditions are to be considered:

a) homogeneous loading conditions at maximum draught

b) ballast conditions. Ballast loading conditions involving partially filled peak and/or other ballast tanks at departure, arrival or during intermediate conditions are not permitted to be used as design conditions unless:

   - The allowable stress limits (defined in Ch 6, Sec 2, [3]) are satisfied for all filling levels between empty and full,
   - To demonstrate compliance with all filling levels between empty and full, it is acceptable if, in each condition at departure, arrival and, where required in [2.1.1], any intermediate condition, the tanks intended to be partially filled are assumed to be:
     - empty
     - full
     - partially filled at the intended level.

     Where multiple tanks are intended to be partially filled, all combinations of empty, full or partially filled at intended level for those tanks are to be investigated.

c) cargo loading conditions. For cargo loading conditions involving partially filled peak and/or other ballast tanks, the requirements specified in b) apply to the peak tanks only

d) sequential ballast water exchange: the requirements specified in b) or c) are not applicable to ballast water exchange using the sequential method

e) special loadings (e.g. light load conditions at less than the maximum draught, deck cargo conditions, etc., where applicable)

f) short voyage or harbour conditions, where applicable

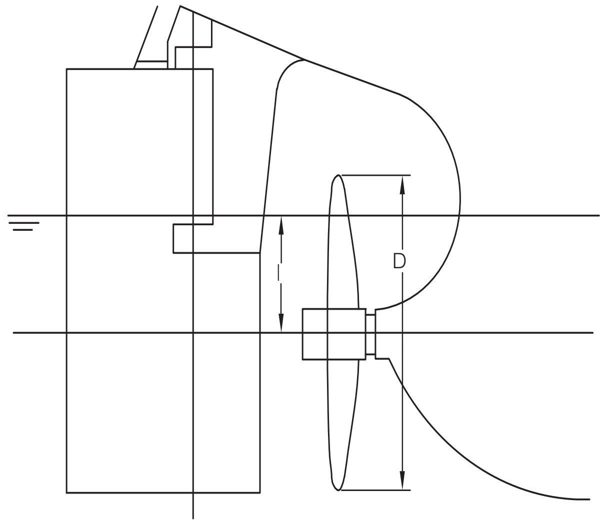
g) loading and unloading transitory conditions, where applicable

h) docking condition afloat

i) ballast exchange at sea, if applicable.

Part E specifies other loading conditions which are to be considered depending on the ship type.

Figure 2 : Propeller immersion and diameter



2.2 Still water bending moments

2.2.1 The design still water bending moments $M_{SW,H}$ and $M_{SW,S}$ at any hull transverse section are the maximum still water bending moments calculated, in hogging and sagging conditions, respectively, at that hull transverse section for the loading conditions specified in [2.1.2].

Where no sagging bending moments act in the hull section considered, the value of $M_{SW,S}$ is to be taken as specified in Chapter 6 and Chapter 7.

2.2.2 If the design still water bending moments are not defined, at a preliminary design stage, at any hull transverse section, the longitudinal distributions shown in:

- Fig 3, for ships with the service notation **oil tanker ESP**, or
- Fig 4, for other ship types,

may be considered.

In Fig 3 and Fig 4, M_{SW} is the design still water bending moment amidships, in hogging or sagging conditions, whose absolute values are to be taken not less than those obtained, in kN.m, from the following formulae:

- hogging conditions:

$$M_{SWM,H} = 175 n_1 C L^2 B (C_B + 0{,}7) 10^{-3} - M_{WV,H}$$

- sagging conditions:

$$M_{SWM,S} = 175 n_1 C L^2 B (C_B + 0{,}7) 10^{-3} + M_{WV,S}$$

where $M_{WV,H}$, $M_{WV,S}$ are the vertical wave bending moments, in kN.m, defined in [3.1].

Figure 3 : Preliminary still water bending moment distribution for oil tankers

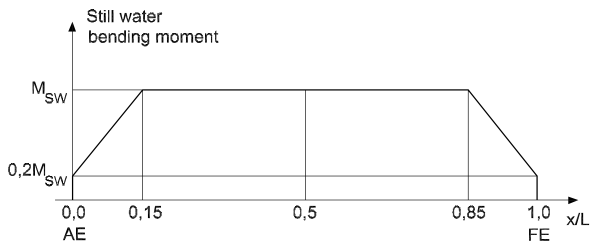
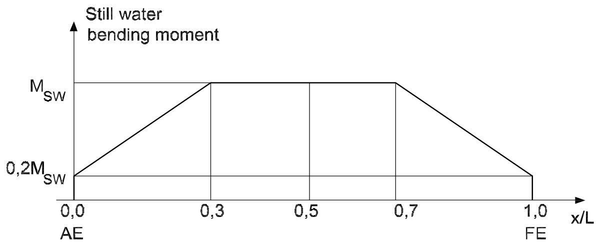


Figure 4 : Preliminary still water bending moment distribution for other ship types



2.3 Still water shear force

2.3.1 The design still water shear force Q_{SW} at any hull transverse section is the maximum positive or negative shear force calculated, at that hull transverse section, for the loading conditions specified in [2.1.2].

3 Wave loads

3.1 Vertical wave bending moments

3.1.1 The vertical wave bending moments at any hull transverse section are obtained, in kN.m, from the following formulae:

- hogging conditions:

$$M_{WV,H} = 190 F_M n C L^2 B C_B 10^{-3}$$

- sagging conditions:

$$M_{WV,S} = -110 F_M n C L^2 B (C_B + 0,7) 10^{-3}$$

where:

F_M : Distribution factor defined in Tab 1 (see also Fig 5).

3.1.2 The effects of bow flare impact are to be taken into account, for the cases specified in [4.1.1], according to [4.2.1].

3.2 Horizontal wave bending moment

3.2.1 The horizontal wave bending moment at any hull transverse section is obtained, in kN.m, from the following formula:

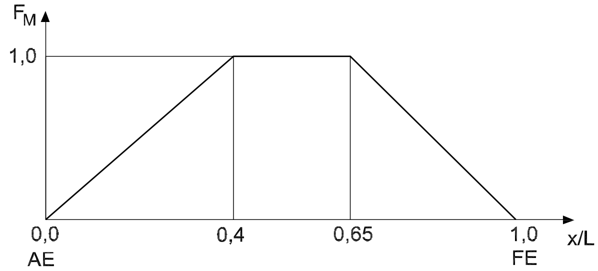
$$M_{WH} = 1,6 F_M n L^{2,1} T C_B$$

where F_M is the distribution factor defined in [3.1.1].

Table 1 : Distribution factor F_M

Hull transverse section location	Distribution factor F_M
$0 \le x < 0,4L$	$2,5\frac{x}{L}$
$0,4L \le x \le 0,65L$	1
$0,65L < x \le L$	$2,86\left(1 - \frac{x}{L}\right)$

Figure 5 : Distribution factor F_M



3.3 Wave torque

3.3.1 The wave torque at any hull transverse section is to be calculated considering the ship in two different conditions:

- condition 1: ship direction forming an angle of 60° with the prevailing sea direction
- condition 2: ship direction forming an angle of 120° with the prevailing sea direction.

The values of the wave torques in these conditions, calculated with respect to the section centre of torsion, are obtained, in kN.m, from the following formula:

$$M_{WT} = \frac{HL}{4} n (F_{TM} C_M + F_{TQ} C_Q d)$$

where:

H : Wave parameter:

$$H = 8,13 - \left(\frac{250 - 0,7L}{125}\right)^3$$

without being taken greater than 8,13

F_{TM}, F_{TQ} : Distribution factors defined in Tab 2 for ship conditions 1 and 2 (see also Fig 6 and Fig 7)

C_M : Wave torque coefficient:

$$C_M = 0,38 B^2 C_W^2$$

C_Q : Horizontal wave shear coefficient:

$$C_Q = 2,8 T C_B$$

C_W : Waterplane coefficient, to be taken not greater than the value obtained from the following formula:

$$C_W = 0,165 + 0,95 C_B$$

where C_B is to be assumed not less than 0,6. In the absence of more precise determination, C_W may be taken equal to the value provided by the above formula.

d : Vertical distance, in m, from the centre of torsion to a point located 0,6T above the baseline.

Table 2 : Distribution factors F_{TM} and F_{TQ}

Ship condition	Distribution factor F_{TM}	Distribution factor F_{TQ}
1	$1 - \cos\frac{2\pi x}{L}$	$\sin\frac{2\pi x}{L}$
2	$1 - \cos\frac{2\pi(L-x)}{L}$	$\sin\frac{2\pi(L-x)}{L}$

Figure 6 : Ship condition 1 - Distribution factors F_{TM} and F_{TQ}

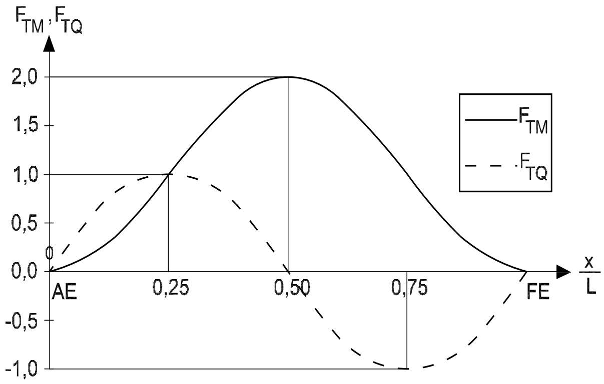
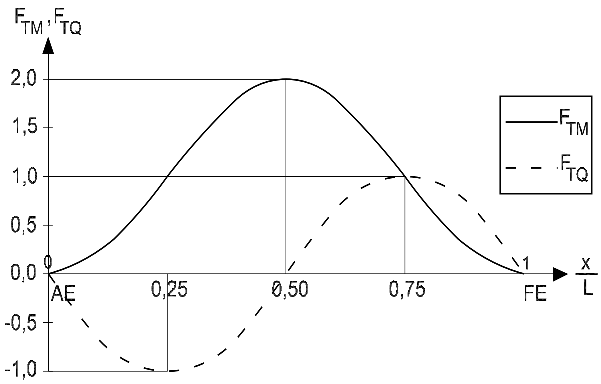


Figure 7 : Ship condition 2 - Distribution factors F_{TM} and F_{TQ}



3.4 Vertical wave shear force

3.4.1 The vertical wave shear force at any hull transverse section is obtained, in kN, from the following formula:

$$Q_{WV} = 30F_QnCLB(C_B + 0{,}7)10^{-2}$$

where:

F_Q : Distribution factor defined in Tab 3 for positive and negative shear forces (see also Fig 8).

4 Dynamic loads due to bow flare impact

4.1 Application

4.1.1 The effects of bow flare impact are to be considered where all the following conditions occur:

- 120 m ≤ L ≤ 180 m
- V ≥ 17,5 knots
- $\frac{100FA_S}{LB} > 1$

where:

A_S : Twice the shaded area shown in Fig 9, which is to be obtained, in m², from the following formula:

$$A_S = ba_0 + 0{,}1L(a_0 + 2a_1 + a_2)$$

b, a_0, a_1, a_2:Distances, in m, shown in Fig 9.

For multideck ships, the upper deck shown in Fig 9 is to be taken as the deck (including superstructures) which extends up to the extreme forward end of the ship and has the largest breadth forward of 0,2L from the fore end.

Figure 8 : Distribution factor F_Q

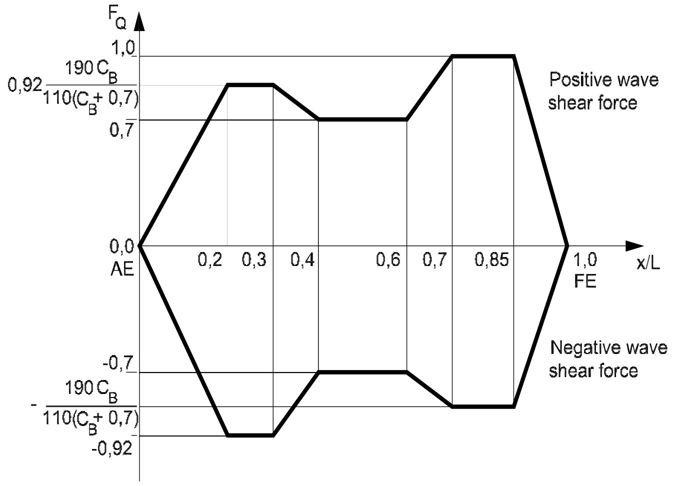


Table 3 : Distribution factor F_Q

Hull transverse section location	Distribution factor F_Q	
	Positive wave shear force	Negative wave shear force
$0 \le x < 0{,}2L$	$4{,}6A\frac{x}{L}$	$-4{,}6\frac{x}{L}$
$0{,}2L \le x \le 0{,}3L$	$0{,}92A$	$-0{,}92$
$0{,}3L < x < 0{,}4L$	$(9{,}2A-7)\left(0{,}4-\frac{x}{L}\right)+0{,}7$	$-2{,}2\left(0{,}4-\frac{x}{L}\right)-0{,}7$
$0{,}4L \le x \le 0{,}6L$	$0{,}7$	$-0{,}7$
$0{,}6L < x < 0{,}7L$	$3\left(\frac{x}{L}-0{,}6\right)+0{,}7$	$-(10A-7)\left(\frac{x}{L}-0{,}6\right)-0{,}7$
$0{,}7L \le x \le 0{,}85L$	1	$-A$
$0{,}85L < x \le L$	$6{,}67\left(1-\frac{x}{L}\right)$	$-6{,}67A\left(1-\frac{x}{L}\right)$

Note 1:

$$A = \frac{190C_B}{110(C_B+0{,}7)}$$

4.1.2 When the effects of bow flare impact are to be considered, according to [4.1.1], the sagging wave bending moment is to be increased as specified in [4.2.1] and [4.2.2].

4.1.3 The Society may require the effects of bow flare impact to be considered also when one of the conditions in [4.1.1] does not occur, if deemed necessary on the basis of the ship's characteristics and intended service.

In such cases, the increase in sagging wave bending moment is defined on a case by case basis.

4.2 Increase in sagging wave bending moment

4.2.1 General

The sagging wave bending moment at any hull transverse section, defined in [3.1], is to be multiplied by the coefficient F_D obtained from the formulae in Tab 4, which takes into account the dynamic effects of bow flare impact.

Where at least one of the conditions in [4.1.1] does not occur, the coefficient F_D may be taken equal to 1.

4.2.2 Direct calculations

As an alternative to the formulae in [4.2.1], the Society may accept the evaluation of the effects of bow flare impact from direct calculations, when justified on the basis of the ship's characteristics and intended service. The calculations are to be submitted to the Society for approval.

Table 4 : Coefficient F_D

Hull transverse section location	Coefficient F_D
$0 \le x < 0,4L$	1
$0,4L \le x < 0,5L$	$1 + 10(C_D - 1)\left(\frac{x}{L} - 0,4\right)$
$0,5L \le x \le L$	C_D

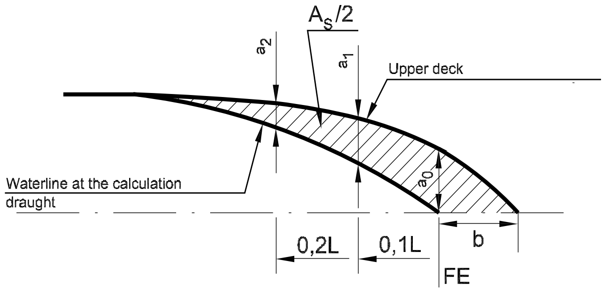
Note 1:

$$C_D = 262,5\frac{A_S}{CLB(C_B + 0,7)} - 0,6$$

without being taken greater than 1,2

A_S : Area, in m², defined in [4.1.1].

Figure 9 : Area A_S



SECTION 3 SHIP MOTIONS AND ACCELERATIONS

Symbols

For the symbols not defined in this Section, refer to the list at the beginning of this Chapter.

a_B : Motion and acceleration parameter:

$$a_B = n\left(0,76F + 1,875\frac{h_W}{L}\right)$$

h_W : Wave parameter, in m:

$$h_W = 11,44 - \left|\frac{L-250}{110}\right|^3 \quad \text{for} \quad L < 350 \text{ m}$$

$$h_W = \frac{200}{\sqrt{L}} \quad \text{for} \quad L \geq 350 \text{ m}$$

a_{SU} : Surge acceleration, in m/s², defined in [2.1]

a_{SW} : Sway acceleration, in m/s², defined in [2.2]

a_H : Heave acceleration, in m/s², defined in [2.3]

α_R : Roll acceleration, in rad/s², defined in [2.4]

α_P : Pitch acceleration, in rad/s², defined in [2.5]

α_Y : Yaw acceleration, in rad/s², defined in [2.6]

T_{SW} : Sway period, in s, defined in [2.2]

T_R : Roll period, in s, defined in [2.4]

T_P : Pitch period, in s, defined in [2.5]

A_R : Roll amplitude, in rad, defined in [2.4]

A_P : Pitch amplitude, in rad, defined in [2.5].

1 General

1.1

1.1.1 Ship motions and accelerations are defined, with their signs, according to the reference co-ordinate system in Ch 1, Sec 2, [4].

1.1.2 Ship motions and accelerations are assumed to be periodic. The motion amplitudes, defined by the formulae in this Section, are half of the crest to through amplitudes.

1.1.3 As an alternative to the formulae in this Section, the Society may accept the values of ship motions and accelerations derived from direct calculations, when justified on the basis of the ship's characteristics and intended service. In general, the values of ship motions and accelerations to be calculated are those which can be reached with a probability of 10^{-5} per cycle. In any case, the calculations, including the assumed sea scatter diagrams and spectra, are to be submitted to the Society for approval.

2 Ship absolute motions and accelerations

2.1 Surge

2.1.1 The surge acceleration a_{SU} is to be taken equal to 0,5 m/s².

2.2 Sway

2.2.1 The sway period and acceleration are obtained from the formulae in Tab 1.

Table 1 : Sway period and acceleration

Period T_{SW}, in s	Acceleration a_{SW}, in m/s²
$\frac{0,8\sqrt{L}}{1,22F+1}$	$0,775\ a_B\ g$

2.3 Heave

2.3.1 The heave acceleration is obtained, in m/s², from the following formula:

$$a_H = a_B g$$

2.4 Roll

2.4.1 The roll amplitude, period and acceleration are obtained from the formulae in Tab 2.

Table 2 : Roll amplitude, period and acceleration

Amplitude A_R, in rad	Period T_R, in s	Acceleration α_R, in rad/s²
$a_B\sqrt{E}$	$2,2\frac{\delta}{\sqrt{GM}}$	$A_R\left(\frac{2\pi}{T_R}\right)^2$

The meaning of symbols in Tab 2 is as follows:

$$E = 1,39\frac{GM}{\delta^2}B \quad \text{to be taken not less than 1,0}$$

GM : Distance, in m, from the ship's centre of gravity to the transverse metacentre, for the loading considered; when GM is not known, the following values may be assumed:

GM = 0,07 B in general

GM = 0,12 B for ships with the service notation **oil tanker ESP**

δ : roll radius of gyration, in m, for the loading considered; when δ is not known, the following values may be assumed:
δ = 0,35 B in general.

2.5 Pitch

2.5.1 The pitch amplitude, period and acceleration are obtained from the formulae in Tab 3.

Table 3 : Pitch amplitude, period and acceleration

Amplitude A_P, in rad	Period T_P, in s	Acceleration α_P, in rad/s²
$0{,}328 a_B\left(1{,}32-\frac{h_W}{L}\right)\left(\frac{0{,}6}{C_B}\right)^{0{,}75}$	$0{,}575\sqrt{L}$	$A_P\left(\frac{2\pi}{T_P}\right)^2$

2.6 Yaw

2.6.1 The yaw acceleration is obtained, in rad/s², from the following formula:

$$\alpha_Y = 1{,}581\frac{a_B g}{L}$$

3 Ship relative motions and accelerations

3.1 Definitions

3.1.1 Ship relative motions

The ship relative motions are the vertical oscillating translations of the sea waterline on the ship side. They are measured, with their sign, from the waterline at draught T_1.

3.1.2 Accelerations

At any point, the accelerations in X, Y and Z direction are the acceleration components which result from the ship motions defined in [2.1] to [2.6].

3.2 Ship conditions

3.2.1 General

Ship relative motions and accelerations are to be calculated considering the ship in the following conditions:

- upright ship condition
- inclined ship condition.

3.2.2 Upright ship condition

In this condition, the ship encounters waves which produce ship motions in the X-Z plane, i.e. surge, heave and pitch.

3.2.3 Inclined ship condition

In this condition, the ship encounters waves which produce ship motions in the X-Y and Y-Z planes, i.e. sway, roll and yaw.

3.3 Ship relative motions

3.3.1 The reference value of the relative motion in the upright ship condition is obtained, at any hull transverse section, from the formulae in Tab 4.

Table 4 : Reference value of the relative motion h_1 in the upright ship condition

Location	Reference value of the relative motion h_1 in the upright ship condition, in m
x = 0	$0{,}7\left(\frac{4{,}35}{\sqrt{C_B}}-3{,}25\right)h_{1,M}$ if $C_B < 0{,}875$ $h_{1,M}$ if $C_B \geq 0{,}875$
0 < x < 0,3L	$h_{1,AE}-\frac{h_{1,AE}-h_{1,M}}{0{,}3}\frac{x}{L}$
0,3L ≤ x ≤ 0,7L	$0{,}42 n C(C_B+0{,}7)$ without being taken greater than D-0,9T
0,7L < x < L	$h_{1,M}+\frac{h_{1,FE}-h_{1,M}}{0{,}3}\left(\frac{x}{L}-0{,}7\right)$
x = L	$\left(\frac{4{,}35}{\sqrt{C_B}}-3{,}25\right)h_{1,M}$

Note 1:
C : Wave parameter defined in Sec 2
$h_{1,AE}$: Reference value h_1 calculated for x = 0
$h_{1,M}$: Reference value h_1 calculated for x = 0,5L
$h_{1,FE}$: Reference value h_1 calculated for x = L

3.3.2 The reference value, in m, of the relative motion in the inclined ship condition is obtained, at any hull transverse section, from the following formula:

$$h_2 = 0{,}5h_1 + A_R\frac{B_W}{2}$$

where:

h_1 : Reference value, in m, of the relative motion in the upright ship, calculated according to [3.3.1]

B_W : Moulded breadth, in m, measured at the waterline at draught T_1 at the hull transverse section considered.

3.4 Accelerations

3.4.1 The reference values of the longitudinal, transverse and vertical accelerations at any point are obtained from the formulae in Tab 5 for upright and inclined ship conditions.

Table 5 : Reference values of the accelerations a_X, a_Y and a_Z

Direction	Upright ship condition	Inclined ship condition
X - Longitudinal a_{X1} and a_{X2} in m/s²	$a_{X1} = \sqrt{a_{SU}^2 + [A_P g + \alpha_p (z - T_1)]^2}$	$a_{x2} = 0$
Y - Transverse a_{Y1} and a_{Y2} in m/s²	$a_{Y1} = 0$	$a_{Y2} = \sqrt{a_{SW}^2 + [A_R g + \alpha_R (z - T_1)]^2 + \alpha_Y^2 K_X L^2}$
Z - Vertical a_{Z1} and a_{Z2} in m/s²	$a_{Z1} = \sqrt{a_H^2 + \alpha_p^2 K_X L^2}$	$a_{Z2} = \alpha_R y$

Note 1:

$K_X = 1{,}2\left(\frac{x}{L}\right)^2 - 1{,}1\frac{x}{L} + 0{,}2$ without being taken less than 0,018

SECTION 4 LOAD CASES

Symbols

h_1 : Reference value of the ship relative motion in the upright ship condition, defined in Sec 3, [3.3]

h_2 : Reference value of the ship relative motion in the inclined ship condition, defined in Sec 3, [3.3]

a_{X1}, a_{Y1}, a_{Z1}: Reference values of the accelerations in the upright ship condition, defined in Sec 3, [3.4]

a_{X2}, a_{Y2}, a_{Z2}: Reference values of the accelerations in the inclined ship condition, defined in Sec 3, [3.4]

M_{WV} : Reference value of the vertical wave bending moment, defined in Sec 2, [3.1]

M_{WH} : Reference value of the horizontal wave bending moment, defined in Sec 2, [3.2]

M_{WT} : Reference value of the wave torque, defined in Sec 2, [3.3]

Q_{WV} : Reference value of the vertical wave shear force, defined in Sec 2, [3.4].

1 General

1.1 Load cases for structural analyses based on partial ship models

1.1.1 The load cases described in this section are those to be used for structural element analyses which do not require complete ship modelling. They are:

- the analyses of plating (see Ch 7, Sec 1)
- the analyses of ordinary stiffeners (see Ch 7, Sec 2)
- the analyses of primary supporting members analysed through isolated beam structural models or three dimensional structural models (see Ch 7, Sec 3)
- the fatigue analysis of the structural details of the above elements (see Ch 7, Sec 4).

1.1.2 These load cases are the mutually exclusive load cases "a", "b", "c" and "d" described in [2].

Load cases "a" and "b" refer to the ship in upright conditions (see Sec 3, [3.2]), i.e. at rest or having surge, heave and pitch motions.

Load cases "c" and "d" refer to the ship in inclined conditions (see Sec 3, [3.2]), i.e. having sway, roll and yaw motions.

1.2 Load cases for structural analyses based on complete ship models

1.2.1 When primary supporting members are to be analysed through complete ship models, according to Ch 7, Sec 3, [1.1.4], specific load cases are to be considered.

These load cases are to be defined considering the ship as sailing in regular waves with different length, height and heading angle, each wave being selected in order to maximise a design load parameter. The procedure for the determination of these load cases is specified in Ch 7, App 3.

2 Load cases

2.1 Upright ship conditions (Load cases "a" and "b")

2.1.1 Ship condition

The ship is considered to encounter a wave which produces (see Fig 1 for load case "a" and Fig 2 for load case "b") a relative motion of the sea waterline (both positive and negative) symmetric on the ship sides and induces wave vertical bending moment and shear force in the hull girder. In load case "b", the wave is also considered to induce heave and pitch motions.

2.1.2 Local loads

The external pressure is obtained by adding to or subtracting from the still water head a wave head corresponding to the relative motion.

The internal loads are the still water loads induced by the weights carried, including those carried on decks. For load case "b", those induced by the accelerations are also to be taken into account.

2.1.3 Hull girder loads

The hull girder loads are:

- the vertical still water bending moment and shear force
- the vertical wave bending moment and the shear force.

Figure 1 : Wave loads in load case “a”

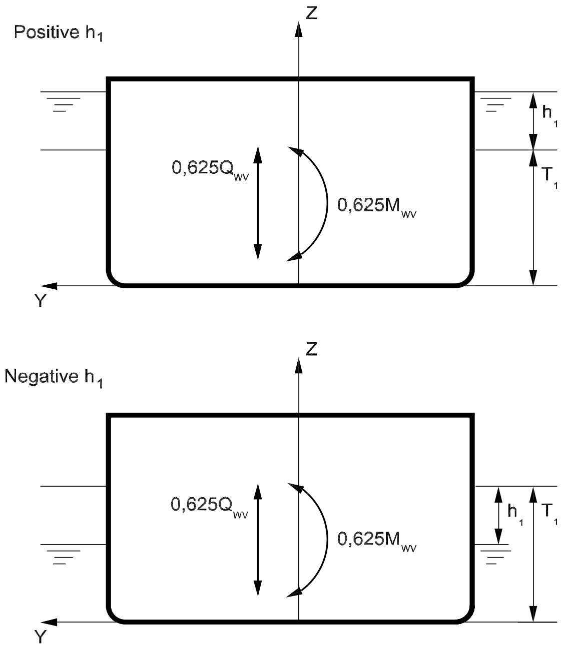
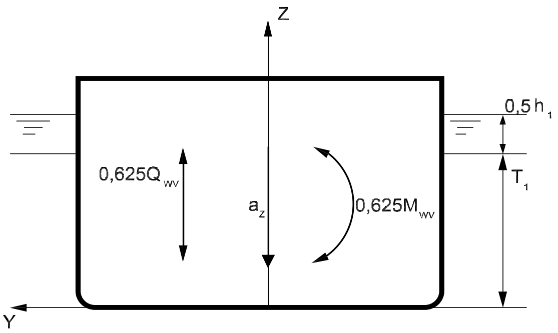


Figure 2 : Wave loads in load case “b”



2.2 Inclined ship conditions (Load cases “c” and “d”)

2.2.1 Ship condition

The ship is considered to encounter a wave which produces (see Fig 3 for load case “c” and Fig 4 for load case “d”):

- sway, roll and yaw motions
- a relative motion of the sea waterline anti-symmetric on the ship sides

and induces:

- vertical wave bending moment and shear force in the hull girder
- horizontal wave bending moment in the hull girder
- in load case “c”, torque in the hull girder.

2.2.2 Local loads

The external pressure is obtained by adding or subtracting from the still water head a wave head linearly variable from positive values on one side of the ship to negative values on the other.

The internal loads are the still water loads induced by the weights carried, including those carried on decks, and the wave loads induced by the accelerations.

Figure 3 : Wave loads in load case “c”

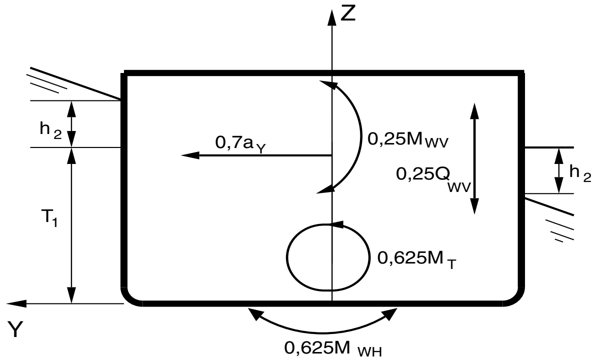
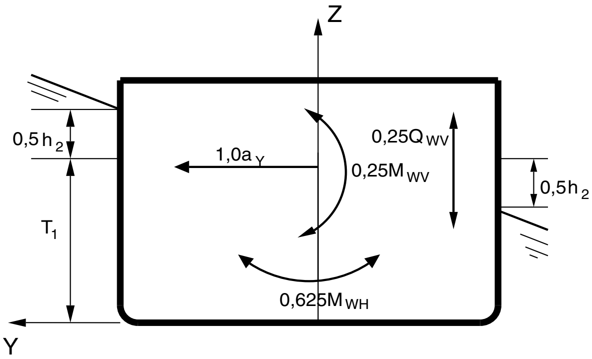


Figure 4 : Wave loads in load case “d”



2.2.3 Hull girder loads

The hull girder loads are:

- the still water bending moment and shear force
- the vertical wave bending moment and shear force
- the horizontal wave bending moment
- the wave torque (for load case “c”).

2.3 Summary of load cases

2.3.1 The wave local and hull girder loads to be considered in each load case are summarised in Tab 1 and Tab 2, respectively.

These loads are obtained by multiplying, for each load case, the reference value of each wave load by the relevant combination factor.

Table 1 : Wave local loads in each load case

Ship condition	Load case	Relative motions		Accelerations a_X, a_Y, a_Z	
		Reference value	Combination factor	Reference value	Combination factor
Upright	"a"	h_1	1,0	a_{X1}; 0; a_{Z1}	0,0
	"b" **(1)**	h_1	0,5	a_{X1}; 0; a_{Z1}	1,0
Inclined	"c" **(2)**	h_2	1,0	0; a_{Y2}; a_{Z2}	0,7
	"d" **(2)**	h_2	0,5	0; a_{Y2}; a_{Z2}	1,0

(1) For a ship moving with a positive heave motion:
- h_1 is positive
- the cargo acceleration a_{X1} is directed towards the positive part of the X axis
- the cargo acceleration a_{Z1} is directed towards the negative part of the Z axis

(2) For a ship rolling with a negative roll angle:
- h_2 is positive for the points located in the positive part of the Y axis and, vice-versa, it is negative for the points located in the negative part of the Y axis
- the cargo acceleration a_{Y2} is directed towards the positive part of the Y axis
- the cargo acceleration a_{Z2} is directed towards the negative part of the Z axis for the points located in the positive part of the Y axis and, vice-versa, it is directed towards the positive part of the Z axis for the points located in the negative part of the Y axis.

Table 2 : Wave hull girder loads in each load case

Ship condition	Load case	Vertical bending moment		Vertical shear force		Horizontal bending moment		Torque	
		Reference value	Comb. factor	Reference value	Comb. factor	Reference value	Comb. factor	Reference value	Comb. factor
Upright	"a"	0,625 M_{WV}	1,0	0,625Q_{WV}	1,0	0,625 M_{WH}	0,0	0,625M_T	0,0
	"b"	0,625 M_{WV}	1,0	0,625Q_{WV}	1,0	0,625 M_{WH}	0,0	0,625M_T	0,0
Inclined	"c"	0,625 M_{WV}	0,4	0,625Q_{WV}	0,4	0,625 M_{WH}	1,0	0,625M_T	1,0
	"d"	0,625 M_{WV}	0,4	0,625Q_{WV}	0,4	0,625 M_{WH}	1,0	0,625M_T	0,0

Note 1: The sign of the hull girder loads, to be considered in association with the wave local loads for the scantling of plating, ordinary stiffeners and primary supporting members contributing to the hull girder longitudinal strength, is defined in Chapter 7.

SECTION 5 SEA PRESSURES

Symbols

For the symbols not defined in this Section, refer to the list at the beginning of this Chapter.

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

h_1 : Reference values of the ship relative motions in the upright ship condition, defined in Sec 3, [3.3]

h_2 : Reference values of the ship relative motions in the inclined ship conditions, defined in Sec 3, [3.3].

1 Still water pressure

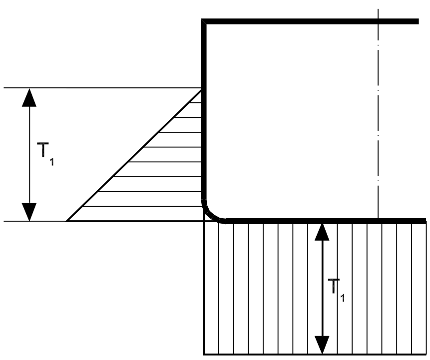
1.1 Pressure on sides and bottom

1.1.1 The still water pressure at any point of the hull is obtained from the formulae in Tab 1 (see also Fig 1).

Table 1 : Still water pressure

Location	Still water pressure p_S, in kN/m^2
Points at and below the waterline ($z \leq T_1$)	$\rho g(T_1 - z)$
Points above the waterline ($z > T_1$)	0

Figure 1 : Still water pressure



1.2 Pressure on exposed decks

1.2.1 On exposed decks, the pressure due to the load carried is to be considered. This pressure is to be defined by the Designer and, in general, it may not be taken less than 10φ kN/m^2, where φ is defined in Tab 2.

The Society may accept pressure values lower than 10φ kN/m^2, when considered appropriate on the basis of the intended use of the deck.

Table 2 : Coefficient for pressure on exposed decks

Exposed deck location	φ
Freeboard deck	1,00
Superstructure deck	0,75
1st tier of deckhouse	0,56
2nd tier of deckhouse	0,42
3rd tier of deckhouse	0,32
4th tier of deckhouse	0,25
5th tier of deckhouse	0,20
6th tier of deckhouse	0,15
7th tier of deckhouse and above	0,10

2 Wave pressure

2.1 Upright ship conditions (Load cases "a" and "b")

2.1.1 Pressure on sides and bottom

The wave pressure at any point of the hull is obtained from the formulae in Tab 3 (see also Fig 2 for load case "a" and Fig 3 for load case "b").

Figure 2 : Wave pressure in load case "a"

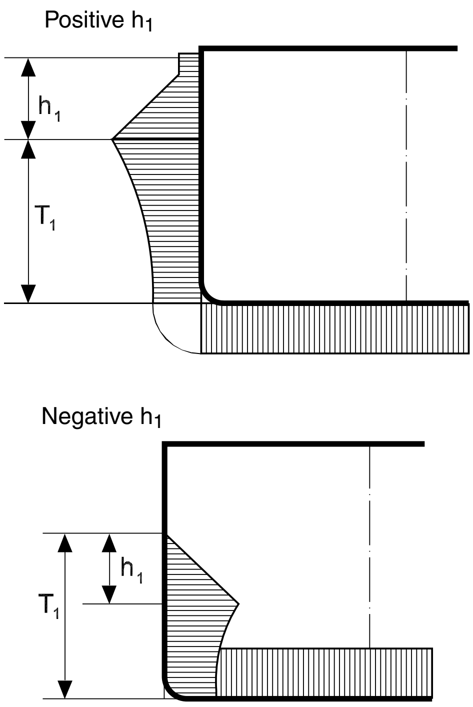
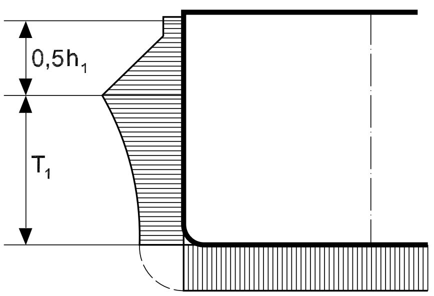


Figure 3 : Wave pressure in load case "b"



2.1.2 Pressure on exposed decks

The wave pressure on exposed decks is to be considered for load cases "a, crest" and "b" only. This pressure is obtained from the formulae in Tab 4.

2.2 Inclined ship conditions (Load cases "c" and "d")

2.2.1 The wave pressure at any point of the hull is obtained from the formulae in Tab 5 (see also Fig 4 for load case "c" and Fig 5 for load case "d").

Figure 4 : Wave pressure in load case "c"

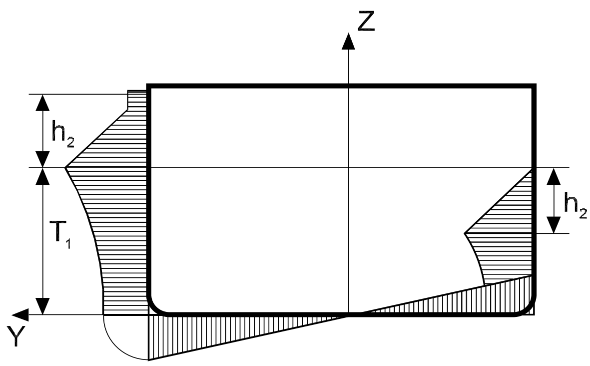


Figure 5 : Wave pressure in load case "d"

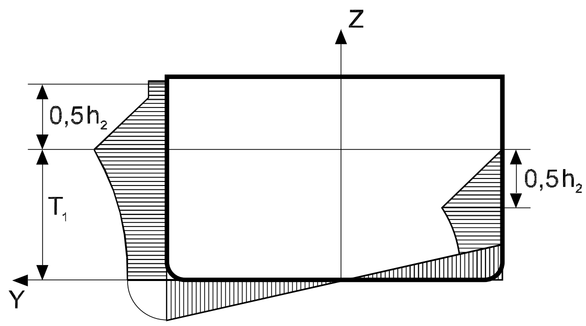


Table 3 : Wave pressure on sides and bottom in upright ship conditions (load cases "a" and "b")

Location	Wave pressure p_W, in kN/m²	C_1 crest	C_1 trough (1)
Bottom and sides below the waterline with: $z \le T_1 - h$	$C_1 \rho g h e^{\frac{-2\pi(T_1 - z)}{L}}$	1,0	-1,0
Sides below the waterline with: $T_1 - h < z \le T_1$	$C_1 \rho g h e^{\frac{-2\pi(T_1 - z)}{L}}$	1,0	$\frac{z - T_1}{h}$
Sides above the waterline: $z > T_1$	$C_1 \rho g (T_1 + h - z)$ without being taken less than 0,15 C_1 L for load case "a" only	1,0	0,0

(1) The wave pressure for load case "b, trough" is to be used only for the fatigue check of structural details according to Ch 7, Sec 4.

Note 1:

$h = C_{F1} h_1$

C_{F1} : Combination factor, to be taken equal to:
- C_{F1} = 1,0 for load case "a"
- C_{F1} = 0,5 for load case "b".

Table 4 : Wave pressure on exposed decks in upright ship conditions (load cases "a" and "b")

Location	Wave pressure p_W, in kN/m²
$0 \le x \le 0,5\ L$	$17,5 n \varphi$
$0,5\ L < x < 0,75\ L$	$\left\{17,5 + \left[\frac{19,6\sqrt{H_F} - 17,5}{0,25}\right]\left(\frac{x}{L} - 0,5\right)\right\} n \varphi$
$0,75\ L \le x \le L$	$19,6 n \varphi \sqrt{H}$

Note 1:

$$H = C_{F1}\left[2,66\left(\frac{x}{L} - 0,7\right)^2 + 0,14\right]\sqrt{\frac{VL}{C_B}} - (z - T_1)$$ without being taken less than 0,8

φ : Coefficient defined in Tab 2

H_F : Value of H calculated at x = 0,75L

C_{F1} : Combination factor, to be taken equal to:
- C_{F1} = 1,0 for load case "a, crest"
- C_{F1} = 0,5 for load case "b"

V : Maximum ahead service speed, in knots, to be taken not less than 13 knots.

Table 5 : Wave pressure in inclined ship conditions (load cases "c" and "d")

Location	Wave pressure p_W, in kN/m²	C_2 (negative roll angle)	
		$y \geq 0$	$y < 0$
Bottom and sides below the waterline with: $z \leq T_1 - h$	$C_2 C_{F2} \rho g \left[\frac{y}{B_W} h_1 e^{\frac{-2\pi(T_1 - z)}{L}} + A_R y e^{\frac{-\pi(T_1 - z)}{L}}\right]$	1,0	1,0
Sides below the waterline with: $T_1 - h < z \leq T_1$	$C_2 C_{F2} \rho g \left[\frac{y}{B_W} h_1 e^{\frac{-2\pi(T_1 - z)}{L}} + A_R y e^{\frac{-\pi(T_1 - z)}{L}}\right]$	1,0	$\frac{T_1 - z}{h}$
Sides above the waterline: $z > T_1$	$C_2 \rho g \left[T_1 + C_{F2}\left(\frac{y}{B_W} h_1 + A_R y\right) - z\right]$ without being taken less than 0,15 C_2 L for load case "c" only	1,0	0,0
Exposed decks	$C_2 \rho g \left[T_1 + C_{F2}\left(\frac{y}{B_W} h_1 + A_R y\right) - z\right]$ without being taken less than 0,15φ C_2 L for load case "c" only	0,4	0,0

Note 1:
$h = C_{F2} h_2$

C_{F2} : Combination factor, to be taken equal to:
- C_{F2} = 1,0 for load case "c"
- C_{F2} = 0,5 for load case "d".

B_W : Moulded breadth, in m, measured at the waterline at draught T_1, at the hull transverse section considered

A_R : Roll amplitude, defined in Sec 3, [2.4.1].

SECTION 6 INTERNAL PRESSURES AND FORCES

Symbols

For the symbols not defined in this Section, refer to the list at the beginning of this Chapter.

ρ_L : Density, in t/m³, of the liquid carried

ρ_B : Density, in t/m³, of the dry bulk cargo carried (see also [3]); in certain cases, such as spoils, the water held by capillarity is to be taken into account

z_{TOP} : Z co-ordinate, in m, of the highest point of the tank in the z direction

z_L : Z co-ordinate, in m, of the highest point of the liquid:

$$z_L = z_{TOP} + 0,5(z_{AP} - z_{TOP})$$

z_{AP} : Z co-ordinate, in m, of the moulded deck line of the deck to which the air pipes extend, to be taken not less than z_{TOP}

p_{PV} : Setting pressure, in bar, of safety valves

M : Mass, in t, of a dry unit cargo carried

a_{X1}, a_{Y1}, a_{Z1}: Reference values of the accelerations in the upright ship condition, defined in Sec 3, [3.4], calculated in way of:

- the centre of gravity of the compartment, in general
- the centre of gravity of any dry unit cargo, in the case of this type of cargo

a_{X2}, a_{Y2}, a_{Z2}: Reference values of the accelerations in the inclined ship condition, defined in Sec 3, [3.4], calculated in way of:

- the centre of gravity of the compartment, in general
- the centre of gravity of any dry unit cargo, in the case of this type of cargo

C_{FA} : Combination factor, to be taken equal to:

- C_{FA} = 0,7 for load case "c"
- C_{FA} = 1,0 for load case "d"

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

d_F : Filling level, in m, of a tank, to be taken as the vertical distance, measured with the ship at rest, from the bottom of the tank to the free surface of the liquid

ℓ_C : Longitudinal distance, in m, between transverse watertight bulkheads or transverse wash bulkheads, if any, or between a transverse watertight bulkhead and the adjacent transverse wash bulkhead; to this end, wash bulkheads are those satisfying the requirements in Ch 4, Sec 7, [5]

b_C : Transverse distance, in m, between longitudinal watertight bulkheads or longitudinal wash bulkheads, if any, or between a longitudinal watertight bulkhead and the adjacent longitudinal wash bulkhead; to this end, wash bulkheads are those satisfying the requirements in Ch 4, Sec 7, [5]

d_{TB} : Vertical distance, in m, from the baseline to the tank bottom.

1 Liquids

1.1 Still water pressure

1.1.1 Still water pressure for completely filled tanks

The still water pressure to be used in combination with the inertial pressure in [1.2] is the greater of the values obtained, in kN/m², from the following formulae:

$$p_S = \rho_L g(z_L - z)$$

$$p_S = \rho_L g(z_{TOP} - z) + 100 p_{PV}$$

In no case is it to be taken, in kN/m², less than:

$$p_S = \rho_L g\left(\frac{0,8L_1}{420 - L_1}\right)$$

1.1.2 Still water pressure for partly filled tanks

The still water pressure to be used in combination with the dynamic pressure in [2] is to be obtained, in kN/m², from the following formulae:

- in the case of no restrictions on the filling level (see [2.2]):

$$p_s = 0,2\rho_L g(z - d_{TB})$$

- in the case of restrictions on the filling level (see [2.3]):

$$p_S = \rho_L g(d_F + d_{TB} - z)$$

1.2 Inertial pressure

1.2.1 Inertial pressure

The inertial pressure is obtained from the formulae in Tab 1, and is to be taken such that:

$$p_S + p_W \geq 0$$

where p_S is defined in [1.1].

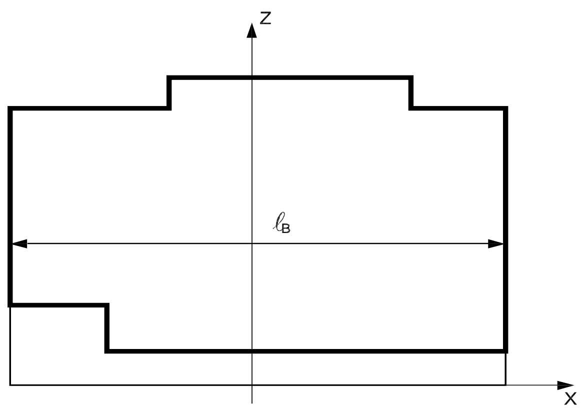
For typical tank arrangements, see also App 1.

Table 1 : Liquids - Inertial pressure

Ship condition	Load case	Inertial pressure p_W, in kN/m²
Upright	"a"	No inertial pressure
	"b"	$\rho_L[0,5a_{X1}\ell_B + a_{Z1}(z_{TOP} - z)]$
Inclined (negative roll angle)	"c"	$\rho_L[a_{TY}(y - y_H) + a_{TZ}(z - z_H) + g(z - z_{TOP})]$
	"d"	

Note 1:
ℓ_B : Longitudinal distance, in m, between the transverse tank boundaries, without taking into account small recesses in the lower part of the tank (see Fig 1)
a_{TY}, a_{TZ} : Y and Z components, in m/s², of the total acceleration vector defined in [1.2.2] for load case "c" and load case "d"
y_H, z_H : Y and Z co-ordinates, in m, of the highest point of the tank in the direction of the total acceleration vector, defined in [1.2.3] for load case "c" and load case "d".

Figure 1 : Upright ship conditions - Distance ℓ_B



1.2.2 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 Sec 3, [3.4]

G : Gravity acceleration vector.

The Y and Z components of the total acceleration vector and the angle it forms with the z direction are defined in Tab 2.

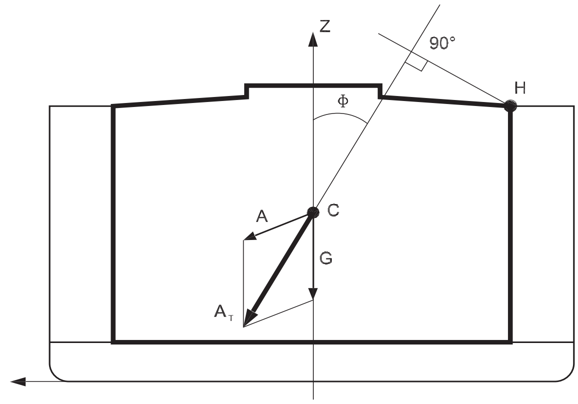
Table 2 : Inclined ship conditions Y and Z components of the total acceleration vector and angle Φ it forms with the z direction

Components (negative roll angle)		Angle Φ, in rad
a_{TY}, in m/s²	a_{TZ}, in m/s²	
$0,7C_{FA}a_{Y2}$	$-0,7C_{FA}a_{Z2} - g$	$\mathrm{atan}\frac{a_{TY}}{a_{TZ}}$

1.2.3 Highest point of the tank in the direction of the total acceleration vector

The highest point of the tank in the direction of the total acceleration vector A_T, defined in [1.2.2], is the point of the tank boundary whose projection on the direction forming the angle Φ with the vertical direction is located at the greatest distance from the tank's centre of gravity. It is to be determined for the inclined ship condition, as indicated in Fig 2, where A and G are the vectors defined in [1.2.2] and C is the tank's centre of gravity.

Figure 2 : Inclined ship conditions Highest point H of the tank in the direction of the total acceleration vector



2 Dynamic pressure in partly filled tanks intended for the carriage of liquid cargoes or ballast

2.1 Risk of resonance

2.1.1 Where tanks are partly filled at a level $0,1H \leq d_F \leq 0,95H$, the risk of resonance between:

- the ship pitch motion and the longitudinal motion of the liquid inside the tank, for upright ship condition
- the ship sway and roll motion and the transverse motion of the liquid inside the tank, for inclined ship condition

is to be evaluated on the basis of the criteria specified in Tab 3.

Table 3 : Criteria for the evaluation of the risk of resonance

Ship condition	Risk of resonance if:	Resonance due to:
Upright	$\frac{T_X}{T_P} > 0,7$ and $\frac{d_F}{\ell_C} > 0,1$	Pitch
Inclined	$0,7 < \frac{T_Y}{T_R} < 1,3$ and $\frac{d_F}{b_C} > 0,1$	Roll
	$\frac{T_Y}{T_{SW}} > 0,7$ and $\frac{d_F}{b_C} > 0,1$	Sway

where:

T_X : Natural period, in s, of the liquid motion in the longitudinal direction:

$$T_X = \sqrt{\frac{4\pi\ell_S}{g\tanh\frac{\pi d_F}{\ell_S}}}$$

T_Y : Natural period, in s, of the liquid motion in the transverse direction:

$$T_Y = \sqrt{\frac{4\pi b_S}{g\tanh\frac{\pi d_F}{b_S}}}$$

ℓ_S : Length, in m, of the free surface of the liquid, measured horizontally with the ship at rest and depending on the filling level d_F, as shown in Fig 3; in this figure, wash bulkheads are those satisfying the requirements in Ch 4, Sec 7, [5]

b_S : Breadth, in m, of the free surface of the liquid, measured horizontally with the ship at rest and depending on the filling level d_F, as shown in Fig 4 for ships without longitudinal watertight or wash bulkheads; for ships fitted with longitudinal watertight or wash bulkheads (see Fig 5), b_S is delimited by these bulkheads (to this end, wash bulkheads are those satisfying the requirements in Ch 4, Sec 7, [5])

T_P : Pitch period, in s, defined in Sec 3, [2]

T_R : Roll period, in s, defined in Sec 3, [2]

T_{SW} : Sway period, in s, defined in Sec 3, [2].

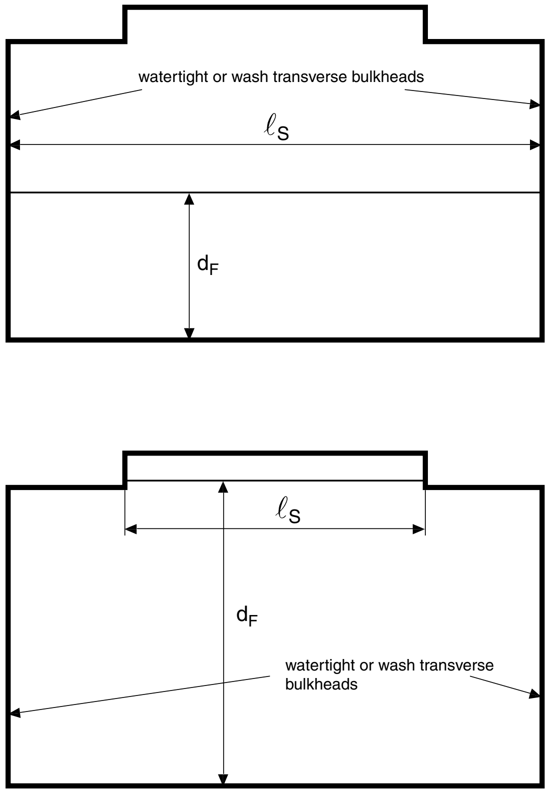
2.1.2 The Society may accept that the risk of resonance is evaluated on the basis of dynamic calculation procedures, where deemed necessary in relation to the tank's dimensions and the ship's characteristics. The calculations are to be submitted to the Society for approval.

2.2 Dynamic pressure in the case of no restrictions on the filling level

2.2.1 Evaluation of the risk of resonance

Where there are no restrictions on the filling level d_F, the risk of resonance is to be evaluated, according to the procedure in [2.1], for various filling levels between 0,1H and 0,95H. In general, filling levels spaced at intervals of 0,1H are to be considered with the additional level of 0,95H. The Society may require examination of other filling levels where deemed necessary on the basis of the tank's shape and the ship's characteristics.

Figure 3 : Length ℓ_S of the free surface of the liquid



2.2.2 Risk of resonance in upright ship condition

Where there is a risk of resonance in upright ship condition, the sloshing pressure calculated according to [2.2.4] is to be considered as acting on the transverse bulkheads which form tank boundaries.

Where tank bottom transverses or wash transverses are fitted, the sloshing pressure calculated according to [2.2.5] is to be considered as acting on them.

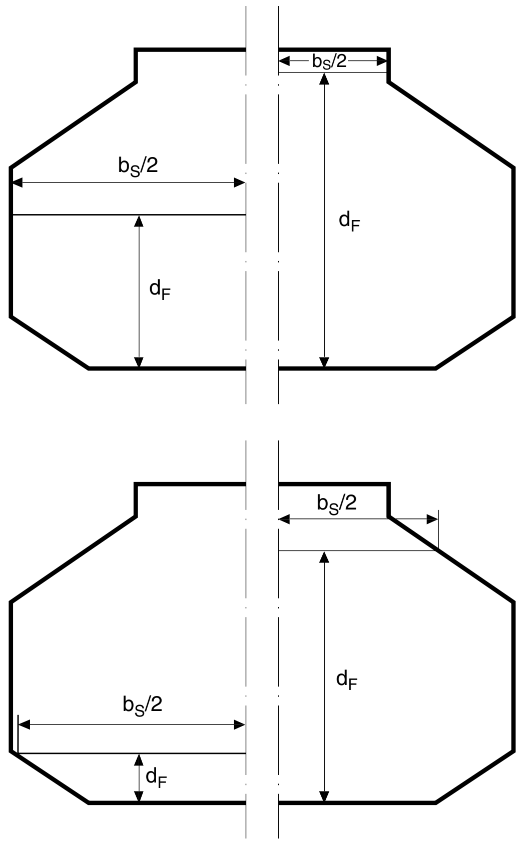
The Society may also require the sloshing pressure to be considered when there is no risk of resonance, but the tank arrangement is such that $\ell_C/L > 0,15$.

2.2.3 Risk of resonance in inclined ship condition

Where there is a risk of resonance in inclined ship condition, the sloshing pressure calculated according to [2.2.4] is to be considered as acting on longitudinal bulkheads, inner sides or sides which, as the case may be, form tank boundaries.

If sloped longitudinal topsides are fitted, they are to be considered as subjected to the sloshing pressure if their height is less than 0,3H.

Figure 4 : Breadth b_S of the free surface of the liquid, for ships without longitudinal bulkheads



2.2.4 Sloshing pressure

The sloshing pressure is obtained, in kN/m², from the following formulae (see Fig 6):

$$p_{SL} = \frac{z - d_{TB}}{0,6H} p_0 \qquad \text{for} \quad z < 0,6H + d_{TB}$$

$$p_{SL} = p_0 \qquad \text{for} \quad 0,6H + d_{TB} \le z \le 0,7H + d_{TB}$$

$$p_{SL} = \frac{H + d_{TB} - z}{0,3H} p_0 \qquad \text{for} \quad z > 0,7H + d_{TB}$$

where p_0 is the reference pressure, in kN/m², defined in Tab 4 for upright and inclined ship conditions.

2.2.5 Sloshing pressure on tank bottom transverses in the case of resonance in upright ship condition

Where there is a risk of resonance in upright ship condition, the sloshing pressure to be considered as acting on tank bottom transverses is obtained, in kN/m², from the following formula:

$$p_{SL,W} = 0,8 \rho_L g (1,95 - 0,12n)(z - d_{TB})$$

where n is the number of bottom transverses in the tank.

Figure 5 : Breadth b_S of the free surface of the liquid, for ships with longitudinal bulkheads

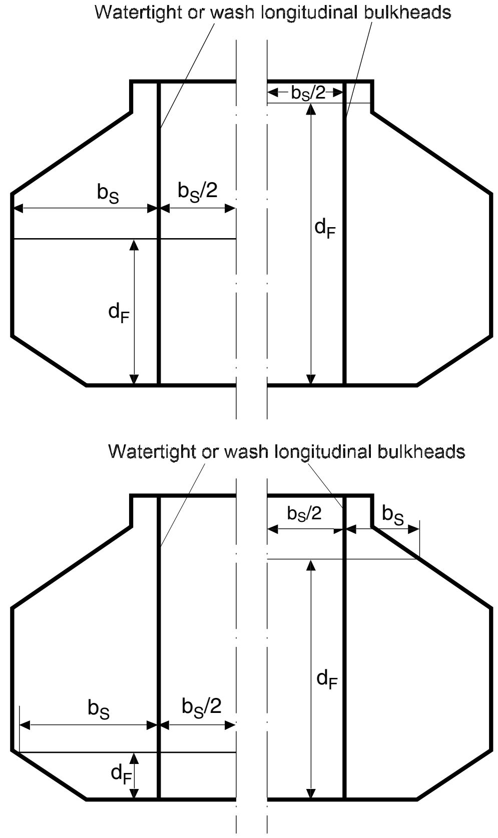


Figure 6 : Sloshing pressure p_{SL} in the case of no restrictions on the filling level

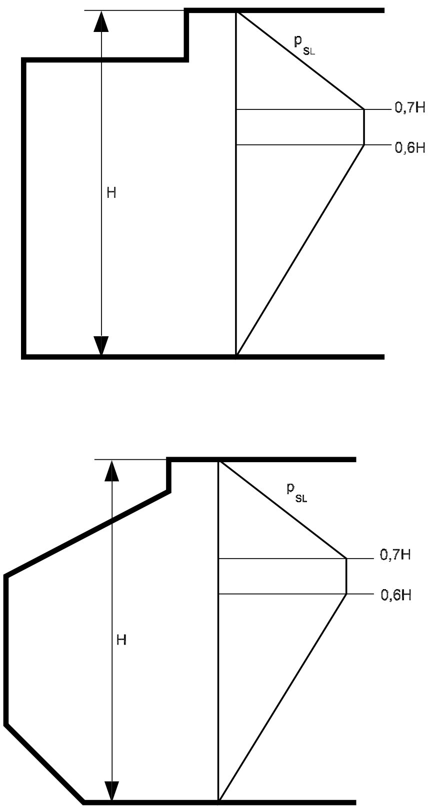


Table 4 : Reference pressure for calculation of sloshing pressures

Ship condition	Reference pressure p_0, in kN/m^2	Meaning of symbols used in the definition of p_0
Upright	$\varphi_U \rho_L g S \ell_C A_P$	φ_U : Coefficient defined as follows: φ_U = 1,0 in the case of smooth tanks or tanks with bottom transverses whose height, in m, measured from the tank bottom, is less than 0,1H φ_U = 0,4 in the case of tanks with bottom transverses whose height, in m, measured from the tank bottom, is not less than 0,1H S : Coefficient defined as follows: S = 0,4 + 0,008 L if $L \le 200$ m S = 1,2 + 0,004 L if $L > 200$ m A_P : Pitch amplitude, in rad, defined in Sec 3, [2].
Inclined	$1{,}15\varphi_I \rho_L g C_S \sqrt{B}\left(1 - 0{,}3\frac{B}{b_C}\right)$	φ_I : Coefficient defined as follows: • if $b_C / B \le 0{,}3$: $\varphi_I = 0$ • if $b_C / B > 0{,}3$: φ_I = 1 in the case of smooth tanks or tanks with bottom girders whose height, in m, measured from the tank bottom, is less than 0,1H φ_I = 0,4 in the case of tanks with bottom girders whose height, in m, measured from the tank bottom, is not less than 0,1H C_S : Coefficient defined as follows: C_S =0,8 b_C A_R if there is a risk of resonance due to roll (see [2.1.1]) C_S = 4,9 - 0,01L if there is a risk of resonance due to sway (see [2.1.1]) A_R : Roll amplitude, in rad, defined in Sec 3, [2].

2.2.6 Impact pressure in the case of resonance in upright ship condition

Where there is a risk of resonance in upright ship condition, the impact pressure due to the liquid motions is to be considered as acting on:

- transverse bulkheads which form tank boundaries, in the area extended vertically 0,15 H from the tank top
- the tank top in the area extended longitudinally 0,3 ℓ_C from the above transverse bulkheads.

The Society may also require the impact pressure to be considered as acting on the above structures when there is no risk of resonance, but the tank arrangement is such that ℓ_C/L > 0,15.

Where the upper part of a transverse bulkhead is sloped, the impact pressure is to be considered as acting on the sloped part of the transverse bulkhead and the tank top (as the case may be) in the area extended longitudinally 0,3 ℓ_C from the transverse bulkhead.

The impact pressure is obtained, in kN/m^2, from the following formula:

$$p_{I,U} = \varphi_U \rho_L g \ell_C A_P\left(0{,}9 + \frac{\ell_C}{L}\right)(2{,}6 + 0{,}007L)$$

where:

φ_U : Coefficient defined in Tab 4

A_P : Pitch amplitude, in rad, defined in Sec 3, [2].

Where the upper part of a transverse bulkhead is sloped, the pressure $p_{I,U}$ may be multiplied by the coefficient ϕ obtained from the following formula:

$$\phi = 1 - \frac{h_T}{0{,}3H}$$

to be taken not less than zero,

where h_T is the height, in m, of the sloped part of the transverse bulkhead.

2.2.7 Impact pressure in the case of resonance in inclined ship condition

Where there is a risk of resonance in inclined ship condition, the impact pressure due to the liquid motions is to be considered as acting on:

- longitudinal bulkheads, inner sides or sides which, as the case may be, form tank boundaries, in the area extended vertically 0,15 H from the tank top
- the tank top in the area extended transversely 0,3b_C from the above longitudinal bulkheads, inner sides or sides.

Where the upper part of a longitudinal bulkhead, inner side or side is sloped, the impact pressure is to be considered as acting on this sloped part and the tank top (as the case may be) in the area extended transversely 0,3b_C from the longitudinal bulkhead, inner side or side.

The impact pressure is obtained, in kN/m^2, from the following formula:

$$p_{I,I} = 0{,}8\varphi_I \rho_L g C_S(0{,}375B - 4)$$

where:

φ_I, C_S : Coefficients defined in Tab 4.

Where the upper part of a longitudinal bulkhead, inner side or side is sloped, the pressure $p_{I,I}$ may be multiplied by the coefficient ϕ obtained from the following formula:

$$\phi = 1 - \frac{h_T}{0,3H}$$

to be taken not less than zero,

where h_T is the height, in m, of the sloped part of the longitudinal bulkhead, inner side or side.

2.2.8 Alternative methods

The Society may accept that the dynamic pressure is evaluated on the basis of dynamic calculation procedures, where deemed necessary in relation to the tank's dimensions and the ship's characteristics. The calculations are to be submitted to the Society for verification.

2.3 Dynamic pressure in the case of restrictions on the filling level

2.3.1 Evaluation of the risk of resonance

Where there are restrictions on the filling level d_F, the risk of resonance is to be evaluated, according to the procedure in [2.1], for the permitted filling levels where these are between 0,1H and 0,95H.

2.3.2 Risk of resonance in upright ship condition

Where there is a risk of resonance in upright ship condition for a permitted d_F, the sloshing pressure calculated according to [2.3.4] is to be considered as acting on transverse bulkheads which form tank boundaries, in the area extended vertically $0,2d_F$ above and below d_F (see Fig 7).

The Society may also require the sloshing pressure to be considered when there is no risk of resonance, but the tank arrangement is such that $\ell_C/L > 0,15$.

2.3.3 Risk of resonance in inclined ship condition

Where there is a risk of resonance in inclined ship condition for a permitted d_F, the sloshing pressure calculated according to [2.3.4] is to be considered as acting on longitudinal bulkheads, inner sides or sides which, as the case may be, form tank boundaries, in the area extended vertically $0,2d_F$ above and below d_F (see Fig 7).

If sloped longitudinal topsides are fitted, they are to be considered as subjected to the sloshing pressure if their height is less than 0,3H.

2.3.4 Sloshing pressure

Where there is a risk of resonance for a permitted d_F, the sloshing pressure is obtained, in kN/m², from the following formulae:

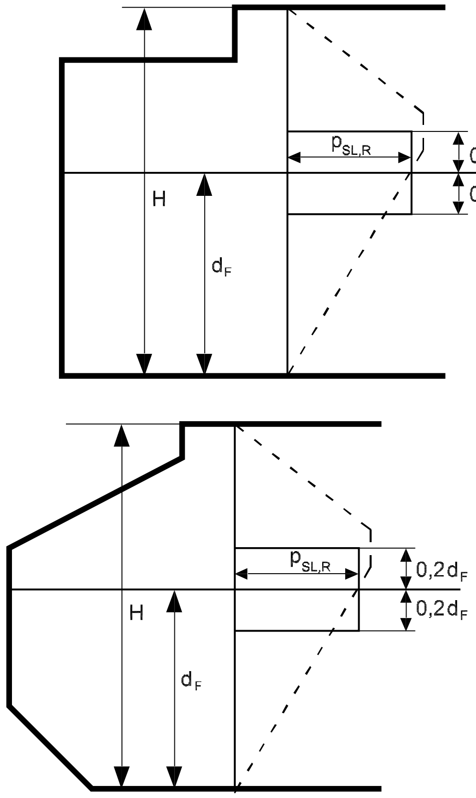
$$p_{SL,R} = \frac{d_F}{0,6H} p_0 \qquad \text{for} \quad d_F < 0,6H$$

$$p_{SL,R} = p_0 \qquad \text{for} \quad 0,6H \le d_F \le 0,7H$$

$$p_{SL,R} = \frac{H - d_F}{0,3H} p_0 \qquad \text{for} \quad d_F > 0,7H$$

where p_0 is the reference pressure defined in Tab 4 for upright and inclined ship conditions.

Figure 7 : Sloshing pressure $p_{SL,R}$ in the case of restrictions on the filling level



2.3.5 Impact pressure

Where there is a risk of resonance for a permitted d_F, the impact pressure due to the liquid motions is to be calculated as per [2.2.6] and [2.2.7] for upright and inclined ship conditions, respectively.

The Society may also require the impact pressure for upright ship condition to be considered when there is no risk of resonance, but the tank arrangement is such that $\ell_C/L > 0,15$.

3 Dry bulk cargoes

3.1 Still water and inertial pressures

3.1.1 Pressures transmitted to the hull structures

The still water and inertial pressures (excluding those acting on the sloping plates of topside tanks, which may be taken equal to zero) are obtained, in kN/m², as specified in Tab 5.

Table 5 : Dry bulk cargoes - Still water and inertial pressures

Ship condition	Load case	Still water pressure p_S and inertial pressure p_W, in kN/m²
Still water		$p_S = \rho_B g (z_B - z)\left\{(\sin\alpha)^2\left[\tan\left(45^o - \frac{\varphi}{2}\right)\right]^2 + (\cos\alpha)^2\right\}$
Upright	"a"	No inertial pressure
	"b"	$p_W = -\rho_B a_{Z1}(z_B - z)\left\{(\sin\alpha)^2\left[\tan\left(45^o - \frac{\varphi}{2}\right)\right]^2 + (\cos\alpha)^2\right\}$
Inclined	"c"	The inertial pressure transmitted to the hull structures in inclined condition may generally be disregarded. Specific cases in which this simplification is not deemed permissible by the Society are considered individually.
	"d"	
Note 1:		
z_B : Z co-ordinate, in m, of the rated upper surface of the bulk cargo (horizontal ideal plane of the volume filled by the cargo); see [3.1.2]		
α : Angle, in degrees, between the horizontal plane and the surface of the hull structure to which the calculation point belongs		
φ : Angle of repose, in degrees, of the bulk cargo (considered drained and removed); in the absence of more precise evaluation, the following values may be taken: • $\varphi = 30^o$ in general • $\varphi = 35^o$ for iron ore • $\varphi = 25^o$ for cement.		

3.1.2 Rated upper surface of the bulk cargo

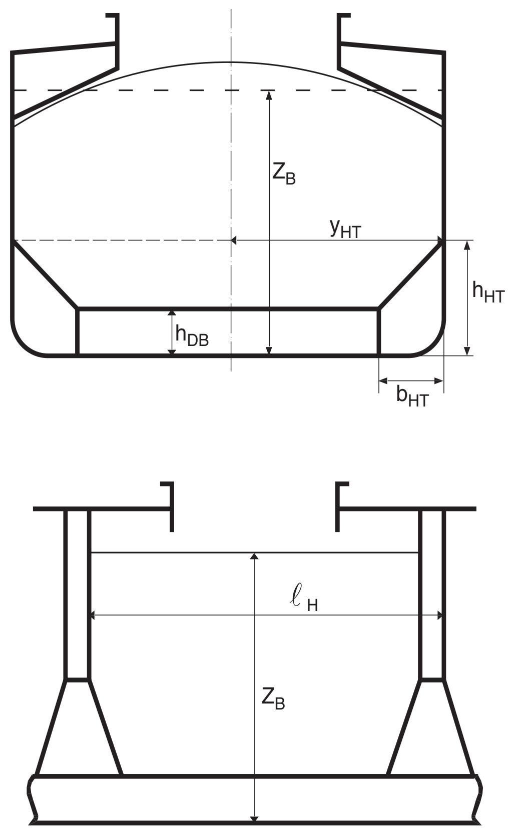
The Z co-ordinate of the rated upper surface of the bulk cargo is obtained, in m, from the following formula (see Fig 8):

$$z_B = \frac{\frac{M_C}{\rho_B \ell_H} + \frac{V_{LS}}{\ell_H} + (h_{HT} - h_{DB})b_{HT}}{2y_{HT}} + h_{DB}$$

where:

- M_C : Mass of cargo, in t, in the hold considered
- ℓ_H : Length, in m, of the hold, to be taken as the longitudinal distance between the transverse bulkheads which form boundaries of the hold considered
- V_{LS} : Volume, in m³, of the transverse bulkhead lower stool (above the inner bottom), to be taken equal to zero in the case of bulkheads fitted without lower stool
- h_{HT} : Height, in m, of the hopper tank, to be taken as the vertical distance from the baseline to the top of the hopper tank
- h_{DB} : Height, in m, of the double bottom, to be taken as the vertical distance from the baseline to the inner bottom
- b_{HT} : Breadth, in m, of the hopper tank, to be taken as the transverse distance from the outermost double bottom girder to the outermost point of the hopper tank
- y_{HT} : Half breadth, in m, of the hold, measured at the middle of ℓ_H and at a vertical level corresponding to the top of the hopper tank.

Figure 8 : Rated upper surface of the bulk cargo



4 Dry uniform cargoes

4.1 Still water and inertial pressures

4.1.1 General

The still water and inertial pressures are obtained, in kN/m², as specified in Tab 6.

In ships with two or more decks, the pressure transmitted to the deck structures by the dry uniform cargoes in cargo compartments is to be considered.

Table 6 : Dry uniform cargoes
Still water and inertial pressures

Ship condition	Load case	Still water pressure p_S and inertial pressure p_W, in kN/m²
Still water		The value of p_S is generally specified by the Designer; in any case, it may not be taken less than 10 kN/m². When the value of p_S is not specified by the Designer, it may be taken, in kN/m², equal to 6,9 h_{TD} , where h_{TD} is the compartment ‘tweendeck height at side, in m.
Upright (positive heave motion)	"a"	No inertial pressure
	"b"	$p_{W,Z} = -p_S \dfrac{a_{Z1}}{g}$ 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 7 : Dry unit cargoes
Still water and inertial forces

Ship condition	Load case	Still water force F_S and inertial force F_W, in kN
Still water		$F_S = Mg$
Upright (positive heave motion)	"a"	No inertial force
	"b"	$F_{W,X} = Ma_{X1}$ in x direction $F_{W,Z} = -Ma_{Z1}$ in z direction
Inclined (negative roll angle)	"c"	$F_{W,Y} = MC_{FA}a_{Y2}$ in y direction
	"d"	$F_{W,Z} = MC_{FA}a_{Z2}$ in z direction

5 Dry unit cargoes

5.1 Still water and inertial forces

5.1.1 The still water and inertial forces transmitted to the hull structures are to be determined on the basis of the forces obtained, in kN, as specified in Tab 7, taking into account the elastic characteristics of the lashing arrangement and/or the structure which contains the cargo.

6 Wheeled cargoes

6.1 Still water and inertial forces

6.1.1 General

Caterpillar trucks and unusual vehicles are considered by the Society on a case by case basis.

The load supported by the crutches of semi-trailers, handling machines and platforms is considered by the Society on a case by case basis.

6.1.2 Tyred vehicles

The forces transmitted through the tyres are comparable to pressure uniformly distributed on the tyre print, whose dimensions are to be indicated by the Designer together with information concerning the arrangement of wheels on axles, the load per axles and the tyre pressures.

With the exception of dimensioning of plating, such forces may be considered as concentrated in the tyre print centre.

The still water and inertial forces transmitted to the hull structures are to be determined on the basis of the forces obtained, in kN, as specified in Tab 8.

6.1.3 Non-tyred vehicles

The requirements of [6.1.2] also apply to tracked vehicles; in this case the print to be considered is that below each wheel or wheelwork.

For vehicles on rails, all the forces transmitted are to be considered as concentrated.

7 Accommodation

7.1 Still water and inertial pressures

7.1.1 The still water and inertial pressures transmitted to the deck structures are obtained, in kN/m², as specified in Tab 9.

8 Machinery

8.1 Still water and inertial pressures

8.1.1 The still water and inertial pressures transmitted to the deck structures are obtained, in kN/m², as specified in Tab 11.

Table 8 : Wheeled cargoes
Still water and inertial forces

Ship condition	Load case	Still water force F_S and inertial force F_W , in kN
Still water **(1) (2)**		$F_S = Mg$
Upright (positive heave motion) **(1)**	"a"	No inertial force
	"b" **(3)**	$F_{W,Z} = -Ma_{Z1}$ in z direction
Inclined (negative roll angle) **(2)**	"c"	$F_{W,Y} = MC_{FA}a_{Y2}$ in y direction
	"d"	$F_{W,Z} = MC_{FA}a_{Z2}$ in z direction

(1) This condition defines the force, applied by one wheel, to be considered for the determination of scantlings of plating, ordinary stiffeners and primary supporting members, as defined in Chapter 7, with M obtained, in t, from the following formula:

$$M = \frac{Q_A}{n_W}$$

where:

Q_A : Axle load, in t. For fork-lift trucks, the value of Q_A is to be taken equal to the total mass of the vehicle, including that of the cargo handled, applied to one axle only.

n_W : Number of wheels for the axle considered.

(2) This condition is to be considered for the racking analysis of ships with the service notation **ro-ro cargo ship** or **ro-ro passenger ship**, as defined in Ch 7, App 1, with M taken equal to the mass, in t, of wheeled loads located on the structural member under consideration.

(3) For fork-lift trucks operating in harbour conditions, the inertial force may be reduced by 50%.

Table 9 : Accommodation
Still water and inertial pressures

Ship condition	Load case	Still water pressure p_S and inertial pressure p_W, in kN/m²
Still water		The value of p_S is defined in Tab 10 depending on the type of the accommodation compartment.
Upright (positive heave motion)	"a"	No inertial pressure
	"b"	$p_W = -p_S \frac{a_{Z1}}{g}$
Inclined	"c"	The inertial pressure transmitted to the deck structures in inclined condition may generally be disregarded. Specific cases in which this simplification is not deemed permissible by the Society are considered individually.
	"d"	

Table 10 : Still water deck pressure
in accommodation compartments

Type of accommodation compartment	p_S , in kN/m²
Large public spaces, such as: restaurants, halls, cinemas, lounges	5,0
Large rooms, such as: games and hobbies rooms, hospitals	3,0
Cabins	3,0
Other compartments	2,5

Table 11 : Machinery
Still water and inertial pressures

Ship condition	Load case	Still water pressure p_S and inertial pressure p_W , in kN/m²
Still water		$p_S = 10$
Upright (positive heave motion)	"a"	No inertial pressure
	"b"	$p_W = -p_S \frac{a_{Z1}}{g}$
Inclined	"c"	The inertial pressure transmitted to the deck structures in inclined condition may generally be disregarded. Specific cases in which this simplification is not deemed permissible by the Society are considered individually.
	"d"	

9 Flooding

9.1 Still water and inertial pressures

9.1.1

Unless otherwise specified, the still water and inertial pressures to be considered as acting on bulkheads inner sides or internal decks, which constitute boundaries of compartments not intended to carry liquids are obtained, in kN/m², from the formulae in Tab 12.

Table 12 : Flooding
Still water and inertial pressures

Still water pressure p_{SF} , in kN/m²	Inertial pressure p_{WF} , in kN/m²
$\rho g(z_F - z)$ without being taken less than $0,4\ g\ d_0$	$0,6\rho a_{Z1}(z_F - z)$ without being taken less than $0,4\ g\ d_0$

Note 1:

z_F : Z co-ordinate, in m, of the deck at side in way of the transverse section considered, to be taken not less than the level corresponding to the deepest equilibrium waterline resulting from the damage stability calculation.

d_0 : Distance, in m, to be taken equal to:

$d_0 = 0,02L$ for $90\ m \le L < 120\ m$

$d_0 = 2,4$ for $L \ge 120\ m$.

APPENDIX 1 INERTIAL PRESSURE FOR TYPICAL TANK ARRANGEMENT

1 Liquid cargoes and ballast - Inertial pressure

1.1 Introduction

1.1.1 Sec 6, [1] defines the criteria to calculate the inertial pressure p_W induced by liquid cargoes and ballast in any type of tank. The relevant formulae are specified in Sec 6, Tab 1 and entail the definition of the highest point of the tank in the direction of the total acceleration vector. As specified in Sec 6, [1.2], this point depends on the geometry of the tank and the values of the acceleration. For typical tank arrangements, the highest point of the tank in the direction of the total acceleration vector can easily be identified and the relevant formulae written using the tank geometric characteristics.

1.1.2 This Appendix provides the formulae for calculating the inertial pressure p_W in the case of typical tank arrangements.

1.2 Formulae for the inertial pressure calculation

1.2.1 For typical tank arrangements, the inertial pressure transmitted to the hull structures at the calculation point P in inclined ship condition may be obtained from the formulae in Tab 1, obtained by applying to those tanks the general formula in Sec 6, Tab 1.

Table 1 : Liquid cargoes and ballast - Inertial pressure for typical tank arrangements

Ship condition	Load case	Inertial pressure p_W , in kN/m²
Inclined (negative roll angle)	"c"	$0,7C_{FA}\rho_L(a_{Y2}b_L + a_{Z2}d_H)$
	"d"	

Note 1:

- C_{FA} : Combination factor, to be taken equal to:
  - C_{FA} = 0,7 for load case "c"
  - C_{FA} = 1,0 for load case "d"
- ρ_L : Density, in t/m³, of the liquid cargo carried
- a_{Y2}, a_{Z2} : Reference values of the acceleration in the inclined ship condition, defined in Sec 3, [3.4], calculated in way of the centre of gravity of the tank
- b_L, d_H : Transverse and vertical distances, in m, to be taken as indicated in Fig 1 to Fig 6 for various types of tanks; for the cases in Fig 1 to Fig 4, where the central cargo area is divided into two or more tanks by longitudinal bulkheads, b_L and d_H for calculation points inside each tank are to be taken as indicated in Fig 5 for the double side. The angle Φ which appears in Fig 3 and Fig 4 is defined in Sec 6, Tab 2.

Figure 1 : Distances b_L and d_H

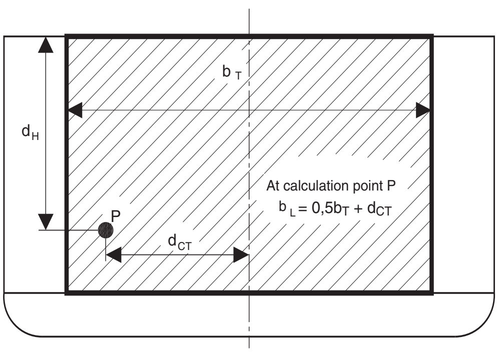


Figure 2 : Distances b_L and d_H

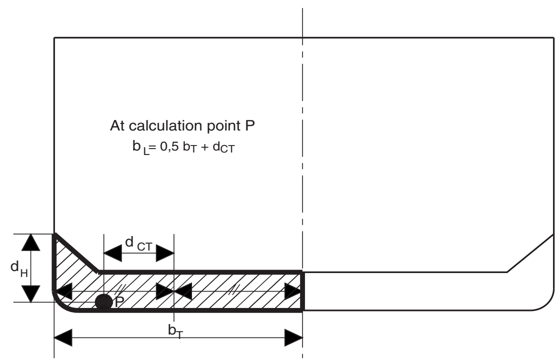


Figure 3 : Distances b_L and d_H

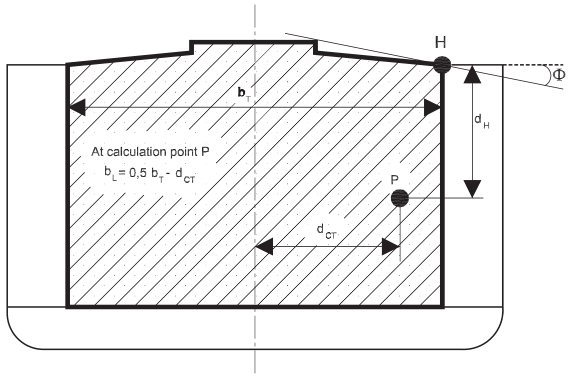


Figure 4 : Distances b_L and d_H

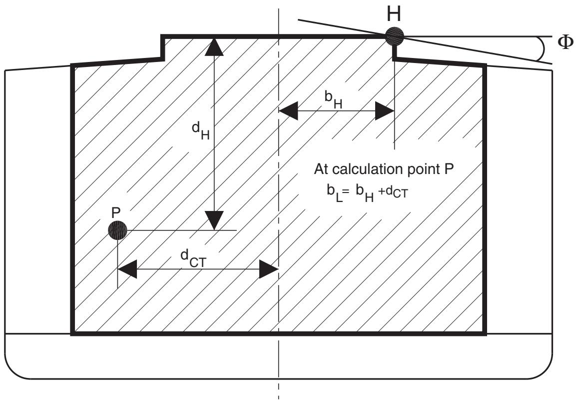


Figure 5 : Distances b_L and d_H

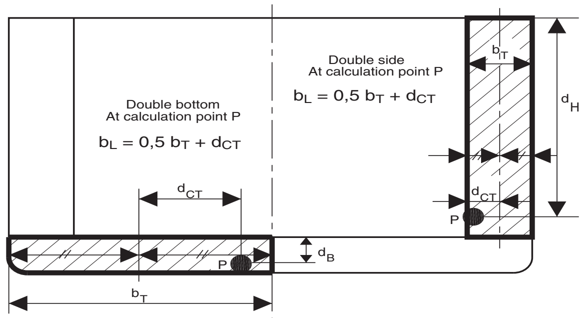
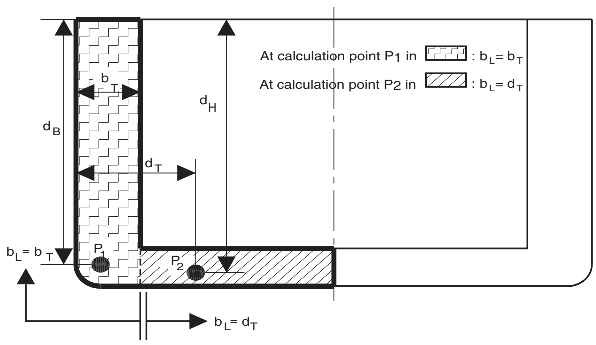


Figure 6 : Distances b_L and d_H



Part B
Hull and Stability

Chapter 6
HULL GIRDER STRENGTH

Symbols used in chapter 6

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

- for steels in general:

  $E = 2,06.10^5$ N/mm^2

- for stainless steels:

  $E = 1,95.10^5$ N/mm^2

- for aluminium alloys:

  $E = 7,0.10^4$ N/mm^2

M_{SW} : Still water bending moment, in kN.m:

- in hogging conditions:

  $M_{SW} = M_{SW,H}$

- in sagging conditions:

  $M_{SW} = M_{SW,S}$

$M_{SW,H}$: Design still water bending moment, in kN.m, in hogging condition, at the hull transverse section considered, defined in Pt B, Ch 5, Sec 2, [2.2],

$M_{SW,S}$: Design still water bending moment, in kN.m, in sagging condition, at the hull transverse section considered, defined in Pt B, Ch 5, Sec 2, [2.2], when the ship in still water is always in hogging condition, $M_{SW,S}$ is to be taken equal to 0,

M_{WV} : Vertical wave bending moment, in kN.m:

- in hogging conditions:

  $M_{WV} = M_{WV,H}$

- in sagging conditions:

  $M_{WV} = M_{WV,S}$

$M_{WV,H}$: Vertical wave bending moment, in kN.m, in hogging condition, at the hull transverse section considered, defined in Pt B, Ch 5, Sec 2, [3.1],

$M_{WV,S}$: Vertical wave bending moment, in kN.m, in sagging condition, at the hull transverse section considered, defined in Pt B, Ch 5, Sec 2, [3.1],

g : Gravity acceleration, in m/s^2:

$g = 9,81$ m/s^2.

SECTION 1 STRENGTH CHARACTERISTICS OF THE HULL GIRDER TRANSVERSE SECTIONS

Symbols

For symbols not defined in this Section, refer to the list at the beginning of this Chapter.

1 Application

1.1

1.1.1 This Section specifies the criteria for calculating the hull girder strength characteristics to be used for the checks in Sec 2 and Sec 3, in association with the hull girder loads specified in Ch 5, Sec 2.

2 Calculation of the strength characteristics of hull girder transverse sections

2.1 Hull girder transverse sections

2.1.1 General

Hull girder transverse sections are to be considered as being constituted by the members contributing to the hull girder longitudinal strength, i.e. all continuous longitudinal members below the strength deck defined in [2.2], taking into account the requirements in [2.1.2] to [2.1.9].

These members are to be considered as having (see also Ch 4, Sec 2):

- gross scantlings, when the hull girder strength characteristics to be calculated are used for the yielding checks in Sec 2
- net scantlings, when the hull girder strength characteristics to be calculated are used for the ultimate strength checks in Sec 3 and for calculating the hull girder stresses for the strength checks of plating, ordinary stiffeners and primary supporting members in Chapter 7.

2.1.2 Continuous trunks and continuous lngitudinal hatch coamings

Continuous trunks and continuous longitudinal hatch coamings may be included in the hull girder transverse sections, provided they are effectively supported by longitudinal bulkheads or primary supporting members.

2.1.3 Longitudinal ordinary stiffeners or girders welded above the decks

Longitudinal ordinary stiffeners or girders welded above the decks (including the deck of any trunk fitted as specified in [2.1.2]) may be included in the hull girder transverse sections.

2.1.4 Longitudinal girders between hatchways

Where longitudinal girders are fitted between hatchways, the sectional area that can be included in the hull girder transverse sections is obtained, in m², from the following formula:

$A_{EFF} = A_{LG} a$

where:

A_{LG} : Sectional area, in m², of longitudinal girders,

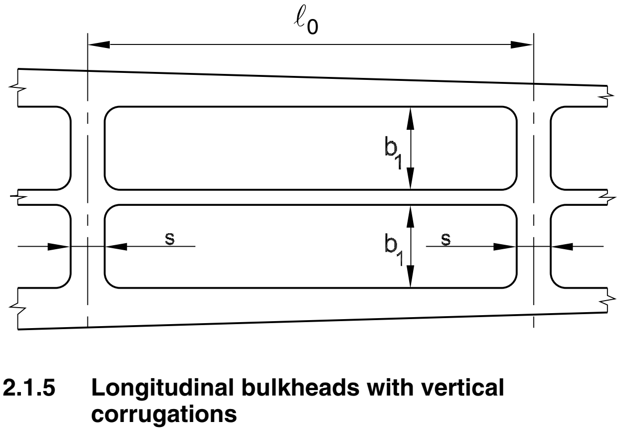
a : Coefficient:
- for longitudinal girders effectively supported by longitudinal bulkheads or primary supporting members:
  $a = 1$
- for longitudinal girders not effectively supported by longitudinal bulkheads or primary supporting members and having dimensions and scantlings such that $\ell_0 / r \le 60$:
  $$a = 0,6\left(\frac{s}{b_1} + 0,15\right)^{0,5}$$
- for longitudinal girders not effectively supported by longitudinal bulkheads or primary supporting members and having dimensions and scantlings such that $\ell_0 / r > 60$:
  $a = 0$

ℓ_0 : Span, in m, of longitudinal girders, to be taken as shown in Fig 1

r : Minimum radius of gyration, in m, of the longitudinal girder transverse section

s, b_1 : Dimensions, in m, defined in Fig 1.

Figure 1 : Longitudinal girders between hatchways



2.1.5 Longitudinal bulkheads with vertical corrugations

Longitudinal bulkheads with vertical corrugations may not be included in the hull girder transverse sections.

2.1.6 Members in materials other than steel

Where a member contributing to the longitudinal strength is made in material other than steel with a Young's modulus E equal to 2,06 10^5 N/mm², the steel equivalent sectional area that may be included in the hull girder transverse sections is obtained, in m², from the following formula:

$$A_{SE} = \frac{E}{2,06 \cdot 10^5} A_M$$

where:

A_M : Sectional area, in m², of the member under consideration.

2.1.7 Large openings

Large openings are:

- elliptical openings exceeding 2,5 m in length or 1,2 m in breadth
- circular openings exceeding 0,9 m in diameter.

Large openings and scallops, where scallop welding is applied, are always to be deducted from the sectional areas included in the hull girder transverse sections.

2.1.8 Small openings

Smaller openings than those in [2.1.7] in one transverse section in the strength deck or bottom area need not be deducted from the sectional areas included in the hull girder transverse sections, provided that:

$$\Sigma b_S \leq 0,06(B - \Sigma b)$$

where:

Σb_S : Total breadth of small openings, in m, in the strength deck or bottom area at the transverse section considered, determined as indicated in Fig 2

Σb : Total breadth of large openings, in m, at the transverse section considered, determined as indicated in Fig 2

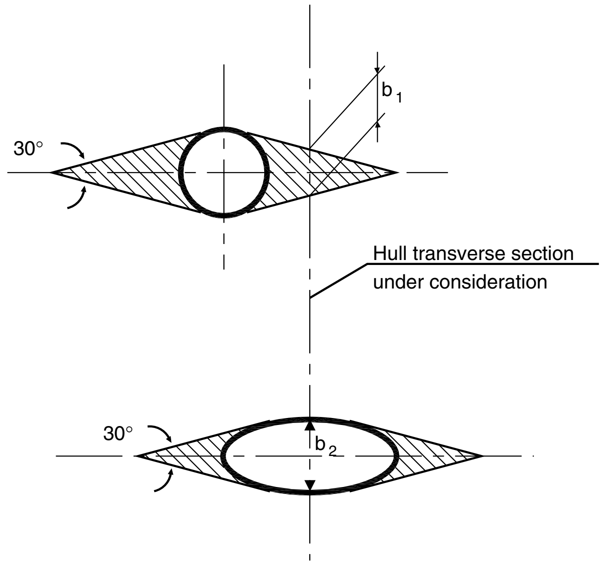
Where the total breadth of small openings Σb_S does not fulfil the above criteria, only the excess of breadth is to be deducted from the sectional areas included in the hull girder transverse sections.

2.1.9 Lightening holes, draining holes and single scallops

Lightening holes, draining holes and single scallops in longitudinals need not be deducted if their height is less than 0,25 h_W 10^{-3}, without being greater than 75 mm, where h_W is the web height, in mm, defined in Ch 4, Sec 3.

Otherwise, the excess is to be deducted from the sectional area or compensated.

Figure 2 : Calculation of Σb and Σb_S



2.2 Strength deck

2.2.1 The strength deck is, in general, the uppermost continuous deck.

In the case of a superstructure or deckhouses contributing to the longitudinal strength, the strength deck is the deck of the superstructure or the deck of the uppermost deckhouse.

2.2.2 A superstructure extending at least 0,15 L within 0,4 L amidships may generally be considered as contributing to the longitudinal strength. For other superstructures and for deckhouses, their contribution to the longitudinal strength is to be assessed on a case by case basis, through a finite element analysis of the whole ship, which takes into account the general arrangement of the longitudinal elements (side, decks, bulkheads).

The presence of openings in the side shell and longitudinal bulkheads is to be taken into account in the analysis. This may be done in two ways:

- by including these openings in the finite element model
- by assigning to the plate panel between the side frames beside each opening an equivalent thickness, in mm, obtained from the following formula:

$$t_{EQ} = 10^3 \left[\ell_P \left(\frac{Gh^2}{12EI_J} + \frac{1}{A_J} \right) \right]^{-1}$$

where (see Fig 3):

ℓ_P : Longitudinal distance, in m, between the frames beside the opening

h : Height, in m, of openings

I_J : Moment of inertia, in m⁴, of the opening jamb about the transverse axis y-y

A_J : Shear area, in m², of the opening jamb in the direction of the longitudinal axis x-x

G : Coulomb's modulus, in N/mm², of the material used for the opening jamb, to be taken equal to:

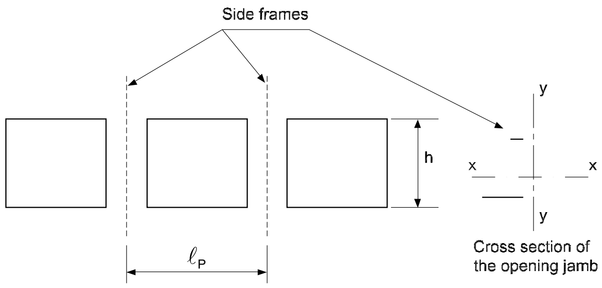
- for steels:

  $G = 8{,}0.10^4$ N/mm²

- for aluminium alloys:

  $G = 2{,}7.10^4$ N/mm².

Figure 3 : Side openings



2.3 Section modulus

2.3.1 The section modulus at any point of a hull transverse section is obtained, in m³, from the following formula:

$$Z_A = \frac{I_Y}{|z - N|}$$

where:

I_Y : Moment of inertia, in m⁴, of the hull transverse section defined in [2.1], about its horizontal neutral axis

z : Z co-ordinate, in m, of the calculation point with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [4]

N : Z co-ordinate, in m, of the centre of gravity of the hull transverse section defined in [2.1], with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [4].

2.3.2 The section moduli at bottom and at deck are obtained, in m³, from the following formulae:

- at bottom:

$$Z_{AB} = \frac{I_Y}{N}$$

- at deck:

$$Z_{AD} = \frac{I_Y}{V_D}$$

where:

I_Y, N : Defined in [2.3.1]

V_D : Vertical distance, in m:

- in general:

  $V_D = z_D - N$

  where:

  z_D : Z co-ordinate, in m, of strength deck, defined in [2.2], with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [4]

- if continuous trunks or hatch coamings are taken into account in the calculation of I_Y, as specified in [2.1.2]:

$$V_D = (z_T - N)\left(0{,}9 + 0{,}2\frac{y_T}{B}\right) \geq z_D - N$$

  where:

  y_T, z_T : Y and Z co-ordinates, in m, of the top of continuous trunk or hatch coaming with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [4]; y_T and z_T are to be measured for the point which maximises the value of V

- if longitudinal ordinary stiffeners or girders welded above the strength deck are taken into account in the calculation of I_Y, as specified in [2.1.3], V_D is to be obtained from the formula given above for continuous trunks and hatch coamings. In this case, y_T and z_T are the Y and Z co-ordinates, in m, of the top of the longitudinal stiffeners or girders with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [4].

2.4 Moments of inertia

2.4.1 The moments of inertia I_Y and I_Z, in m⁴, are those, calculated about the horizontal and vertical neutral axes, respectively, of the hull transverse sections defined in [2.1].

2.5 First moment

2.5.1 The first moment S, in m³, at a level z above the baseline is that, calculated with respect to the horizontal neutral axis, of the portion of the hull transverse sections defined in [2.1] located above the z level.

2.6 Structural models for the calculation of normal warping stresses and shear stresses

2.6.1 The structural models that can be used for the calculation of normal warping stresses, induced by torque, and shear stresses, induced by shear forces or torque, are:

- three dimensional finite element models
- thin walled beam models

representing the members which constitute the hull girder transverse sections according to [2.1].

SECTION 2 YIELDING CHECKS

Symbols

For symbols not defined in this Section, refer to the list at the beginning of this Chapter.

M_{WH} : Horizontal wave bending moment, in kN.m, defined in Ch 5, Sec 2, [3.2]

M_{WT} : Wave torque, in kN.m, defined in Ch 5, Sec 2, [3.3]

Q_{SW} : Design still water shear force, in kN, defined in Ch 5, Sec 2, [2.3]

Q_{WV} : Vertical wave shear force, to be calculated according to Ch 5, Sec 2, [3.4]:

- if $Q_{SW} \geq 0$, Q_{WV} is the positive wave shear force
- if $Q_{SW} < 0$, Q_{WV} is the negative wave shear force

k : Material factor, as defined in Ch 4, Sec 1, [2.3]

x : X co-ordinate, in m, of the calculation point with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [4]

I_Y : Moment of inertia, in m^4, of the hull transverse section about its horizontal neutral axis, to be calculated according to Sec 1, [2.4]

I_Z : Moment of inertia, in m^4, of the hull transverse section about its vertical neutral axis, to be calculated according to Sec 1, [2.4]

S : First moment, in m^3, of the hull transverse section, to be calculated according to Sec 1, [2.5]

Z_A : Section modulus, in m^3, at any point of the hull transverse section, to be calculated according to Sec 1, [2.3.1]

Z_{AB},Z_{AD} : Section moduli, in m^3, at bottom and deck, respectively, to be calculated according to Sec 1, [2.3.2]

n_1 : Navigation coefficient defined in Ch 5, Sec 1, [2.6.1]

C : Wave parameter defined in Ch 5, Sec 2.

1 Application

1.1

1.1.1 The requirements of this Section apply to ships having the following characteristics:

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

Ships not having one or more of these characteristics, ships intended for the carriage of heated cargoes and ships of unusual type or design are considered by the Society on a case by case basis.

2 Hull girder stresses

2.1 Normal stresses induced by vertical bending moments

2.1.1 The normal stresses induced by vertical bending moments are obtained, in N/mm^2, from the following formulae:

- at any point of the hull transverse section:

$$\sigma_1 = \frac{M_{SW} + M_{WV}}{Z_A} 10^{-3}$$

- at bottom:

$$\sigma_1 = \frac{M_{SW} + M_{WV}}{Z_{AB}} 10^{-3}$$

- at deck:

$$\sigma_1 = \frac{M_{SW} + M_{WV}}{Z_{AD}} 10^{-3}$$

2.1.2 The normal stresses in a member made in material other than steel with a Young's modulus E equal to $2,06\ 10^5$ N/mm^2, included in the hull girder transverse sections as specified in Sec 1, [2.1.6], are obtained from the following formula:

$$\sigma_1 = \frac{E}{2,06 \cdot 10^5} \sigma_{1S}$$

where:

σ_{1S} : Normal stress, in N/mm^2, in the member under consideration, calculated according to [2.1.1] considering this member as having the steel equivalent sectional area A_{SE} defined in Sec 1, [2.1.6].

2.2 Normal stresses induced by torque and bending moments

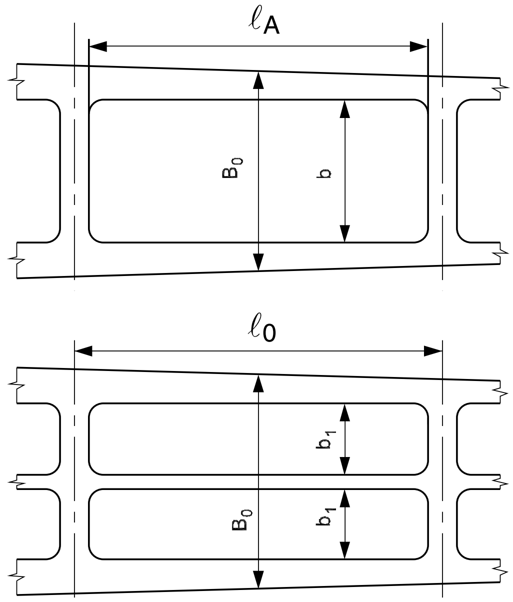
2.2.1 Ships having large openings in the strength deck

The normal stresses induced by torque and bending moments are to be considered for ships having large openings in the strength decks, i.e. ships for which at least one of the three following conditions occur:

- $b / B_0 > 0,7$
- $\ell_A / \ell_0 > 0,89$
- $b / B_0 > 0,6$ and $\ell_A / \ell_0 > 0,7$

where b, B_0, ℓ_A and ℓ_0 are the dimensions defined in Fig 1. In the case of two or more openings in the same hull transverse section, b is to be taken as the sum of the breadth b_1 of each opening.

Figure 1 : Ships with large openings



2.2.2 Normal stresses

The normal stresses are to be calculated for the load case constituted by the hull girder loads specified in Tab 1 together with their combination factors. They are to be obtained, in N/mm², from the following formula:

$$\sigma_1 = \frac{M_{SW}}{Z_A} + \frac{0{,}4 M_{WV}}{Z_A} + \frac{M_{WH}}{I_Z}|y| + \sigma_\Omega$$

where:

σ_Ω : Warping stress, in N/mm², induced by the torque M_{WT} and obtained through direct calculation analyses based on a structural model in accordance with Sec 1, [2.6];

y : Y co-ordinate, in m, of the calculation point with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [4].

2.3 Shear stresses

2.3.1 The shear stresses induced by shear forces and torque are obtained through direct calculation analyses based on a structural model in accordance with Sec 1, [2.6].

The shear force corrections ΔQ_C and ΔQ are to be taken into account, in accordance with [2.4.1] and [2.4.2], respectively.

2.3.2 The hull girder loads to be considered in these analyses are:

- for all ships, the vertical shear forces Q_{SW} and Q_{WV}
- for ships having large openings in the strength decks, also the torques M_T and $M_{T,SW}$ as specified in [2.2].

When deemed necessary by the Society on the basis of the ship's characteristics and intended service, the horizontal shear force is also to be calculated, using direct calculations, and taken into account in the calculation of shear stresses.

2.3.3 As an alternative to the above procedure, the shear stresses induced by the vertical shear forces QSW and QWV may be obtained through the simplified procedure in [2.4].

2.4 Simplified calculation of shear stresses induced by vertical shear forces

2.4.1 Ships without effective longitudinal bulkheads or with one effective longitudinal bulkhead

In this context, effective longitudinal bulkhead means a bulkhead extending from the bottom to the strength deck.

The shear stresses induced by the vertical shear forces in the calculation point are obtained, in N/mm², from the following formula:

$$\tau_1 = (Q_{SW} + Q_{WV} - \varepsilon \Delta Q_C)\frac{S}{I_Y t}\delta$$

where:

t : Minimum thickness, in mm, of side, inner side and longitudinal bulkhead plating, as applicable according to Tab 2

δ : Shear distribution coefficient defined in Tab 2

$\varepsilon = \mathrm{sgn}(Q_{SW})$

Table 1 : Torque and bending moments

Still water loads		Wave loads					
Vertical bending moment		Torque		Vertical bending moment		Horizontal bending moment	
Reference value	Comb. factor	Reference value	Comb. factor	Reference value	Comb. factor	Reference value	Comb. factor
M_{SW}	1,0	M_{WT}	1,0	M_{WV}	0,4	M_{WH}	1,0

Table 2 : Shear stresses induced by vertical shear forces

Ship typology	Location	t, in mm	δ	Meaning of symbols used in the definition of δ
Single side ships without effective longitudinal bulkheads - see Fig 3 (a)	Sides	t_S	0,5	
Double side ships without effective longitudinal bulkheads - see Fig 3 (b)	Sides	t_S	$(1-\Phi)/2$	$\Phi = 0{,}275 + 0{,}25\,\alpha$ $\alpha = t_{ISM}/t_{SM}$
	Inner sides	t_{IS}	$\Phi/2$	
Double side ships with one effective longitudinal bulkhead - see Fig 3 (c)	Sides	t_S	$(1-\Phi)\Psi/2$	$\Phi = 0{,}275 + 0{,}25\,\alpha$ $\alpha = t_{ISM}/t_{SM}$
	Inner sides	t_{IS}	$\Phi\Psi/2$	$\Psi = 1{,}9\beta\left[\gamma\left(2\delta+1+\frac{1}{\alpha_0}\right)-0{,}17\right]$ $\chi = \frac{\Psi}{0{,}85+0{,}17\alpha}$
	Longitudinal bulkhead	t_B	$1-\chi$	$\alpha_0 = \frac{0{,}5t_{BM}}{t_{SM}+t_{ISM}}$ $\beta = \frac{0{,}75}{3\delta+\alpha_0+1}$ $\gamma = \frac{2\delta+1}{4\delta+1+\frac{1}{\alpha_0}}$ $\delta = \frac{B}{2D}$

Note 1:
t_S, t_{IS}, t_B : Minimum thicknesses, in mm, of side, inner side and longitudinal bulkhead plating, respectively
t_{SM}, t_{ISM}, t_{BM} : Mean thicknesses, in mm, over all the strakes of side, inner side and longitudinal bulkhead plating, respectively. They are calculated as $\Sigma(\ell_i t_i)/\Sigma\ell_i$, where ℓ_i and t_i are the length, in m, and the thickness, in mm, of the i^{th} strake of side, inner side and longitudinal bulkhead.

ΔQ_C : Shear force correction (see Fig 2), which takes into account, when applicable, the portion of loads transmitted by the double bottom girders to the transverse bulkheads:

- for ships with double bottom in alternate loading conditions:

$$\Delta Q_C = \alpha\left|\frac{P}{B_H\ell_C} - \rho T_1\right|$$

- for other ships:

$$\Delta Q_C = 0$$

$$\alpha = g\frac{\ell_0 b_0}{2+\varphi\frac{\ell_0}{b_0}}$$

$$\varphi = 1{,}38 + 1{,}55\frac{\ell_0}{b_0} \le 3{,}7$$

ℓ_0, b_0 : Length and breadth, respectively, in m, of the flat portion of the double bottom in way of the hold considered; b_0 is to be measured on the hull transverse section at the middle of the hold

ℓ_C : Length, in m, of the hold considered, measured between transverse bulkheads

B_H : Ship's breadth, in m, measured on the hull transverse section at the middle of the hold considered

P : Total mass of cargo, in t, in the transversely adjacent holds in the section considered

ρ : Sea water density, in t/m^3:

$\rho = 1{,}025$ t/m^3

T_1 : Draught, in m, measured vertically on the hull transverse section at the middle of the hold considered, from the moulded baseline to the waterline in the loading condition considered.

Figure 2 : Shear force correction ΔQ_C

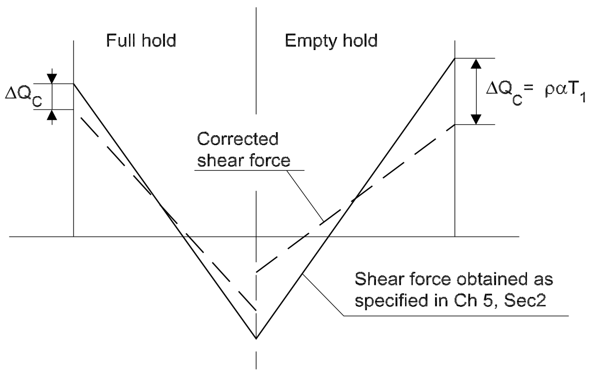
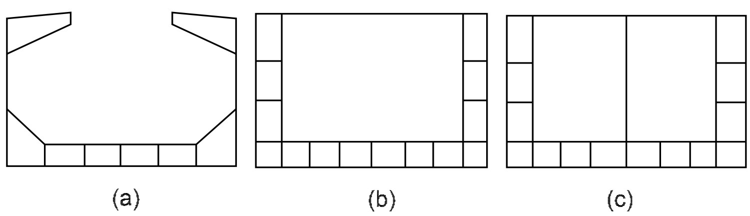


Figure 3 : Ship typologies (with reference to Tab 2)



2.4.2 Ships with two effective longitudinal bulkheads

In this context, effective longitudinal bulkhead means a bulkhead extending from the bottom to the strength deck.

The shear stresses induced by the vertical shear force in the calculation point are obtained, in N/mm², from the following formula:

$$\tau_1 = [(Q_{SW} + Q_{WV})\delta + \varepsilon_Q \Delta Q]\frac{S}{I_Y t}$$

where:

δ : Shear distribution coefficient defined in Tab 3

$$\varepsilon_Q = \text{sgn}\left(\frac{Q_F - Q_A}{\ell_C}\right)$$

Q_F, Q_A : Value of Q_{SW}, in kN, in way of the forward and aft transverse bulkhead, respectively, of the hold considered

ℓ_C : Length, in m, of the hold considered, measured between transverse bulkheads

t : Minimum thickness, in mm, of side, inner side and longitudinal bulkhead plating, as applicable according to Tab 3

ΔQ : Shear force correction, in kN, which takes into account the redistribution of shear force between sides and longitudinal bulkheads due to possible transverse non-uniform distribution of cargo:

- in sides:

$$\Delta Q = \frac{g\varepsilon(p_C - p_W)\ell_C b_C}{4}\left[\frac{n}{3(n+1)} - (1-\Phi)\right]$$

- in longitudinal bulkheads:

$$\Delta Q = \frac{g\varepsilon(p_C - p_W)\ell_C b_C}{4}\left[\frac{2n}{3(n+1)} - \Phi\right]$$

$$\varepsilon = \text{sgn}(Q_{SW})$$

p_C : Pressure, in kN/m², acting on the inner bottom in way of the centre hold in the loading condition considered

p_W : Pressure, in kN/m², acting on the inner bottom in way of the wing hold in the loading condition considered, to be taken not greater than p_C

b_C : Breadth, in m, of the centre hold, measured between longitudinal bulkheads

n : Number of floors in way of the centre hold

Φ : Coefficient defined in Tab 3.

3 Checking criteria

3.1 Normal stresses induced by vertical bending moments

3.1.1 It is to be checked that the normal stresses σ_1 calculated according to [2.1] and, when applicable, [2.2] are in compliance with the following formula:

$\sigma_1 \leq \sigma_{1,ALL}$

where:

$\sigma_{1,ALL}$: Allowable normal stress, in N/mm²:

$\sigma_{1,ALL} = 175/k$ N/mm²

3.2 Shear stresses

3.2.1 It is to be checked that the normal stresses τ_1 calculated according to [2.3] are in compliance with the following formula:

$\tau_1 \leq \tau_{1,ALL}$

where:

$\tau_{1,ALL}$: Allowable shear stress, in N/mm²:

$\tau_{1,ALL} = 110/k$ N/mm².

4 Section modulus and moment of inertia

4.1 General

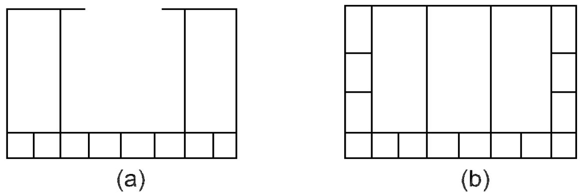
4.1.1 The requirements in [4.2] to [4.5] provide for the minimum hull girder section modulus, complying with the checking criteria indicated in [3], and the midship section moment of inertia required to ensure sufficient hull girder rigidity.

Table 3 : Shear stresses induced by vertical shear forces

Ship typology	Location	t, in mm	δ	Meaning of symbols used in the definition of δ
Single side ships with two effective longitudinal bulkheads - see Fig 4 (a)	Sides	t_S	(1- Φ) / 2	Φ = 0,3 + 0,21 α $\alpha = t_{BM} / t_{SM}$
	Longitudinal bulkheads	t_B	Φ / 2	
Double side ships with two effective longitudinal bulkheads - see Fig 4 (b)	Sides	t_S	(1- Φ) / 4	Φ = 0,275 + 0,25 α $\alpha = \frac{t_{BM}}{t_{SM} + t_{ISM}}$
	Inner sides	t_{IS}	(1- Φ) / 4	
	Longitudinal bulkheads	t_B	Φ / 2	

Note 1:
t_S, t_{IS}, t_B : Minimum thicknesses, in mm, of side, inner side and longitudinal bulkhead plating, respectively
t_{SM}, t_{ISM}, t_{BM} : Mean thicknesses, in mm, over all the strakes of side, inner side and longitudinal bulkhead plating, respectively. They are calculated as $\Sigma(\ell_i t_i)/\Sigma\ell_i$, where ℓ_i and t_i are the length, in m, and the thickness, in mm, of the i[th] strake of side, inner side and longitudinal bulkheads.

Figure 4 : Ship typologies (with reference to Tab 3)



As a minimum, hull girder bending strength checks are to be carried out at the following locations:

- in way of the forward end of the engine room
- in way of the forward end of the foremost cargo hold
- at any locations where there are significant changes in hull cross-section
- at any locations where there are changes in the framing system.

Buckling strength of members contributing to the longitudinal strength and subjected to compressive and shear stresses is to be checked, in particular in regions where changes in the framing system or significant changes in the hull cross-section occur. The buckling evaluation criteria used for this check are determined by the Society.

Continuity of structure is be maintained throughout the length of the ship. Where significant changes in structural arrangement occur, adequate transitional structure is to be provided.

For ships with large deck openings, sections at or near to the aft and forward quarter length positions are to be checked. For such ships with cargo holds aft of the superstructure, deckhouse or engine room, strength checks of sections in way of the aft end of the aft-most holds, and the aft end of the deckhouse or engine room are to be performed.

4.2 Section modulus within 0,4L amidships

4.2.1 For ships with C_B greater than 0,8, the gross section moduli Z_{AB} and Z_{AD} within 0,4L amidships are to be not less than the greater value obtained, in m³, from the following formulae:

- $Z_{R,MIN} = n_1 C L^2 B (C_B + 0,7) k 10^{-6}$
- $Z_R = \dfrac{M_{SW} + M_{WV}}{175/k} 10^{-3}$

4.2.2 For ships with C_B less than or equal to 0,8, the gross section moduli Z_{AB} and Z_{AD} at the midship section are to be not less than the value obtained, in m³, from the following formula:

$$Z_{R,MIN} = n_1 C L^2 B (C_B + 0,7) k 10^{-6}$$

In addition, the gross section moduli Z_{AB} and Z_{AD} within 0,4L amidships are to be not less than the value obtained, in m³, from the following formula:

$$Z_R = \frac{M_{SW} + M_{WV}}{175/k} 10^{-3}$$

4.2.3 The k material factors are to be defined with respect to the materials used for the bottom and deck members contributing to the longitudinal strength according to Sec 1, [2]. When material factors for higher strength steels are used, the requirements in [4.5] apply.

4.2.4 Where the total breadth Σb_S of small openings, as defined in Sec 1, [2.1.8], is deducted from the sectional areas included in the hull girder transverse sections, the values Z_R and $Z_{R,MIN}$ defined in [4.2.3] may be reduced by 3%.

4.2.5 Scantlings of members contributing to the longitudinal strength (see Sec 1, [2]) are to be maintained within 0,4L amidships.

4.3 Section modulus outside 0,4L amidships

4.3.1

Scantlings of members contributing to the hull girder longitudinal strength (see Sec 1, [2]) may be gradually reduced, outside 0,4L amidships, to the minimum required for local strength purposes at fore and aft parts, as specified in Chapter 9.

4.4 Midship section moment of inertia

4.4.1 The gross midship section moment of inertia about its horizontal neutral axis is to be not less than the value obtained, in m⁴, from the following formula:

$$I_{YR} = 3 Z'_{R,MIN} L 10^{-2}$$

where $Z'_{R,MIN}$ is the required midship section modulus $Z_{R,MIN}$, in m³, calculated as specified in [4.2.3], but assuming k = 1.

4.5 Extent of higher strength steel

4.5.1 When a material factor for higher strength steel is used in calculating the required section modulus at bottom or deck according to [4.2] or [4.3], the relevant higher strength steel is to be adopted for all members contributing to the longitudinal strength (see Sec 1, [2]), at least up to a vertical distance, in m, obtained from the following formulae:

- above the baseline (for section modulus at bottom):

$$V_{HB} = \frac{\sigma_{1B} - 175}{\sigma_{1B} + \sigma_{1D}} z_D$$

- below a horizontal line located at a distance V_D (see Sec 1, [2.3.2]) above the neutral axis of the hull transverse section (for section modulus at deck):

$$V_{HD} = \frac{\sigma_{1D} - 175}{\sigma_{1B} + \sigma_{1D}} (N + V_D)$$

where:

σ_{1B}, σ_{1D} : Normal stresses, in N/mm², at bottom and deck, respectively, calculated according to [2.1.1]

z_D : Z co-ordinate, in m, of the strength deck, defined in Sec 1, [2.2], with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [4]

N : Z co-ordinate, in m, of the centre of gravity of the hull transverse section defined in Sec 1, [2.1], with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [4]

V_D : Vertical distance, in m, defined in Sec 1, [2.3.2].

4.5.2 When a higher strength steel is adopted at deck, members not contributing to the longitudinal strength and welded on the strength deck (e.g. hatch coamings, strengthening of deck openings) are also generally to be made of the same higher strength steel.

4.5.3 The higher strength steel is to extend in length at least throughout the whole midship area where it is required for strength purposes according to the provisions of Part B.

5 Permissible still water bending moment and shear force during navigation

5.1 Permissible still water bending moment

5.1.1 The permissible still water bending moment at any hull transverse section during navigation, in hogging or sagging conditions, is the value M_{SW} considered in the hull girder section modulus calculation according to [4].

In the case of structural discontinuities in the hull transverse sections, the distribution of permissible still water bending moments is considered on a case by case basis.

5.2 Permissible still water shear force

5.2.1 Direct calculations

Where the shear stresses are obtained through calculation analyses according to [2.3], the permissible positive or negative still water shear force at any hull transverse section is obtained, in kN, from the following formula:

$$Q_P = \varepsilon|Q_T| - Q_{WV}$$

where:

$$\varepsilon = \mathrm{sgn}(Q_{SW})$$

Q_T : Shear force, in kN, which produces a shear stress τ = 110/k N/mm^2 in the most stressed point of the hull transverse section, taking into account the shear force correction ΔQ_C and ΔQ in accordance with [2.4.1] and [2.4.2], respectively.

5.2.2 Ships without effective longitudinal bulkeads or with one effective longitudinal bulkhead

Where the shear stresses are obtained through the simplified procedure in [2.4.1], the permissible positive or negative still water shear force at any hull transverse section is obtained, in kN, from the following formula:

$$Q_P = \varepsilon\left(\frac{110}{k\delta}\cdot\frac{I_Y t}{S} + \Delta Q_C\right) - Q_{WV}$$

where:

$$\varepsilon = \mathrm{sgn}(Q_{SW})$$

δ : Shear distribution coefficient defined in Tab 2

t : Minimum thickness, in mm, of side, inner side and longitudinal bulkhead plating, as applicable according to Tab 2

ΔQ_C : Shear force correction defined in [2.4.1].

5.2.3 Ships with two effective longitudinal bulkeads

Where the shear stresses are obtained through the simplified procedure in [2.4.2], the permissible positive or negative still water shear force at any hull transverse section is obtained, in kN, from the following formula:

$$Q_P = \frac{1}{\delta}\left(\varepsilon\frac{110}{k}\cdot\frac{I_Y t}{S} - \varepsilon_Q \Delta Q\right) - Q_{WV}$$

where:

δ : Shear distribution coefficient defined in Tab 3

$$\varepsilon = \mathrm{sgn}(Q_{SW})$$

t : Minimum thickness, in mm, of side, inner side and longitudinal bulkhead plating, as applicable according to Tab 3

ε_Q : Defined in [2.4.2]

ΔQ : Shear force correction defined in [2.4.2].

6 Permissible still water bending moment and shear force in harbour conditions

6.1 Permissible still water bending moment

6.1.1 The permissible still water bending moment at any hull transverse section in harbour conditions, in hogging or sagging conditions, is obtained, in kN.m, from the following formula:

$$M_{P,H} = M_P + 0,6 M_{WV}$$

where M_P is the permissible still water bending moment during navigation, in kN.m, to be calculated according to [5.1.1].

6.2 Permissible shear force

6.2.1 The permissible positive or negative still water shear force at any hull transverse section, in harbour conditions, is obtained, in kN, from the following formula:

$$Q_{P,H} = \varepsilon Q_P + 0,7\, Q_{WV}$$

where:

$$\varepsilon = \mathrm{sgn}(Q_{SW})$$

Q_P : Permissible still water shear force during navigation, in kN, to be calculated according to [5.2].

SECTION 3 ULTIMATE STRENGTH CHECK

Symbols

For symbols not defined in this Section, refer to the list at the beginning of this Chapter.

1 Application

1.1

1.1.1 The requirements of this Section apply to ships equal to or greater than 150 m in length.

2 Partial safety factors

2.1

2.1.1 The partial safety factors to be considered for checking the ultimate strength of the hull girder are specified in Tab 1.

Table 1 : Partial safety factors

Partial safety factor covering uncertainties on:	Symbol	Value
Still water hull girder loads	γ_{S1}	1,00
Wave induced hull girder loads	γ_{W1}	1,15
Material	γ_m	1,02
Resistance	γ_R	1,08

3 Hull girder ultimate strength check

3.1 Hull girder loads

3.1.1 Bending moments

The bending moment in sagging and hogging conditions, to be considered in the ultimate strength check of the hull girder, is to be obtained, in kN.m, from the following formula:

$$M = \gamma_{S1} M_{SW} + \gamma_{W1} M_{WV}$$

3.2 Hull girder ultimate bending moment capacities

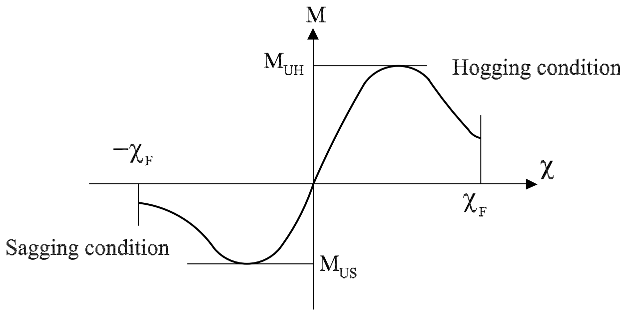
3.2.1 Curve M-χ

The ultimate bending moment capacities of a hull girder transverse section, in hogging and sagging conditions, are defined as the maximum values of the curve of bending moment capacity M versus the curvature χ of the transverse section considered (see Fig 1).

The curvature χ is positive for hogging condition and negative for sagging condition.

The curve M-χ is to be obtained through an incremental-iterative procedure according to the criteria specified in App 1.

Figure 1 : Curve bending moment capacity M versus curvature χ



3.2.2 Hull girder transverse sections

The hull girder transverse sections are constituted by the elements contributing to the hull girder longitudinal strength, considered with their net scantlings, according to Sec 1, [2].

3.3 Checking criteria

3.3.1 It is to be checked that the hull girder ultimate bending capacity at any hull transverse section is in compliance with the following formula:

$$\frac{M_U}{\gamma_R \gamma_m} \geq M$$

where:

M_U : Ultimate bending moment capacity of the hull transverse section considered, in kN.m:

- in hogging conditions:

  $M_U = M_{UH}$

- in sagging conditions:

  $M_U = M_{US}$

M_{UH} : Ultimate bending moment capacity in hogging conditions, defined in [3.2.1]

M_{US} : Ultimate bending moment capacity in sagging conditions, defined in [3.2.1]

M : Bending moment, in kN.m, defined in [3.1.1].

APPENDIX 1 HULL GIRDER ULTIMATE STRENGTH

Symbols

For symbols not defined in this Appendix, refer to the list at the beginning of this Chapter.

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

I_Y : Moment of inertia, in m^4, of the hull transverse section around its horizontal neutral axis, to be calculated according to Sec 1, [2.4]

Z_{AB} ,Z_{AD} : Section moduli, in cm^3, at bottom and deck, respectively, defined in Sec 1, [2.3.2]

s : Spacing, in m, of ordinary stiffeners

ℓ : Span, in m, of ordinary stiffeners, measured between the supporting members (see Ch 4, Sec 3, Fig 2 to Ch 4, Sec 3, Fig 5)

h_w : Web height, in mm, of an ordinary stiffener

t_w : Web net thickness, in mm, of an ordinary stiffener

b_f : Face plate width, in mm, of an ordinary stiffener

t_f : Face plate net thickness, in mm, of an ordinary stiffener

A_S : Net sectional area, in cm^2, of an ordinary stiffener

t_p : Net thickness, in mm, of the plating attached to an ordinary stiffener.

1 Hull girder ultimate strength check

1.1 Introduction

1.1.1 Sec 3, [2] defines the criteria for calculating the ultimate bending moment capacities in hogging condition M_{UH} and sagging condition M_{US} of a hull girder transverse section.

As specified in Sec 3, [2], the ultimate bending moment capacities are defined as the maximum values of the curve of bending moment capacity M versus the curvature χ of the transverse section considered (see Fig 1).

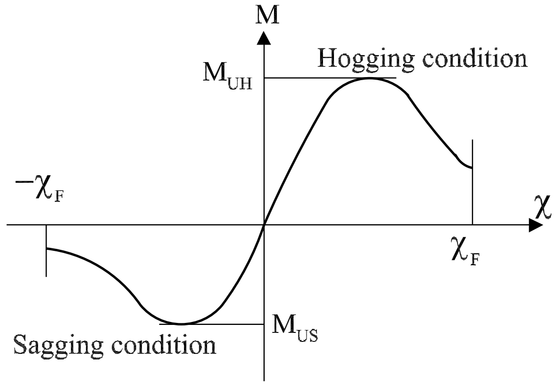
1.1.2 This Appendix provides the criteria for obtaining the curve M-χ.

1.2 Criteria for the calculation of the curve M-χ

1.2.1 Procedure

The curve M-χ is to be obtained by means of an incremental-iterative approach, summarised in the flow chart in Fig 2.

Figure 1 : Curve bending moment capacity M versus curvature χ



Each step of the incremental procedure is represented by the calculation of the bending moment M_i which acts on the hull transverse section as the effect of an imposed curvature χ_i.

For each step, the value χ_i is to be obtained by summing an increment of curvature $\Delta\chi$ to the value relevant to the previous step χ_{i-1}.This increment of curvature corresponds to an increment of the rotation angle of the hull girder transverse section around its horizontal neutral axis.

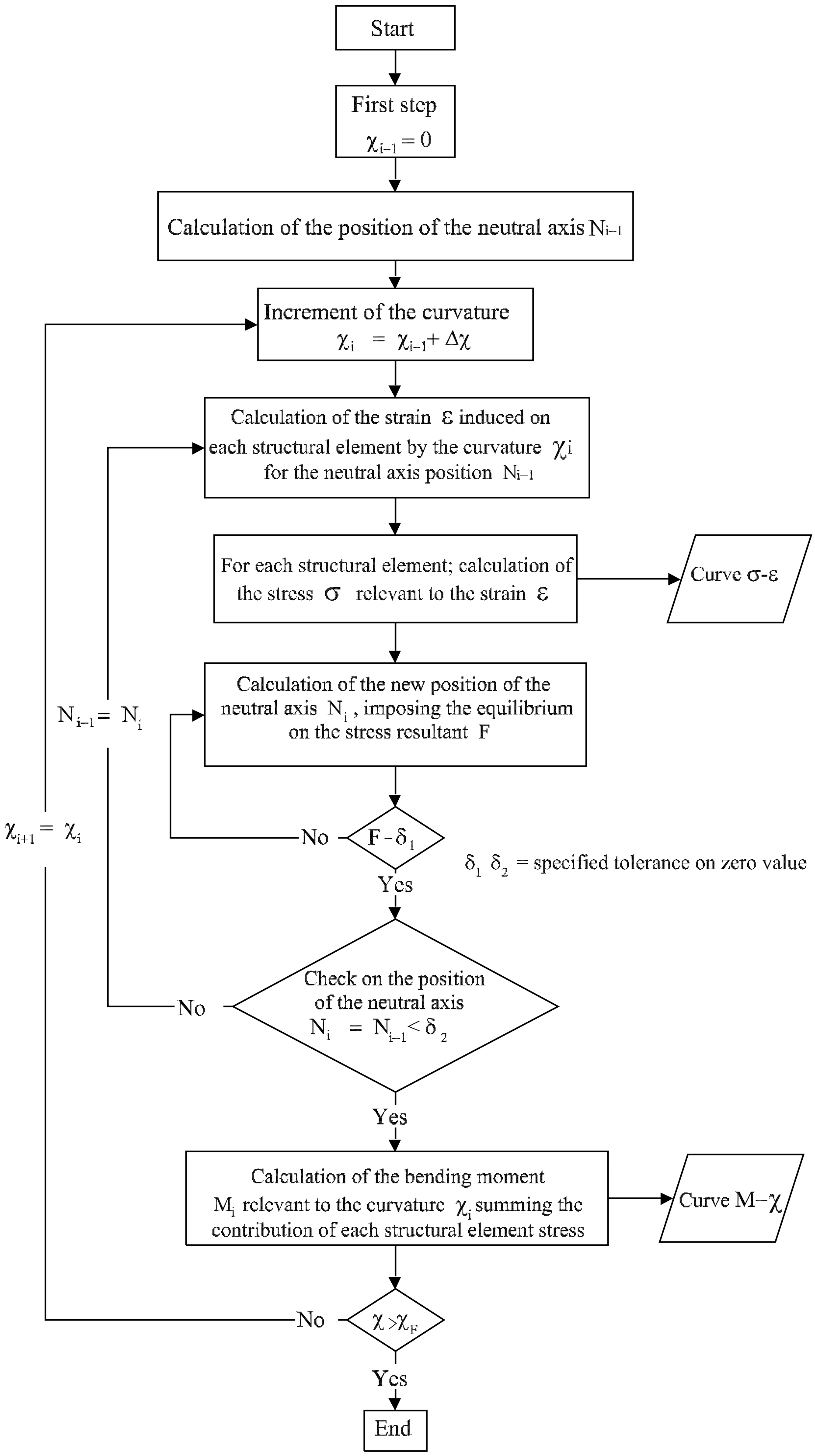
This rotation increment induces axial strains ε in each hull structural element, whose value depends on the position of the element. In hogging condition, the structural elements above the neutral axis are lengthened, while the elements below the neutral axis are shortened. Vice-versa in sagging condition.

The stress σ induced in each structural element by the strain ε is to be obtained from the load-end shortening curve σ-ε of the element, which takes into account the behaviour of the element in the non-linear elasto-plastic domain.

The distribution of the stresses induced in all the elements composing the hull transverse section determines, for each step, a variation of the neutral axis position, since the relationship σ-ε is non-linear. The new position of the neutral axis relevant to the step considered is to be obtained by means of an iterative process, imposing the equilibrium among the stresses acting in all the hull elements.

Once the position of the neutral axis is known and the relevant stress distribution in the section structural elements is obtained, the bending moment of the section M_i around the new position of the neutral axis, which corresponds to the curvature χ_i imposed in the step considered, is to be obtained by summing the contribution given by each element stress.

Figure 2 : Flow chart of the procedure for the evaluation of the curve M-χ



1.2.2 Assumption

In applying the procedure described in [1.2.1], the following assumptions are generally to be made:

- The ultimate strength is calculated at hull transverse sections between two adjacent reinforced rings.
- The hull girder transverse section remains plane during each curvature increment.
- The hull material has an elasto-plastic behaviour.
- The hull girder transverse section is divided into a set of elements, which are considered to act independently. These elements are:
  - transversely framed plating panels and/or ordinary stiffeners with attached plating, whose structural behaviour is described in [1.3.1]
  - hard corners, constituted by plating crossing, whose structural behaviour is described in [1.3.2].
- According to the iterative procedure, the bending moment M_i acting on the transverse section at each curvature value χ_i is obtained by summing the contribution given by the stress σ acting on each element. The stress σ, corresponding to the element strain ε, is to be obtained for each curvature increment from the non-linear load-end shortening curves σ-ε of the element.

  These curves are to be calculated, for the failure mechanisms of the element, from the formulae specified in [1.3]. The stress σ is selected as the lowest among the values obtained from each of the considered load-end shortening curves σ-ε.
- The procedure is to be repeated for each step, until the value of the imposed curvature reaches the value χ_F, in m^{-1}, in hogging and sagging condition, obtained from the following formula:

  $$\chi_F = \pm 0{,}003\frac{M_Y}{EI_Y}$$

  where:

  M_Y : the lesser of the values M_{Y1} and M_{Y2}, in kN.m:

  $$M_{Y1} = 10^{-3}\, R_{eH}\, Z_{AB}$$

  $$M_{Y2} = 10^{-3}\, R_{eH}\, Z_{AD}$$

  If the value χ_F is not sufficient to evaluate the peaks of the curve M-χ, the procedure is to be repeated until the value of the imposed curvature permits the calculation of the maximum bending moments of the curve.

1.3 Load-end shortening curves σ-ε

1.3.1 Plating panels and ordinary stiffeners

Plating panels and ordinary stiffeners composing the hull girder transverse sections may collapse following one of the modes of failure specified in Tab 1.

1.3.2 Hard corners

Hard corners are sturdier elements composing the hull girder transverse section, which collapse mainly according to an elasto-plastic mode of failure. The relevant load-end shortening curve σ-ε is to be obtained for lengthened and shortened hard corners according to [1.3.3].

Table 1 : Modes of failure of plating panels and ordinary stiffeners

Element	Mode of failure	Curve σ-ε defined in
Lengthened transversely framed plating panel or ordinary stiffeners	Elasto-plastic collapse	[1.3.3]
Shortened ordinary stiffeners	Beam column buckling	[1.3.4]
	Torsional buckling	[1.3.5]
	Web local buckling of flanged profiles	[1.3.6]
	Web local buckling of flat bars	[1.3.7]
Shortened transversely framed plating panel	Plate buckling	[1.3.8]

1.3.3 Elasto-plastic collapse

The equation describing the load-end shortening curve σ-ε for the elasto-plastic collapse of structural elements composing the hull girder transverse section is to be obtained from the following formula, valid for both positive (shortening) and negative (lengthening) strains (see Fig 3):

$$\sigma = \Phi R_{eH}$$

where:

Φ : Edge function:

$\Phi = -1$ for $\varepsilon < -1$

$\Phi = \varepsilon$ for $-1 < \varepsilon < 1$

$\Phi = 1$ for $\varepsilon > 1$

ε : Relative strain:

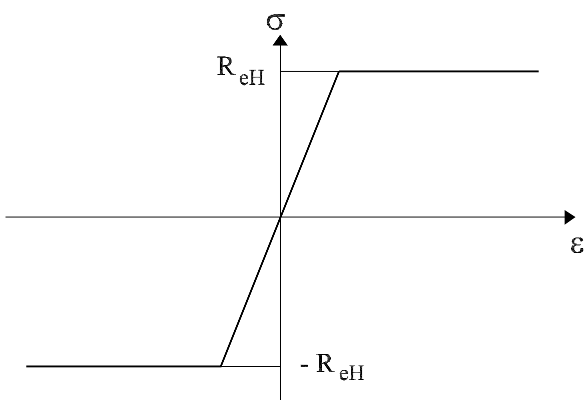
$$\varepsilon = \frac{\varepsilon_E}{\varepsilon_Y}$$

ε_E : Element strain

ε_Y : Strain inducing yield stress in the element:

$$\varepsilon_Y = \frac{R_{eH}}{E}$$

Figure 3 : Load-end shortening curve σ-ε for elasto-plastic collapse



1.3.4 Beam column buckling

The equation describing the load-end shortening curve σ_{CR1}-ε for the beam column buckling of ordinary stiffeners composing the hull girder transverse section is to be obtained from the following formula (see Fig 4):

$$\sigma_{CR1} = \Phi\sigma_{C1}\frac{A_S + 10b_E t_P}{A_S + 10st_P}$$

where:

Φ : Edge function defined in [1.3.3]

σ_{C1} : Critical stress, in N/mm²:

$$\sigma_{C1} = \frac{\sigma_{E1}}{\varepsilon} \quad \text{for} \quad \sigma_{E1} \le \frac{R_{eH}}{2}\varepsilon$$

$$\sigma_{C1} = R_{eH}\left(1 - \frac{\Phi R_{eH}\varepsilon}{4\sigma_{E1}}\right) \quad \text{for} \quad \sigma_{E1} > \frac{R_{eH}}{2}\varepsilon$$

ε : Relative strain defined in [1.3.3]

σ_{E1} : Euler column buckling stress, in N/mm²:

$$\sigma_{E1} = \pi^2 E\frac{I_E}{A_E l^2}10^4$$

I_E : Net moment of inertia of ordinary stiffeners, in cm⁴, with attached shell plating of width b_{E1}

b_{E1} : Width, in m, of the attached shell plating:

$$b_{E1} = \frac{s}{\beta_E} \quad \text{for} \quad \beta_E > 1,0$$

$$b_{E1} = s \quad \text{for} \quad \beta_E \le 1,0$$

$$\beta_E = 10^3\frac{s}{t_p}\sqrt{\frac{\varepsilon R_{eH}}{E}}$$

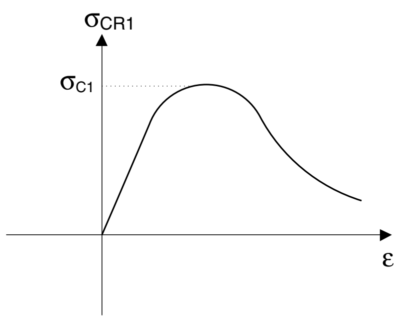
A_E : Net sectional area, in cm², of ordinary stiffeners with attached shell plating of width b_E

b_E : Width, in m, of the attached shell plating:

$$b_E = \left(\frac{2,25}{\beta_E} - \frac{1,25}{\beta_E^2}\right)s \quad \text{for} \quad \beta_E > 1,25$$

$$b_E = s \quad \text{for} \quad \beta_E \le 1,25$$

Figure 4 : Load-end shortening curve σ_{CR1}-ε for beam column buckling



1.3.5 Torsional buckling

The equation describing the load-end shortening curve σ_{CR2}-ε for the lateral-flexural buckling of ordinary stiffeners composing the hull girder transverse section is to be obtained according to the following formula (see Fig 5):

$$\sigma_{CR2} = \Phi\frac{A_S\sigma_{C2} + 10st_P\sigma_{CP}}{A_S + 10st_P}$$

where:

Φ : Edge function defined in [1.3.3]

σ_{C2} : Critical stress, in N/mm²:

$$\sigma_{C2} = \frac{\sigma_{E2}}{\varepsilon} \quad \text{for} \quad \sigma_{E2} \le \frac{R_{eH}}{2}\varepsilon$$

$$\sigma_{C2} = R_{eH}\left(1 - \frac{\Phi R_{eH}\varepsilon}{4\sigma_{E2}}\right) \quad \text{for} \quad \sigma_{E2} > \frac{R_{eH}}{2}\varepsilon$$

σ_{E2} : Euler torsional buckling stress, in N/mm², defined in Ch 7, Sec 2, [4.3.3]

ε : Relative strain defined in [1.3.3]

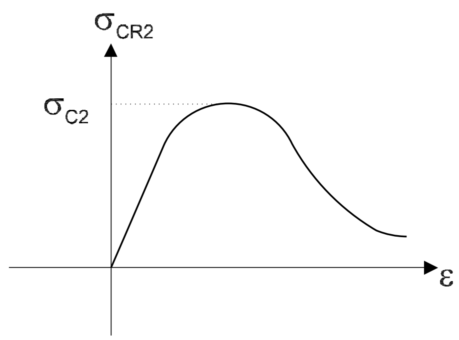
σ_{CP} : Buckling stress of the attached plating, in N/mm²:

$$\sigma_{CP} = \left(\frac{2,25}{\beta_E} - \frac{1,25}{\beta_E^2}\right)R_{eH} \quad \text{for} \quad \beta_E > 1,25$$

$$\sigma_{CP} = R_{eH} \quad \text{for} \quad \beta_E \le 1,25$$

β_E : Coefficient defined in [1.3.4].

Figure 5 : Load-end shortening curve σ_{CR2}-ε for flexural-torsional buckling



1.3.6 Web local buckling of flanged ordinary stiffeners

The equation describing the load-end shortening curve σ_{CR3}-ε for the web local buckling of flanged ordinary stiffeners composing the hull girder transverse section is to be obtained from the following formula:

$$\sigma_{CR3} = \Phi R_{eH}\frac{10^3 b_E t_P + h_{WE}t_W + b_F t_F}{10^3 st_P + h_W t_W + b_F t_F}$$

where:

Φ : Edge function defined in [1.3.3]

b_E : Width, in m, of the attached shell plating, defined in [1.3.4]

h_{WE} : Effective height, in mm, of the web:

$$h_{WE} = \left(\frac{2,25}{\beta_E} - \frac{1,25}{\beta_E^2}\right)h_W \quad \text{for} \quad \beta_W > 1,25$$

$$h_{WE} = h_W \quad \text{for} \quad \beta_W \le 1,25$$

β_E : Coefficient defined in [1.3.4]

$$\beta_W = 10^3\frac{h_W}{t_W}\sqrt{\frac{\varepsilon R_{eH}}{E}}$$

ε : Relative strain defined in [1.3.3].

1.3.7 Web local buckling of flat bar ordinary stiffeners

The equation describing the load-end shortening curve σ_{CR4}-ε for the web local buckling of flat bar ordinary stiffeners composing the hull girder transverse section is to be obtained from the following formula (see Fig 6):

$$\sigma_{CR4} = \Phi \frac{10 s t_P \sigma_{CP} + A_S \sigma_{C4}}{A_S + 10 s t_P}$$

where:

Φ : Edge function defined in [1.3.3]

σ_{CP} : Buckling stress of the attached plating, in N/mm², defined in [1.3.5]

σ_{C4} : Critical stress, in N/mm²:

$$\sigma_{C4} = \frac{\sigma_{E4}}{\varepsilon} \quad \text{for} \quad \sigma_{E4} \le \frac{R_{eH}}{2}\varepsilon$$

$$\sigma_{C4} = R_{eH}\left(1 - \frac{\Phi R_{eH} \varepsilon}{4\sigma_{E4}}\right) \quad \text{for} \quad \sigma_{E4} > \frac{R_{eH}}{2}\varepsilon$$

σ_{E4} : Local Euler buckling stress, in N/mm²:

$$\sigma_{E4} = 160000\left(\frac{t_W}{h_W}\right)^2$$

ε : Relative strain defined in [1.3.3].

1.3.8 Plate buckling

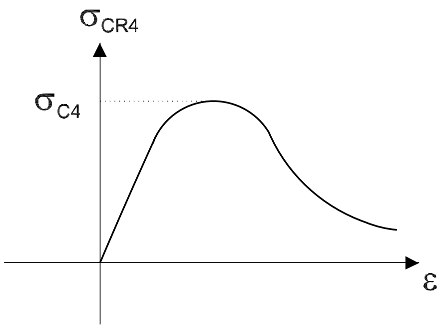
The equation describing the load-end shortening curve σ_{CR5}-ε for the buckling of transversely stiffened panels composing the hull girder transverse section is to be obtained from the following formula:

$$\sigma_{CR5} = R_{eH}\left[\frac{s}{l}\left(\frac{2,25}{\beta_E} - \frac{1,25}{\beta_E^2}\right) + 0,1\left(1 - \frac{s}{l}\right)\left(1 + \frac{1}{\beta_E^2}\right)^2\right]$$

where:

β_E : Coefficient defined in [1.3.4].

Figure 6 : Load-end shortening curve σ_{CR4}-ε for web local buckling of flat bars



Part B
Hull and Stability

Chapter 7
HULL SCANTLINGS

Symbols used in chapter 7

L_1, L_2 : Lengths, in m, defined in Pt B, Ch 1, Sec 2, [2.1.1],

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

- for steels in general:

  E = 2,06.10^5 N/mm^2
- for stainless steels:

  E = 1,95.10^5 N/mm^2
- for aluminium alloys:

  E = 7,0.10^4 N/mm^2

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

k : material factor, defined in:

- Pt B, Ch 4, Sec 1, [2.3], for steel,
- Pt B, Ch 4, Sec 1, [4.4], for aluminium alloys,

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

t_c : Corrosion addition, in mm, defined in Pt B, Ch 4, Sec 2, Tab 2,

I_Y : Net moment of inertia, in m^4, of the hull transverse section around its horizontal neutral axis, to be calculated according to Pt B, Ch 6, Sec 1, [2.4] considering the members contributing to the hull girder longitudinal strength as having their net scantlings,

I_Z : Net moment of inertia, in m^4, of the hull transverse section around its vertical neutral axis, to be calculated according to Pt B, Ch 6, Sec 1, [2.4] considering the members contributing to the hull girder longitudinal strength as having their net scantlings,

x, y, z : X, Y and Z co-ordinates, in m, of the calculation point with respect to the reference co-ordinate system defined in Pt B, Ch 1, Sec 2, [4],

N : Z co-ordinate, in m, with respect to the reference co-ordinate system defined in Pt B, Ch 1, Sec 2, [4], of the centre of gravity of the hull transverse section constituted by members contributing to the hull girder longitudinal strength considered as having their net scantlings (see Pt B, Ch 6, Sec 1, [2]),

$M_{SW,H}$: Design still water bending moment, in kN.m, in hogging condition, at the hull transverse section considered, defined in Pt B, Ch 5, Sec 2, [2.2],

$M_{SW,S}$: Design still water bending moment, in kN.m, in sagging condition, at the hull transverse section considered, defined in Pt B, Ch 5, Sec 2, [2.2],

$M_{SW,Hmin}$: Minimum still water bending moment, in kN.m, in hogging condition, at the hull transverse section considered, without being taken greater than 0,3$M_{WV,S}$,

$M_{WV,H}$: Vertical wave bending moment, in kN.m, in hogging condition, at the hull transverse section considered, defined in Pt B, Ch 5, Sec 2, [3.1],

$M_{WV,S}$: Vertical wave bending moment, in kN.m, in sagging condition, at the hull transverse section considered, defined in Pt B, Ch 5, Sec 2, [3.1],

M_{WH} : Horizontal wave bending moment, in kN.m, at the hull transverse section considered, defined in Pt B, Ch 5, Sec 2, [3.2],

M_{WT} : Wave torque, in kN.m, at the hull transverse section considered, defined in Pt B, Ch 5, Sec 2, [3.3].

SECTION 1 PLATING

Symbols

For symbols not defined in this Section, refer to the list at the beginning of this Chapter.

p_S : Still water pressure, in kN/m², see [3.2.2]

p_W : Wave pressure and, if necessary, dynamic pressures, according to the criteria in Ch 5, Sec 5 and Ch 5, Sec 6, [2], in kN/m² (see [3.2.2])

p_{SF}, p_{WF} : Still water and wave pressure, in kN/m², in flooding conditions, defined in Ch 5, Sec 6, [9] (see [3.2.3])

F_S : Still water wheeled force, in kN, see [4.2.2]

$F_{W,Z}$: Inertial wheeled force, in kN, see [4.2.2]

σ_{X1} : In-plane hull girder normal stress, in N/mm², defined in:

- [3.2.4] for the strength check of plating subjected to lateral pressure
- [5.2.2] for the buckling check of plating

τ_1 : In-plane hull girder shear stress, in N/mm², defined in [3.2.5]

R_{eH} : Minimum yield stress, in N/mm², of the plating material, defined in Ch 4, Sec 1, [2]

ℓ : Length, in m, of the longer side of the plate panel

s : Length, in m, of the shorter side of the plate panel

c_a : Aspect ratio of the plate panel, equal to:

$$c_a = 1{,}21\sqrt{1 + 0{,}33\left(\frac{s}{\ell}\right)^2} - 0{,}69\frac{s}{\ell}$$

to be taken not greater than 1,0

c_r : Coefficient of curvature of the panel, equal to:

$$c_r = 1 - 0{,}5s/r$$

to be taken not less than 0,75

r : Radius of curvature, in m

t_{net} : Net thickness, in mm, of a plate panel

1 General

1.1 Net thicknesses

1.1.1 As specified in Ch 4, Sec 2, [1], all thicknesses referred to in this Section are net, i.e. they do not include any margin for corrosion.

The gross thicknesses are obtained as specified in Ch 4, Sec 2.

1.2 Partial safety factors

1.2.1 The partial safety factors to be considered for the checking of the plating are specified in Tab 1.

1.3 Elementary plate panel

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

1.4 Load point

1.4.1 Unless otherwise specified, lateral pressure and hull girder stresses are to be calculated:

- for longitudinal framing, at the lower edge of the elementary plate panel or, in the case of horizontal plating, at the point of minimum y-value among those of the elementary plate panel considered
- for transverse framing, at the lower edge of the strake.

Table 1 : Plating - Partial safety factors

Partial safety factors covering uncertainties regarding:	Symbol	Strength check of plating subjected to lateral pressure		Buckling check (see [5])
		General (see [3.2], [3.3.1], [3.4.1], [3.5.1] and [4])	Watertight bulkhead plating **(1)** (see [3.3.2], [3.4.2] and [3.5.2])	
Still water hull girder loads	γ_{S1}	1,00	1,00	1,00
Wave hull girder loads	γ_{W1}	1,15	1,15	1,15
Still water pressure	γ_{S2}	1,00	1,00	Not applicable
Wave pressure	γ_{W2}	1,20	1,20	Not applicable
Material	γ_m	1,02	1,02	1,02
Resistance	γ_R	1,20	1,05 **(2)**	1,10

(1) Applies also to plating of bulkheads or inner side which constitute boundary of compartments not intended to carry liquids.
(2) For plating of the collision bulkhead, γ_R =1,25

2 General requirements

2.1 General

2.1.1 The requirements in [2.2] and [2.3] are to be applied to plating in addition of those in [3] to [5].

2.2 Minimum net thicknesses

2.2.1 The net thickness of plating is to be not less than the values given in Tab 2.

2.3 Bilge plating

2.3.1 The bilge plating net thickness is to be not less than the values obtained from:

- strength check of plating subjected to lateral pressure:
  - criteria in [3.3.1] for longitudinally framed bilges
  - criteria in [3.4.1] for transversely framed bilges
- buckling check:
  - criteria in [5] for longitudinally framed bilge, to be checked as plane plating
  - criteria in [5.3.4] for transversely framed bilge, considering only the case of compression stresses perpendicular to the curved edges.

The net thickness of longitudinally framed bilge plating is to be not less than that required for the adjacent bottom or side plating, whichever is the greater.

The net thickness of transversely framed bilge plating may be taken not greater than that required for the adjacent bottom or side plating, whichever is the greater.

2.4 Sheerstrake

2.4.1 Welded sheerstrake

The net thickness of a welded sheerstrake is to be not less than that of the adjacent side plating, taking into account higher strength steel corrections if needed.

In general, the required net thickness of the adjacent side plating is to be taken as a reference. In specific case, depending on its actual net thickness, this latter may be required to be considered when deemed necessary by the Society.

2.4.2 Rounded sheerstrake

The net thickness of a rounded sheerstrake is to be not less than the actual net thickness of the adjacent deck plating.

2.4.3 Net thickness of the sheerstrake in way of breaks of long superstructures

The net thickness of the sheerstrake is to be increased in way of breaks of long superstructures occurring within 0,5L amidships, over a length of about one sixth of the ship's breadth on each side of the superstructure end.

This increase in net thickness is to be equal to 40%, but need not exceed 4,5 mm.

Where the breaks of superstructures occur outside 0,5L amidships, the increase in net thickness may be reduced to 30%, but need not exceed 2,5 mm.

Table 2 : Minimum net thickness of plating

Plating	Minimum net thickness, in mm
Keel	$3,8 + 0,040Lk^{1/2} + 4,5s$
Bottom	
• longitudinal framing	$1,9 + 0,032Lk^{1/2} + 4,5s$
• transverse framing	$2,8 + 0,032Lk^{1/2} + 4,5s$
Inner bottom	
• outside the engine room	$1,9 + 0,024Lk^{1/2} + 4,5s$
• engine room	$3,0 + 0,024Lk^{1/2} + 4,5s$
Side	
• below freeboard deck	$2,1 + 0,031Lk^{1/2} + 4,5s$
• between freeboard deck and strength deck	$2,1 + 0,013Lk^{1/2} + 4,5s$
Inner side	
• L < 120 m	$1,7 + 0,013Lk^{1/2} + 4,5s$
• L ≥ 120 m	$3,6 + 2,2k^{1/2} + s$
Weather strength deck and trunk deck, if any	
• area within 0,4 L amidships	
- longitudinal framing	$1,6 + 0,032Lk^{1/2} + 4,5s$
- transverse framing	$1,6 + 0,040Lk^{1/2} + 4,5s$
• area outside 0,4 L amidships	**(1)**
• between hatchways	$2,1 + 0,013Lk^{1/2} + 4,5s$
• at fore and aft part	$2,1 + 0,013Lk^{1/2} + 4,5s$
Cargo deck	
• general	$8sk^{1/2}$
• wheeled load only	4,5
Accommodation deck	
• L < 120 m	$1,3 + 0,004Lk^{1/2} + 4,5s$
• L ≥ 120 m	$2,1 + 2,2k^{1/2} + s$
Platform in engine room	
• L < 120 m	$1,7 + 0,013Lk^{1/2} + 4,5s$
• L ≥ 120 m	$3,6 + 2,2k^{1/2} + s$
Transverse watertight bulkhead	
• L < 120 m	$1,3 + 0,004Lk^{1/2} + 4,5s$
• L ≥ 120 m	$2,1 + 2,2k^{1/2} + s$
Longitudinal watertight bulkhead	
• L < 120 m	$1,7 + 0,013Lk^{1/2} + 4,5s$
• L ≥ 120 m	$3,6 + 2,2k^{1/2} + s$
Tank and wash bulkheads	
• L < 120 m	$1,7 + 0,013Lk^{1/2} + 4,5s$
• L ≥ 120 m	$3,6 + 2,2k^{1/2} + s$

(1) The minimum net thickness is to be obtained by linearly interpolating between that required for the area within 0,4 L amidships and that at the fore and aft part.

2.4.4 Net thickness of the sheerstrake in way of breaks of short superstructures

The net thickness of the sheerstrake is to be increased in way of breaks of short superstructures occurring within 0,6L amidships, over a length of about one sixth of the ship's breadth on each side of the superstructure end.

This increase in net thickness is to be equal to 15%, but need not exceed 4,5 mm.

2.5 Stringer plate

2.5.1 General

The net thickness of the stringer plate is to be not less than the actual net thickness of the adjacent deck plating.

2.5.2 Net thickness of the stringer plate in way of breaks of long superstructures

The net thickness of the stringer plate is to be increased in way of breaks of long superstructures occurring within 0,5L amidships, over a length of about one sixth of the ship's breadth on each side of the superstructure end.

This increase in net thickness is to be equal to 40%, but need not exceed 4,5 mm.

Where the breaks of superstructures occur outside 0,5L amidships, the increase in net thickness may be reduced to 30%, but need not exceed 2,5 mm.

2.5.3 Net thickness of the stringer plate in way of breaks of short superstructures

The net thickness of the stringer plate is to be increased in way of breaks of short superstructures occurring within 0,6L amidships, over a length of about one sixth of the ship breadth on each side of the superstructure end.

This increase in net thickness is to be equal to 15%, but need not exceed 4,5 mm.

3 Strength check of plating subjected to lateral pressure

3.1 General

3.1.1 The requirements of this Article apply for the strength check of plating subjected to lateral pressure and, for plating contributing to the longitudinal strength, to in-plane hull girder normal and shear stresses.

3.2 Load model

3.2.1 General

The still water and wave lateral pressures induced by the sea and the various types of cargoes and ballast in intact conditions are to be considered, depending on the location of the plating under consideration and the type of the compartments adjacent to it, in accordance with Ch 5, Sec 1, [2.4].

The plating of bulkheads or inner side which constitute the boundary of compartments not intended to carry liquids is to be subjected to lateral pressure in flooding conditions.

The wave lateral pressures and hull girder loads are to be calculated in the mutually exclusive load cases "a", "b", "c" and "d" in Ch 5, Sec 4.

3.2.2 Lateral pressure in intact conditions

The lateral pressure in intact conditions is constituted by still water pressure and wave pressure.

Still water pressure (p_S) includes:

- the still water sea pressure, defined in Ch 5, Sec 5, [1]
- the still water internal pressure, defined in Ch 5, Sec 6 for the various types of cargoes and for ballast.

Wave pressure (p_W) includes:

- the wave pressure, defined in Ch 5, Sec 5, [2] for each load case "a", "b", "c" and "d"
- the inertial pressure, defined in Ch 5, Sec 6 for the various types of cargoes and for ballast, and for each load case "a", "b", "c" and "d"
- the dynamic pressures, according to the criteria in Ch 5, Sec 6, [2].

3.2.3 Lateral pressure in flooding conditions

The lateral pressure in flooding conditions is constituted by the still water pressure p_{SF} and wave pressure p_{WF} defined in Ch 5, Sec 6, [9].

3.2.4 In-plane hull girder normal stresses

The in-plane hull girder normal stresses to be considered for the strength check of plating are obtained, in N/mm², from the following formulae:

- for plating contributing to the hull girder longitudinal strength:

  $$\sigma_{X1} = \gamma_{S1}\sigma_{S1} + \gamma_{W1}(C_{FV}\sigma_{WV1} + C_{FH}\sigma_{WH1} + C_{F\Omega}\sigma_{\Omega})$$

- for plating not contributing to the hull girder longitudinal strength:

  $$\sigma_{X1} = 0$$

where:

σ_{S1}, σ_{WV1}, σ_{WH1} : Hull girder normal stresses, in N/mm², defined in Tab 3

σ_{Ω} : Absolute value of the warping stress, in N/mm², induced by the torque $0,625M_{WT}$ and obtained through direct calculation analyses based on a structural model in accordance with Ch 6, Sec 1, [2.6]

C_{FV}, C_{FH}, $C_{F\Omega}$: Combination factors defined in Tab 4.

Table 3 : Hull girder normal stresses

Condition	σ_{S1}, in N/mm² **(1)**	σ_{WV1}, in N/mm²	σ_{WH1}, in N/mm²
$\frac{\lvert\gamma_{S1}M_{SW,S}+0,625\gamma_{W1}C_{FV}M_{WV,S}\rvert}{\gamma_{S1}M_{SW,H}+0,625\gamma_{W1}C_{FV}M_{WV,H}} \geq 1$	$\left\lvert\frac{M_{SW,S}}{I_Y}(z-N)\right\rvert 10^{-3}$	$\left\lvert\frac{0,625F_DM_{WV,S}}{I_Y}(z-N)\right\rvert 10^{-3}$	$\left\lvert\frac{0,625M_{WH}}{I_Z}y\right\rvert 10^{-3}$
$\frac{\lvert\gamma_{S1}M_{SW,S}+0,625\gamma_{W1}C_{FV}M_{WV,S}\rvert}{\gamma_{S1}M_{SW,H}+0,625\gamma_{W1}C_{FV}M_{WV,H}} < 1$	$\left\lvert\frac{M_{SW,H}}{I_Y}(z-N)\right\rvert 10^{-3}$	$\left\lvert\frac{0,625M_{WV,H}}{I_Y}(z-N)\right\rvert 10^{-3}$	

(1) When the ship in still water is always in hogging condition, $M_{SW,S}$ is to be taken equal to 0.
Note 1:
F_D : Coefficient defined in Ch 5, Sec 2, [4].

Table 4 : Combination factors C_{FV}, C_{FH} and $C_{F\Omega}$

Load case	C_{FV}	C_{FH}	$C_{F\Omega}$
"a"	1,0	0	0
"b"	1,0	0	0
"c"	0,4	1,0	1,0
"d"	0,4	1,0	0

3.2.5 In-plane hull girder shear stresses

The in-plane hull girder shear stresses to be considered for the strength check of plating which contributes to the longitudinal strength are obtained, in N/mm², from the following formula:

$$\tau_1 = \gamma_{S1}\tau_{S1} + 0,625C_{FV}\gamma_{W1}\tau_{W1}$$

where:

τ_{S1} : Absolute value of the hull girder shear stresses, in N/mm², induced by the maximum still water hull girder vertical shear force

τ_{W1} : Absolute value of the hull girder shear stresses, in N/mm², induced by the maximum wave hull girder vertical shear force

C_{FV} : Combination factor defined in Tab 4.

τ_{S1} and τ_{W1} may be calculated as indicated in Tab 5 where, at a preliminary design stage, the still water hull girder vertical shear force is not defined.

3.3 Longitudinally framed plating contributing to the hull girder longitudinal strength

3.3.1 General

The net thickness of laterally loaded plate panels subjected to in-plane normal stress acting on the shorter sides is to be not less than the value obtained, in mm, from the following formula:

$$t = 14,9c_ac_rs\sqrt{\gamma_R\gamma_m\frac{\gamma_{S2}p_S+\gamma_{W2}p_W}{\lambda_LR_y}}$$

where:

- for bottom, bilge, inner bottom and decks (excluding possible longitudinal sloping plates):

$$\lambda_L = \sqrt{1-0,95\left(\gamma_m\frac{\sigma_{x1}}{R_y}\right)^2}-0,225\gamma_m\frac{\sigma_{x1}}{R_y}$$

- for side, inner side and longitudinal bulkheads (including possible longitudinal sloping plates):

$$\lambda_L = \sqrt{1-3\left(\gamma_m\frac{\tau_1}{R_y}\right)^2-0,95\left(\gamma_m\frac{\sigma_{x1}}{R_y}\right)^2}-0,225\gamma_m\frac{\sigma_{x1}}{R_y}$$

3.3.2 Flooding conditions

The plating of bulkheads or inner side which constitute the boundary of compartments not intended to carry liquids is to be checked in flooding conditions. To this end, its net thickness is to be not less than the value obtained, in mm, from the following formula:

$$t = 14,9c_ac_rs\sqrt{\gamma_R\gamma_m\frac{\gamma_{S2}p_{SF}+\gamma_{W2}p_{WF}}{\lambda_LR_y}}$$

where λ_L is defined in [3.3.1].

Table 5 : Hull girder shear stresses

Structural element	τ_{S1}, τ_{W1} in N/mm²
Bottom, bilge, inner bottom and decks (excluding possible longitudinal sloping plates)	0
Side, inner side and longitudinal bulkheads (including possible longitudinal sloping plates):	
• $0 \leq z \leq 0,25D$	$\tau_0\left(0,5+2\frac{z}{D}\right)$
• $0,25D < z \leq 0,75D$	τ_0
• $0,75D < z \leq D$	$\tau_0\left(2,5-2\frac{z}{D}\right)$

Note 1:

$$\tau_0 = \frac{47}{k}\left\{1-\frac{6,3}{\sqrt{L_1}}\right\} \text{ N/mm}^2$$

3.4 Transversely framed plating contributing to the hull girder longitudinal strength

3.4.1 General

The net thickness of laterally loaded plate panels subjected to in-plane normal stress acting on the longer sides is to be not less than the value obtained, in mm, from the following formula:

$$t = C_T c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{\lambda_T R_y}}$$

where:

- for bottom, bilge, inner bottom and decks (excluding possible longitudinal sloping plates):

  C_T : Coefficient equal to 17,2

  $$\lambda_T = 1 - 0{,}89 \gamma_m \frac{\sigma_{x1}}{R_y}$$

- for side, inner side and longitudinal bulkheads (including possible longitudinal sloping plates):

  C_T : Coefficient equal to:

  17,2 for side

  14,9 for inner side and longitudinal bulkheads (including possible longitudinal sloping plates)

  $$\lambda_T = \sqrt{1 - 3\left(\gamma_m \frac{\tau_1}{R_y}\right)^2} - 0{,}89 \gamma_m \frac{\sigma_{x1}}{R_y}$$

3.4.2 Flooding conditions

The plating of bulkheads or inner side which constitute the boundary of compartments not intended to carry liquids is to be checked in flooding conditions. To this end, its net thickness is to be not less than the value obtained, in mm, from the following formula:

$$t = 14{,}9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{\lambda_T R_y}}$$

where λ_T is defined in [3.4.1].

3.5 Plating not contributing to the hull girder longitudinal strength

3.5.1 General

The net thickness of plate panels subjected to lateral pressure is to be not less than the value obtained, in mm, from the following formula:

$$t = 14{,}9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y}}$$

3.5.2 Flooding conditions

The plating of bulkheads or inner side which constitute the boundary of compartments not intended to carry liquids is to be checked in flooding conditions. To this end, its net thickness is to be not less than the value obtained, in mm, from the following formula:

$$t = 14{,}9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{R_y}}$$

4 Strength check of plating subjected to wheeled loads

4.1 General

4.1.1 The requirements of this Article apply for the strength check of plating subjected to wheeled loads.

4.2 Load model

4.2.1 General

The still water and inertial forces induced by the sea and the various types of wheeled vehicles are to be considered, depending on the location of the plating.

The inertial forces induced by the sea are to be calculated in load case "b", as defined in Ch 5, Sec 4.

4.2.2 Wheeled forces

The wheeled force applied by one wheel is constituted by still water force and inertial force.

Still water force is the vertical force (F_S) defined in Ch 5, Sec 6, [6.1].

Inertial force is the vertical force ($F_{W,Z}$) defined in Ch 5, Sec 6, [6.1], for load case "b", with the acceleration a_{Z1} calculated at x = 0,5L.

4.3 Plating

4.3.1 The net thickness of plate panels subjected to wheeled loads is to be not less than the value obtained, in mm, from the following formula:

$$t = C_{WL}(n P_0 k)^{0,5} - t_c$$

where:

C_{WL} : Coefficient to be taken equal to:

$$C_{WL} = 2{,}15 - \frac{0{,}05\ell}{s} + 0{,}02\left(4 - \frac{\ell}{s}\right)\alpha^{0,5} - 1{,}7\alpha^{0,25}$$

where ℓ/s is to be taken not greater than 3

$\alpha = \frac{A_T}{\ell s}$ where ℓ is to be taken not greater than 5s

A_T : Tyre print area, in m². In the case of double or triple wheels, the area is that corresponding to the group of wheels.

n : Number of wheels on the plate panel, taken equal to:

- 1 in the case of a single wheel
- the number of wheels in a group of wheels in the case of double or triple wheels

P_0 : wheeled force, in kN, taken equal to:

$$P_0 = \gamma_{S2} F_S + 0{,}4 \gamma_{W2} F_{W,Z}$$

4.3.2 When the tyre print area is not known, it may be taken equal to:

$$A_T = \frac{n Q_A}{n_W p_T}$$

where:

n : Number of wheels on the plate panel, defined in [4.3.1]

Q_A : Axle load, in t

n_W : Number of wheels for the axle considered

p_T : Tyre pressure, in kN/m². When the tyre pressure is not indicated by the designer, it may be taken as defined in Tab 6.

Table 6 : Tyre pressures p_T for vehicles

Vehicle type	Tyre pressure p_T , in kN/m²	
	Pneumatic tyres	Solid rubber tyres
Private cars	250	Not applicable
Vans	600	Not applicable
Trucks and trailers	800	Not applicable
Handling machines	1100	1600

4.3.3 For vehicles with the four wheels of the axle located on a plate panel as shown in Fig 1, the net thickness of deck plating is to be not less than the greater of the values obtained, in mm, from the following formulae:

$$t = t_1$$

$$t = t_2(1 + \beta_2 + \beta_3 + \beta_4)^{0,5}$$

where:

t_1 : Net thickness obtained from [4.3.1] for n = 2, considering one group of two wheels located on the plate panel

t_2 : Net thickness obtained from [4.3.1] for n = 1, considering one wheel located on the plate panel

β_2, β_3, β_4: Coefficients obtained from the following formula, by replacing i by 2, 3 and 4, respectively (see Fig 1):

- for $x_i/b < 2$:

$$\beta_i = 0,8(1,2 - 2,02\alpha_i + 1,17\alpha_i^2 - 0,23\alpha_i^3)$$

- for $x_i/b \geq 2$:

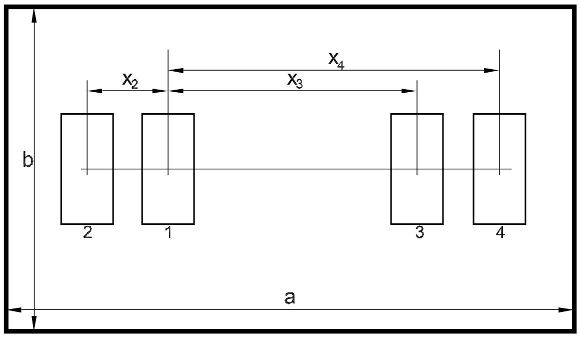
$$\beta_i = 0$$

x_i : Distance, in m, from the wheel considered to the reference wheel (see Fig 1)

b : Dimension, in m, of the plate panel side perpendicular to the axle

$$\alpha_i = \frac{x_i}{b}$$

Figure 1 : Four wheel axle located on a plate panel



5 Buckling check

5.1 General

5.1.1 Application

The requirements of this Article apply for the buckling check of plating subjected to in-plane compression stresses, acting on one or two sides, or to shear stress.

Rectangular plate panels are considered as being simply supported. For specific designs, other boundary conditions may be considered, at the Society's discretion, provided that the necessary information is submitted for review.

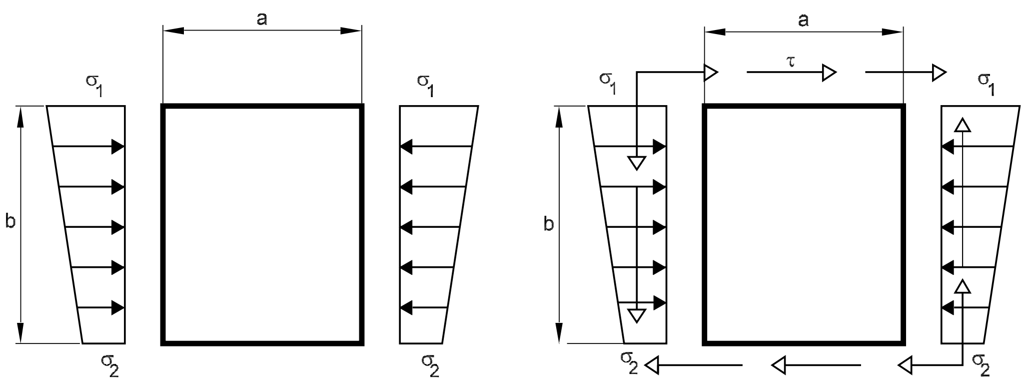
5.1.2 Compression and bending with or without shear

For plate panels subjected to compression and bending along one side, with or without shear, as shown in Fig 2, side "b" is to be taken as the loaded side. In such case, the compression stress varies linearly from σ_1 to $\sigma_2 = \psi\ \sigma_1$ ($\psi \leq 1$) along edge "b".

5.1.3 Shear

For plate panels subjected to shear, as shown in Fig 3, side "b" may be taken as either the longer or the shorter side of the panel.

Figure 2 : Buckling of a simply supported rectangular plate panel subjected to compression and bending, with and without shear



5.1.4 Bi-axial compression and shear

For plate panels subjected to bi-axial compression along sides "a" and "b", and to shear, as shown in Fig 4, side "a" is to be taken as the side in the direction of the primary supporting members.

Figure 3 : Buckling of a simply supported rectangular plate panel subjected to shear

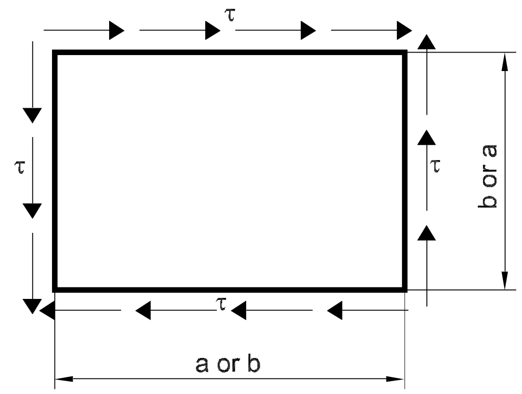
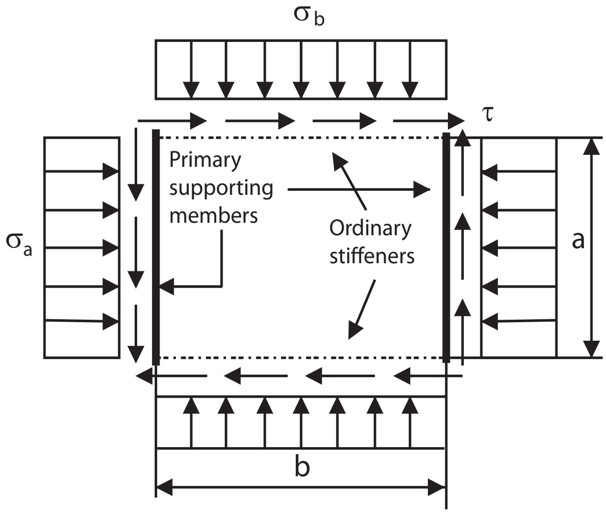


Figure 4 : Buckling of a simply supported rectangular plate panel subjected to bi-axial compression and shear



5.2 Load model

5.2.1 Sign convention for normal stresses

The sign convention for normal stresses is as follows:

- tension: positive
- compression: negative.

5.2.2 In-plane hull girder compression normal stresses

The in-plane hull girder compression normal stresses to be considered for the buckling check of plating contributing to the longitudinal strength are obtained, in N/mm², from the following formula:

$$\sigma_{X1} = \gamma_{S1}\sigma_{S1} + \gamma_{W1}(C_{FV}\sigma_{WV1} + C_{FH}\sigma_{WH1} + C_{F\Omega}\sigma_{\Omega})$$

where:

σ_{S1}, σ_{WV1}, σ_{WH1} : Hull girder normal stresses, in N/mm², defined in Tab 7

σ_{Ω} : Compression warping stress, in N/mm², induced by the torque $0,625M_{WT}$ and obtained through direct calculation analyses based on a structural model in accordance with Ch 6, Sec 1, [2.6]

C_{FV}, C_{FH}, $C_{F\Omega}$:Combination factors defined in Tab 4.

σ_{X1} is to be taken as the maximum compression stress on the plate panel considered.

In no case may σ_{X1} be taken less than 30/k N/mm².

When the ship in still water is always in hogging condition, σ_{X1} may be evaluated by means of direct calculations when justified on the basis of the ship's characteristics and intended service. The calculations are to be submitted to the Society for approval.

5.2.3 In-plane hull girder shear stresses

The in-plane hull girder shear stresses to be considered for the buckling check of plating are obtained as specified in [3.2.5] for the strength check of plating subjected to lateral pressure, which contributes to the longitudinal strength.

5.2.4 Combined in-plane hull girder and local compression normal stresses

The combined in-plane compression normal stresses to be considered for the buckling check of plating are to take into account the hull girder stresses and the local stresses resulting from the bending of the primary supporting members. These local stresses are to be obtained from a direct structural analysis using the design loads given in Chapter 5.

With respect to the reference co-ordinate system defined in Ch 1, Sec 2, [4.1], the combined stresses in x and y direction are obtained, in N/mm², from the following formulae:

$$\sigma_X = \sigma_{X1} + \gamma_{S2}\sigma_{X2,S} + \gamma_{W2}\sigma_{X2,W}$$

$$\sigma_Y = \gamma_{S2}\sigma_{Y2,S} + \gamma_{W2}\sigma_{Y2,W}$$

where:

σ_{X1} : Compression normal stress, in N/mm², induced by the hull girder still water and wave loads, defined in [5.2.2]

$\sigma_{X2,S}$,$\sigma_{Y2,S}$: Compression normal stress in x and y direction, respectively, in N/mm², induced by the local bending of the primary supporting members and obtained from a direct structural analysis using the still water design loads given in Chapter 5

$\sigma_{X2,W}$,$\sigma_{Y2,W}$: Compression normal stress in x and y direction, respectively, in N/mm², induced by the local bending of the primary supporting members and obtained from a direct structural analysis using the wave design loads given in Chapter 5.

Table 7 : Hull girder normal compression stresses

Condition	σ_{S1} in N/mm² **(1)**	σ_{WV1} in N/mm²	σ_{WH1} in N/mm²
$z \geq N$	$\frac{M_{SW,S}}{I_Y}(z-N)10^{-3}$	$\frac{0{,}625 F_D M_{WV,S}}{I_Y}(z-N)10^{-3}$	$-\left\|\frac{0{,}625 M_{WH}}{I_Z} y\right\| 10^{-3}$
$z < N$	$\frac{M_{SW,H}}{I_Y}(z-N)10^{-3}$	$\frac{0{,}625 M_{WV,H}}{I_Y}(z-N)10^{-3}$	

(1) When the ship in still water is always in hogging condition, σ_{S1} for $z \geq N$ is to be obtained, in N/mm², from the following formula, unless σ_{X1} is evaluated by means of direct calculations (see [5.2.2]):

$$\sigma_{S1} = \frac{M_{SW,Hmin}}{I_Y}(z-N)10^{-3}$$

Note 1:

F_D : Coefficient defined in Ch 5, Sec 2, [4].

5.2.5 Combined in-plane hull girder and local shear stresses

The combined in-plane shear stresses to be considered for the buckling check of plating are to take into account the hull girder stresses and the local stresses resulting from the bending of the primary supporting members. These local stresses are to be obtained from a direct structural analysis using the design loads given in Chapter 5.

The combined stresses are obtained, in N/mm², from the following formula:

$$\tau = \tau_1 + \gamma_{S2}\tau_{2,S} + \gamma_{W2}\tau_{2,W}$$

where:

τ_1 : Shear stress, in N/mm², induced by the hull girder still water and wave loads, defined in [5.2.3]

$\tau_{2,S}$: Shear stress, in N/mm², induced by the local bending of the primary supporting members and obtained from a direct structural analysis using the still water design loads given in Chapter 5

$\tau_{2,W}$: Shear stress, in N/mm², induced by the local bending of the primary supporting members and obtained from a direct structural analysis using the wave design loads given in Chapter 5.

5.3 Critical stresses

5.3.1 Compression and bending for plane panel

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

$$\sigma_c = \sigma_E \quad \text{for} \quad \sigma_E \leq \frac{R_{eH}}{2}$$

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

where:

σ_E : Euler buckling stress, to be obtained, in N/mm², from the following formula:

$$\sigma_E = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t_{net}}{b}\right)^2 K_1 \varepsilon$$

K_1 : Buckling factor defined in Tab 8

ε : Coefficient to be taken equal to:

- $\varepsilon = 1$ for $\alpha \geq 1$,
- $\varepsilon = 1{,}05$ for $\alpha < 1$ and side "b" stiffened by flat bar
- $\varepsilon = 1{,}10$ for $\alpha < 1$ and side "b" stiffened by bulb section
- $\varepsilon = 1{,}21$ for $\alpha < 1$ and side "b" stiffened by angle or T-section
- $\varepsilon = 1{,}30$ for $\alpha < 1$ and side "b" stiffened by primary supporting members.

$\alpha = a/b$

5.3.2 Shear for plane panel

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

$$\tau_c = \tau_E \quad \text{for} \quad \tau_E \leq \frac{R_{eH}}{2\sqrt{3}}$$

$$\tau_c = \frac{R_{eH}}{\sqrt{3}}\left(1 - \frac{R_{eH}}{4\sqrt{3}\tau_E}\right) \quad \text{for} \quad \tau_E > \frac{R_{eH}}{2\sqrt{3}}$$

where:

τ_E : Euler shear buckling stress, to be obtained, in N/mm², from the following formula:

$$\tau_E = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t_{net}}{b}\right)^2 K_2$$

K_2 : Buckling factor to be taken equal to:

$$K_2 = 5{,}34 + \frac{4}{\alpha^2} \quad \text{for} \quad \alpha > 1$$

$$K_2 = \frac{5{,}34}{\alpha^2} + 4 \quad \text{for} \quad \alpha \leq 1$$

α : Coefficient defined in [5.3.1].

Table 8 : Buckling factor K_1 for plate panels

Load pattern	Aspect ratio	Buckling factor K_1
$0 \le \psi \le 1$	$\alpha \ge 1$ $\alpha < 1$	$\dfrac{8,4}{\psi + 1,1}$ $\left(\alpha + \dfrac{1}{\alpha}\right)^2 \dfrac{2,1}{\psi + 1,1}$
$-1 < \psi < 0$		$(1+\psi)K_1' - \psi K_1'' + 10\psi(1+\psi)$
$\psi \le -1$	$\alpha\dfrac{1-\psi}{2} \ge \dfrac{2}{3}$ $\alpha\dfrac{1-\psi}{2} < \dfrac{2}{3}$	$23,9\left(\dfrac{1-\psi}{2}\right)^2$ $\left(15,87 + \dfrac{1,87}{\left(\alpha\dfrac{1-\psi}{2}\right)^2} + 8,6\left(\alpha\dfrac{1-\psi}{2}\right)^2\right)\left(\dfrac{1-\psi}{2}\right)^2$

Note 1:

$\psi = \dfrac{\sigma_2}{\sigma_1}$

K_1' : Value of K_1 calculated for $\psi = 0$
K_1'' : Value of K_1 calculated for $\psi = -1$

5.3.3 Bi-axial compression and shear for plane panel

The critical buckling stress $\sigma_{c,a}$ for compression on side "a" of the panel is to be obtained, in N/mm², from the following formula:

$$\sigma_{c,a} = \left(\frac{2,25}{\beta} - \frac{1,25}{\beta^2}\right) R_{eH}$$

where:

β : Slenderness of the panel, to be taken equal to:

$$\beta = 10^3 \frac{a}{t_{net}} \sqrt{\frac{R_{eH}}{E}}$$

without being taken less than 1,25.

The critical buckling stress $\sigma_{c,b}$ for compression on side "b" of the panel is to be obtained, in N/mm², from the formulae in [5.3.1].

The critical shear buckling stress is to be obtained, in N/mm², from the formulae in [5.3.2].

5.3.4 Compression and shear for curved panels

For curved panels, the effects of lateral pressure are also to be taken into account.

The critical buckling stress of curved panels subjected to compression on curved edges and to lateral pressure is to be obtained, in N/mm², from the following formulae:

$$\sigma_c = \sigma_E \quad \text{for} \quad \sigma_E \le \frac{R_{eH}}{2}$$

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

where:

σ_E : Euler buckling stress, to be obtained, in N/mm², from the following formula:

$$\sigma_E = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t_{net}}{b}\right)^2 K_3$$

b : Width of curved panel, in mm, measured on arc

K_3 : Buckling factor defined in Tab 9, depending on the load acting on the panel.

Table 9 : Buckling factor K_3 for curved panels

Load	Buckling factor K_3
Compression stress perpendicular to the curved edges	$2\left\{1 + \sqrt{1 + \dfrac{12(1-\nu^2)}{\pi^4}\dfrac{b^4}{r^2 t_{net}^2}}\right\}$
Lateral pressure perpendicular to the panel	$4 - \left(\dfrac{b}{\pi r}\right)^2$

Note 1:
r : radius of curvature, in mm.

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

$$\tau_c = \tau_E \quad \text{for} \quad \tau_E \le \frac{R_{eH}}{2\sqrt{3}}$$

$$\tau_c = \frac{R_{eH}}{\sqrt{3}}\left(1 - \frac{R_{eH}}{4\sqrt{3}\tau_E}\right) \quad \text{for} \quad \tau_E > \frac{R_{eH}}{2\sqrt{3}}$$

where:

τ_E : Euler shear buckling stress, to be obtained, in N/mm², from the following formula:

$$\tau_E = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t_{net}}{b}\right)^2 K_4$$

K_4 : Buckling factor to be taken equal to:

$$K_4 = \frac{12(1-\nu^2)}{\pi^2}\left(5 + 0{,}1\frac{b^2}{rt_{net}}\right)$$

b, r : Defined above.

5.3.5 Compression for corrugation flanges

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

$$\sigma_c = \sigma_E \qquad \text{for} \quad \sigma_E \le \frac{R_{eH}}{2}$$

$$\sigma_c = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_E}\right) \qquad \text{for} \quad \sigma_E > \frac{R_{eH}}{2}$$

where:

σ_E : Euler buckling stress, to be obtained, in N/mm², from the following formula:

$$\sigma_E = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t_f}{V}\right)^2 K_5$$

K_5 : Buckling factor to be taken equal to:

$$K_5 = \left(1 + \frac{t_w}{t_f}\right)\left\{3 + 0{,}5\frac{V'}{V} - 0{,}33\left(\frac{V'}{V}\right)^2\right\}$$

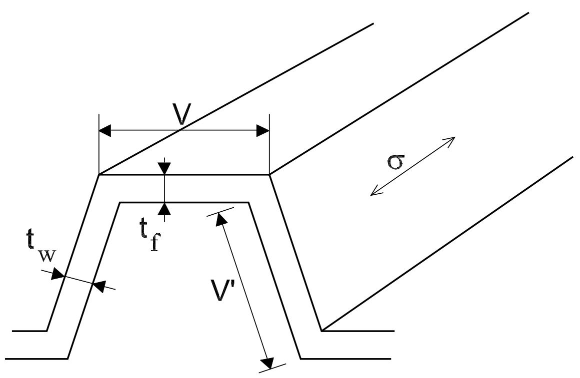
t_f : Net thickness, in mm, of the corrugation flange

t_w : Net thickness, in mm, of the corrugation web

V, V′ : Dimensions of a corrugation, in mm, shown in Fig 5.

When the thicknesses t_f and t_w of the corrugation flange and web varies along the corrugation span, σ_C is to be calculated for every adjacent actual pair of t_f and t_w.

Figure 5 : Dimensions of a corrugation



5.4 Checking criteria

5.4.1 Acceptance of results

The net thickness of plate panels is to be such as to satisfy the buckling check, as indicated in [5.4.2] to [5.4.5] depending on the type of stresses acting on the plate panel considered. When the buckling criteria is exceeded by less than 15 %, the scantlings may still be considered as acceptable, provided that the stiffeners located on the plate panel satisfy the buckling and the ultimate strength checks as specified in Sec 2, [4] and Sec 2, [5].

5.4.2 Compression and bending

For plate panels subjected to compression and bending on one side, the critical buckling stress is to comply with the following formula:

$$\frac{\sigma_c}{\gamma_R \gamma_m} \ge |\sigma_b|$$

where:

σ_c : Critical buckling stress, in N/mm², defined in [5.3.1], [5.3.4] or [5.3.5], as the case may be

σ_b : Compression stress, in N/mm², acting on side "b" of the plate panel, to be calculated, as specified in [5.2.2] or [5.2.4], as the case may be.

In the case of corrugation flanges, when the thicknesses t_f and t_w of the corrugation flange and web varies along the corrugation span, σ_b is to be taken as the maximum compression stress calculated in each zone of adjacent actual pairs of t_f and t_w.

5.4.3 Shear

For plate panels subjected to shear, the critical shear buckling stress is to comply with the following formula:

$$\frac{\tau_c}{\gamma_R \gamma_m} \ge |\tau_b|$$

where:

τ_c : Critical shear buckling stress, in N/mm², defined in [5.3.2] or [5.3.4], as the case may be

τ_b : Shear stress, in N/mm², acting on the plate panel, to be calculated as specified in [5.2.3] or [5.2.5], as the case may be.

5.4.4 Compression, bending and shear

For plate panels subjected to compression, bending and shear, the combined critical stress is to comply with the following formulae:

$$F \le 1 \qquad \text{for} \quad \frac{\sigma_{comb}}{F} \le \frac{R_{eH}}{2\gamma_R\gamma_m}$$

$$F \le \frac{4\sigma_{comb}}{R_{eH}/\gamma_R\gamma_m}\left(1 - \frac{\sigma_{comb}}{R_{eH}/\gamma_R\gamma_m}\right) \qquad \text{for} \quad \frac{\sigma_{comb}}{F} > \frac{R_{eH}}{2\gamma_R\gamma_m}$$

where:

$$\sigma_{comb} = \sqrt{\sigma_1^2 + 3\tau^2}$$

$$F = \gamma_R\gamma_m\left[\frac{1+\psi}{4}\frac{|\sigma_1|}{\sigma_E} + \sqrt{\left(\frac{3-\psi}{4}\right)^2\left(\frac{\sigma_1}{\sigma_E}\right)^2 + \left(\frac{\tau}{\tau_E}\right)^2}\right]$$

σ_E : Euler buckling stress, in N/mm², defined in [5.3.1], [5.3.4] or [5.3.5] as the case may be,

τ_E : Euler shear buckling stress, in N/mm², defined in [5.3.2] or [5.3.4], as the case may be,

$$\psi = \frac{\sigma_2}{\sigma_1}$$

σ_1, σ_2 and τ are defined in Fig 2 and are to be calculated, in N/mm², as specified in [5.2].

5.4.5 Bi-axial compression, taking account of shear stress

For plate panels subjected to bi-axial compression and shear, the critical buckling stresses are to comply with the following formula:

$$\left|\frac{\sigma_a}{\frac{\sigma_{c,a}}{\gamma_R\gamma_m}R_a}\right|^n + \left|\frac{\sigma_b}{\frac{\sigma_{c,b}}{\gamma_R\gamma_m}R_b}\right|^n \leq 1$$

where:

- $\sigma_{c,a}$: Critical buckling stress for compression on side "a", in N/mm², defined in [5.3.3]
- $\sigma_{c,b}$: Critical buckling stress for compression on side "b", in N/mm², defined in [5.3.3]
- σ_a : Compression stress acting on side "a", in N/mm², to be calculated as specified in [5.2.2] or [5.2.4], as the case may be
- σ_b : Compression stress acting on side "b", in N/mm², to be calculated as specified in [5.2.2] or [5.2.4], as the case may be
- n : Coefficient to be taken equal to:

  $n = 1$ for $\alpha \geq 1/\sqrt{2}$

  $n = 2$ for $\alpha < 1/\sqrt{2}$

$\alpha = a/b$

$$R_a = 1 - \left|\frac{\tau}{\tau_c}\right|^{n_a}$$

$$R_b = 1 - \left|\frac{\tau}{\tau_c}\right|^{n_b}$$

- τ : Shear stress, in N/mm², to be calculated as specified in [5.2.3] or [5.2.5], as the case may be
- τ_c : Critical shear buckling stress, in N/mm², defined in [5.3.2]
- n_a : Coefficient to be taken equal to:

  $n_a = 1 + 1/\alpha$ for $\alpha \geq 0,5$

  $n_a = 3$ for $\alpha < 0,5$
- n_b : Coefficient to be taken equal to:

  $n_b = 1,9 + 0,1/\alpha$ for $\alpha \geq 0,5$

  $n_b = 0,7(1 + 1/\alpha)$ for $\alpha < 0,5$

SECTION 2 ORDINARY STIFFENERS

Symbols

For symbols not defined in this Section, refer to the list at the beginning of this Chapter.

p_S : Still water pressure, in kN/m², see [3.3.2] and [5.3.2]

p_W : Wave pressure and, if necessary, dynamic pressures, according to the criteria in Ch 5, Sec 5 and Ch 5, Sec 6, [2], in kN/m² (see [3.3.2] and [5.3.2])

p_{SF}, p_{WF} : Still water and wave pressures, in kN/m², in flooding conditions, defined in Ch 5, Sec 6, [9]

F_S : Still water wheeled force, in kN, see [3.3.4]

$F_{W,Z}$: Inertial wheeled force, in kN, see [3.3.4]

σ_{X1} : Hull girder normal stress, in N/mm², defined in:
- [3.3.5] for the yielding check of ordinary stiffeners
- [4.2.2] for the buckling check of ordinary stiffeners
- [5.3.3] for the ultimate strength check of ordinary stiffeners

σ_N : Normal stress, in N/mm², defined in [3.3.5]

$R_{eH,P}$: Minimum yield stress, in N/mm², of the plating material, defined in Ch 4, Sec 1, [2]

$R_{eH,S}$: Minimum yield stress, in N/mm², of the stiffener material, defined in Ch 4, Sec 1, [2]

s : Spacing, in m, of ordinary stiffeners

ℓ : Span, in m, of ordinary stiffeners, measured between the supporting members, see Ch 4, Sec 3, [3.2]

ℓ_b : Length, in m, of one bracket, see [3.2.2], Ch 4, Sec 3, Fig 4 and Ch 4, Sec 3, Fig 5

h_w : Web height, in mm

t_w : Net web thickness, in mm

b_f : Face plate width, in mm

t_f : Net face plate thickness, in mm

b_p : Width, in m, of the plating attached to the stiffener, for the yielding check, defined in Ch 4, Sec 3, [3.3.1]

b_e : Width, in m, of the plating attached to the stiffener, for the buckling check, defined in [4.1]

b_U : Width, in m, of the plating attached to the stiffener, for the ultimate strength check, defined in [5.2]

t_p : Net thickness, in mm, of the attached plating

w : Net section modulus, in cm³, of the stiffener, with an attached plating of width b_p , to be calculated as specified in Ch 4, Sec 3, [3.4]

A_S : Net sectional area, in cm², of the stiffener with attached plating of width s

A_e : Net sectional area, in cm², of the stiffener with attached plating of width b_e

A_U : Net sectional area, in cm², of the stiffener with attached plating of width b_U

A_{Sh} : Net shear sectional area, in cm², of the stiffener, to be calculated as specified in Ch 4, Sec 3, [3.4]

I : Net moment of inertia, in cm⁴, of the stiffener without attached plating, about its neutral axis parallel to the plating (see Ch 4, Sec 3, Fig 4 and Ch 4, Sec 3, Fig 5)

I_S : Net moment of inertia, in cm⁴, of the stiffener with attached shell plating of width s, about its neutral axis parallel to the plating

I_e : Net moment of inertia, in cm⁴, of the stiffener with attached shell plating of width b_e , about its neutral axis parallel to the plating

I_U : Net moment of inertia, in cm⁴, of the stiffener with attached shell plating of width b_U , about its neutral axis parallel to the plating

I_B : Net moment of inertia, in cm⁴, of the stiffener with bracket and without attached plating, about its neutral axis parallel to the plating, calculated at mid-length of the bracket (see Ch 4, Sec 3, Fig 4 and Ch 4, Sec 3, Fig 5)

ρ_S : Radius of gyration, in cm, of the stiffener with attached plating of width s

ρ_U : Radius of gyration, in cm, of the stiffener with attached plating of width b_U .

c_c : Coefficient which tanks into account the effects of stiffener connections, equal to:

c_c = 1,0 in general,

c_c = 0,9 when the stiffener is provided with a soft toe connection with the supporting structure and no brackets are fitted.

$\chi = I_B / I$

$\alpha = \ell_b / \ell$

1 General

1.1 Net scantlings

1.1.1 As specified in Ch 4, Sec 2, [1], all scantlings referred to in this Section are net, i.e. they do not include any margin for corrosion.

The gross scantlings are obtained as specified in Ch 4, Sec 2.

1.2 Partial safety factors

1.2.1 The partial safety factors to be considered for the checking of ordinary stiffeners are specified in Tab 1.

1.3 Load point

1.3.1 Lateral pressure

Unless otherwise specified, lateral pressure is to be calculated at mid-span of the ordinary stiffener considered.

1.3.2 Hull girder stresses

For longitudinal ordinary stiffeners contributing to the hull girder longitudinal strength, the hull girder normal stresses are to be calculated in way of the neutral axis of the stiffener considered.

1.4 Net dimensions of ordinary stiffeners

1.4.1 Flat bar

The net dimensions of a flat bar ordinary stiffener (see Fig 1) are to comply with the following requirement:

$$\frac{h_w}{t_w} \le 20\sqrt{k}$$

1.4.2 T-section

The net dimensions of a T-section ordinary stiffener (see Fig 2) are to comply with the following two requirements:

$$\frac{h_w}{t_w} \le 55\sqrt{k}$$

$$\frac{b_f}{t_f} \le 33\sqrt{k}$$

$$b_f t_f \ge \frac{h_w t_w}{6}$$

1.4.3 Angle

The net dimensions of an angle ordinary stiffener (see Fig 3) are to comply with the following two requirements:

$$\frac{h_w}{t_w} \le 55\sqrt{k}$$

$$\frac{b_f}{t_f} \le 16,5\sqrt{k}$$

$$b_f t_f \ge \frac{h_w t_w}{6}$$

Figure 1 : Net dimensions of a flat bar

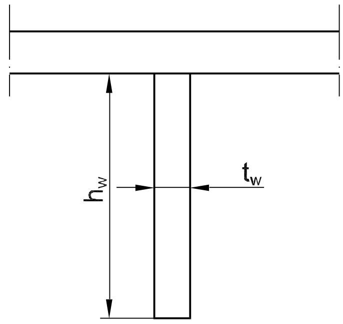


Figure 2 : Net dimensions of a T-section

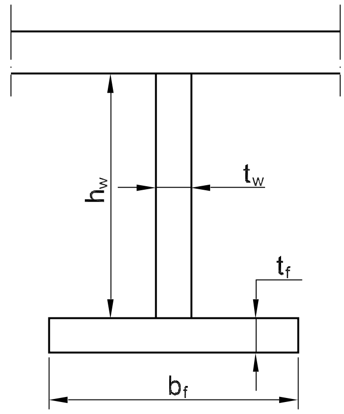
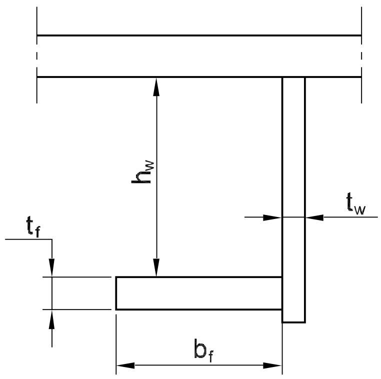


Table 1 : Ordinary stiffeners - Partial safety factors

Partial safety factors covering uncertainties regarding:	Symbol	Yielding check: General (see [3.3] to [3.7])	Yielding check: Watertight bulkhead ordinary stiffeners **(1)** (see [3.8])	Buckling check (see [4])	Ultimate strength check of ordinary stiffeners contributing to the longitudinal strength (see [5])
Still water hull girder loads	γ_{S1}	1,00	1,00	1,00	1,00
Wave hull girder loads	γ_{W1}	1,15	1,15	1,15	1,30
Still water pressure	γ_{S2}	1,00	1,00	Not applicable	1,00
Wave pressure	γ_{W2}	1,20	1,05	Not applicable	1,40
Material	γ_m	1,02	1,02	1,02	1,02
Resistance	γ_R	1,02	1,02 **(2)**	1,10	1,02

(1) Applies also to ordinary stiffeners of bulkheads or inner side which constitute boundary of compartments not intended to carry liquids.
(2) For ordinary stiffeners of the collision bulkhead, γ_R =1,25.

Figure 3 : Net dimensions of an angle



2 General requirements

2.1 General

2.1.1 The requirements in [2.2] and [2.3] are to be applied to ordinary stiffeners in addition of those in [3] to [5].

2.2 Minimum net thicknesses

2.2.1 The net thickness of the web of ordinary stiffeners is to be not less than the lesser of:

- the value obtained, in mm, from the following formulae:

  $t_{MIN} = 0,8 + 0,004Lk^{1/2} + 4,5s$ for $L < 120$ m

  $t_{MIN} = 1,6 + 2,2k^{1/2} + s$ for $L \geq 120$ m

- the net as built thickness of the attached plating.

2.3 Struts of open floors

2.3.1 The sectional area A_{ST}, in cm², and the moment of inertia I_{ST} about the main axes, in cm⁴, of struts of open floors are to be not less than the values obtained from the following formulae:

$$A_{ST} = \frac{p_{ST} s \ell}{20}$$

$$I_{ST} = \frac{0,75 s \ell (p_{STB} + p_{STU}) A_{AST} \ell_{ST}^2}{47,2 A_{AST} - s \ell (p_{STB} + p_{STU})}$$

where:

p_{ST} : Pressure to be taken equal to the greater of the values obtained, in kN/m², from the following formulae:

$p_{ST} = 0,5\ (p_{STB} + p_{STU})$

$p_{ST} = p_{STD}$

p_{STB} : Sea pressure, in kN/m², acting on the bottom in way of the strut equal to:

$p_{STB} = \gamma_{S2} p_S + \gamma_{W2} p_W$

p_{STU} : Pressure, in kN/m², acting on the inner bottom in way of the strut due to the load in the tank or hold above, equal to:

$p_{STU} = \gamma_{S2} p_S + \gamma_{W2} p_W$

p_{STD} : Pressure, in kN/m², in double bottom at mid-span of the strut equal to:

$p_{STD} = \gamma_{S2} p_S + \gamma_{W2} p_W$

ℓ : Span, in m, of transverse ordinary stiffeners constituting the open floor (see Ch 4, Sec 3, [3.2.2])

ℓ_{ST} : Length, in m, of the strut

A_{AST} : Actual net sectional area, in cm², of the strut.

3 Yielding check

3.1 General

3.1.1 The requirements of this Article apply for the yielding check of ordinary stiffeners subjected to lateral pressure or to wheeled loads and, for ordinary stiffeners contributing to the hull girder longitudinal strength, to hull girder normal stresses.

3.1.2 The yielding check is also to be carried out for ordinary stiffeners subjected to specific loads, such as concentrated loads.

3.2 Structural model

3.2.1 Boundary conditions

The requirements in [3.4], [3.7.3], [3.7.4] and [3.8] apply to stiffeners considered as clamped at both ends, whose end connections comply with the requirements in [3.2.2].

The requirements in [3.5] and [3.7.5] apply to stiffeners considered as simply supported at both ends. Other boundary conditions may be considered by the Society on a case by case basis, depending on the distribution of wheeled loads.

For other boundary conditions, the yielding check is to be considered on a case by case basis.

3.2.2 Bracket arrangement

The requirements of this Article apply to ordinary stiffeners without end brackets, with a bracket at one end or with two equal end brackets, where the bracket length is not greater than $0,2\ell$.

In the case of ordinary stiffeners with two different end brackets of length not greater than $0,2\ell$, the determination of normal and shear stresses due to design loads and the required section modulus and shear sectional area are considered by the Society on a case by case basis. In general, an acceptable solution consists in applying the criteria for equal brackets, considering both brackets as having the length of the smaller one.

In the case of ordinary stiffeners with end brackets of length greater than $0,2\ell$, the determination of normal and shear stresses due to design loads and the required section modulus and shear sectional area are considered by the Society on a case by case basis.

3.3 Load model

3.3.1 General

The still water and wave lateral loads induced by the sea and the various types of cargoes and ballast in intact conditions are to be considered, depending on the location of the ordinary stiffener under consideration and the type of compartments adjacent to it, in accordance with Ch 5, Sec 1, [2.4].

Ordinary stiffeners of bulkheads or inner side which constitute the boundary of compartments not intended to carry liquids are to be subjected to the lateral pressure in flooding conditions.

The wave lateral loads and hull girder loads are to be calculated in the mutually exclusive load cases “a”, “b”, “c” and “d” in Ch 5, Sec 4.

3.3.2 Lateral pressure in intact conditions

The lateral pressure in intact conditions is constituted by still water pressure and wave pressure.

Still water pressure (p_S) includes:

- the still water sea pressure, defined in Ch 5, Sec 5, [1]
- the still water internal pressure, defined in Ch 5, Sec 6 for the various types of cargoes and for ballast.

Wave pressure (p_W) includes:

- the wave pressure, defined in Ch 5, Sec 5, [2] for each load case “a”, “b”, “c” and “d”
- the inertial pressure, defined in Ch 5, Sec 6 for the various types of cargoes and for ballast, and for each load case “a”, “b”, “c” and “d”
- the dynamic pressures, according to the criteria in Ch 5, Sec 6, [2].

3.3.3 Lateral pressure in flooding conditions

The lateral pressure in flooding conditions is constituted by the still water pressure p_{SF} and wave pressure p_{WF} defined in Ch 5, Sec 6, [9].

3.3.4 Wheeled forces

The wheeled force applied by one wheel is constituted by still water force and inertial force:

- Still water force is the vertical force (F_S) defined in Ch 5, Sec 6, [6.1]
- Inertial force is the vertical force ($F_{W,Z}$) defined in Ch 5, Sec 6, [6.1], for load case “b”.

3.3.5 Normal stresses

The normal stresses to be considered for the yielding check of ordinary stiffeners are obtained, in N/mm², from the following formulae:

- for longitudinal stiffeners contributing to the hull girder longitudinal strength:

$$\sigma_N = \sigma_{X1} = \gamma_{S1}\sigma_{S1} + \gamma_{W1}(C_{FV}\sigma_{WV1} + C_{FH}\sigma_{WH1} + C_{F\Omega}\sigma_{\Omega})$$

to be taken not less than 60/k N/mm².

- for longitudinal stiffeners not contributing to the hull girder longitudinal strength, transverse stiffeners and vertical stiffeners, excluding side frames:

$$\sigma_N = 45/k\,N/mm^2$$

- for side frames:

$\sigma_N = 0$ for load cases "a" and "c"

$\sigma_N = 30/k$ for load cases "b" and "d"

where:

σ_{S1}, σ_{WV1}, σ_{WH1} : Hull girder normal stresses, in N/mm², defined in:
- Tab 2 for ordinary stiffeners subjected to lateral pressure,
- Tab 3 for ordinary stiffeners subjected to wheeled loads

σ_{Ω} : Absolute value of the warping stress, in N/mm², induced by the torque $0,625M_{WT}$ and obtained through direct calculation analyses based on a structural model in accordance with Ch 6, Sec 1, [2.6]

C_{FV}, C_{FH}, $C_{F\Omega}$: Combination factors defined in Tab 4.

Table 2 : Hull girder normal stresses - Ordinary stiffeners subjected to lateral pressure

Condition	σ_{S1}, in N/mm² **(1)**	σ_{WV1}, in N/mm²	σ_{WH1}, in N/mm²
Lateral pressure applied on the side opposite to the ordinary stiffener, with respect to the plating:			$\left\|\frac{0,625M_{WH}}{I_Z}y\right\|10^{-3}$
• $z \geq N$	$\left\|\frac{M_{SW,S}}{I_Y}(z-N)\right\|10^{-3}$	$\left\|\frac{0,625F_DM_{WV,S}}{I_Y}(z-N)\right\|10^{-3}$	
• $z < N$	$\left\|\frac{M_{SW,H}}{I_Y}(z-N)\right\|10^{-3}$	$\left\|\frac{0,625M_{WV,H}}{I_Y}(z-N)\right\|10^{-3}$	
Lateral pressure applied on the same side as the ordinary stiffener:			
• $z \geq N$	$\left\|\frac{M_{SW,H}}{I_Y}(z-N)\right\|10^{-3}$	$\left\|\frac{0,625M_{WV,H}}{I_Y}(z-N)\right\|10^{-3}$	
• $z < N$	$\left\|\frac{M_{SW,S}}{I_Y}(z-N)\right\|10^{-3}$	$\left\|\frac{0,625F_DM_{WV,S}}{I_Y}(z-N)\right\|10^{-3}$	

(1) When the ship in still water is always in hogging condition, $M_{SW,S}$ is to be taken equal to 0.

Note 1:

F_D : Coefficient defined in Ch 5, Sec 2, [4].

Table 3 : Hull girder normal stresses - Ordinary stiffeners subjected to wheeled loads

Condition	σ_{S1} in N/mm² **(1)**	σ_{WV1} in N/mm²	σ_{WH1} in N/mm²
• $z \geq N$	$\left\lvert \frac{M_{SW,H}}{I_Y}(z-N) \right\rvert 10^{-3}$	$\left\lvert \frac{0,625 M_{WV,H}}{I_Y}(z-N) \right\rvert 10^{-3}$	$\left\lvert \frac{0,625 M_{WH}}{I_Z} y \right\rvert 10^{-3}$
• $z < N$	$\left\lvert \frac{M_{SW,S}}{I_Y}(z-N) \right\rvert 10^{-3}$	$\left\lvert \frac{0,625 F_D M_{WV,S}}{I_Y}(z-N) \right\rvert 10^{-3}$	

(1) When the ship in still water is always in hogging condition, $M_{SW,S}$ is to be taken equal to 0.
Note 1:
F_D : Coefficient defined in Ch 5, Sec 2, [4].

Table 4 : Combination factors C_{FV}, C_{FH} and $C_{F\Omega}$

Load case	C_{FV}	C_{FH}	$C_{F\Omega}$
"a"	1,0	0	0
"b"	1,0	0	0
"c"	0,4	1,0	1,0
"d"	0,4	1,0	0

3.4 Normal and shear stresses due to lateral pressure in intact conditions

3.4.1 General

Normal and shear stresses, induced by lateral pressures, in ordinary stiffeners without end brackets are to be obtained from the formulae in:

- [3.4.2] in the case of longitudinal and transverse stiffeners
- [3.4.5] in the case of vertical stiffeners.

Normal and shear stresses, induced by lateral pressures, in ordinary stiffeners with a bracket at one end or with two equal end brackets, are to be obtained from the formulae in:

- [3.4.3] and [3.4.4] in the case of longitudinal and transverse stiffeners
- [3.4.6] and [3.4.7] in the case of vertical stiffeners.

Normal and shear stresses, induced by lateral pressures, in multispan ordinary stiffeners are to be obtained from the formulae in [3.4.8].

3.4.2 Longitudinal and transverse ordinary stiffeners without brackets at ends

The maximum normal stress σ and shear stress τ are to be obtained, in N/mm², from the following formulae:

$$\sigma = c_c \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{12 w}\left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3 + \sigma_N$$

$$\tau = 5 \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{A_{Sh}}\left(1 - \frac{s}{2\ell}\right) s \ell$$

3.4.3 Longitudinal and transverse ordinary stiffeners with a bracket at one end

The maximum normal stress σ and shear stress τ are to be obtained, in N/mm², from the following formulae:

$$\sigma = \beta_{b1} \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{12 w}\left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3 + \sigma_N$$

$$\tau = 5 \beta_{s1} \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{A_{Sh}}\left(1 - \frac{s}{2\ell}\right) s \ell$$

where:

$$\beta_{b1} = \frac{\chi(1-\alpha)^5 + \alpha(1-\alpha)(6 - 3\alpha + 8\alpha^2)}{\chi(1-\alpha)^3 + 2\alpha(2-\alpha)}$$

to be taken not less than 0,55

$$\beta_{s1} = \frac{\chi(1-\alpha)^4 + 5\alpha(1 - \alpha + \alpha^2)}{\chi(1-\alpha)^3 + 2\alpha(2-\alpha)}$$

3.4.4 Longitudinal and transverse ordinary stiffeners with equal brackets at ends

The maximum normal stress σ and shear stress τ are to be obtained, in N/mm², from the following formulae:

$$\sigma = \beta_{b2} \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{12 w}\left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3 + \sigma_N$$

$$\tau = 5 \beta_{s2} \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{A_{Sh}}\left(1 - \frac{s}{2\ell}\right) s \ell$$

where:

$$\beta_{b2} = \frac{\chi(1-2\alpha)^3 + 2\alpha^2(4\alpha - 3)}{\chi(1-2\alpha) + 2\alpha}$$

to be taken not less than 0,55

$$\beta_{s2} = 1 - 2\alpha$$

3.4.5 Vertical ordinary stiffeners without brackets at ends

The maximum normal stress σ and shear stress τ are to be obtained, in N/mm², from the following formulae:

$$\sigma = c_c \frac{\gamma_{S2} \lambda_{bS} p_S + \gamma_{W2} \lambda_{bW} p_W}{12 w}\left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3 + \sigma_N$$

$$\tau = 5 \frac{\gamma_{S2} \lambda_{sS} p_S + \gamma_{W2} \lambda_{sW} p_W}{A_{Sh}}\left(1 - \frac{s}{2\ell}\right) s \ell$$

where:

$$\lambda_{bS} = 1 + 0{,}2\frac{p_{Sd} - p_{Su}}{p_{Sd} + p_{Su}}$$

$$\lambda_{bW} = 1 + 0{,}2\frac{p_{Wd} - p_{Wu}}{p_{Wd} + p_{Wu}}$$

$$\lambda_{sS} = 1 + 0{,}4\frac{p_{Sd} - p_{Su}}{p_{Sd} + p_{Su}}$$

$$\lambda_{sW} = 1 + 0{,}4\frac{p_{Wd} - p_{Wu}}{p_{Wd} + p_{Wu}}$$

p_{Sd} : Still water pressure, in kN/m², at the lower end of the ordinary stiffener considered

p_{Su} : Still water pressure, in kN/m², at the upper end of the ordinary stiffener considered

p_{Wd} : Wave pressure, in kN/m², at the lower end of the ordinary stiffener considered.

p_{Wu} : Wave pressure, in kN/m², at the upper end of the ordinary stiffener considered

3.4.6 Vertical ordinary stiffeners with a bracket at lower end

The maximum normal stress σ and shear stress τ are to be obtained, in N/mm², from the following formulae:

$$\sigma = \beta_{b1}\frac{\gamma_{S2}\lambda_{bS}p_S + \gamma_{W2}\lambda_{bW}p_W}{12w}\left(1 - \frac{s}{2\ell}\right)s\ell^2 10^3 + \sigma_N$$

$$\tau = 5\beta_{s1}\frac{\gamma_{S2}\lambda_{sS}p_S + \gamma_{W2}\lambda_{sW}p_W}{A_{Sh}}\left(1 - \frac{s}{2\ell}\right)s\ell$$

where:

β_{b1}, β_{s1} : Coefficients defined in [3.4.3]

λ_{bS}, λ_{bW}, λ_{sS}, λ_{sW}: Coefficients defined in [3.4.5].

3.4.7 Vertical ordinary stiffeners with equal brackets at ends

The maximum normal stress σ and shear stress τ are to be obtained, in N/mm², from the following formulae:

$$\sigma = \beta_{b2}\frac{\gamma_{S2}\lambda_{bS}p_S + \gamma_{W2}\lambda_{bW}p_W}{12w}\left(1 - \frac{s}{2\ell}\right)s\ell^2 10^3 + \sigma_N$$

$$\tau = 5\beta_{s2}\frac{\gamma_{S2}\lambda_{sS}p_S + \gamma_{W2}\lambda_{sW}p_W}{A_{Sh}}\left(1 - \frac{s}{2\ell}\right)s\ell$$

where:

β_{b2}, β_{s2} : Coefficients defined in [3.4.4]

λ_{bS}, λ_{bW}, λ_{sS}, λ_{sW}: Coefficients defined in [3.4.5].

3.4.8 Multispan ordinary stiffeners

The maximum normal stress σ and shear stress τ in a multispan ordinary stiffener are to be determined by a direct calculation taking into account:

- the distribution of still water and wave pressure and forces, to be determined on the basis of the criteria specified in Ch 5, Sec 5 and Ch 5, Sec 6
- the number of intermediate decks or girders
- the condition of fixity at the ends of the stiffener and at intermediate supports
- the geometrical characteristics of the stiffener on the intermediate spans.

3.5 Normal and shear stresses due to wheeled loads

3.5.1 General

Normal and shear stresses, induced by the wheeled loads, in ordinary stiffeners are to be determined from the formulae given in [3.5.2] for longitudinal and transverse stiffeners.

3.5.2 Longitudinal and transverse ordinary stiffeners subjected to wheeled loads

The maximum normal stress σ and shear stress τ are to be obtained, in N/mm², from the following formulae:

$$\sigma = \frac{\alpha_S P_0 \ell}{6w}10^3 + \sigma_N$$

$$\tau = 5\frac{\alpha_T P_0}{A_{Sh}}$$

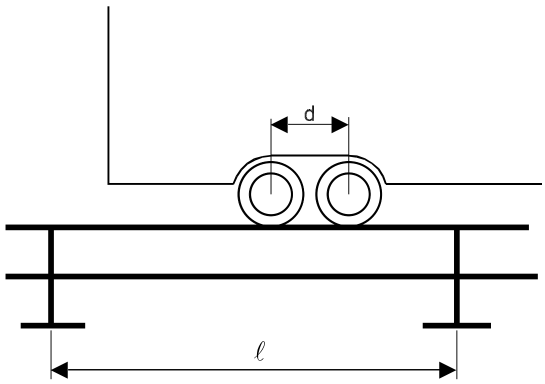
where:

P_0 : Wheeled force, in kN, taken equal to:

$$P_0 = \gamma_{S2}F_S + 0{,}4\gamma_{W2}F_{W,Z}$$

α_S, α_T : Coefficients taking account of the number of axles and wheels per axle considered as acting on the stiffener, defined in Tab 5 (see Fig 4).

Figure 4 : Wheeled load on stiffeners - Double axles



3.6 Checking criteria

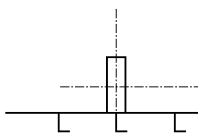
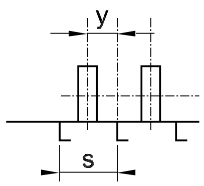
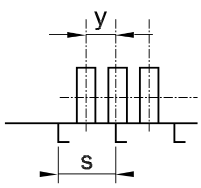
3.6.1 General

It is to be checked that the normal stress σ and the shear stress τ, calculated according to [3.4] and [3.5], are in compliance with the following formulae:

$$\frac{R_y}{\gamma_R\gamma_m} \geq \sigma$$

$$0{,}5\frac{R_y}{\gamma_R\gamma_m} \geq \tau$$

Table 5 : Wheeled loads - Coefficients α_S and α_T

Configuration	Single axle		Double axles	
	α_S	α_T	α_S	α_T
Single wheel 	1	1	$0{,}5\left(2-\frac{d}{\ell}\right)^2$	$2+\frac{d}{\ell}$
Double wheels 	$2\left(1-\frac{y}{s}\right)$	$2\left(1-\frac{y}{s}\right)$	$\left(1-\frac{y}{s}\right)\left(2-\frac{d}{\ell}\right)^2$	$2\left(1-\frac{y}{s}\right)\left(2+\frac{d}{\ell}\right)$
Triple wheels 	$3-2\frac{y}{s}$	$3-2\frac{y}{s}$	$0{,}5\left(3-2\frac{y}{s}\right)\left(2-\frac{d}{\ell}\right)^2$	$\left(3-2\frac{y}{s}\right)\left(2+\frac{d}{\ell}\right)$

Note 1:
d : Distance, in m, between two axles (see Fig 4)
y : Distance, in m, from the external wheel of a group of wheels to the stiffener under consideration, to be taken equal to the distance from the external wheel to the centre of the group of wheels.

3.7 Net section modulus and net shear sectional area of ordinary stiffeners, complying with the checking criteria

3.7.1 General

The requirements in [3.7.3] and [3.7.4] provide the minimum net section modulus and net shear sectional area of ordinary stiffeners subjected to lateral pressure in intact conditions, complying with the checking criteria indicated in [3.6].

The requirements in [3.7.5] provide the minimum net section modulus and net shear sectional area of ordinary stiffeners subjected to wheeled loads, complying with the checking criteria indicated in [3.6].

3.7.2 Groups of equal ordinary stiffeners

Where a group of equal ordinary stiffeners is fitted, it is acceptable that the minimum net section modulus in [3.7.1] is calculated as the average of the values required for all the stiffeners of the same group, but this average is to be taken not less than 90% of the maximum required value.

The same applies for the minimum net shear sectional area.

3.7.3 Longitudinal and transverse ordinary stiffeners subjected to lateral pressure

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh} , in cm^2, of longitudinal or transverse ordinary stiffeners subjected to lateral pressure are to be not less than the values obtained from the following formulae:

$$w = c_c\gamma_R\gamma_m\beta_b\frac{\gamma_{S2}p_S+\gamma_{W2}p_W}{12(R_y-\gamma_R\gamma_m\sigma_N)}\left(1-\frac{s}{2\ell}\right)s\ell^2 10^3$$

$$A_{Sh} = 10\gamma_R\gamma_m\beta_s\frac{\gamma_{S2}p_S+\gamma_{W2}p_W}{R_y}\left(1-\frac{s}{2\ell}\right)s\ell$$

where:

β_b : Coefficient to be taken equal to:

$\beta_b = 1$ in the case of an ordinary stiffener without brackets at ends

$\beta_b = \beta_{b1}$ defined in [3.4.3], in the case of an ordinary stiffener with a bracket of length not greater than $0{,}2\ell$ at one end

$\beta_b = \beta_{b2}$ defined in [3.4.4], in the case of an ordinary stiffener with equal brackets of length not greater than $0{,}2\ell$ at ends

β_s : Coefficient to be taken equal to:

$\beta_s = 1$ in the case of an ordinary stiffener without brackets at ends

$\beta_s = \beta_{s1}$ defined in [3.4.3], in the case of an ordinary stiffener with a bracket of length not greater than $0{,}2\ell$ at one end

$\beta_s = \beta_{s2}$ defined in [3.4.4], in the case of an ordinary stiffener with equal brackets of length not greater than $0{,}2\ell$ at ends.

3.7.4 Vertical ordinary stiffeners subjected to lateral pressure

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh}, in cm^2, of vertical ordinary stiffeners subjected to lateral pressure are to be not less than the values obtained from the following formulae:

$$w = c_c \gamma_R \gamma_m \beta_b \frac{\gamma_{S2}\lambda_{bS} p_S + \gamma_{W2}\lambda_{bW} p_W}{12(R_y - \gamma_R \gamma_m \sigma_N)}\left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2}\lambda_{sS} p_S + \gamma_{W2}\lambda_{sW} p_W}{R_y}\left(1 - \frac{s}{2\ell}\right) s \ell$$

where:

β_b, β_s : Coefficients defined in [3.7.3]

λ_{bS}, λ_{bW}, λ_{sS}, λ_{sW}: Coefficients defined in [3.4.5].

3.7.5 Ordinary stiffeners subjected to wheeled loads

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh}, in cm^2, of ordinary stiffeners subjected to wheeled loads are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \frac{\alpha_S P_0 \ell}{6(R_y - \gamma_R \gamma_m \sigma_N)} 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \frac{\alpha_T P_0}{R_y}$$

where:

P_0 : Wheeled force, in kN, defined in [3.5.2]

α_S, α_T : Coefficients defined in [3.5.2].

3.8 Net section modulus and net shear sectional area of ordinary stiffeners subjected to lateral pressure in flooding conditions

3.8.1 General

The requirements in [3.8.1] to [3.8.4] apply to ordinary stiffeners of bulkheads or inner side which constitute boundary of compartments not intended to carry liquids.

These ordinary stiffeners are to be checked in flooding conditions as specified in [3.8.3] and [3.8.4], depending on the type of stiffener.

3.8.2 Groups of equal ordinary stiffeners

Where a group of equal ordinary stiffeners is fitted, it is acceptable that the minimum net section modulus in [3.8.1] is calculated as the average of the values required for all the stiffeners of the same group, but this average is to be taken not less than 90% of the maximum required value.

The same applies for the minimum net shear sectional area.

3.8.3 Longitudinal and transverse ordinary stiffeners

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh}, in cm^2, of longitudinal or transverse ordinary stiffeners are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{16 c_P (R_y - \gamma_R \gamma_m \sigma_N)}\left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{R_y}\left(1 - \frac{s}{2\ell}\right) s \ell$$

where:

β_b, β_s : Coefficients defined in [3.7.3]

c_P : Ratio of the plastic section modulus to the elastic section modulus of the ordinary stiffeners with an attached shell plating b_p, to be taken equal to 1,16 in the absence of more precise evaluation.

3.8.4 Vertical ordinary stiffeners

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh}, in cm^2, of vertical ordinary stiffeners are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2}\lambda_{bS} p_{SF} + \gamma_{W2}\lambda_{bW} p_{WF}}{16 c_P (R_y - \gamma_R \gamma_m \sigma_N)}\left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2}\lambda_{sS} p_{SF} + \gamma_{W2}\lambda_{sW} p_{WF}}{R_y}\left(1 - \frac{s}{2\ell}\right) s \ell$$

where:

β_b, β_s : Coefficients defined in [3.7.3]

c_P : Ratio defined in [3.8.3]

$$\lambda_{bS} = 1 + 0{,}2 \frac{p_{SFd} - p_{SFu}}{p_{SFd} + p_{SFu}}$$

$$\lambda_{bW} = 1 + 0{,}2 \frac{p_{WFd} - p_{WFu}}{p_{WFd} + p_{WFu}}$$

$$\lambda_{sS} = 1 + 0{,}4 \frac{p_{SFd} - p_{SFu}}{p_{SFd} + p_{SFu}}$$

$$\lambda_{sW} = 1 + 0{,}4 \frac{p_{WFd} - p_{WFu}}{p_{WFd} + p_{WFu}}$$

p_{SFd} : Still water pressure, in kN/m^2, in flooding conditions, at the lower end of the ordinary stiffener considered

p_{SFu} : Still water pressure, in kN/m^2, in flooding conditions, at the upper end of the ordinary stiffener considered

p_{WFd} : Wave pressure, in kN/m^2, in flooding conditions, at the lower end of the ordinary stiffener considered.

p_{WFu} : Wave pressure, in kN/m^2, in flooding conditions, at the upper end of the ordinary stiffener considered

Table 6 : Hull girder normal compression stresses

Condition	σ_{S1} in N/mm² **(1)**	σ_{WV1} in N/mm²	σ_{WH1} in N/mm²
$z \geq N$	$\frac{M_{SW,S}}{I_Y}(z-N)10^{-3}$	$\frac{0{,}625 F_D M_{WV,S}}{I_Y}(z-N)10^{-3}$	$-\left\lvert\frac{0{,}625 M_{WH}}{I_Z}y\right\rvert 10^{-3}$
$z < N$	$\frac{M_{SW,H}}{I_Y}(z-N)10^{-3}$	$\frac{0{,}625 M_{WV,H}}{I_Y}(z-N)10^{-3}$	

(1) When the ship in still water is always in hogging condition, σ_{S1} for $z \geq N$ is to be obtained, in N/mm², from the following formula, unless σ_{X1} is evaluated by means of direct calculations (see [4.2.2]):

$$\sigma_{S1} = \frac{M_{SW,Hmin}}{I_Y}(z-N)10^{-3}$$

Note 1:

F_D : Coefficient defined in Ch 5, Sec 2, [4].

4 Buckling check

4.1 Width of attached plating

4.1.1 The width of the attached plating to be considered for the buckling check of ordinary stiffeners is to be obtained, in m, from the following formulae:

- where no local buckling occurs on the attached plating (see Sec 1, [5.4.1]):

  $b_e = s$

- where local buckling occurs on the attached plating (see Sec 1, [5.4.1]):

  $$b_e = \left(\frac{2{,}25}{\beta_e} - \frac{1{,}25}{\beta_e^2}\right)s$$

  to be taken not greater than s

where:

$$\beta_e = \frac{s}{t_p}\sqrt{\frac{\sigma_b}{E}}10^3$$

σ_b : Compression stress σ_X or σ_Y, in N/mm², acting on the plate panel, defined in Sec 1, [5.2.4], according to the direction x or y considered.

4.2 Load model

4.2.1 Sign convention for normal stresses

The sign convention for normal stresses is as follows:

- tension: positive
- compression: negative.

4.2.2 Hull girder compression normal stresses

The hull girder compression normal stresses to be considered for the buckling check of ordinary stiffeners contributing to the hull girder longitudinal strength are obtained, in N/mm², from the following formula:

$$\sigma_{X1} = \gamma_{S1}\sigma_{S1} + \gamma_{W1}(C_{FV}\sigma_{WV1} + C_{FH}\sigma_{WH1} + C_{F\Omega}\sigma_{\Omega})$$

where:

σ_{S1}, σ_{WV1}, σ_{WH1} : Hull girder normal stresses, in N/mm², defined in Tab 6

σ_{Ω} : Compression warping stress, in N/mm², induced by the torque $0{,}625 M_{WT}$ and obtained through direct calculation analyses based on a structural model in accordance with Ch 6, Sec 1, [2.6]

C_{FV}, C_{FH}, $C_{F\Omega}$: Combination factors defined in Tab 4.

For longitudinal stiffeners, σ_{X1} is to be taken as the maximum compression stress on the stiffener considered.

In no case may σ_{X1} be taken less than 30/k N/mm².

When the ship in still water is always in hogging condition, σ_{X1} may be evaluated by means of direct calculations when justified on the basis of the ship's characteristics and intended service. The calculations are to be submitted to the Society for approval.

4.2.3 Combined hull girder and local compression normal stresses

The combined compression normal stresses to be considered for the buckling check of ordinary stiffeners are to take into account the hull girder stresses and the local stresses resulting from the bending of the primary supporting members. These local stresses are to be obtained from a direct structural analysis using the design loads as given in Chapter 5.

With respect to the reference co-ordinate system defined in Ch 1, Sec 2, [4.1], the combined stresses in x and y direction are obtained, in N/mm², from the following formulae:

$$\sigma_X = \sigma_{X1} + \gamma_{S2}\sigma_{X2,S} + \gamma_{W2}\sigma_{X2,W}$$

$$\sigma_Y = \gamma_{S2}\sigma_{Y2,S} + \gamma_{W2}\sigma_{Y2,W}$$

where:

σ_{X1} : Compression normal stress, in N/mm², induced by the hull girder still water and wave loads, defined in [4.2.2]

$\sigma_{X2,S}$, $\sigma_{Y2,S}$: Compression normal stress in x and y direction, respectively, in N/mm², induced by the local bending of the primary supporting members and obtained from a direct structural analysis using the still water design loads as given in Chapter 5

$\sigma_{X2,W}$, $\sigma_{Y2,W}$: Compression normal stress in x and y direction, respectively, in N/mm², induced by the local bending of the primary supporting members and obtained from a direct structural analysis using the wave design loads as given in Chapter 5.

4.3 Critical stress

4.3.1 General

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

$$\sigma_c = \sigma_E \qquad \text{for } \sigma_E \le \frac{R_{eH,S}}{2}$$

$$\sigma_c = R_{eH,S}\left(1 - \frac{R_{eH,S}}{4\sigma_E}\right) \qquad \text{for } \sigma_E > \frac{R_{eH,S}}{2}$$

where:

$\sigma_E = \min(\sigma_{E1}, \sigma_{E2}, \sigma_{E3})$

σ_{E1} : Euler column buckling stress, in N/mm², given in [4.3.2]

σ_{E2} : Euler torsional buckling stress, in N/mm², given in [4.3.3]

σ_{E3} : Euler web buckling stress, in N/mm², given in [4.3.4].

4.3.2 Column buckling of axially loaded stiffeners

The Euler column buckling stress is obtained, in N/mm², from the following formula:

$$\sigma_E = \pi^2 E \frac{I_e}{A_e \ell^2} 10^{-4}$$

4.3.3 Torsional buckling of axially loaded stiffeners

The Euler torsional buckling stresses is obtained, in N/mm², from the following formula:

$$\sigma_E = \frac{\pi^2 E I_w}{10^4 I_p \ell^2}\left(\frac{K_C}{m^2} + m^2\right) + 0{,}385 E \frac{I_t}{I_p}$$

where:

I_w : Net sectorial moment of inertia, in cm⁶, of the stiffener about its connection to the attached plating:

- for flat bars:

$$I_w = \frac{h_w^3 t_w^3}{36} 10^{-6}$$

- for T-sections:

$$I_w = \frac{t_f b_f^3 h_w^2}{12} 10^{-6}$$

- for angles and bulb sections:

$$I_w = \frac{b_f^3 h_w^2}{12(b_f + h_w)^2}[t_f b_f^2 + 2 b_f h_w + 4 h_w^2 + 3 t_w b_f h_w]\ 10^{-6}$$

I_p : Net polar moment of inertia, in cm⁴, of the stiffener about its connection to the attached plating:

- for flat bars:

$$I_p = \frac{h_w^3 t_w}{3} 10^{-4}$$

- for stiffeners with face plate:

$$I_p = \left(\frac{h_w^3 t_w}{3} + h_w^2 b_f t_f\right) 10^{-4}$$

I_t : St. Venant's net moment of inertia, in cm⁴, of the stiffener without attached plating:

- for flat bars:

$$I_t = \frac{h_w t_w^3}{3} 10^{-4}$$

- for stiffeners with face plate:

$$I_t = \frac{1}{3}\left[h_w t_w^3 + b_f t_f^3\left(1 - 0{,}63\frac{t_f}{b_f}\right)\right] 10^{-4}$$

m : Number of half waves, to be taken equal to the integer number such that (see also Tab 7):

$$m^2(m-1)^2 \le K_C < m^2(m+1)^2$$

$$K_C = \frac{C_0 \ell^4}{\pi^4 E I_w} 10^6$$

C_0 : Spring stiffness of the attached plating:

$$C_0 = \frac{E t_p^3}{2{,}73 s} 10^{-3}$$

Table 7 : Torsional buckling of axially loaded stiffeners - Number m of half waves

K_C	$0 \le K_C < 4$	$4 \le K_C < 36$	$36 \le K_C < 144$
m	1	2	3

4.3.4 Web buckling of axially loaded stiffeners

The Euler buckling stress of the stiffener web is obtained, in N/mm², from the following formulae:

- for flat bars:

$$\sigma_E = 16\left(\frac{t_W}{h_W}\right)^2 10^4$$

- for stiffeners with face plate:

$$\sigma_E = 78\left(\frac{t_W}{h_W}\right)^2 10^4$$

4.4 Checking criteria

4.4.1 Stiffeners parallel to the direction of compression

The critical buckling stress of the ordinary stiffener is to comply with the following formula:

$$\frac{\sigma_c}{\gamma_R \gamma_m} \ge |\sigma_b|$$

where:

σ_c : Critical buckling stress, in N/mm², as calculated in [4.3.1]

σ_b : Compression stress σ_{xb} or σ_{yb}, in N/mm², in the stiffener, as calculated in [4.2.2] or [4.2.3].

Figure 5 : Buckling of stiffeners parallel to the direction of compression

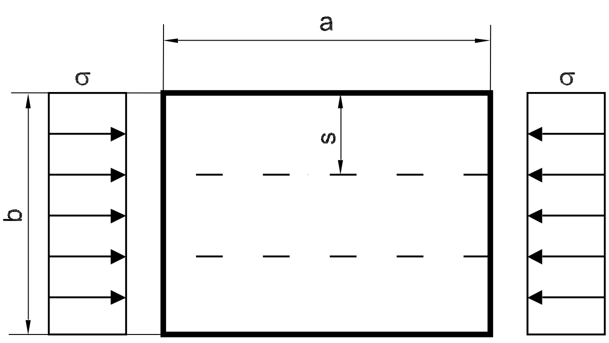
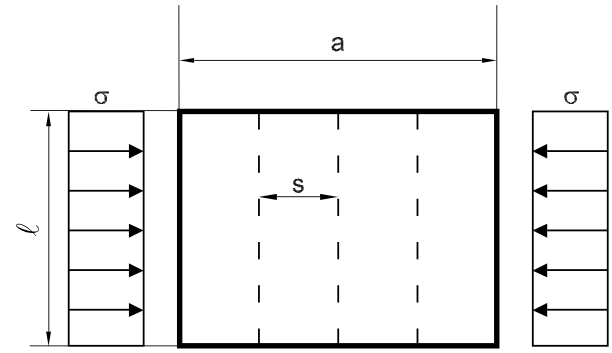


Figure 6 : Buckling of stiffeners perpendicular to the direction of compression



4.4.2 Stiffeners perpendicular to the direction of compression

The net moment of inertia of stiffeners, in cm⁴, is to be not less than the greatest value obtained from the following formulae:

- $I = 360\ell^2$
- for $\sigma \le R_{eH,P}/2$:

$$I = \frac{st_p^3}{485}\left[\frac{\left(\frac{\ell}{s}\right)^4 - 4}{\sigma_{E,1} - \sigma_{E,0}}\right](\sigma - \sigma_{E,0})$$

- for $\sigma > R_{eH,P}/2$:

$$I = \frac{st_p^3}{485}\left[\frac{\left(\frac{\ell}{s}\right)^4 - 4}{\sigma_{E,1} - \sigma_{E,0}}\right]\left[\frac{R_{eH,P}}{4\left(1 - \frac{\sigma}{R_{eH,P}}\right)} - \sigma_{E,0}\right]$$

where:

ℓ/s : Ratio to be taken not less than 1,41

$\sigma_{E,0}$: Euler buckling stress, in N/mm², of the unstiffened plate taken equal to:

$$\sigma_{E,0} = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t_p}{\ell}\right)^2 \varepsilon K_{1,0}$$

$K_{1,0}$: Coefficient defined in Sec 1, Tab 8 for:

$0 \le \Psi \le 1$ and $\alpha = a/\ell$

ε : Coefficient defined in Sec 1, [5.3.1]

$\sigma_{E,1}$: Euler buckling stress, in N/mm², of the plate panel taken equal to:

$$\sigma_{E,1} = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t_p}{\ell}\right)^2 \varepsilon K_{1,1}$$

$K_{1,1}$: Coefficient defined in Sec 1, Tab 8 for:

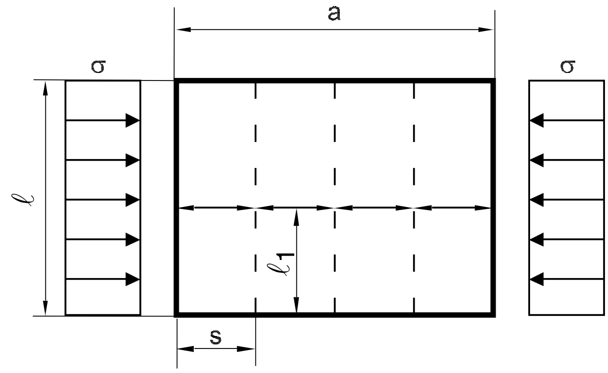
$0 \le \Psi \le 1$ and $\alpha = s/\ell$.

Where intercostal stiffeners are fitted, as shown in Fig 7, the check of the moment of inertia of stiffeners perpendicular to the direction of compression is to be carried out with the equivalent net thickness $t_{eq,net}$, in mm, obtained from the following formula:

$$t_{eq,net} = \frac{1 + \left(\frac{s}{\ell_1}\right)^2}{1 + \left(\frac{s}{\ell}\right)^2} t_{net}$$

where ℓ_1 is to be taken not less than s.

Figure 7 : Buckling of stiffeners perpendicular to the direction of compression (intercostal stiffeners)



5 Ultimate strength check of ordinary stiffeners contributing to the hull girder longitudinal strength

5.1 Application

5.1.1 The requirements of this Article apply to ships equal to or greater than 150 m in length. For such ships, the ultimate strength of stiffeners subjected to lateral pressure and to hull girder normal stresses is to be checked.

5.2 Width of attached plating

5.2.1 The width of the attached plating to be considered for the ultimate strength check of ordinary stiffeners is to be obtained, in m, from the following formulae:

- if $\beta_U \le 1,25$:

  $b_U = s$

- if $\beta_U > 1,25$:

  $$b_U = \left(\frac{2,25}{\beta_U} - \frac{1,25}{\beta_U^2}\right)s$$

where:

$$\beta_U = \frac{s}{t_p}\sqrt{\frac{\sigma_{X1E}}{E}}10^3$$

σ_{X1E} : Stress defined in [5.4].

5.3 Load model

5.3.1 General

The still water and wave lateral pressures induced by the sea and the various types of cargoes and ballast in intact conditions are to be considered, depending on the location of the ordinary stiffener under consideration and the type of compartments adjacent to it, in accordance with Ch 5, Sec 1, [2.4].

The wave lateral pressures and hull girder loads are to be calculated in the mutually exclusive load cases "a", "b", "c" and "d" in Ch 5, Sec 4.

5.3.2 Lateral pressure

Lateral pressure is constituted by still water pressure and wave pressure.

Still water pressure (p_S) includes:

- the still water sea pressure, defined in Ch 5, Sec 5, [1]
- the still water internal pressure, defined in Ch 5, Sec 6 for the various types of cargoes and for ballast.

Wave induced pressure (p_W) includes:

- the wave pressure, defined in Ch 5, Sec 5, [2] for each load case "a", "b", "c" and "d"
- the inertial pressure, defined in Ch 5, Sec 6 for the various types of cargoes and for ballast, and for each load case "a", "b", "c" and "d".

5.3.3 Hull girder compression normal stresses

The hull girder compression normal stresses σ_{X1} to be considered for the ultimate strength check of stiffeners contributing to the longitudinal strength are those given in [4.2.2], where the partial safety factors are those specified in Tab 1 for the ultimate strength check.

5.4 Ultimate strength stress

5.4.1 The ultimate strength stress σ_U is to be obtained, in N/mm², from the formulae in Tab 8, for resultant lateral pressure acting either on the side opposite to the ordinary stiffener, with respect to the plating, or on the same side as the ordinary stiffener.

5.5 Checking criteria

5.5.1 The ultimate strength stress of the ordinary stiffener is to comply with the following formula:

$$\frac{\sigma_U}{\gamma_R \gamma_m} \ge |\sigma_{X1}|$$

where:

σ_U : Ultimate strength stress, in N/mm², as calculated in [5.4.1]

σ_{X1} : Compression stress, in N/mm², as calculated in [5.3.3].

Table 8 : Ultimate strength stress

Symbol	Resultant load pressure acting on the side opposite to the ordinary stiffener, with respect to the plating, in N/mm²	Resultant load pressure acting on the same side as the ordinary stiffener, in N/mm²
σ_U	$f\dfrac{A_U}{A_S}\left(1-\dfrac{s}{10b_U}\right)R_{eH,P}$	$R_{eH,S}\, f$
f	$\dfrac{\zeta}{2}-\sqrt{\dfrac{\zeta^2}{4}-\dfrac{1-\mu}{(1+\eta_P)\lambda_U^2}}$	
ζ	$\dfrac{1-\mu}{1+\eta_P}+\dfrac{1+\eta_P+\eta}{(1+\eta_P)\lambda_U^2}$	
μ	$\dfrac{125ps\ell^2 d_{P,U}}{R_{eH,P}I_U\left(1-\dfrac{s}{10b_U}\right)}$	$\dfrac{41,7ps\ell^2 d_{F,S}}{R_{eH,S}I_S}$
η	$\left(\delta_0+\dfrac{13ps\ell^4}{E_TI_S}10^4\right)\dfrac{d_{P,U}}{\rho_U^2}$	$\left(0,577\delta_0+\dfrac{1,5ps\ell^4}{E_TI_S}10^4\right)\dfrac{d_{F,S}}{\rho_S^2}$
η_P	$d_PA\left(\dfrac{1}{A_U}-\dfrac{1}{A_S}\right)\dfrac{d_{P,U}}{\rho_U^2}$	0
λ_U	$\dfrac{31,8\ell}{\rho_U}\sqrt{\dfrac{R_{eH,P}}{E_T}\left(1-\dfrac{s}{10b_U}\right)}$	$\dfrac{18,4\ell}{\rho_S}\sqrt{\dfrac{R_{eH,S}}{E_T}}$

Note 1:

σ_{C2} : Critical torsional buckling stress, in N/mm², defined in [4.3.1]

$d_{P,U}$: Distance, in cm, between the neutral axis of the cross-section of the stiffener with attached plating of width b_U and the fibre at half-thickness of the plating

$d_{F,S}$: Distance, in cm, between the neutral axis of the cross-section of the stiffener with attached plating of width s and the fibre at half-thickness of the face plate of the stiffener

d_P : Distance, in cm, between the neutral axis of the ordinary stiffener without attached plating and the fibre at half-thickness of the attached plating

A : Net sectional area, in cm², of the stiffener without attached plating

p : Lateral pressure acting on the stiffener, equal to: $p = \gamma_{S2}\, p_S + \gamma_{W2U}\, p_W$

δ_0 : Pre-deformation, in cm, of the ordinary stiffener, to be assumed, in the absence of more accurate evaluation: $\delta_0 = 0,2\,\ell$

E_T : Structural tangent modulus, equal to:

$$E_T = 4E\frac{\sigma_{X1E}}{R_{eH,P}}\left(1-\frac{\sigma_{X1E}}{R_{eH,P}}\right) \quad \text{for} \quad \sigma_{X1E} > 0,5R_{eH,P}$$

$$E_T = E \quad \text{for} \quad \sigma_{X1E} \le 0,5R_{eH,P}$$

σ_{X1E} : Stress to be obtained, in N/mm², from the following formulae:

$$\sigma_{X1E} = \left\{\frac{-\dfrac{22,5st_P}{\alpha}+\sqrt{\left(\dfrac{22,5st_P}{\alpha}\right)^2+4A\left[(A_S+10st_P)\sigma_{X1}+\dfrac{12,5st_P}{\alpha^2}\right]}}{2A}\right\}^2 \quad \text{if} \quad \alpha > \frac{1,25}{\sqrt{|\sigma_{X1}|}}$$

$$\sigma_{X1E} = \sigma_{X1} \quad \text{if} \quad \alpha \le \frac{1,25}{\sqrt{|\sigma_{X1}|}}$$

$$\alpha = 1000\frac{s}{t_P\sqrt{E}}$$

σ_{X1} : Compression stress, in N/mm², acting on the stiffener, as defined in [5.3.3].

SECTION 3 PRIMARY SUPPORTING MEMBERS

Symbols

For symbols not defined in this Section, refer to the list at the beginning of this Chapter.

p_S : Still water pressure, in kN/m², see [3.4.2] and [3.4.4]

p_W : Wave pressure, in kN/m², see [3.4.2] and [3.4.4]

p_{SF}, p_{WF} : Still water and wave pressures, in kN/m², in flooding conditions, defined in Ch 5, Sec 6, [9]

σ_{X1} : Hull girder normal stress, in N/mm², defined in [3.4.5]

σ_N : Normal stress, in N/mm², defined in [3.4.5]

s : Spacing, in m, of primary supporting members

ℓ : Span, in m, of primary supporting members, measured between the supporting elements, see Ch 4, Sec 3, [4.1]

ℓ_b : Length, in m, of one bracket, see [3.2] and Ch 4, Sec 3, [4.4]

b_p : Width, in m, of the plating attached to the primary supporting member, for the yielding check, defined in Ch 4, Sec 3, [4.2]

w : Net section modulus, in cm³, of the primary supporting member, with an attached plating of width b_p, to be calculated as specified in Ch 4, Sec 3, [4.3]

A_{Sh} : Net shear sectional area, in cm², of the primary supporting member, to be calculated as specified in Ch 4, Sec 3, [4.3]

m : Boundary coefficient, to be taken equal to:
- m = 10 in general
- m = 12 for bottom and side girders

I : Net moment of inertia, in cm⁴, of the primary supporting member without attached plating, about its neutral axis parallel to the plating

I_B : Net moment of inertia, in cm⁴, of the primary supporting member with bracket and without attached plating, about its neutral axis parallel to the plating, calculated at mid-length of the bracket

$\chi = I_B / I$

$\alpha = \ell_b / \ell$

1 General

1.1 Application

1.1.1 Analysis criteria

The requirements of this Section apply for the yielding and buckling checks of primary supporting members.

Depending on their arrangement, primary supporting members are to be analysed through one of the following models:

- an isolated beam structural model
- a three dimensional structural model
- a complete ship structural model.

1.1.2 Isolated beam models

In general, an isolated beam model is to be adopted where the primary supporting member arrangement is not of a grillage type, i.e. where the primary supporting members are fitted in one direction, or where the primary supporting members are fitted in two directions and their inertia in one direction is at least three times that in the other direction.

1.1.3 Three dimensional models

Where the conditions in [1.1.2] do not occur, primary supporting members are to be analysed through three dimensional models, according to [4], unless analyses using complete ship models are required on the basis of the criteria in [5].

In general, a three dimensional model is to be adopted for the analysis of primary supporting members of ships greater than 120 m in length.

1.1.4 Complete ship models

Complete ship models may be required to be carried out in order to analyse primary supporting members for the cases specified in [5].

1.1.5 Analysis documentation

Adequate documentation of the analyses based on three dimensional models (structural model, load and stress calculation, strength checks) carried out by the Designer are to be submitted to the Society for review.

1.1.6 Yielding check

The yielding check is to be carried out according to:

- [3] for primary supporting members analysed through isolated beam models
- [4] for primary supporting members analysed through three dimensional models
- [5] for primary supporting members analysed through complete ship models.

1.1.7 Buckling check

The buckling check is to be carried out according to [6], on the basis of the stresses in primary supporting members calculated according to [3], [4] or [5], depending on the structural model adopted.

Table 1 : Primary supporting members analysed through isolated beam models - Partial safety factors

Partial safety factors covering uncertainties regarding:	Symbol	Yielding check		Buckling check	
		General (see [3.4] to [3.7])	Watertight bulkhead primary supporting members **(1)** (see [3.8])	Plate panels (see [6.1])	Pillars (see [6.2] and [6.3])
Still water hull girder loads	γ_{S1}	1,00	1,00	1,00	1,00
Wave hull girder loads	γ_{W1}	1,15	1,15	1,15	1,15
Still water pressure	γ_{S2}	1,00	1,00	1,00	1,00
Wave pressure	γ_{W2}	1,20	1,05	1,20	1,20
Material	γ_m	1,02	1,02	1,02	1,02
Resistance	γ_R	• 1,02 in general • 1,15 for bottom and side girders	1,02 **(2)**	1,10	For [6.2]: see Tab 13 For [6.3]: 1,15

(1) Applies also to primary supporting members of bulkheads or inner side which constitute boundary of compartments not intended to carry liquids.
(2) For primary supporting members of the collision bulkhead, γ_R =1,25

Table 2 : Primary supporting members analysed through three dimensional models - Partial safety factors

Partial safety factors covering uncertainties regarding:	Symbol	Yielding check (see [4])		Buckling check	
		General	Watertight bulkhead primary supporting members **(1)**	Plate panels (see [6.1])	Pillars (see [6.2] and [6.3])
Still water hull girder loads	γ_{S1}	1,05	1,05	1,05	1,05
Wave hull girder loads	γ_{W1}	1,05	1,05	1,05	1,05
Still water pressure	γ_{S2}	1,00	1,00	1,00	1,00
Wave pressure	γ_{W2}	1,10	1,10	1,10	1,10
Material	γ_m	1,02	1,02	1,02	1,02
Resistance	γ_R	Defined in Tab 4 and Tab 5	Defined in Tab 4 and Tab 5	1,02	For [6.2]: see Tab 13 For [6.3]: 1,15

(1) Applies also to primary supporting members of bulkheads or inner side which constitute boundary of compartments not intended to carry liquids.
Note 1: For primary supporting members of the collision bulkhead, γ_R =1,25

Table 3 : Primary supporting members analysed through complete ship models - Partial safety factors

Partial safety factors covering uncertainties regarding:	Symbol	Yielding check (see [5])	Buckling check	
			Plate panels (see [6.1])	Pillars (see [6.2] and [6.3])
Still water hull girder loads	γ_{S1}	1,00	1,00	1,00
Wave hull girder loads	γ_{W1}	1,10	1,10	1,10
Still water pressure	γ_{S2}	1,00	1,00	1,00
Wave pressure	γ_{W2}	1,10	1,10	1,10
Material	γ_m	1,02	1,02	1,02
Resistance	γ_R	Defined in Tab 4 and Tab 5	1,02	For [6.2]: see Tab 13 For [6.3]: 1,15

Table 4 : Primary supporting members analysed through three dimensional or complete ship models Resistance partial safety factor

Type of three dimensional model (see App 1)	Resistance partial safety factor γ_R (see [4.3.1] and [5.3.1])	
	General	Watertight bulkhead primary supporting members
Beam model	1,20	1,02
Coarse mesh finite element model	1,20	1,02
Fine mesh finite element model	1,10	1,02

Table 5 : Additional criteria for analyses based on fine mesh finite element models Resistance partial safety factor

Symbol	Resistance partial safety factor (see [4.3.2] and [5.3.2])	
	General	Watertight bulkhead primary supporting members
γ_R	1,10	1,02

1.1.8 Minimum net thicknesses

In addition to the above, the scantlings of primary supporting members are to comply with the requirements in [2].

1.2 Net scantlings

1.2.1 As specified in Ch 4, Sec 2, [1], all scantlings referred to in this Section are net, i.e. they do not include any margin for corrosion.

The gross scantlings are obtained as specified in Ch 4, Sec 2.

1.3 Partial safety factors

1.3.1 The partial safety factors to be considered for checking primary supporting members are specified in:

- Tab 1 for analyses based on isolated beam models
- Tab 2 for analyses based on three dimensional models
- Tab 3 for analyses based on complete ship models.

2 Minimum net thicknesses

2.1 General

2.1.1 The net thickness of plating which forms the webs of primary supporting members is to be not less than the value obtained, in mm, from the following formulae:

$t_{MIN} = 3,7 + 0,015Lk^{1/2}$ for $L < 120$ m

$t_{MIN} = 3,7 + 1,8k^{1/2}$ for $L \geq 120$ m

2.2 Double bottom

2.2.1 In addition to the requirements in [2.1], the net thickness of plating which forms primary supporting members of the double bottom is to be not less than the values given in Tab 6.

Table 6 : Minimum net thicknesses of double bottom primary supporting members

Primary supporting member	Minimum net thickness, in mm	
	Area within 0,4L amidships	Area outside 0,4L amidships
Centre girder	$2,2\ L^{1/3}\ k^{1/6}$	$1,8\ L^{1/3}\ k^{1/6}$
Side girders	$1,7\ L^{1/3}\ k^{1/6}$	$1,6\ L^{1/3}\ k^{1/6}$
Floors	$1,7\ L^{1/3}\ k^{1/6}$	$1,6\ L^{1/3}\ k^{1/6}$
Girder bounding a duct keel **(1)**	$1,5 + 0,8\ L^{1/2}\ k^{1/4}$	$1,5 + 0,8\ L^{1/2}\ k^{1/4}$
Margin plate	$L^{1/2}\ k^{1/4}$	$0,9\ L^{1/2}\ k^{1/4}$

(1) The minimum net thickness is to be taken not less than that required for the centre girder.

2.3 Single bottom

2.3.1 In addition to the requirements in [2.1], the net thickness of plating which forms the webs of primary supporting members of the single bottom is to be not less than the values given in Tab 7.

Table 7 : Minimum net thicknesses of the webs of single bottom primary supporting members

Primary supporting member	Minimum net thickness, in mm	
	Area within 0,4L amidships	Area outside 0,4L amidships
Centre girder	$6,0 + 0,05L_2\ k^{1/2}$	$5,0 + 0,05L_2\ k^{1/2}$
Floors and side girders	$5,5 + 0,05L_2\ k^{1/2}$	$4,0 + 0,05L_2\ k^{1/2}$

3 Yielding check of primary supporting members analysed through an isolated beam structural model

3.1 General

3.1.1 The requirements of this Article apply for the yielding check of primary supporting members subjected to lateral pressure or to wheeled loads and, for those contributing to the hull girder longitudinal strength, to hull girder normal stresses, which are to be analysed through an isolated beam model, according to [1.1.2].

3.1.2 The yielding check is also to be carried out for primary supporting members subjected to specific loads, such as concentrated loads.

3.2 Bracket arrangement

3.2.1 The requirements of this Article apply to primary supporting members with brackets at both ends of length not greater than $0{,}2\ell$.

In the case of a significantly different bracket arrangement, the determination of normal and shear stresses due to design loads and the required section modulus and shear sectional area are considered by the Society on a case by case basis.

3.3 Load point

3.3.1 Lateral pressure

Unless otherwise specified, lateral pressure is to be calculated at mid-span of the primary supporting member considered.

3.3.2 Hull girder normal stresses

For longitudinal primary supporting members contributing to the hull girder longitudinal strength, the hull girder normal stresses are to be calculated in way of the face plate of the primary supporting member considered.

For bottom and deck girders, it may generally be assumed that the hull girder normal stresses in the face plate are equal to 0,75 times those in the relevant plating.

3.4 Load model

3.4.1 General

The still water and wave lateral pressures induced by the sea and the various types of cargoes and ballast in intact conditions are to be considered, depending on the location of the primary supporting member under consideration and the type of compartments adjacent to it, in accordance with Ch 5, Sec 1, [2.4].

Primary supporting members of bulkheads or inner side which constitute the boundary of compartments not intended to carry liquids are to be subjected to the lateral pressure in flooding conditions.

The wave lateral pressures and hull girder loads are to be calculated in the mutually exclusive load cases "a", "b", "c" and "d" in Ch 5, Sec 4.

3.4.2 Lateral pressure in intact conditions

The lateral pressure in intact conditions is constituted by still water pressure and wave pressure.

Still water pressure (p_S) includes:

- the still water sea pressure, defined in Ch 5, Sec 5, [1]
- the still water internal pressure, defined in Ch 5, Sec 6 for the various types of cargoes and for ballast.

Wave pressure (p_W) includes:

- the wave pressure, defined in Ch 5, Sec 5, [2] for each load case "a", "b", "c" and "d"
- the inertial pressure, defined in Ch 5, Sec 6 for the various types of cargoes and for ballast, and for each load case "a", "b", "c" and "d".

3.4.3 Lateral pressure in flooding conditions

The lateral pressure in flooding conditions is constituted by the still water pressure p_{SF} and the wave pressure p_{WF} defined in Ch 5, Sec 6, [9].

3.4.4 Wheeled loads

For primary supporting members subjected to wheeled loads, the yielding check may be carried out according to [3.5] to [3.7] considering uniform pressures equivalent to the distribution of vertical concentrated forces, when such forces are closely located.

For the determination of the equivalent uniform pressures, the most unfavourable case, i.e. where the maximum number of axles are located on the same primary supporting member, according to Fig 1 to Fig 3, is to be considered.

The equivalent still water pressure and inertial pressure are indicated in Tab 8.

For arrangements different from those shown in Fig 1 to Fig 3, the yielding check of primary supporting members is to be carried out by a direct calculation, taking into account the distribution of concentrated loads induced by vehicle wheels.

In particular, the load redistribution effect of longitudinal girders not supported by pillars is to be taken into account by a grillage direct calculation or, as an a alternative, an equivalent load obtained by previous analysis can be used.

Table 8 : Wheeled loads
Equivalent uniform still water and inertial pressures

Ship condition	Load case	Still water pressure p_S and inertial pressure p_W, in kN/m²
Still water condition		$p_S = 10\ p_{eq}$
Upright condition	"a"	No inertial pressure
	"b"	$p_W = p_{eq} a_{Z1}$
Inclined condition	"c"	The inertial pressure may be disregarded
	"d"	$p_W = p_{eq} a_{Z2}$

Note 1:

$$p_{eq} = \frac{n_V Q_A}{\ell s}\left(3 - \frac{X_1 + X_2}{s}\right)$$

- n_V : Maximum number of vehicles possible located on the primary supporting member
- Q_A : Maximum axle load, in t, defined in Ch 5, Sec 6, Tab 8
- X_1 : Minimum distance, in m, between two consecutive axles (see Fig 2 and Fig 3)
- X_2 : Minimum distance, in m, between axles of two consecutive vehicles (see Fig 3). In the case indicated in Fig 2, X_2 is to be taken equal to s.

Figure 1 : Wheeled loads - Distribution of vehicles on a primary supporting member

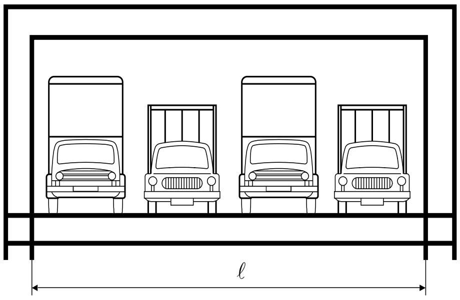


**Figure 2 : Wheeled loads
Distance between two consecutive axles**

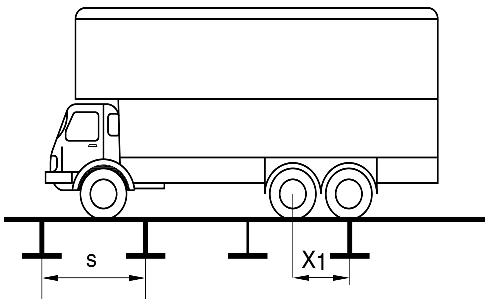
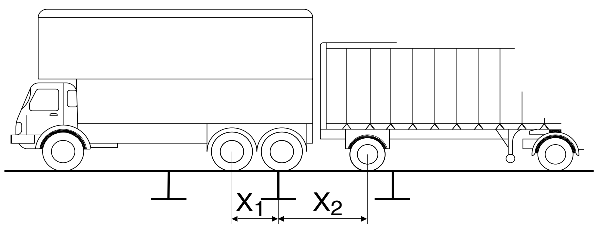


**Figure 3 : Wheeled loads
Distance between axles of two consecutive vehicles**



3.4.5 Normal stresses

The normal stresses to be considered for the yielding check of primary supporting members are obtained, in N/mm², from the following formulae:

- for longitudinal primary supporting members contributing to the hull girder longitudinal strength:

$$\sigma_N = \sigma_{X1} = \gamma_{S1}\sigma_{S1} + \gamma_{W1}(C_{FV}\sigma_{WV1} + C_{FH}\sigma_{WH1} + C_{F\Omega}\sigma_{\Omega})$$

- for longitudinal primary supporting members not contributing to the hull girder longitudinal strength and for transverse primary supporting members:

$$\sigma_N = 45 / kN / mm^2$$

where:

σ_{S1}, σ_{WV1}, σ_{WH1} : Hull girder normal stresses, in N/mm², defined in:

- Tab 9 for primary supporting members subjected to lateral pressure,
- Tab 10 for primary supporting members subjected to wheeled loads

σ_{Ω} : absolute value of the warping stress, in N/mm², induced by the torque $0{,}625 M_{WT}$ and obtained through direct calculation analyses based on a structural model in accordance with Ch 6, Sec 1, [2.6],

C_{FV}, C_{FH}, $C_{F\Omega}$: Combination factors defined in Tab 11.

3.5 Normal and shear stresses due to lateral pressure in intact conditions

3.5.1 General

Normal and shear stresses, induced by lateral pressures, in primary supporting members are to be determined from the formulae given in:

- [3.5.2] in the case of longitudinal and transverse primary supporting members
- [3.5.3] in the case of vertical primary supporting members.

Table 9 : Hull girder normal stresses - Primary supporting members subjected to lateral pressure

Condition		σ_{S1}, in N/mm² **(1)**	σ_{WV1}, in N/mm²	σ_{WH1}, in N/mm²
Lateral pressure applied on the side opposite to the primary supporting member, with respect to the plating:	$z \geq N$	$\left\lvert \frac{M_{SW,S}}{I_Y}(z-N) \right\rvert 10^{-3}$	$\left\lvert \frac{0{,}625 F_D M_{WV,S}}{I_Y}(z-N) \right\rvert 10^{-3}$	$\left\lvert \frac{0{,}625 M_{WH}}{I_Z} y \right\rvert 10^{-3}$
	$z < N$	$\left\lvert \frac{M_{SW,H}}{I_Y}(z-N) \right\rvert 10^{-3}$	$\left\lvert \frac{0{,}625 M_{WV,H}}{I_Y}(z-N) \right\rvert 10^{-3}$	
Lateral pressure applied on the same side as the primary supporting member:	$z \geq N$	$\left\lvert \frac{M_{SW,H}}{I_Y}(z-N) \right\rvert 10^{-3}$	$\left\lvert \frac{0{,}625 M_{WV,H}}{I_Y}(z-N) \right\rvert 10^{-3}$	
	$z < N$	$\left\lvert \frac{M_{SW,S}}{I_Y}(z-N) \right\rvert 10^{-3}$	$\left\lvert \frac{0{,}625 F_D M_{WV,S}}{I_Y}(z-N) \right\rvert 10^{-3}$	

(1) When the ship in still water is always in hogging condition, $M_{SW,S}$ is to be taken equal to 0.
Note 1:
F_D : Coefficient defined in Ch 5, Sec 2, [4].

Table 10 : Hull girder normal stresses - Primary supporting members subjected to wheeled loads

Condition	σ_{S1} in N/mm² **(1)**	σ_{WV1} in N/mm²	σ_{WH1} in N/mm²
$z \geq N$	$\left\lvert \frac{M_{SW,H}}{I_Y}(z-N) \right\rvert 10^{-3}$	$\left\lvert \frac{0,625 M_{WV,H}}{I_Y}(z-N) \right\rvert 10^{-3}$	$\left\lvert \frac{0,625 M_{WH}}{I_Z} y \right\rvert 10^{-3}$
$z < N$	$\left\lvert \frac{M_{SW,S}}{I_Y}(z-N) \right\rvert 10^{-3}$	$\left\lvert \frac{0,625 F_D M_{WV,S}}{I_Y}(z-N) \right\rvert 10^{-3}$	

(1) When the ship in still water is always in hogging condition, $M_{SW,S}$ is to be taken equal to 0.
Note 1:
F_D : Coefficient defined in Ch 5, Sec 2, [4].

Table 11 : Combination factors C_{FV}, C_{FH} and $C_{F\Omega}$

Load case	C_{FV}	C_{FH}	$C_{F\Omega}$
"a"	1,0	0	0
"b"	1,0	0	0
"c"	0,4	1,0	1,0
"d"	0,4	1,0	0

3.5.2 Longitudinal and transverse primary supporting members

The maximum normal stress σ and shear stress τ are to be obtained, in N/mm², from the following formulae:

$$\sigma = \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{m w} s \ell^2 10^3 + \sigma_N$$

$$\tau = 5 \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{A_{Sh}} s \ell$$

where:

$$\beta_b = \frac{\chi(1-2\alpha)^3 + 2\alpha^2(4\alpha-3)}{\chi(1-2\alpha)+2\alpha}$$

to be taken not less than 0,55.

$$\beta_s = 1 - 2\alpha$$

3.5.3 Vertical primary supporting members

The maximum normal stress σ and shear stress τ are to be obtained, in N/mm², from the following formulae:

$$\sigma = \beta_b \frac{\gamma_{S2} \lambda_{bS} p_S + \gamma_{W2} \lambda_{bW} p_W}{m w} s \ell^2 10^3 + \sigma_A$$

$$\tau = 5 \beta_s \frac{\gamma_{S2} \lambda_{sS} p_S + \gamma_{W2} \lambda_{sW} p_W}{A_{Sh}} s \ell$$

where:

β_b, β_s : Coefficients defined in [3.5.2]

$$\lambda_{bS} = 1 + 0,2 \frac{p_{Sd} - p_{Su}}{p_{Sd} + p_{Su}}$$

$$\lambda_{bW} = 1 + 0,2 \frac{p_{Wd} - p_{Wu}}{p_{Wd} + p_{Wu}}$$

$$\lambda_{sS} = 1 + 0,4 \frac{p_{Sd} - p_{Su}}{p_{Sd} + p_{Su}}$$

$$\lambda_{sW} = 1 + 0,4 \frac{p_{Wd} - p_{Wu}}{p_{Wd} + p_{Wu}}$$

p_{Sd} : Still water pressure, in kN/m², at the lower end of the primary supporting member considered

p_{Su} : Still water pressure, in kN/m², at the upper end of the primary supporting member considered

p_{Wd} : Wave pressure, in kN/m², at the lower end of the primary supporting member considered

p_{Wu} : Wave pressure, in kN/m², at the upper end of the primary supporting member considered

σ_A : Axial stress, to be obtained, in N/mm², from the following formula:

$$\sigma_A = 10 \frac{F_A}{A}$$

F_A : Axial load (still water and wave) transmitted to the vertical primary supporting members by the structures above. For multideck ships, the criteria in [6.2.1] for pillars are to be adopted.

A : Net sectional area, in cm², of the vertical primary supporting members with attached plating of width b_P.

3.6 Checking criteria

3.6.1 General

It is to be checked that the normal stress σ and the shear stress τ, calculated according to [3.5], are in compliance with the following formulae:

$$\frac{R_y}{\gamma_R \gamma_m} \geq \sigma$$

$$0,5 \frac{R_y}{\gamma_R \gamma_m} \geq \tau$$

3.7 Net section modulus and net sectional shear area complying with the checking criteria

3.7.1 General

The requirements in [3.7.2] and [3.7.3] provide the minimum net section modulus and net shear sectional area of primary supporting members subjected to lateral pressure in intact conditions, complying with the checking criteria indicated in [3.6].

3.7.2 Longitudinal and transverse primary supporting members

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh}, in cm^2, of longitudinal or transverse primary supporting members are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{m(R_y - \gamma_R \gamma_m \sigma_N)} s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y} s \ell$$

where β_b and β_s are the coefficients defined in [3.5.2].

3.7.3 Vertical primary supporting members

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh}, in cm^2, of vertical primary supporting members are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} \lambda_{bS} p_S + \gamma_{W2} \lambda_{bW} p_W}{m(R_y - \gamma_R \gamma_m \sigma_A)} s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} \lambda_{sS} p_S + \gamma_{W2} \lambda_{sW} p_W}{R_y} s \ell$$

where:

β_b, β_s : Coefficients defined in [3.5.2]

λ_{bS}, λ_{bW}, λ_{sS}, λ_{sW} : Coefficients defined in [3.5.3]

σ_A : Defined in [3.5.3].

3.8 Net section modulus and net shear sectional area of primary supporting members subjected to lateral pressure in flooding conditions

3.8.1 General

The requirements in [3.8.1] to [3.8.3] apply to primary supporting members of bulkheads or inner side which constitute the boundary of compartments not intended to carry liquids.

These primary supporting members are to be checked in flooding conditions as specified in [3.8.2] and [3.8.3], depending on the type of member.

3.8.2 Longitudinal and transverse primary supporting members

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh}, in cm^2, of longitudinal or transverse primary supporting members are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{16 c_P (R_y - \gamma_R \gamma_m \sigma_N)} s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{R_y} s \ell$$

where:

β_b, β_s : Coefficients defined in [3.5.2]

c_P : Ratio of the plastic section modulus to the elastic section modulus of the primary supporting members with an attached plating b_p, to be taken equal to 1,16 in the absence of more precise evaluation.

3.8.3 Vertical primary supporting members

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh}, in cm^2, of vertical primary supporting members are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} \lambda_{bS} p_{SF} + \gamma_{W2} \lambda_{bW} p_{WF}}{16 c_P (R_y - \gamma_R \gamma_m \sigma_A)} s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} \lambda_{sS} p_{SF} + \gamma_{W2} \lambda_{sW} p_{WF}}{R_y} s \ell$$

where:

β_b, β_s : Coefficients defined in [3.5.2]

c_P : Ratio defined in [3.8.2]

$$\lambda_{bS} = 1 + 0{,}2 \frac{p_{SFd} - p_{SFu}}{p_{SFd} + p_{SFu}}$$

$$\lambda_{bW} = 1 + 0{,}2 \frac{p_{WFd} - p_{WFu}}{p_{WFd} + p_{WFu}}$$

$$\lambda_{sS} = 1 + 0{,}4 \frac{p_{SFd} - p_{SFu}}{p_{SFd} + p_{SFu}}$$

$$\lambda_{sW} = 1 + 0{,}4 \frac{p_{WFd} - p_{WFu}}{p_{WFd} + p_{WFu}}$$

p_{SFd} : Still water pressure, in kN/m^2, in flooding conditions, at the lower end of the primary supporting member considered

p_{SFu} : Still water pressure, in kN/m^2, in flooding conditions, at the upper end of the primary supporting member considered

p_{WFd} : Wave pressure, in kN/m^2, in flooding conditions, at the lower end of the primary supporting member considered.

p_{WFu} : Wave pressure, in kN/m^2, in flooding conditions, at the upper end of the primary supporting member considered

σ_A : Defined in [3.5.3].

4 Yielding check of primary supporting members analysed through a three dimensional structural model

4.1 General

4.1.1 The requirements of this Article apply for the yielding check of primary supporting members subjected to lateral pressure or to wheeled loads and, for those contributing to the hull girder longitudinal strength, to hull girder normal stresses, which are to be analysed through a three dimensional structural model, according to [1.1.3].

4.1.2 The yielding check is also to be carried out for primary supporting members subjected to specific loads, such as concentrated loads.

4.2 Analysis criteria

4.2.1 The analysis of primary supporting members based on three dimensional models is to be carried out according to:

- the requirements in App 1 for primary supporting members subjected to lateral pressure
- the requirements in App 2 for primary supporting members subjected to wheeled loads.

These requirements apply for:

- the structural modelling
- the load modelling
- the stress calculation.

4.3 Checking criteria

4.3.1 General

For all types of analysis (see App 1, [2]), it is to be checked that the equivalent stress σ_{VM} , calculated according to App 1, [5] is in compliance with the following formula:

$$\frac{R_y}{\gamma_R \gamma_m} \geq \sigma_{VM}$$

4.3.2 Additional criteria for analyses based on fine mesh finite element models

Fine mesh finite element models are defined with reference to App 1, [3.4].

For all the elements of the fine mesh models, it is to be checked that the normal stresses σ_1 and σ_2 and the shear stress τ_{12}, calculated according to App 1, [5], are in compliance with the following formulae:

$$\frac{R_y}{\gamma_R \gamma_m} \geq \max(\sigma_1, \sigma_2)$$

$$0{,}5\frac{R_y}{\gamma_R \gamma_m} \geq \tau_{12}$$

4.3.3 Specific case of primary supporting members subjected to wheeled loads

For all types of analysis (see App 2, [2]), it is to be checked that the equivalent stress σ_{VM}, calculated according to App 2, [5] is in compliance with the following formula:

$$\frac{R_y}{\gamma_R \gamma_m} \geq \sigma_{VM}$$

5 Yielding check of primary supporting members analysed through a complete ship structural model

5.1 General

5.1.1 The requirements of this Article apply for the yielding check of primary supporting members which are to be analysed through a complete ship structural model.

5.1.2 A complete ship structural model is to be carried out, when deemed necessary by the Society, to analyse primary supporting members of ships with one or more of the following characteristics:

- ships having large deck openings
- ships having large space arrangements
- multideck ships having series of openings in side or longitudinal bulkheads, when the stresses due to the different contribution of each deck to the hull girder strength are to be taken into account.

5.2 Analysis criteria

5.2.1 The analysis of primary supporting members based on complete ship models is to be carried out according to App 3.

These requirements apply for:

- the structural modelling
- the load modelling
- the stress calculation.

5.3 Checking criteria

5.3.1 General

It is to be checked that the equivalent stress σ_{VM} , calculated according to App 3, [4] is in compliance with the following formula:

$$\frac{R_y}{\gamma_R \gamma_m} \geq \sigma_{VM}$$

5.3.2 Additional criteria for elements modelled with fine meshes

Fine meshes are defined with reference to App 3, [2.4].

For all the elements modelled with fine meshes, it is to be checked that the normal stresses σ_1 and σ_2 and the shear stress τ_{12} , calculated according to App 3, [4], are in compliance with the following formulae:

$$\frac{R_y}{\gamma_R \gamma_m} \geq \max(\sigma_1, \sigma_2)$$

$$0{,}5\frac{R_y}{\gamma_R \gamma_m} \geq \tau_{12}$$

6 Buckling check

6.1 Local buckling of plate panels

6.1.1 A local buckling check is to be carried out, according to Sec 1, [5], for plate panels which constitute primary supporting members.

In carrying out this check, the stresses in the plate panels are to be calculated according to [3], [4] or [5], depending on the structural model adopted for the analysis of primary supporting members.

6.2 Buckling of pillars subjected to compression axial load

6.2.1 Compression axial load

The compression axial load in the pillar is to be obtained, in kN, from the following formula:

$$F_A = A_D(\gamma_{S2} p_S + \gamma_{W2} p_W) + \sum_i r(\gamma_{S2} Q_{i,S} + \gamma_{W2} Q_{i,W})$$

where:

A_D : Area, in m², of the portion of the deck or the platform supported by the pillar considered

r : Coefficient which depends on the relative position of each pillar above the one considered, to be taken equal to:

- r = 1,0 for the pillar considered
- r = 0,9 for the pillar immediately above that considered
- r = $0,9^i$ for the i^{th} pillar of the line above the pillar considered, to be taken not less than 0,478

$Q_{i,S}$,$Q_{i,W}$: Still water and wave load, respectively, in kN, from the i^{th} pillar of the line above the pillar considered, if any.

6.2.2 Critical column buckling stress of pillars

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

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

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

where:

σ_{E1} : Euler column buckling stress, to be obtained, in N/mm², from the following formula:

$$\sigma_{E1} = \pi^2 E \frac{I}{A(f\ell)^2} 10^{-4}$$

I : Minimum net moment of inertia, in cm⁴, of the pillar

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

ℓ : Span, in m, of the pillar

f : Coefficient, to be obtained from Tab 12.

6.2.3 Critical torsional buckling stress of built-up pillars

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

$$\sigma_{cT} = \sigma_{E2} \quad \text{for} \quad \sigma_{E2} \le \frac{R_{eH}}{2}$$

$$\sigma_{cT} = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_{E2}}\right) \quad \text{for} \quad \sigma_{E2} > \frac{R_{eH}}{2}$$

where:

σ_{E2} : Euler torsional buckling stress, to be obtained, in N/mm², from the following formula:

$$\sigma_{E2} = \frac{\pi^2 E I_w}{10^4 I_p \ell^2} + 0{,}41 E \frac{I_t}{I_p}$$

I_w : Net sectorial moment of inertia of the pillar, to be obtained, in cm⁶, from the following formula:

$$I_w = \frac{t_f b_f^3 h_w^2}{24} 10^{-6}$$

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

I_p : Net polar moment of inertia of the pillar, to be obtained, in cm⁴, from the following formula:

$$I_P = I_{XX} + I_{YY}$$

I_{XX} : Net moment of inertia about the XX axis of the pillar section (see Fig 4)

I_{YY} : Net moment of inertia about the YY axis of the pillar section (see Fig 4)

I_t : St. Venant's net moment of inertia of the pillar, to be obtained, in cm⁴, from the following formula:

$$I_t = \frac{1}{3}[h_w t_w^3 + 2 b_f t_f^3] 10^{-4}$$

Table 12 : Coefficient f

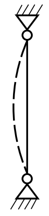
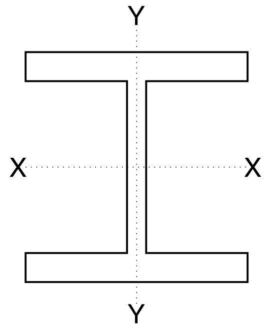
Boundary conditions of the pillar	f
Both ends fixed 	0,5
One end fixed, one end pinned 	$\frac{\sqrt{2}}{2}$
Both ends pinned 	1

Figure 4 : Reference axes for the calculation of the moments of inertia of a built-up section



6.2.4 Critical local buckling stress of built-up pillars

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

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

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

where:

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

- $\sigma_{E3} = 78\left(\frac{t_W}{h_W}\right)^2 10^4$
- $\sigma_{E3} = 32\left(\frac{t_F}{b_F}\right)^2 10^4$

t_W, h_W, t_F, b_F : Dimensions, in mm, of the built-up section, defined in [6.2.3].

6.2.5 Critical local buckling stress of pillars having hollow rectangular section

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

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

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

where:

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

- $\sigma_{E4} = 78\left(\frac{t_2}{b}\right)^2 10^4$
- $\sigma_{E4} = 78\left(\frac{t_1}{h}\right)^2 10^4$

b : Length, in mm, of the shorter side of the section

t_2 : Net web thickness, in mm, of the shorter side of the section

h : Length, in mm, of the longer side of the section

t_1 : Net web thickness, in mm, of the longer side of the section.

6.2.6 Checking criteria

The net scantlings of the pillar loaded by the compression axial stress F_A defined in [6.2.1] are to comply with the formulae in Tab 13.

6.3 Buckling of pillars subjected to compression axial load and bending moments

6.3.1 Checking criteria

In addition to the requirements in [6.2], the net scantlings of the pillar loaded by the compression axial load and bending moments are to comply with the following formula:

$$10F\left(\frac{1}{A} + \frac{\Phi e}{w_P}\right) + \left(10^3\frac{M_{max}}{w_P}\right) \le \frac{R_{eH}}{\gamma_R \gamma_m}$$

where:

F : Compression load, in kN, acting on the pillar

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

e : Eccentricity, in cm, of the compression load with respect to the centre of gravity of the cross-section

$$\Phi = \frac{1}{1 - \frac{10F}{\sigma_{E1}A}}$$

σ_{E1} : Euler column buckling stress, in N/mm², defined in [6.2.2]

w_P : Minimum net section modulus, in cm³, of the cross-section of the pillar

M_{max} : Max (M_1, M_2, M_0)

M_1 : Bending moment, in kN.m, at the upper end of the pillar

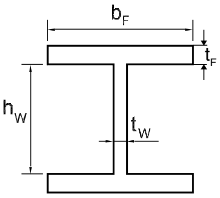
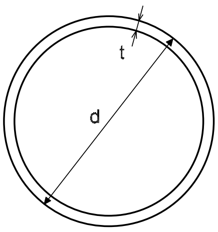
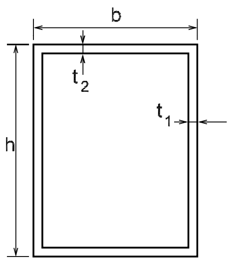
M_2 : Bending moment, in kN.m, at the lower end of the pillar

$$M_0 = \frac{0{,}5(\sqrt{1+t^2})(M_1 + M_2)}{\cos(u)}$$

$$u = 0{,}5\pi\sqrt{\frac{10F}{\sigma_{E1}A}}$$

$$t = \frac{1}{\tan(u)}\left(\frac{M_2 - M_1}{M_2 + M_1}\right)$$

Table 13 : Buckling check of pillars subject to compression axial load

Pillar cross-section	Column buckling check	Torsional buckling check	Local buckling check	Geometric condition
Built-up 	$\frac{\sigma_{cB}}{\gamma_R \gamma_m} \geq 10 \frac{F_A}{A}$	$\frac{\sigma_{cT}}{\gamma_R \gamma_m} \geq 10 \frac{F_A}{A}$	$\frac{\sigma_{cL}}{\gamma_R \gamma_m} \geq 10 \frac{F_A}{A}$	$\frac{b_F}{t_F} \leq 40$
Hollow tubular 	$\frac{\sigma_{cB}}{\gamma_R \gamma_m} \geq 10 \frac{F_A}{A}$	Not required	Not required	$\frac{d}{t} \leq 55$ $t \geq 5,5$ mm
Hollow rectangular 	$\frac{\sigma_{cB}}{\gamma_R \gamma_m} \geq 10 \frac{F_A}{A}$	Not required	$\frac{\sigma_{cL}}{\gamma_R \gamma_m} \geq 10 \frac{F_A}{A}$	$\frac{b}{t_2} \leq 55$ $\frac{h}{t_1} \leq 55$ $t_1 \geq 5,5$ mm $t_2 \geq 5,5$ mm

Note 1:

σ_{cB} : Critical column buckling stress, in N/mm², defined in [6.2.2]

σ_{cT} : Critical torsional buckling stress, in N/mm², defined in [6.2.3]

σ_{cL} : Critical local buckling stress, in N/mm², defined in [6.2.4] for built-up section or in [6.2.5] for hollow rectangular section

γ_R : Resistance partial safety factor, to be taken equal to:
- 2,00 for column buckling
- 1,05 for torsional and local buckling

F_A : compression axial load in the pillar, in kN, defined in [6.2.1]

A : Net sectional area, in cm², of the pillar.

SECTION 4 FATIGUE CHECK OF STRUCTURAL DETAILS

Symbols

For symbols not defined in this Section, refer to the list at the beginning of this Chapter.

p_W : Wave pressure, in kN/m², see [2.2]

s : Spacing, in m, of ordinary stiffeners

ℓ : Span, in m, of ordinary stiffeners, measured between the supporting members, see Ch 4, Sec 3, [3.2]

w : Net section modulus, in cm³, of the stiffener, with an attached plating of width b_p , to be calculated as specified in Ch 4, Sec 3, [3.4]

K_h, $K\ell$: Stress concentration factors, defined in Ch 12, Sec 2 for the special structural details there specified

K_F : Fatigue notch factor, defined in [3.3.1]

K_m : Stress concentration factor, taking account of misalignment, defined in [3.3.1]

$\Delta\sigma_{P0}$: Allowable stress range, defined in [4].

1 General

1.1 Net scantlings

1.1.1 As specified in Ch 4, Sec 2, [1], all scantlings referred to in this Section are net, i.e. they do not include any margin for corrosion.

The gross scantlings are obtained as specified in Ch 4, Sec 2.

1.2 Application

1.2.1 Structural details to be checked

The requirements of this Section apply for the fatigue check of special structural details, according to Ch 12, Sec 2.

The Society may require other details to be checked, when deemed necessary on the basis of the detail geometry and stress level.

1.2.2 Categorisation of details

With respect to the method to be adopted to calculate the stresses acting on structural members, the details for which the fatigue check is to be carried out may be grouped as follows:

- details where the stresses are to be calculated through a three dimensional structural model (e.g. connections between primary supporting members)
- details located at ends of ordinary stiffeners, for which an isolated structural model can be adopted.

1.2.3 Details where the stresses are to be calculated through a three dimensional structural model

The requirements of App 1, [6] apply, in addition of those of [1] to [5] of this Section.

1.2.4 Details located at ends of ordinary stiffeners

The requirements of [1] to [6] of this Section apply.

1.2.5 Other details

In general, for details other than those in [1.2.2], the stresses are to be calculated through a method agreed by the Society on a case by case basis, using the load model defined in [2].

The checking criterion in [5] is generally to be applied.

1.3 Definitions

1.3.1 Hot spots

Hot spots are the locations where fatigue cracking may occur. They are indicated in the relevant figures of special structural details in Ch 12, Sec 2.

1.3.2 Nominal stress

Nominal stress is the stress in a structural component taking into account macro-geometric effects but disregarding the stress concentration due to structural discontinuities and to the presence of welds (see Fig 1).

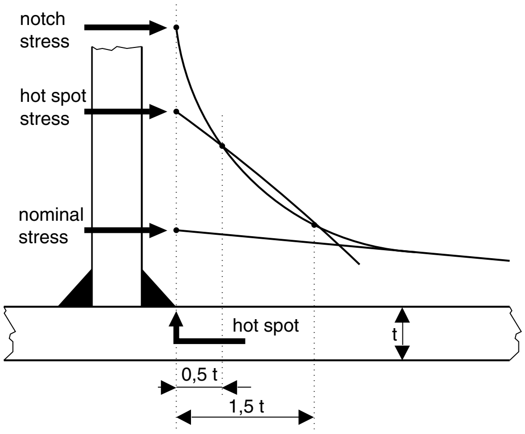
1.3.3 Hot spot stress

Hot spot stress is a local stress at the hot spot taking into account the influence of structural discontinuities due to the geometry of the detail, but excluding the effects of welds (see Fig 1).

1.3.4 Notch stress

Notch stress is a peak stress in a notch such as the root of a weld or the edge of a cut-out. This peak stress takes into account the stress concentrations due to the presence of notches (see Fig 1).

Figure 1 : Nominal, hot spot and notch stresses



1.3.5 Elementary stress range

Elementary stress range is the stress range determined for one of the load cases “a”, “b”, “c” or “d” (see Ch 5, Sec 4, [2]) and for either of the loading conditions (see Ch 5, Sec 1, [2.4] and Ch 5, Sec 1, [2.5]).

1.3.6 Equivalent stress range

Equivalent stress range is a stress range obtained from a combination of elementary stress ranges, as indicated in [3.3.2] for notch stress and [6.2.1] for hull girder nominal stress.

1.4 Partial safety factors

1.4.1 The partial safety factors to be considered for the fatigue check of structural details are specified in Tab 1.

Table 1 : Fatigue check - Partial safety factors

Partial safety factors covering uncertainties regarding:	Symbol	Value	
		General	Details at ends of ordinary stiffeners
Still water hull girder loads	γ_{S1}	1,00	1,00
Wave hull girder loads	γ_{W1}	1,05	1,15
Still water pressure	γ_{S2}	1,00	1,00
Wave pressure	γ_{W2}	1,10	1,20
Resistance	γ_R	1,02	1,10

2 Load model

2.1 General

2.1.1 Load point

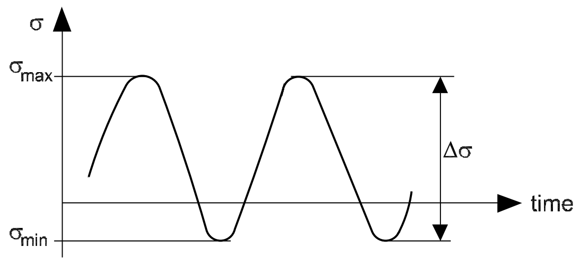
Unless otherwise specified, design loads are to be determined at points defined in:

- Sec 2, [1.3] for ordinary stiffeners
- Sec 3, [1] for primary supporting members.

2.1.2 Local and hull girder loads

The fatigue check is based on the stress range induced at the hot spot by the time variation of local and hull girder loads in each load case “a”, “b”, “c” and “d” defined in [2.2] for the loading conditions defined in [2.1.4] and [2.1.3] (see Fig 2).

Figure 2 : Stress range



2.1.3 Loading conditions for details where the stresses are to be calculated through a three dimensional structural model

The most severe full load and ballast conditions for the detail concerned are to be considered in accordance with Ch 5, Sec 1, [2.5].

2.1.4 Loading conditions for details located at ends of ordinary stiffeners

The cargo and ballast distribution is to be considered in accordance with Ch 5, Sec 1, [2.4].

2.1.5 Spectral fatigue analysis

For ships with non-conventional shapes or with restricted navigation, the Society may require a spectral fatigue analysis to be carried out.

In this analysis, the loads and stresses are to be evaluated through long-term stochastic analysis taking into account the characteristics of the ship and the navigation notation.

The load calculations and fatigue analysis are to be submitted to the Society for approval.

2.2 Lateral pressure

2.2.1 General

Lateral pressure is constituted by the wave pressure.

2.2.2 Upright ship conditions (Load cases “a” and “b”)

Wave pressure (p_W) includes:

- maximum and minimum wave pressures obtained from Tab 2
- inertial pressures:
  - no inertial pressures are considered for load case “a”
  - maximum and minimum inertial pressures for load case “b” are to be obtained from Tab 3 for the various types of cargoes.

Table 2 : Load cases "a" and "b" - Maximum and minimum wave pressures for fatigue check

Case	Wave pressures, in kN/m²	
Load case "a"	p_{Wmax}	p_W defined in Ch 5, Sec 5, [2.1.1] for "load case a, crest"
	p_{Wmin}	p_W defined in Ch 5, Sec 5, [2.1.1] for "load case a, trough"
Load case "b"	p_{Wmax}	p_W defined in Ch 5, Sec 5, [2.1.1] for "load case b, crest"
	p_{Wmin}	p_W defined in Ch 5, Sec 5, [2.1.1] for "load case b, trough"

Table 3 : Load case "b" - Maximum and minimum inertial pressures for fatigue check

Cargo	Inertial pressures, in kN/m²	
	p_{Wmax}	p_{Wmin}
Liquids	p_W defined in Ch 5, Sec 6, Tab 1 for: • load case "b" • $a_{X1} > 0$ and $a_{Z1} > 0$	p_W defined in Ch 5, Sec 6, Tab 1 for: • load case "b" • $a_{X1} < 0$ and $a_{Z1} < 0$
Dry bulk cargoes	p_W defined in Ch 5, Sec 6, Tab 5 for: • load case "b" • $a_{Z1} > 0$	p_W defined in Ch 5, Sec 6, Tab 5 for: • load case "b" • $a_{Z1} < 0$
Dry uniform cargoes	p_W defined in Ch 5, Sec 6, Tab 6 for: • load case "b" • $a_{Z1} > 0$	p_W defined in Ch 5, Sec 6, Tab 6 for: • load case "b" • $a_{Z1} < 0$

2.2.3 Inclined ship conditions (Load cases "c" and "d")

Wave pressure (p_W) includes:

- maximum and minimum wave pressures obtained from Tab 4
- maximum and minimum inertial pressures obtained from Tab 5 for liquid cargoes.

  For dry bulk cargoes and dry uniform cargoes, no inertial pressures are to be considered.

2.3 Hull girder normal stresses

2.3.1 The hull girder normal stresses to be considered for the fatigue check are the following, multiplied by γ_{W1}:

$\sigma_{WV,H}$, $\sigma_{WV,S}$, σ_{WH}: Hull girder normal stresses, in N/mm², defined in Tab 6

σ_Ω : Warping stresses, in N/mm², induced by the torque $0,625M_{WT}$ and obtained through direct calculation analyses based on a structural model in accordance with Ch 6, Sec 1, [2.6].

Table 4 : Load cases "c" and "d" - Maximum and minimum wave pressures for fatigue check

Case	Wave pressures, in kN/m²	
Load case "c"	p_{Wmax}	p_W defined in Ch 5, Sec 5, [2.2.1] for: • load case "c" • negative roll angle
	p_{Wmin}	p_W defined in Ch 5, Sec 5, [2.2.1] for: • load case "c" • positive roll angle
Load case "d"	p_{Wmax}	p_W defined in Ch 5, Sec 5, [2.2.1] for: • load case "d" • negative roll angle
	p_{Wmin}	p_W defined in Ch 5, Sec 5, [2.2.1] for: • load case "d" • positive roll angle

Table 5 : Load cases "c" and "d" - Maximum and minimum inertial pressures (liquid cargoes) for fatigue check

Load case	Inertial pressures, in kN/m²	
Load case "c"	p_{Wmax}	p_W defined in Ch 5, Sec 6, Tab 1 for: • load case "c" • negative roll angle
	p_{Wmin}	p_W defined in Ch 5, Sec 6, Tab 1 for: • load case "c" • positive roll angle
Load case "d"	p_{Wmax}	p_W defined in Ch 5, Sec 6, Tab 1 for: • load case "d" • negative roll angle
	p_{Wmin}	p_W defined in Ch 5, Sec 6, Tab 1 for: • load case "d" • positive roll angle

Table 6 : Hull girder normal stresses for fatigue check

Load condition	Symbol	Normal stress, in N/mm²
Vertical wave bending moment in hogging	$\sigma_{WV,H}$	$\left\lvert\frac{0,625M_{WV,H}}{I_Y}(z-N)\right\rvert 10^{-3}$
Vertical wave bending moment in sagging	$\sigma_{WV,S}$	$\left\lvert\frac{0,625M_{WV,S}}{I_Y}(z-N)\right\rvert 10^{-3}$
Horizontal wave bending moment	σ_{WH}	$\left\lvert\frac{0,625M_{WH}}{I_Z}y\right\rvert 10^{-3}$

3 Stress range

3.1 General

3.1.1 Calculation point

Unless otherwise specified, stresses are to be determined at the hot spots indicated, for each detail, in the relevant figures in Ch 12, Sec 2.

3.1.2 Stress components

For the details in [1.2.2], the stresses to be used in the fatigue check are the normal stresses in the directions indicated, for each detail, in the relevant figures in Ch 12, Sec 2.

Where the fatigue check is required for details other than those in [1.2.2], the stresses to be used are the principal stresses at the hot spots which form the smallest angle with the crack rising surface.

3.2 Hot spot stress range

3.2.1 Elementary hot spot stress range

The elementary hot spot stress range $\Delta\sigma_{S,ij}$ is to be obtained, in N/mm², in accordance with:

- App 1, [6] for details where the stresses are to be calculated through a three dimensional structural models
- [6.2] for details located at ends of ordinary stiffeners.

3.3 Notch stress range

3.3.1 Elementary notch stress range

The elementary notch stress range is to be obtained, in N/mm², from the following formula:

$$\Delta\sigma_{N,ij} = 0{,}7 K_F K_m K_{C,ij} \Delta\sigma_{S,ij}$$

where:

i : Denotes the load case "a"; "b", "c" or "d"

j : Denotes the loading condition "Full load" or "Ballast"

K_F : Fatigue notch factor, equal to:

$$K_F = \lambda\sqrt{\frac{\theta}{30}}$$

for flame-cut edges, K_F may be taken equal to 1,4

λ : Coefficient depending on the weld configuration, and given in Tab 7

θ : Mean weld toe angle, in degrees, without being taken less than 30°. Unless otherwise specified, θ may be taken equal to:

- 30° for butt joints
- 45° for T joints or cruciform joints

K_m : Additional stress concentration factor, taking account of misalignment, defined in Tab 9, and to be taken not less than 1

$\Delta\sigma_{S,ij}$: Elementary hot spot stress range, defined in [3.2.1]

$$K_{C,ij} = \frac{0{,}4 R_y}{\Delta\sigma_{S,ij}} + 0{,}6 \quad \text{with} \quad 0{,}8 \le K_{C,ij} \le 1$$

Table 7 : Weld coefficient λ

Weld configuration	Coefficient λ	
	Grind welds	Other cases
Butt joints:		
• Stresses parallel to weld axis		
- full penetration	1,85	2,10
- partial penetration	1,85	2,10
• Stresses perpendicular to weld axis		
- full penetration	2,10	2,40
- partial penetration	3,95	4,50
T joints:		
• Stresses parallel to weld axis; fillet weld and partial penetration	1,60	1,80
• Stresses perpendicular to weld axis and in plane of continuous element **(1)**; fillet weld and partial penetration	1,90	2,15
• Stresses perpendicular to weld axis and in plane of welded element; fillet weld and partial penetration	3,95	4,50
Cruciform joints:		
• Full penetration	1,85	2.10
• Partial penetration	2,05	2,35

(1) This case includes the hot spots indicated in the sheets of special structural details in Ch 12, Sec 2 , relevant to the connections of longitudinal ordinary stiffeners with transverse primary supporting members.

3.3.2 Equivalent notch stress range

The equivalent notch stress range is to be obtained, in N/mm², from the following formula:

$$\Delta\sigma_{N,eq} = \left(\frac{\alpha}{2}\Sigma_{3N,F} + \frac{1-\alpha}{2}\Sigma_{3N,B}\right)^{1/3}$$

where:

α : Part of the ship's life in full load condition, given in Tab 8 for various ship types.

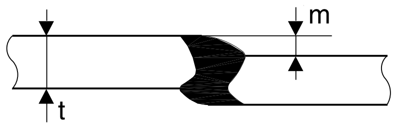
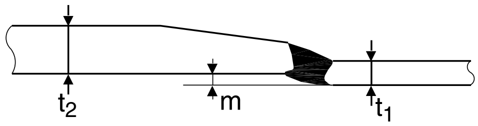
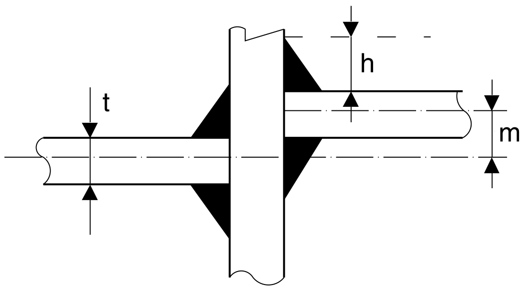
Table 8 : Part of the ship's life in full load condition

Service notation	Coefficient α
oil tanker ESP **tanker**	0,5
Others	0,75

$$\Sigma_{3N,F} = \max(\mu_{aF}\Delta\sigma^3_{N,aF};\mu_{bF}\Delta\sigma^3_{N,bF}) + \max(\mu_{cF}\Delta\sigma^3_{N,cF};\mu_{dF}\Delta\sigma^3_{N,dF})$$

$$\Sigma_{3N,B} = \max(\mu_{aB}\Delta\sigma^3_{N,aB};\mu_{bB}\Delta\sigma^3_{N,bB}) + \max(\mu_{cB}\Delta\sigma^3_{N,cB};\mu_{dB}\Delta\sigma^3_{N,dB})$$

Table 9 : Stress concentration factor K_m for misalignment

<table>
<tr><th>Geometry</th><th>K_m</th></tr>
<tr><td>Axial misalignment between flat plates
</td><td>$1+\frac{3(m-m_0)}{t}$</td></tr>
<tr><td>Axial misalignment between flat plates of different thicknesses
</td><td>$1+\frac{6(m-m_0)}{t_1}\frac{t_1^{3/2}}{t_1^{3/2}+t_2^{3/2}}$</td></tr>
<tr><td>Axial misalignment in fillet welded cruciform joints
</td><td>$1+\frac{m-m_0}{t+h}$</td></tr>
<tr><td colspan="2">Note 1:
m : Actual misalignment between two abutting members
m_0 : Permissible misalignment for the detail considered, given in Ch 12, Sec 2.</td></tr>
</table>

$\Delta\sigma_{N,aF}$, $\Delta\sigma_{N,bF}$, $\Delta\sigma_{N,cF}$, $\Delta\sigma_{N,dF}$: Elementary notch stress ranges for load cases "a", "b", "c" and "d", respectively, in "Full load" condition, defined in [3.3.1]

$\Delta\sigma_{N,aB}$, $\Delta\sigma_{N,bB}$, $\Delta\sigma_{N,cB}$, $\Delta\sigma_{N,dB}$: Elementary notch stress ranges for load cases "a", "b", "c" and "d", respectively, in "Ballast" condition, defined in [3.3.1]

$$\mu_{ij} = 1-\frac{\Gamma_N\left[\frac{3}{\xi}+1,\nu_{ij}\right]-\Gamma_N\left[\frac{5}{\xi}+1,\nu_{ij}\right]\nu_{ij}^{-2/\xi}}{\Gamma_C\left[\frac{3}{\xi}+1\right]}$$

$$\xi = \frac{73-0{,}07L}{60}$$ without being less than 0,85

$$\nu_{ij} = \left(\frac{S_q}{\Delta\sigma_{N,ij}}\right)^{\xi}\ln N_R$$

$$S_q = (K_p 10^{-7})^{1/3}$$

$$K_p = 5{,}802\left(\frac{16}{t}\right)^{0,9}10^{12}$$

$$N_R = 10^5$$

t : Net thickness, in mm, of the element under consideration not being taken less than 16 mm

$\Gamma_N[X+1, \nu_{ij}]$: Incomplete Gamma function, calculated for X= 3/ξ or X= 5/ξ and equal to:

$$\Gamma_N[X+1,\nu_{ij}] = \int_0^{\nu_{ij}} t^X e^{-t} dt$$

Values of $\Gamma_N[X+1,\nu_{ij}]$ are also indicated in Tab 10. For intermediate values of X and ν_{ij}, Γ_N may be obtained by linear interpolation

$\Gamma_C[X+1]$: Complete Gamma function, calculated for X=3/ξ, equal to:

$$\Gamma_C[X+1] = \int_0^{\infty} t^X e^{-t} dt$$

Values of $\Gamma_C[X+1]$ are also indicated in Tab 11. For intermediate values of X, Γ_C may be obtained by linear interpolation.

Table 10 : Function Γ_N [X+1, ν_{ij}]

X	ν_{ij} = 1,5	ν_{ij} = 2	ν_{ij} = 2,5	ν_{ij} = 3	ν_{ij} = 3,5	ν_{ij} = 4	ν_{ij} = 4,5
2,6	0,38	0,75	1,19	1,63	2,04	2,41	2,71
2,7	0,39	0,78	1,25	1,73	2,20	2,62	2,97
2,8	0,39	0,80	1,31	1,85	2,38	2,85	3,26
2,9	0,39	0,83	1,38	1,98	2,57	3,11	3,58
3,0	0,39	0,86	1,45	2,12	2,78	3,40	3,95
3,1	0,40	0,89	1,54	2,27	3,01	3,72	4,35
3,2	0,40	0,92	1,62	2,43	3,27	4,08	4,81
3,3	0,41	0,95	1,72	2,61	3,56	4,48	5,32
3,4	0,41	0,99	1,82	2,81	3,87	4,92	5,90
3,5	0,42	1,03	1,93	3,03	4,22	5,42	6,55
3,6	0,42	1,07	2,04	3,26	4,60	5,97	7,27
3,7	0,43	1,12	2,17	3,52	5,03	6,59	8,09
3,8	0,43	1,16	2,31	3,80	5,50	7,28	9,02
3,9	0,44	1,21	2,45	4,10	6,02	8,05	10,06
4,0	0,45	1,26	2,61	4,43	6,59	8,91	11,23
4,1	0,45	1,32	2,78	4,80	7,22	9,87	12,55
4,2	0,46	1,38	2,96	5,20	7,93	10,95	14,05
4,3	0,47	1,44	3,16	5,63	8,70	12,15	15,73
4,4	0,48	1,51	3,37	6,11	9,56	13,50	17,64
4,5	0,49	1,57	3,60	6,63	10,52	15,01	19,79
4,6	0,49	1,65	3,85	7,20	11,57	16,70	22,23
4,7	0,50	1,73	4,12	7,82	12,75	18,59	24,98
4,8	0,52	1,81	4,40	8,50	14,04	20,72	28,11
4,9	0,52	1,90	4,71	9,25	15,49	23,11	31,64
5,0	0,53	1,99	5,04	10,07	17,09	25,78	35,65
5,1	0,55	2,09	5,40	10,97	18,86	28,79	40,19
5,2	0,56	2,19	5,79	11,95	20,84	32,17	45,34
5,3	0,57	2,30	6,21	13,03	23,03	35,96	51,19
5,4	0,58	2,41	6,66	14,21	25,46	40,23	57,83
5,5	0,59	2,54	7,14	15,50	28,17	45,03	65,37
5,6	0,61	2,67	7,67	16,92	31,18	50,42	73,93
5,7	0,62	2,80	8,23	18,48	34,53	56,49	83,66
5,8	0,64	2,95	8,84	20,19	38,25	63,33	94,73
5,9	0,65	3,10	9,50	22,07	42,39	71,02	107,32

4 Allowable stress range

4.1 General

4.1.1 The allowable notch stress range $\Delta\sigma_{p0}$ is to be obtained, in N/mm², from the following formula:

$$\Delta\sigma_{p0} = (\ln N_R)^{1/\xi}\left(\frac{K_p}{N_t\Gamma_C\left[\frac{3}{\xi}+1\right]}\right)^{1/3}$$

where:

N_R, K_p : Coefficients defined in [3.3.2]

N_t : Number of cycles, to be taken equal to:

$$N_t = \frac{536}{T_A}10^6$$

T_A : Average period, in seconds, to be taken equal to:

$$T_A = 4\log L$$

Γ_C[X+1] : Complete Gamma function, defined in [3.3.2] and calculated for X = 3/ξ .

Table 11 : Function Γ_C [X+1]

X	Γ_C [X+1]
2,6	3,717
2,7	4,171
2,8	4,694
2,9	5,299
3,0	6,000
3,1	6,813
3,2	7,757
3,3	8,855
3,4	10,136
3,5	11,632
3,6	13,381

5 Checking criteria

5.1 General

5.1.1 The equivalent notch stress range $\Delta\sigma_{N,eq}$, calculated according to [3.3.2], is to comply with the following formula:

$$\Delta\sigma_{N,eq} \le \frac{\Delta\sigma_{p0}}{\gamma_R^{1/3}}$$

6 Structural details located at ends of ordinary stiffeners

6.1 General

6.1.1 For the fatigue check of connections located at ends of ordinary stiffeners, an approach equivalent to the checking criteria indicated in [5] is given in [6.3] in terms of the net section modulus of the stiffener.

6.2 Determination of equivalent stress and pressure ranges

6.2.1 Hull girder equivalent stress range

The hull girder equivalent stress range is to be obtained, in N/mm², from the following formula:

$$\Delta\sigma_{h,eq} = \left(\frac{\max(\Delta\sigma_{h,a};\Delta\sigma_{h,b})^3}{2} + \frac{\max(\Delta\sigma_{h,c};\Delta\sigma_{h,d})^3}{2}\right)^{1/3}$$

where $\Delta\sigma_{h,a}$, $\Delta\sigma_{h,b}$, $\Delta\sigma_{h,c}$, $\Delta\sigma_{h,d}$ are the hull girder elementary stress ranges for load cases "a", "b", "c" and "d", respectively, obtained, in N/mm², from the following formulae:

- for members contributing to the hull girder longitudinal strength:

$$\Delta\sigma_{h,i} = \{C_{FV}|\sigma_{WV,H}| + C_{FV}|\sigma_{WV,S}| + 2C_{FH}|\sigma_{WH}| + 2C_{F\Omega}|\sigma_\Omega|\}_i$$

- for members not contributing to the hull girder longitudinal strength:

$$\Delta\sigma_{h,i} = 0$$

where:

$\sigma_{WV,H}$, $\sigma_{WV,S}$, σ_{WH}, σ_Ω:H
ull girder normal stresses defined in [2.3]

C_{FV}, C_{FH}, $C_{F\Omega}$: Combination factors defined in Tab 12.

Table 12 : Combination factors C_{FV}, C_{FH} and $C_{F\Omega}$

Load case	C_{FV}	C_{FH}	$C_{F\Omega}$
"a"	1,0	0	0
"b"	1,0	0	0
"c"	0,4	1,0	1,0
"d"	0,4	1,0	0

6.2.2 Equivalent pressure range

The equivalent pressure range is to be obtained, in kN/m², from the following formula:

$$\Delta P_{W,eq} = \left(\frac{\alpha}{2}\Sigma_{3P,F} + \frac{1-\alpha}{2}\Sigma_{3P,B}\right)^{1/3}$$

where:

α : Part of the ship's life in full load condition, given in Tab 8

$$\Sigma_{3P,F} = \max(\Delta P_{W,aF};\Delta P_{W,bF})^3 + \max(\Delta P_{W,cF};\Delta P_{W,dF})^3$$

$$\Sigma_{3P,B} = \max(\Delta P_{W,aB};\Delta P_{W,bB})^3 + \max(\Delta P_{W,cB};\Delta P_{W,dB})^3$$

$\Delta P_{W,ij}$: Elementary pressure range for load case "i" (i.e. "a" , "b", "c" or "d"), in "j" load condition (i.e. "Full load" condition or "Ballast" condition), obtained, in kN/m², from the following formula:

$$\Delta P_{W,ij} = \{|P_{Wmax} - P_{Wmin}|\}_{ij}$$

P_{Wmax}, P_{Wmin}:Maximum and minimum resultant wave or inertial pressures, in kN/m², defined in [2.2].

6.3 Net section modulus of ordinary stiffeners

6.3.1 Longitudinal ordinary stiffeners contributing to the hull girder longitudinal strength

It is to be checked that the equivalent range of hull girder equivalent stress $\Delta\sigma_{h,eq}$, calculated according to [6.2.1] complies with the following formula:

$$\Delta\sigma_{h,eq} < \frac{\Delta\sigma_{p0}}{0,287K_FK_mK_h\gamma_R^{1/3}}$$

Moreover, the stiffener net section modulus is to be not less than the value obtained, in cm³, from the following formula:

$$w = 0,7K_FK_mK_GK_\ell\frac{\beta_b\gamma_{W2}\Delta P_{W,eq}}{12\left(\frac{\Delta\sigma_{p0}}{0,41\gamma_R^{1/3}} - 0,7K_FK_mK_h\Delta\sigma_{h,eq}\right)}\left(1-\frac{s}{2\ell}\right)s\ell^2 10^3$$

where:

K_G : Coefficient taking account of the stiffener section geometry, equal to:

$$K_G = 1 + \left[\frac{t_f(a^2-b^2)}{2w_B}\right]\left[1 - \frac{b}{a+b}\left(1+\frac{w_B}{w_A}\right)\right]10^{-3}$$

t_f : Face plate net thickness, in mm

a, b : Eccentricities of the stiffener, in mm, defined in Fig 3

w_A, w_B : Net section moduli of the stiffener, in cm^3, in A and B, respectively, about its vertical axis and without attached plating

β_b : Coefficient to be taken equal to:

$\beta_b = 1$ in the case of an ordinary stiffener without brackets at ends

$\beta_b = \beta_{b1}$ defined in Sec 2, [3.4.3], in the case of an ordinary stiffener with a bracket of length not greater than $0,2\ell$ at one end

$\beta_b = \beta_{b2}$ defined in Sec 2, [3.4.4], in the case of an ordinary stiffener with symmetrical brackets of length not greater than $0,2\ell$ at both ends.

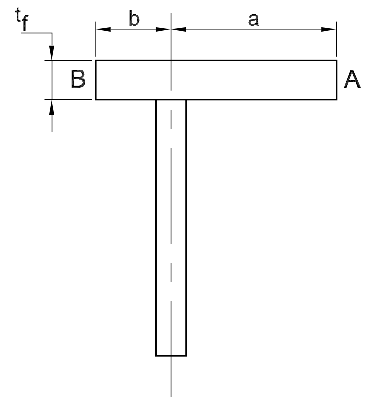
6.3.2 Longitudinal ordinary stiffeners not contributing to the hull girder longitudinal strength and transverse stiffeners

The stiffener net section modulus is to be not less than the value obtained, in cm^3, from the following formula:

$$w = 0,287 K_F K_m K_G K_\ell \frac{\beta_b \gamma_{W2} \gamma_R^{1/3} \Delta P_{W,eq}}{12 \Delta\sigma_{p0}} \left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$$

where K_G and β_b are the coefficients defined in [6.3.1].

Figure 3 : Geometry of a stiffener section



6.3.3 Vertical ordinary stiffeners

The stiffener net section modulus is to be not less than the value obtained, in cm^3, from the following formula:

$$w = 0,287 K_F K_m K_G K_\ell \frac{\beta_b \lambda_{bW} \gamma_{W2} \gamma_R^{1/3} \Delta P_{W,eq}}{12 \Delta\sigma_{p0}} \left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$$

where:

K_G, β_b : Coefficients defined in [6.3.1]

λ_{bW} : Coefficient defined in Sec 2, [3.4.5].

APPENDIX 1 ANALYSES BASED ON THREE DIMENSIONAL MODELS

Symbols

For symbols not defined in this Appendix, refer to the list at the beginning of this Chapter.

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

g : Gravity acceleration, in m/s^2:

$g = 9,81$ m/s^2

h_1 : Reference values of the ship relative motions in the upright ship condition, defined in Ch 5, Sec 3, [3.3]

h_2 : Reference values of the ship relative motions in the inclined ship conditions, defined in Ch 5, Sec 3, [3.3]

$\alpha = \frac{T_1}{T}$

T_1 : draught, in m, corresponding to the loading condition considered

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

M_{WV} : Vertical wave bending moment, in kN.m, at the hull transverse section considered, defined in Ch 5, Sec 2, [3.1], having the same sign as M_{SW}

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

Q_{WV} : Vertical wave shear force, in kN, at the hull transverse section considered, defined in Ch 5, Sec 2, [3.4], having sign:

- where M_{WV} is positive (hogging condition):
  - positive for $x < 0,5L$
  - negative for $x \geq 0,5L$
- where M_{WV} is negative (sagging condition):
  - negative for $x < 0,5L$
  - positive for $x \geq 0,5L$

γ_{S1}, γ_{W1} : Partial safety factors, defined in Sec 3.

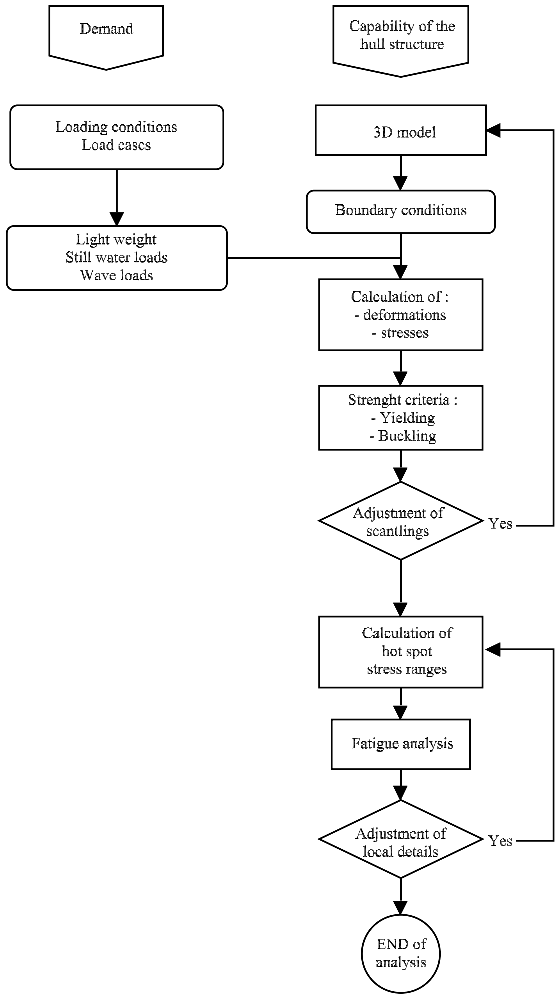
1 General

1.1 Application

1.1.1 The requirements of this Appendix apply for the analysis criteria, structural modelling, load modelling and stress calculation of primary supporting members which are to be analysed through three dimensional structural models, according to Sec 3.

The analysis application procedure is shown graphically in Fig 1.

Figure 1 : Application procedure of the analyses based on three dimensional models



1.1.2 This Appendix deals with that part of the structural analysis which aims at:

- calculating the stresses in the primary supporting members in the midship area and, when necessary, in other areas, which are to be used in the yielding and buckling checks
- calculating the hot spot stress ranges in the structural details which are to be used in the fatigue check.

1.1.3 The yielding and buckling checks of primary supporting members are to be carried out according to Sec 3.

The fatigue check of structural details is to be carried out according to Sec 4.

1.2 Information required

1.2.1 The following information is necessary to perform these structural analyses:

- general arrangement
- capacity plan
- structural plans of the areas involved in the analysis
- longitudinal sections and decks.

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 For ships more than 150 m in length, finite element models, built according to [3.2] and [3.4], are generally to be adopted.

The analysis of primary supporting members is to be carried out on fine mesh models, as defined in [3.4.3].

2.2.2 Areas which appear, from the primary supporting member analysis, to be highly stressed may be required to be further analysed through appropriately meshed structural models, as defined in [3.4.4].

2.3 Beam model analyses

2.3.1 For ships less than 150 m in length, beam models built according to [3.5] may be adopted in lieu of the finite element models in [2.2.1], provided that:

- primary supporting members are not so stout that the beam theory is deemed inapplicable by the Society
- their behaviour is not substantially influenced by the transmission of shear stresses through the shell plating.

In any case, finite element models may need to be adopted when deemed necessary by the Society on the basis of the ship's structural arrangement.

2.4 Structural detail analysis

2.4.1 Structural details in Sec 4, [1.2.3], for which a fatigue analysis is to be carried out, are to be modelled as specified in [6].

3 Primary supporting members structural modelling

3.1 Model construction

3.1.1 Elements

The structural model is to represent the primary supporting members with the plating to which they are connected.

Ordinary stiffeners are also to be represented in the model in order to reproduce the stiffness and inertia of the actual hull girder structure. The way ordinary stiffeners are represented in the model depends on the type of model (beam or finite element), as specified in [3.4] and [3.5].

3.1.2 Net scantlings

All the elements in [3.1.1] are to be modelled with their net scantlings according to Ch 4, Sec 2, [1]. Therefore, also the hull girder stiffness and inertia to be reproduced by the model are those obtained by considering the net scantlings of the hull structures.

3.2 Model extension

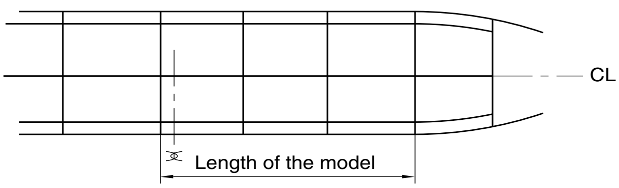
3.2.1 The longitudinal extension of the structural model is to be such that:

- the hull girder stresses in the area to be analysed are properly taken into account in the structural analysis
- the results in the areas to be analysed are not influenced by the unavoidable inaccuracy in the modelling of the boundary conditions.

3.2.2 In general, for multitank/hold ships more than 150 m in length, the conditions in [3.2.1] are considered as being satisfied when the model is extended over at least three cargo tank/hold lengths.

For the analysis of the midship area, this model is to be such that its aft end corresponds to the first transverse bulkhead aft of the midship, as shown in Fig 2. The structure of the fore and aft transverse bulkheads located within the model, including the bulkhead plating, is to be modelled.

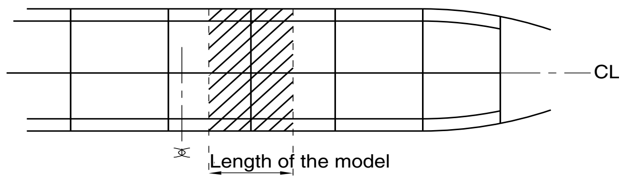
Figure 2 : Model longitudinal extension
Ships more than 150 m in length



3.2.3 For ships less than 150 m in length, the model may be limited to one cargo tank/hold length (one half cargo tank/hold length on either side of the transverse bulkhead; see Fig 3).

However, larger models may need to be adopted when deemed necessary by the Society on the basis of the ship's structural arrangement.

**Figure 3 : Model longitudinal extension
Ships less than 150 m in length**



3.2.4 In the case of structural symmetry with respect to the ship's centreline longitudinal plane, the hull structures may be modelled over half the ship's breadth.

3.3 Finite element modelling criteria

3.3.1 Modelling of primary supporting members

The analysis of primary supporting members based on fine mesh models, as defined in [3.4.3], is to be carried out by applying one of the following procedures (see Fig 4), depending on the computer resources:

- an analysis of the whole three dimensional model based on a 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 Modelling 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

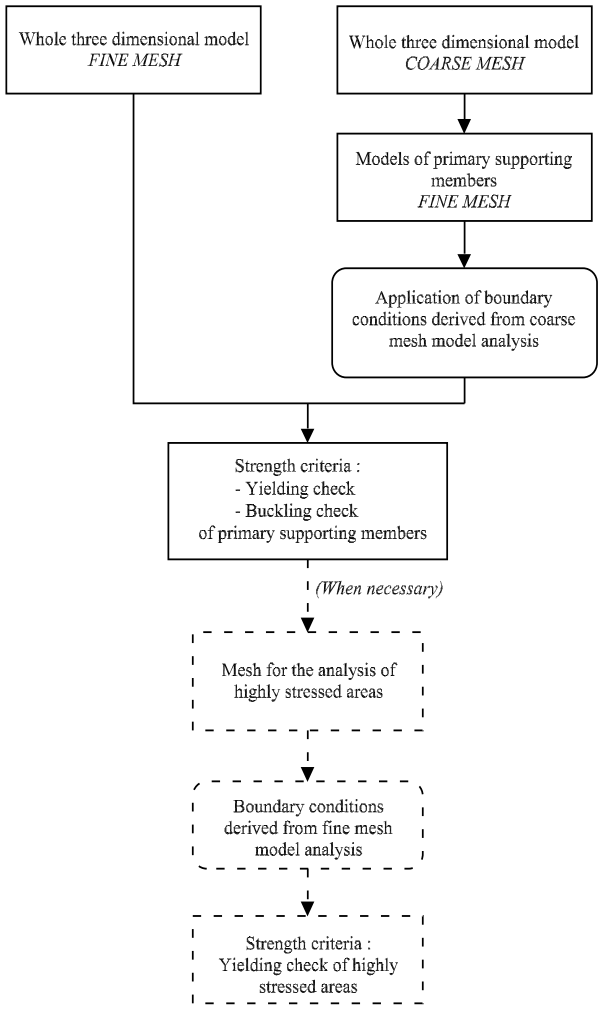
Finite element models are generally to be based on linear assumptions. The mesh is to be executed using membrane or shell elements, with or without mid-side nodes.

Meshing is to be carried out following uniformity criteria among the different elements.

In general, for some of the most common elements, the quadrilateral elements are to be such that the ratio between the longer side length and the shorter side length does not exceed 4 and, in any case, is less than 2 for most elements. Their angles are to be greater than 60° and less than 120°. The triangular element angles are to be greater than 30° and less than 120°.

Further modelling criteria depend on the accuracy level of the mesh, as specified in [3.4.2] to [3.4.4].

Figure 4 : Finite element modelling criteria



3.4.2 Coarse mesh

The number of nodes and elements is to be such that the stiffness and inertia of the model properly represent those of the actual hull girder structure, and the distribution of loads among the various load carrying members is correctly taken into account.

To this end, the structural model is to be built on the basis of the following criteria:

- ordinary stiffeners contributing to the hull girder longitudinal strength and which are not individually represented in the model are to be modelled by rod elements and grouped at regular intervals
- webs of primary supporting members may be modelled with only one element on their height
- face plates may be simulated with bars having the same cross-section
- the plating between two primary supporting members may be modelled with one element 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 Fine mesh

The ship's structure may be considered as finely meshed when each longitudinal ordinary stiffener is modelled; as a consequence, the standard size of finite elements used is based on the spacing of ordinary stiffeners.

The structural model is to be built on the basis of the following criteria:

- webs of primary members are to be modelled with at least three elements on their height
- the plating between two primary supporting members is to be modelled with at least two element stripes
- the ratio between the longer side and the shorter side of elements is to be less than 3 in the areas expected to be highly stressed
- holes for the passage of ordinary stiffeners may be disregarded.

In some specific cases, some of the above simplifications may not be deemed acceptable by the Society in relation to the type of structural model and the analysis performed.

3.4.4 Mesh for the analysis of structural details

The structural modelling is to be accurate; the mesh dimensions are to be such as to enable a faithful representation of the stress gradients. The use of membrane elements is only allowed when significant bending effects are not present; in other cases, elements with general behaviour are to be used.

3.5 Beam models

3.5.1 Beams representing primary supporting members

Primary supporting members are to be modelled by beam elements with shear strain, positioned on their neutral axes, whose inertia characteristics are to be calculated as specified in Ch 4, Sec 3, [4].

3.5.2 Torsional moments of inertia

Whenever the torsional effects of the modelling beams are to be taken into account (e.g. for modelling the double bottom, hopper tanks and lower stools), their net torsional moments of inertia are obtained, in cm⁴, from the following formulae:

- for open section beams (see Fig 5):

$$I_T = \frac{1}{3}\sum_i (t_i^3 \ell_i) 10^{-4}$$

- for box-type section beams, e.g. those with which hopper tanks and lower stools are modelled (see Fig 6):

$$I_T = \frac{4\Omega^2}{\sum_i \frac{\ell_i}{t_i}} 10^{-4}$$

- for beams of double skin structures (see Fig 7):

$$I_T = \frac{t_1 t_2 (b_1 + b_2) H_D^2}{2(t_1 + t_2)} 10^{-4}$$

where:

Σi : Sum of all the profile segments that constitute the beam section

t_i, ℓ_i : Net thickness and length, respectively, in mm, of the i-th profile segment of the beam section (see Fig 5 and Fig 6)

Ω : Area, in mm², of the section enclosed by the beam box profile (see Fig 6)

t_1, t_2 : Net thickness, in mm, of the inner and outer plating, respectively, (see Fig 7)

b_1, b_2 : Distances, in mm, from the beam considered to the two adjacent beams (see Fig 7)

H_D : Height, in mm, of the double skin (see Fig 7).

Figure 5 : Open section beams

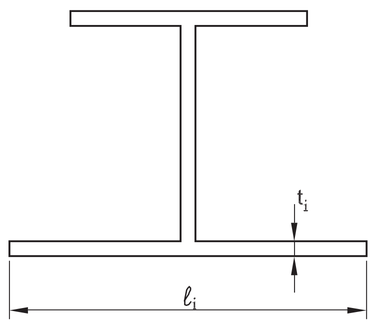


Figure 6 : Box-type section beams

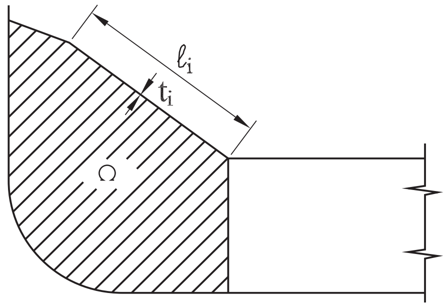
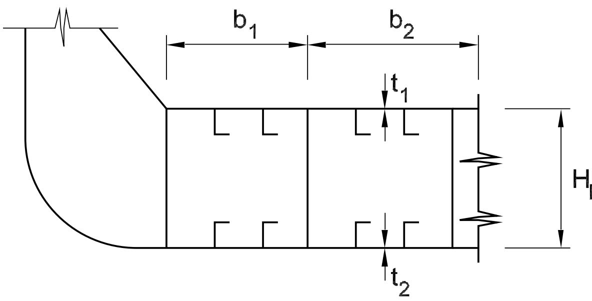


Figure 7 : Beams of double skin structures



3.5.3 Variable cross-section primary supporting members

In the case of variable cross-section primary supporting members, the inertia characteristics of the modelling beams may be assumed as a constant and equal to their average value along the length of the elements themselves.

3.5.4 Modelling of primary supporting members ends

The presence of end brackets may be disregarded; in such case their presence is also to be neglected for the evaluation of the beam inertia characteristics.

Rigid end beams are generally to be used to connect ends of the various primary supporting members, such as:

- floors and side vertical primary supporting members
- bottom girders and vertical primary supporting members of transverse bulkheads
- cross ties and side/longitudinal bulkhead primary supporting members.

3.5.5 Beams representing hull girder characteristics

The stiffness and inertia of the hull girder are to be taken into account by longitudinal beams positioned as follows:

- on deck and bottom in way of side shell and longitudinal bulkheads, if any, for modelling the hull girder bending strength
- on deck, side shell, longitudinal bulkheads, if any, and bottom for modelling the hull girder shear strength.

3.6 Boundary conditions of the whole three dimensional model

3.6.1 Structural model extended over at least three cargo tank/hold lengths

The whole three dimensional model is assumed to be fixed at its aft end, while shear forces and bending moments are applied at its fore end to ensure equilibrium (see [4]).

At the fore end section, rigid constraint conditions are to be applied to all nodes located on longitudinal members, in such a way that the transverse section remains plane after deformation.

When the hull structure is modelled over half the ship's breadth (see [3.2.4]), in way of the ship's centreline longitudinal plane, symmetry or anti-symmetry boundary conditions as specified in Tab 1 are to be applied, depending on the loads applied to the model (symmetrical or anti-symmetrical, respectively).

Table 1 : Symmetry and anti-symmetry conditions in way of the ship's centreline longitudinal plane

Boundary conditions	DISPLACEMENTS in directions **(1)**		
	X	Y	Z
Symmetry	free	fixed	free
Anti-symmetry	fixed	free	fixed

Boundary conditions	ROTATION around axes **(1)**		
	X	Y	Z
Symmetry	fixed	free	fixed
Anti-symmetry	free	fixed	free

(1) X, Y and Z directions and axes are defined with respect to the reference co-ordinate system in Ch 1, Sec 2, [4].

3.6.2 Structural models extended over one cargo tank/hold length

Symmetry conditions are to be applied at the fore and aft ends of the model, as specified in Tab 2.

Table 2 : Symmetry conditions at the model fore and aft ends

DISPLACEMENTS in directions **(1)**:			ROTATION around axes **(1)**:		
X	Y	Z	X	Y	Z
fixed	free	free	free	fixed	fixed

(1) X, Y and Z directions and axes are defined with respect to the reference co-ordinate system in Ch 1, Sec 2, [4].

When the hull structure is modelled over half the ship's breadth (see [3.2.4]), in way of the ship's centreline longitudinal plane, symmetry or anti-symmetry boundary conditions as specified in Tab 1 are to be applied, depending on the loads applied to the model (symmetrical or anti-symmetrical, respectively).

Vertical supports are to be fitted at the nodes positioned in way of the connection of the transverse bulkhead with longitudinal bulkheads, if any, and with sides.

4 Primary supporting members load model

4.1 General

4.1.1 Loading conditions and load cases in intact conditions

The still water and wave loads are to be calculated for the most severe loading conditions as given in the loading manual, with a view to maximising the stresses in the longitudinal structure and primary supporting members.

The following loading conditions are generally to be considered:

- homogeneous loading conditions at draught T
- non-homogeneous loading conditions at draught T, when applicable
- partial loading conditions at the relevant draught
- ballast conditions at the relevant draught.

The wave local and hull girder loads are to be calculated in the mutually exclusive load cases "a", "b", "c" and "d" in Ch 5, Sec 4.

4.1.2 Loading conditions and load cases in flooding conditions

When applicable, the pressures in flooding conditions are to be calculated according to Ch 5, Sec 6, [9].

4.1.3 Lightweight

The lightweight of the modelled portion of the hull is to be uniformly distributed over the length of the model in order to obtain the actual longitudinal distribution of the still water bending moment.

4.1.4 Models extended over half ship's breadth

When the ship is symmetrical with respect to her centreline longitudinal plane and the hull structure is modelled over half the ship's breadth, non-symmetrical loads are to be broken down into symmetrical and anti-symmetrical loads and applied separately to the model with symmetry and anti-symmetry boundary conditions in way of the ship's centreline longitudinal plane (see [3.6]).

4.2 Local loads

4.2.1 General

Still water loads include:

- the still water sea pressure, defined in Ch 5, Sec 5, [1]
- the still water internal loads, defined in Ch 5, Sec 6 for the various types of cargoes and for ballast.

Wave loads include:

- the wave pressure, defined in [4.2.2] for each load case "a", "b", "c" and "d"
- the inertial loads, defined in Ch 5, Sec 6 for the various types of cargoes and for ballast, and for each load case "a", "b", "c" and "d".

4.2.2 Wave loads

The wave pressure at any point of the model is obtained from the formulae in Tab 3 for upright ship conditions (load cases "a" and "b") and in Tab 4 for inclined ship conditions (load cases "c" and "d").

4.2.3 Distributed loads

Distributed loads are to be applied to the plating panels.

In the analyses carried out on the basis of membrane finite element models or beam models, the loads distributed perpendicularly to the plating panels are to be applied on the ordinary stiffeners proportionally to their areas of influence. When ordinary stiffeners are not modelled or are modelled with rod elements (see [3.4]), the distributed loads are to be applied to the primary supporting members actually supporting the ordinary stiffeners.

4.2.4 Concentrated loads

When the elements directly supporting the concentrated loads are not represented in the structural model, the loads are to be distributed on the adjacent structures according to the actual stiffness of the structures which transmit them.

In the analyses carried out on the basis of coarse mesh finite element models or beam models, concentrated loads applied in 5 or more points almost equally spaced inside the same span may be applied as equivalent linearly distributed loads.

4.2.5 Cargo in sacks, bales and similar packages

The vertical loads are comparable to distributed loads. The loads on vertical walls may be disregarded.

Table 3 : Wave pressure in upright ship conditions (load cases "a" and "b")

Location	Wave pressure p_W, in kN/m²	C_1	
		crest	trough **(1)**
Bottom and sides below the waterline with: $z \le T_1 - h$	$C_1 \rho g h e^{\frac{-2\pi(T_1 - z)}{\alpha L}}$	1,0	-1,0
Sides below the waterline with: $T_1 - h < z \le T_1$	$C_1 \rho g h e^{\frac{-2\pi(T_1 - z)}{\alpha L}}$	1,0	$\frac{z - T_1}{h}$
Sides above the waterline: $z > T_1$	$C_1 \rho g (T_1 + h - z)$	1,0	0,0

(1) The wave pressure for load case "b, trough" is to be used only for the fatigue check of structural details.
Note 1:
$h = \alpha^{1/4} C_{F1} h_1$
C_{F1} : Combination factor, to be taken equal to:
- $C_{F1} = 1,0$ for load case "a"
- $C_{F1} = 0,5$ for load case "b".

Table 4 : Wave pressure in inclined ship conditions (load cases "c" and "d")

Location	Wave pressure p_W, in kN/m²	C_2 (negative roll angle)	
		$y \geq 0$	$y < 0$
Bottom and sides below the waterline with: $z \leq T_1 - h$	$C_2 C_{F2} \alpha^{1/4} \rho g \left[\frac{y}{B_W} h_1 e^{\frac{-2\pi(T_1 - z)}{\alpha L}} + A_R y e^{\frac{-\pi(T_1 - z)}{\alpha L}}\right]$	1,0	1,0
Sides below the waterline with: $T_1 - h < z \leq T_1$	$C_2 C_{F2} \alpha^{1/4} \rho g \left[\frac{y}{B_W} h_1 e^{\frac{-2\pi(T_1 - z)}{\alpha L}} + A_R y e^{\frac{-\pi(T_1 - z)}{\alpha L}}\right]$	1,0	$\frac{T_1 - z}{h}$
Sides above the waterline: $z > T_1$	$C_2 \rho g \left[T_1 + C_{F2} \alpha^{1/4} \left(\frac{y}{B_W} h_1 + A_R y\right) - z\right]$	1,0	0,0

Note 1:
$h = \alpha^{1/4} C_{F2} h_2$
C_{F2} : Combination factor, to be taken equal to:
- $C_{F2} = 1{,}0$ for load case "c"
- $C_{F2} = 0{,}5$ for load case "d"

B_W : Moulded breadth, in m, measured at the waterline at draught T_1, at the hull transverse section considered
A_R : Roll amplitude, defined in Ch 5, Sec 3, [2.4.1].

Table 5 : Hull girder loads - Maximal bending moments at the middle of the central tank/hold

Ship condition	Load case	Vertical bending moments at the middle of the central tank/hold		Horizontal wave bending moment at the middle of the central tank/hold	Vertical shear forces at the middle of the central tank/hold	
		Still water	Wave		Still water	Wave
Upright	"a" crest	$\gamma_{S1} M_{SW}$	$0{,}625\ \gamma_{W1} M_{WV,H}$	0	0	0
	"a" trough	$\gamma_{S1} M_{SW}$	$0{,}625\ \gamma_{W1} M_{WV,S}$	0	0	0
	"b"	$\gamma_{S1} M_{SW}$	$0{,}625\ \gamma_{W1} M_{WV,S}$	0	0	0
Inclined	"c"	$\gamma_{S1} M_{SW}$	$0{,}25\ \gamma_{W1} M_{WV}$	$0{,}625\ \gamma_{W1} M_{WH}$	$\gamma_{S1} Q_{SW}$	$0{,}25\ \gamma_{W1} Q_{WV}$
	"d"	$\gamma_{S1} M_{SW}$	$0{,}25\ \gamma_{W1} M_{WV}$	$0{,}625\ \gamma_{W1} M_{WH}$	$\gamma_{S1} Q_{SW}$	$0{,}25\ \gamma_{W1} Q_{WV}$

Note 1: Hull girder loads are to be calculated at the middle of the central tank/hold.

4.2.6 Other cargoes

The modelling of cargoes other than those mentioned under [4.2.3] to [4.2.5] will be considered by the Society on a case by case basis.

4.3 Hull girder loads

4.3.1 Structural model extended over at least three cargo tank/hold lengths

The hull girder loads are constituted by:

- the still water and wave vertical bending moments
- the horizontal wave bending moment
- the still water and wave vertical shear forces

and are to be applied at the model fore 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 separately for the following two conditions:

- maximal bending moments at the middle of the central tank/hold: the hull girder loads applied at the fore end section are to be such that the values of the hull girder loads in Tab 5 are obtained
- maximal shear forces in way of the aft transverse bulkhead of the central tank/hold: the hull girder loads applied at the fore end section are to be such that the values of the hull girder loads in Tab 6 are obtained.

4.3.2 Structural model extended over one cargo tank/hold length

The normal and shear stresses induced by the hull girder loads in Tab 7 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 8, to compensate the portion of distributed loads which, due to the positioning of beams on their neutral axes, are not modelled.

In this figure, F_Y and F_Z represent concentrated loads equivalent to the dashed portion of the distributed loads which is not directly modelled.

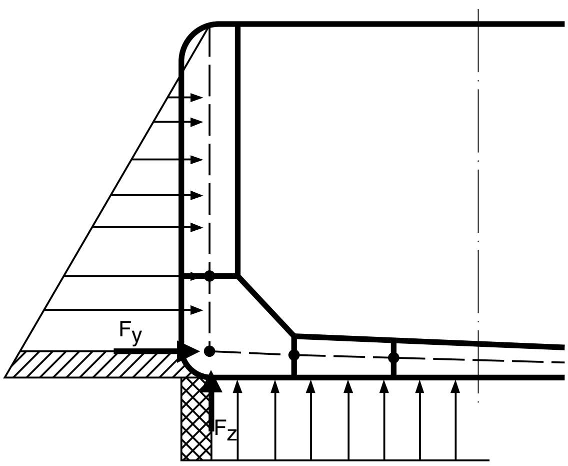
Table 6 : Hull girder loads - Maximal shear forces in way of the aft bulkhead of the central tank/hold

Ship condition	Load case	Vertical bending moments in way of the aft bulkhead of the central tank/hold		Vertical shear forces in way of the aft bulkhead of the central tank/hold	
		Still water	Wave	Still water	Wave
Upright	"a" crest	$\gamma_{S1} M_{SW}$	$0,4\ \gamma_{W1} M_{WV}$	$\gamma_{S1} Q_{SW}$	$0,625\ \gamma_{W1} Q_{WV}$
	"a" trough	$\gamma_{S1} M_{SW}$	$0,4\ \gamma_{W1} M_{WV}$	$\gamma_{S1} Q_{SW}$	$0,625\ \gamma_{W1} Q_{WV}$
	"b"	$\gamma_{S1} M_{SW}$	$0,4\ \gamma_{W1} M_{WV}$	$\gamma_{S1} Q_{SW}$	$0,625\ \gamma_{W1} Q_{WV}$
Inclined	"c"	$\gamma_{S1} M_{SW}$	$0,4\ \gamma_{W1} M_{WV}$	$\gamma_{S1} Q_{SW}$	$0,25\ \gamma_{W1} Q_{WV}$
	"d"	$\gamma_{S1} M_{SW}$	$0,4\ \gamma_{W1} M_{WV}$	$\gamma_{S1} Q_{SW}$	$0,25\ \gamma_{W1} Q_{WV}$
Note 1: Hull girder loads are to be calculated in way of the aft bulkhead of the central tank/hold.					

Table 7 : Hull girder loads for a structural model extended over one cargo tank/hold length

Ship condition	Load case	Vertical bending moments at the middle of the model		Horizontal wave bending moment at the middle of the model	Vertical shear forces at the middle of the model	
		Still water	Wave		Still water	Wave
Upright	"a" crest	$\gamma_{S1} M_{SW}$	$0,625\ \gamma_{W1} M_{WV,H}$	0	$\gamma_{S1} Q_{SW}$	$0,625\ \gamma_{W1} Q_{WV}$
	"a" trough	$\gamma_{S1} M_{SW}$	$0,625\ \gamma_{W1} M_{WV,S}$	0	$\gamma_{S1} Q_{SW}$	$0,625\ \gamma_{W1} Q_{WV}$
	"b"	$\gamma_{S1} M_{SW}$	$0,625\ \gamma_{W1} M_{WV,S}$	0	$\gamma_{S1} Q_{SW}$	$0,625\ \gamma_{W1} Q_{WV}$
Inclined	"c"	$\gamma_{S1} M_{SW}$	$0,25\ \gamma_{W1} M_{WV}$	$0,625\ \gamma_{W1} M_{WH}$	$\gamma_{S1} Q_{SW}$	$0,25\ \gamma_{W1} Q_{WV}$
	"d"	$\gamma_{S1} M_{SW}$	$0,25\ \gamma_{W1} M_{WV}$	$0,625\ \gamma_{W1} M_{WH}$	$\gamma_{S1} Q_{SW}$	$0,25\ \gamma_{W1} Q_{WV}$
Note 1: Hull girder loads are to be calculated at the middle of the model.						

Figure 8 : Concentrated loads equivalent to non-modelled distributed loads



5 Stress calculation

5.1 Analyses based on finite element models

5.1.1 Stresses induced by local and hull girder loads

When finite element models extend over at least three cargo tank/hold lengths, both local and hull girder loads are to be directly applied to the model, as specified in [4.3.1]. In this case, the stresses calculated by the finite element program include the contribution of both local and hull girder loads.

When finite element models extend over one cargo tank/hold length, only local loads are directly applied to the structural model, as specified in [4.3.2]. In this case, the stresses calculated by the finite element program include the contribution of local loads only. Hull girder stresses are to be calculated separately and added to the stresses induced by local loads.

5.1.2 Stress components

Stress components are generally identified with respect to the element co-ordinate system, as shown, by way of example, in Fig 9. The orientation of the element co-ordinate system may or may not coincide with that of the reference co-ordinate system in Ch 1, Sec 2, [4].

The following stress components are to be calculated at the centroid of each element:

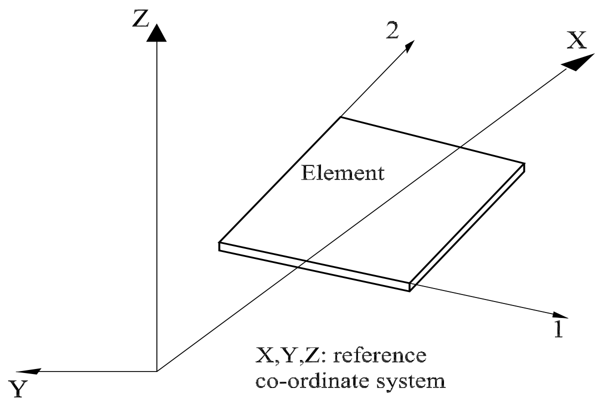
- the normal stresses σ_1 and σ_2 in the directions of the element co-ordinate system axes
- the shear stress τ_{12} with respect to the element co-ordinate system axes
- the Von Mises equivalent stress, obtained from the following formula:

$$\sigma_{VM} = \sqrt{\sigma_1^2 + \sigma_2^2 - \sigma_1 \sigma_2 + 3\tau_{12}^2}$$

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 9 : 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 [3.2.3]), only local loads are directly applied to the structural model, as specified in [4.3.2]. Therefore, the stresses calculated by the beam program include the contribution of local loads only. Hull girder stresses are to be calculated separately and added to the stresses induced by local loads.

5.2.2 Stress components

The following stress components are to be calculated:

- the normal stress σ_1 in the direction of the beam axis
- the shear stress τ_{12} in the direction of the local loads applied to the beam
- the Von Mises equivalent stress, obtained from the following formula:

$$\sigma_{VM} = \sqrt{\sigma_1^{\,2} + 3\tau_{12}^{\,2}}$$

5.2.3 Stress calculation points

Stresses are to be calculated at least in the following points of each primary supporting member:

- in the primary supporting member span where the maximum bending moment occurs
- at the connection of the primary supporting member with other structures, assuming as resistant section that formed by the member, the bracket (if any and if represented in the model) and the attached plating
- at the toe of the bracket (if any and if represented in the model) assuming as resistant section that formed by the member and the attached plating.

The values of the stresses are to be used for carrying out the checks required.

6 Fatigue analysis

6.1 Elementary hot spot stress range calculation

6.1.1 General

The requirements of this Article apply for calculating the elementary hot spot stress range for the fatigue check of structural details at the connections of primary supporting members analysed through a three dimensional structural model. The fatigue check of these details is to be carried out in accordance with the general requirements of Sec 4, [1] to Sec 4, [5].

The definitions in Sec 4, [1.3] apply.

6.1.2 Net scantlings

The three dimensional structural model is to be built considering all the structures with their net scantlings according to Ch 4, Sec 2, [1].

6.1.3 Hot spot stresses directly obtained through finite element analyses

Where the structural detail is analysed through a finite element analysis based on a very fine mesh, the elementary hot spot stress range may be obtained as the difference between the maximum and minimum stresses induced by the wave loads in the hot spot considered.

The requirements for:

- the finite element modelling, and
- the calculation of the hot spot stresses and the hot spot stress range

are specified in [6.2].

6.1.4 Hot spot stresses directly obtained through the calculation of nominal stresses

Where the structural detail is analysed through a finite element analysis based on a mesh less fine than that in [6.1.3], the elementary hot spot stress range may be obtained by multiplying the nominal stress range, obtained as the difference between the maximum and minimum nominal stresses induced by the wave loads in the vicinity of the hot spot considered, by the appropriate stress concentration factors.

The requirements for:

- the finite element modelling
- the calculation of the nominal stresses and the nominal stress range
- the stress concentration factors
- the calculation of the hot spot stresses and the hot spot stress range

are specified in [6.3].

6.2 Hot spot stresses directly obtained through finite element analyses

6.2.1 Finite element model

In general, the determination of hot spot stresses necessitates carrying out a very fine mesh finite element analysis, further to a coarser mesh finite element analysis. The boundary nodal displacements or forces obtained from the coarser mesh model are applied to the very fine mesh model as boundary conditions.

The model extension is to be such as to enable a faithful representation of the stress gradient in the vicinity of the hot spot and to avoid it being incorrectly affected by the application of the boundary conditions.

6.2.2 Finite element modelling criteria

The finite element model is to be built according to the following requirements:

- the detail may be considered as being realised with no misalignment
- the size of finite elements located in the vicinity of the hot spot is to be about twice to three times the thickness of the structural member. Where the details is the connection between two or more members of different thickness, the thickness to be considered is that of the thinnest member
- the centre of the first element adjacent to a weld toe is to be located between the weld toe and 0,4 times the thickness of the thinnest structural member connected by the weld
- plating, webs and face plates of primary and secondary members are to be modelled by 4-node thin shell or 8-node solid elements. In the case of a steep stress gradient, 8-node thin shell elements or 20-node solid elements are recommended
- when thin shell elements are used, the structure is to be modelled at mid-face of the plates
- the aspect ratio of elements is to be not greater than 3

6.2.3 Calculation of hot spot stresses

The hot spot stresses are to be calculated at the centroid of the first element adjacent to the hot spot.

The stress components to be considered are those specified in Sec 4, [3.1.2]. They are to be calculated at the surface of the plate in order to take into account the plate bending moment, where relevant.

Where the detail is the free edge of an opening (e.g. a cut-out for the passage of an ordinary stiffener through a primary supporting member), fictitious truss elements with minimal stiffness may needed to be fitted along the edge to calculate the hot spot stresses.

6.2.4 Calculation of the elementary hot spot stress range

The elementary hot spot stress range is to be obtained, in N/mm², from the following formula:

$$\Delta\sigma_{S,ij} = |\sigma_{S,ij,max} - \sigma_{S,ij,min}|$$

where:

$\sigma_{S,ij,max}$, $\sigma_{S,ij,min}$: Maximum and minimum values of the hot spot stress, induced by the maximum and minimum loads, defined in Sec 4, [2.2] and Sec 4, [2.3]

i : Denotes the load case

j : Denotes the loading condition.

6.3 Hot spot stresses obtained through the calculation of nominal stresses

6.3.1 Finite element model

A finite element is to be adopted, to be built according to the requirements in [3.3] and [3.4]. The areas in the vicinity of the structural details are to be modelled with fine mesh models, as defined in [3.4.3].

6.3.2 Calculation of the elementary nominal stress range

The elementary nominal stress range is to be obtained, in N/mm², from the following formula:

$$\Delta\sigma_{n,ij} = |\sigma_{n,ij,max} - \sigma_{n,ij,min}|$$

where:

$\sigma_{n,ij,max}$, $\sigma_{n,ij,min}$: Maximum and minimum values of the nominal stress, induced by the maximum and minimum loads, defined in Sec 4, [2.2] and Sec 4, [2.3]

i : Denotes the load case

j : Denotes the loading condition.

6.3.3 Calculation of the elementary hot spot stress range

The elementary hot spot stress range is to be obtained, in N/mm², from the following formula:

$$\Delta\sigma_{S,ij} = K_S \Delta\sigma_{n,ij}$$

where:

K_S : Stress concentration factor, defined in Ch 12, Sec 2, [2], for the relevant detail configuration

$\Delta\sigma_{n,ij}$: Elementary nominal stress range, defined in [6.3.2].

APPENDIX 2 ANALYSES OF PRIMARY SUPPORTING MEMBERS SUBJECTED TO WHEELED LOADS

1 General

1.1 Scope

1.1.1 The requirements of this Appendix apply for the analysis criteria, structural modelling, load modelling and stress calculation of primary supporting members subjected to wheeled loads which are to be analysed through three dimensional structural models, according to Sec 3.

1.1.2 The purpose of these structural analyses is to determine:

- the distribution of the forces induced by the vertical acceleration acting on wheeled cargoes, among the various primary supporting members of decks, sides and possible bulkheads
- the behaviour of the above primary supporting members under the racking effects due to the transverse forces induced by the transverse acceleration acting on wheeled cargoes, when the number or location of transverse bulkheads are not sufficient to avoid such effects

and to calculate the stresses in primary supporting members.

The above calculated stresses are to be used in the yielding and buckling checks.

In addition, the results of these analyses may be used, where deemed necessary by the Society, to determine the boundary conditions for finer mesh analyses of the most highly stressed areas.

1.1.3 When the behaviour of primary supporting members under the racking effects, due to the transverse forces induced by the transverse acceleration, is not to be determined, the stresses in deck primary supporting members may be calculated according to the simplified analysis in [6], provided that the conditions for its application are fulfilled (see [6.1]).

1.1.4 The yielding and buckling checks of primary supporting members are to be carried out according to Sec 3, [4.3].

1.2 Application

1.2.1 The requirements of this Appendix apply to ships whose structural arrangement is such that the following assumptions may be considered as being applicable:

- primary supporting members of side and possible bulkheads may be considered fixed in way of the double bottom (this is generally the case when the stiffness of floors is at least three times that of the side primary supporting members)
- under transverse inertial forces, decks behave as beams loaded in their plane and supported at the ship ends; their effect on the ship transverse rings (side primary supporting members and deck beams) may therefore be simulated by means of elastic supports in the transverse direction or transverse displacements assigned at the central point of each deck beam.

1.2.2 When the assumptions in [1.2.1] are considered by the Society as not being applicable, the analysis criteria are defined on a case by case basis, taking into account the ship's structural arrangement and loading conditions. In such cases, the analysis is generally to be carried out on the basis of a finite element model of the whole ship, built according to the requirements in App 1, as far as applicable.

1.3 Information required

1.3.1 The following information is necessary to perform these structural analyses:

- general arrangement
- structural plans of the areas involved in the analysis
- longitudinal sections and decks
- characteristics of vehicles loaded: load per axles, arrangement of wheels on axles, tyre dimensions.

1.4 Lashing of vehicles

1.4.1 The presence of lashing for vehicles is generally to be disregarded, but may be given consideration by the Society, on a case by case basis, at the request of the interested parties.

2 Analysis criteria

2.1 Finite element model analyses

2.1.1 For ships greater than 200 m in length, finite element models, built according to App 1, [3.4], are generally to be adopted.

The analysis of primary supporting members is to be carried out on fine mesh models, as defined in App 1, [3.4.3].

2.1.2 Areas which appear, from the primary supporting member analysis, to be highly stressed may be required to be further analysed through appropriately meshed structural models, as defined in App 1, [3.4.4].

2.2 Beam model analyses

2.2.1 For ships less than 200 m in length, beam models, built according to App 1, [3.5], may be adopted in lieu of the finite element models in [2.1], provided that:

- primary supporting members are not so stout that the beam theory is deemed inapplicable by the Society
- their behaviour is not substantially influenced by the transmission of shear stresses through the shell plating.

2.2.2 In any case, finite element models may need to be adopted when deemed necessary by the Society on the basis of the ship's structural arrangement.

3 Primary supporting members structural modelling

3.1 Model construction

3.1.1 Elements

The structural model is to represent the primary supporting members with the plating to which they are connected. In particular, the following primary supporting members are to be included in the model:

- deck beams
- side primary supporting members
- primary supporting members of longitudinal and transverse bulkheads, if any
- pillars
- deck beams, deck girders and pillars supporting ramps and deck openings, if any.

3.1.2 Net scantlings

All the elements in [3.1.1] are to be modelled with their net scantlings according to Ch 4, Sec 2, [1].

3.2 Model extension

3.2.1 The structural model is to represent a hull portion which includes the zone under examination and which is repeated along the hull. The non-modelled hull parts are to be considered through boundary conditions as specified in [3.3].

In addition, the longitudinal extension of the structural model is to be such that the results in the areas to be analysed are not influenced by the unavoidable inaccuracy in the modelling of the boundary conditions.

3.2.2 Double bottom structures are not required to be included in the model, based on the assumptions in [1.2.1].

3.3 Boundary conditions of the three dimensional model

3.3.1 Boundary conditions at the lower ends of the model

The lower ends of the model (i.e. the lower ends of primary supporting members of side and possible bulkheads) are to be considered as being clamped in way of the inner bottom.

3.3.2 Boundary conditions at the fore and aft ends of the model

Symmetry conditions are to be applied at the fore and aft ends of the model, as specified in Tab 1.

Table 1 : Symmetry conditions at the model fore and aft ends

DISPLACEMENTS in directions (1):			ROTATION around axes (1):		
X	Y	Z	X	Y	Z
fixed	free	free	free	fixed	fixed
(1) X, Y and Z directions and axes are defined with respect to the reference co-ordinate system in Ch 1, Sec 2, [4].					

3.3.3 Additional boundary conditions at the fore and aft ends of models subjected to transverse loads

When the model is subjected to transverse loads, i.e. when the loads in inclined ship conditions (as defined in Ch 5, Sec 4) are applied to the model, the transverse displacements of the deck beams are to be obtained by means of a racking analysis and applied at the fore and aft ends of the model, in way of each deck beam.

For ships with a traditional arrangement of fore and aft parts, a simplified approximation may be adopted, when deemed acceptable by the Society, defining the boundary conditions without taking into account the racking calculation and introducing springs, acting in the transverse direction, at the fore and aft ends of the model, in way of each deck beam (see Fig 1). Each spring, which simulates the effects of the deck in way of which it is modelled, has a stiffness obtained, in kN/m, from the following formula:

$$R_D = \frac{48 E J_D s_a 10^3}{2x^4 - 4L_D x^3 + L_D^2\left(x^2 + 15{,}6\frac{J_D}{A_D}\right) + L_D^3 x}$$

where:

J_D : Net moment of inertia, in m^4, of the average cross-section of the deck, with the attached side shell plating

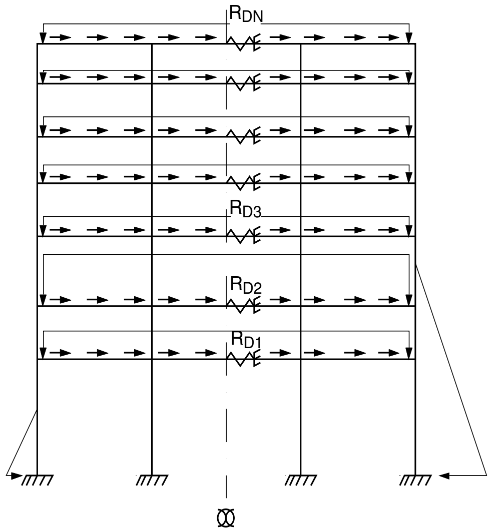
A_D : Net area, in m^2, of the average cross-section of deck plating.

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 ship'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 still water and wave loads are to be calculated for the most severe loading conditions as given in the loading manual, with a view to maximising the stresses in primary supporting members.

The loads transmitted by vehicles are to be applied taking into account the most severe axle positions for the ship structures.

The wave local loads and hull girder loads are to be calculated in the mutually exclusive load cases "b" and "d" in Ch 5, Sec 4. Load cases "a" and "c" may be disregarded for the purposes of the structural analyses dealt with in this Appendix.

4.1.3 Loading conditions and load cases: dry uniform cargoes

When the ship's decks are also designed to carry dry uniform cargoes, the loading conditions which envisage the transportation of such cargoes are also to be considered. The still water and wave loads induced by these cargoes are to be calculated for the most severe loading conditions, with a view to maximising the stresses in primary supporting members.

The wave local loads and hull girder loads are to be calculated in the mutually exclusive load cases "b" and "d" in Ch 5, Sec 4. Load cases "a" and "c" may be disregarded for the purposes of the structural analyses dealt with in this Appendix.

4.2 Local loads

4.2.1 General

Still water loads include:

- the still water sea pressure, defined in Ch 5, Sec 5, [1]
- the still water forces induced by wheeled cargoes, defined in Ch 5, Sec 6, Tab 8.

Wave induced loads include:

- the wave pressure, defined in Ch 5, Sec 5, [2] for load cases "b" and "d"
- the inertial forces defined in Ch 5, Sec 6, Tab 8 for load cases "b" and "d".

When the ship's decks are also designed to carry dry uniform cargoes, local loads also include the still water and inertial pressures defined in Ch 5, Sec 6, [4]. Inertial pressures are to be calculated for load cases "b" and "d".

4.2.2 Tyred vehicles

For the purpose of primary supporting members analyses, the forces transmitted through the tyres may be considered as concentrated loads in the tyre print centre.

The forces acting on primary supporting members are to be determined taking into account the area of influence of each member and the way ordinary stiffeners transfer the forces transmitted through the tyres.

4.2.3 Non-tyred vehicles

The requirements in [4.2.2] also apply to tracked vehicles. In this case, the print to be considered is that below each wheel or wheelwork.

For vehicles on rails, the loads transmitted are to be applied as concentrated loads.

4.2.4 Distributed loads

In the analyses carried out on the basis of beam models or membrane finite element models, the loads distributed perpendicularly to the plating panels are to be applied on the primary supporting members proportionally to their areas of influence.

4.3 Hull girder loads

4.3.1 The normal stresses induced by the hull girder loads in Tab 2 are to be added to the stresses induced in the primary supporting members by local loads.

Table 2 : Hull girder loads

Ship condition	Load case	Vertical bending moments at the middle of the model		Horizontal wave bending moment at the middle of the model
		Still water	Wave	
Upright	"b"	M_{SW}	0,625 $M_{WV,S}$	0
Inclined	"d"	M_{SW}	0,25 M_{WV}	0,625 M_{WH}

Note 1:
M_{SW} : Still water bending moment at the middle of the model, for the loading condition considered
$M_{WV,S}$: Sagging wave bending moments at the middle of the model, defined in Ch 5, Sec 2
M_{WV} : Wave bending moment at the middle of the model, defined in Ch 5, Sec 2, having the same sign as M_{SW}
M_{WH} : Horizontal wave bending moment at the middle of the model, defined in Ch 5, Sec 2.

5 Stress calculation

5.1 Stresses induced by local and hull girder loads

5.1.1 Only local loads are directly applied to the structural model, as specified in [4.1.1]. Therefore, the stresses calculated by the program include the contribution of local loads only. Hull girder stresses are to be calculated separately and added to the stresses induced by local loads.

5.2 Analyses based on finite element models

5.2.1 Stress components

Stress components are generally identified with respect to the element co-ordinate system, as shown, by way of example, in Fig 2. The orientation of the element co-ordinate system may or may not coincide with that of the reference co-ordinate system in Ch 1, Sec 2, [4].

The following stress components are to be calculated at the centroid of each element:

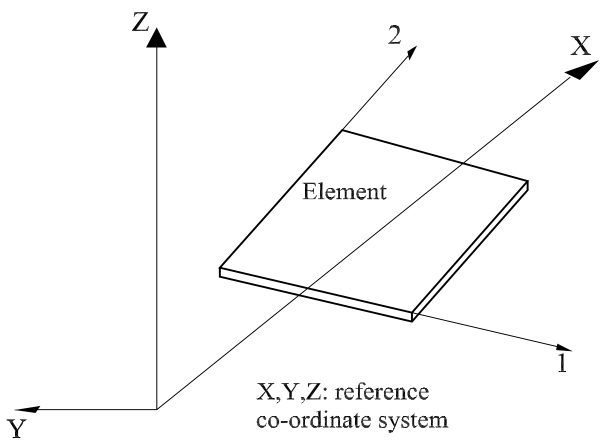
- the normal stresses σ_1 and σ_2 in the directions of element co-ordinate system axes
- the shear stress τ_{12} with respect to the element co-ordinate system axes
- the Von Mises equivalent stress, obtained from the following formula:

$$\sigma_{VM} = \sqrt{\sigma_1^2 + \sigma_2^2 - \sigma_1\sigma_2 + 3\tau_{12}^2}$$

5.2.2 Stress calculation points

Stresses are generally calculated by the computer programs for each element. The values of these stresses are to be used for carrying out the checks required.

Figure 2 : Reference and element co-ordinate systems



5.3 Analyses based on beam models

5.3.1 Stress components

The following stress components are to be calculated:

- the normal stress σ_1 in the direction of the beam axis
- the shear stress τ_{12} in the direction of the local loads applied to the beam
- the Von Mises equivalent stress, obtained from the following formula:

$$\sigma_{VM} = \sqrt{\sigma_1^2 + 3\tau_{12}^2}$$

5.3.2 Stress calculation points

Stresses are to be calculated at least in the following points of each primary supporting member:

- in the primary supporting member span where the maximum bending moment occurs
- at the connection of the primary supporting member with other structures, assuming as resistant section that formed by the member, the bracket (if any and if represented in the model) and the attached plating
- at the toe of the bracket (if any and if represented in the model) assuming as resistant section that formed by the member and the attached plating.

The values of the stresses calculated in the above points are to be used for carrying out the checks required.

6 Grillage analysis of primary supporting members of decks

6.1 Application

6.1.1 For the sole purpose of calculating the stresses in deck primary supporting members, due to the forces induced by the vertical accelerations acting on wheeled cargoes, these members may be subjected to the simplified two dimensional analysis described in [6.2].

This analysis is generally considered as being acceptable for usual structural typology, where there are neither pillar lines, nor longitudinal bulkheads.

6.2 Analysis criteria

6.2.1 Structural model

The structural model used to represent the deck primary supporting members is a beam grillage model.

6.2.2 Model extension

The structural model is to represent a hull portion which includes the zone under examination and which is repeated along the hull. The non-modelled hull parts are to be considered through boundary conditions as specified in [3.3].

6.3 Boundary conditions

6.3.1 Boundary conditions at the fore and aft ends of the model

Symmetry conditions are to be applied at the fore and aft ends of the model, as specified in Tab 1.

6.3.2 Boundary conditions at the connections of deck beams with side vertical primary supporting members

Vertical supports are to be fitted at the nodes positioned in way of the connection of deck beams with side primary supporting members.

The contribution of flexural stiffness supplied by the side primary supporting members to the deck beams is to be simulated by springs, applied at their connections, having rotational stiffness, in the plane of the deck beam webs, obtained, in kN.m/rad, from the following formulae:

- for intermediate decks:

$$R_F = \frac{3E(J_1 + J_2)(\ell_1 + \ell_2)}{\ell_1^2 + \ell_2^2 - \ell_1\ell_2} 10^{-5}$$

- for the uppermost deck:

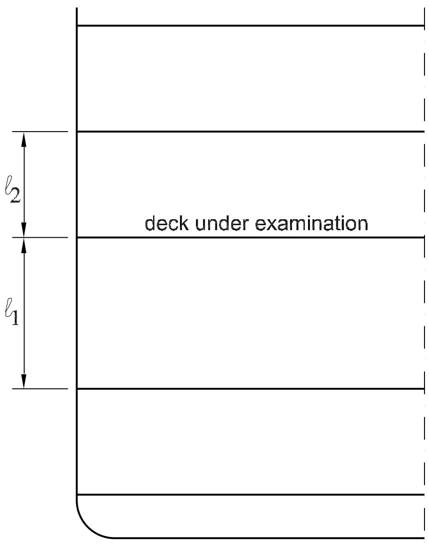
$$R_F = \frac{6EJ_1}{\ell_1} 10^{-5}$$

where:

ℓ_1, ℓ_2 : Height, in m, of the 'tweendecks, respectively below and above the deck under examination (see Fig 3)

J_1, J_2 : Net moments of inertia, in cm^4, of side primary supporting members with attached shell plating, relevant to the 'tweendecks, respectively below and above the deck under examination.

Figure 3 : Heights of tween-decks for grillage analysis of deck primary supporting members



6.4 Load model

6.4.1 Hull girder and local loads are to be calculated and applied to the model according to [4].

Wave loads are to be calculated considering load case "b" only.

6.5 Stress calculation

6.5.1 Stress components are to be calculated according to [5.1] and [5.3].

APPENDIX 3 ANALYSES BASED ON COMPLETE SHIP MODELS

Symbols

$\gamma_{S1},\gamma_{W1},\gamma_{S2},\gamma_{W2}$: Partial safety factors defined in Sec 3

λ : Wave length, in m.

1 General

1.1 Application

1.1.1 The requirements of this Appendix apply for the analysis criteria, structural modelling, load modelling and stress calculation of primary supporting members which are to be analysed through a complete ship model, according to Sec 3.

1.1.2 This Appendix deals with that part of the structural analysis which aims at calculating the stresses in the primary supporting members and more generally in the hull plating, to be used for yielding and buckling checks.

1.1.3 The yielding and buckling checks of primary supporting members are to be carried out according to Sec 3.

1.2 Information required

1.2.1 The following information is necessary to perform these structural analyses:

- general arrangement
- capacity plan
- lines plan
- structural plans
- longitudinal sections and decks
- loading manual.

2 Structural modelling

2.1 Model construction

2.1.1 Elements

The structural model is to represent the primary supporting members with the plating to which they are connected.

Ordinary stiffeners are also to be represented in the model in order to reproduce the stiffness and the inertia of the actual hull girder structure.

2.1.2 Net scantlings

All the elements in [2.1.1] are to be modelled with their net scantlings according to Ch 4, Sec 2. Therefore, also the hull girder stiffness and inertia to be reproduced by the model are those obtained by considering the net scantlings of the hull structures.

2.2 Model extension

2.2.1 The complete ship is to be modelled so that the coupling between torsion and horizontal bending is properly taken into account in the structural analysis.

Superstructures are to be modelled in order to reproduce the correct lightweight distribution.

2.2.2 In the case of structural symmetry with respect to the ship's centreline longitudinal plane, the hull structures may be modelled over half the ship's breadth.

2.3 Finite element modelling criteria

2.3.1 Modelling of primary supporting members

The analyses of primary supporting members are to be based on fine mesh models, as defined in App 1, [3.4.3].

Such analyses may be carried out deriving the nodal displacements or forces, to be used as boundary conditions, from analyses of the complete ships based on coarse meshes, as defined in App 1, [3.4.2].

Other areas may be required to be analysed through fine mesh models, where deemed necessary by the Society, depending on the ship's structural arrangement and loading conditions as well as the results of the coarse mesh analysis.

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2.3.2 Modelling 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 App 1, [3.4.4].

2.4 Finite element models

2.4.1 General

Finite element models are generally to be based on linear assumptions. The mesh is to be executed using membrane or shell elements, with or without mid-side nodes.

Meshing is to be carried out following uniformity criteria among the different elements.

In general, for some of the most common elements, the quadrilateral elements are to be such that the ratio between the longer side length and the shorter side length does not exceed 4 and, in any case, is less than 2 for most elements. Their angles are to be greater than 60° and less than 120°. The triangular element angles are to be greater than 30° and less than 120°.

Further modelling criteria depend on the accuracy level of the mesh, as specified in [2.4.2] to [2.4.4].

2.4.2 Coarse mesh

The number of nodes and elements is to be such that the stiffness and the inertia of the model represent properly those of the actual hull girder structure, and the distribution of loads among the various load carrying members is correctly taken into account.

To this end, the structural model is to be built on the basis of the following criteria:

- ordinary stiffeners contributing to the hull girder longitudinal strength and which are not individually represented in the model are to be modelled by rod elements and grouped at regular intervals
- webs of primary supporting members may be modelled with only one element on their height
- face plates may be simulated with bars having the same cross-section
- the plating between two primary supporting members may be modelled with one element stripe
- holes for the passage of ordinary stiffeners or small pipes may be disregarded
- manholes (and similar discontinuities) in the webs of primary supporting members may be disregarded, but the element thickness is to be reduced in proportion to the hole height and the web height ratio.

In some specific cases, some of the above simplifications may not be deemed acceple by the Society in relation to the type of structural model and the analysis performed.

2.4.3 Fine mesh

The ship's structure may be considered as finely meshed when each longitudinal secondary stiffener is modelled; as a consequence, the standard size of finite elements used is based on the spacing of ordinary stiffeners.

The structural model is to be built on the basis of the following criteria:

- webs of primary members are to be modelled with at least three elements on their height
- the plating between two primary supporting members is to be modelled with at least two element stripes
- the ratio between the longer side and the shorter side of elements is to be less than 3 in the areas expected to be highly stressed
- holes for the passage of ordinary stiffeners may be disregarded.

In some specific cases, some of the above simplifications may not be deemed acceple by the Society in relation to the type of structural model and the analysis performed.

2.4.4 Mesh for the analysis of structural details

The structural modelling is to be accurate; the mesh dimensions are to be such as to enable a faithful representation of the stress gradients. The use of membrane elements is only allowed when significant bending effects are not present; in other cases, elements with general behaviour are to be used.

2.5 Boundary conditions of the model

2.5.1 In order to prevent rigid body motions of the overall model, the constraints specified in Tab 1 are to be applied.

2.5.2 When the hull structure is modelled over half the ship's breadth (see [2.2.2]), in way of the ship's centreline longitudinal plane, symmetry or anti-symmetry boundary conditions as specified in Tab 2 are to be applied, depending on the loads applied to the model (respectively symmetrical or anti-symmetrical).

Table 1 : Boundary conditions to prevent rigid body motion of the model

Boundary conditions	DISPLACEMENTS in directions **(1)**		
	X	Y	Z
One node on the fore end of the ship	free	fixed	fixed
One node on the port side shell at aft end of the ship **(2)**	fixed	free	fixed
One node on the starboard side shell at aft end of the ship **(2)**	free	fixed	fixed

Boundary conditions	ROTATION around axes **(1)**		
	X	Y	Z
One node on the fore end of the ship	free	free	free
One node on the port side shell at aft end of the ship **(2)**	free	free	free
One node on the starboard side shell at aft end of the ship **(2)**	free	free	free

(1) X, Y and Z directions and axes are defined with respect to the reference co-ordinate system in Ch 1, Sec 2, [4].
(2) The nodes on the port side shell and that on the starboard side shell are to be symmetrical with respect to the ship's longitudinal plane of symmetry.

Table 2 : Symmetry and anti-symmetry conditions in way of the ship's centreline longitudinal plane

Boundary conditions	DISPLACEMENTS in directions **(1)**		
	X	Y	Z
Symmetry	free	fixed	free
Anti-symmetry	fixed	free	fixed

Boundary conditions	ROTATION around axes **(1)**		
	X	Y	Z
Symmetry	fixed	free	fixed
Anti-symmetry	free	fixed	free

(1) X, Y and Z directions and axes are defined with respect to the reference co-ordinate system in Ch 1, Sec 2, [4].

3 Load model

3.1 General

3.1.1 Local loads

Still water loads include:

- the still water sea pressure, defined in Ch 5, Sec 5, [1]
- the still water internal loads, defined in Ch 5, Sec 6 for the various types of cargoes and for ballast.

Wave loads, determined by mean of hydrodynamic calculations according to [3.2], include:

- the wave pressure
- the inertial loads.

3.1.2 Hull girder loads

The hull girder loads are constituted by:

- still water hull girder loads
- wave hull girder loads, to be calculated according to [3.2].

3.1.3 Lightweight

The lightweight of the ship is to be uniformly distributed over the model length, in order to obtain the actual longitudinal distribution of the still water bending moment.

3.1.4 Models extended over half ship's breadth

When the ship is symmetrical with respect to her centreline longitudinal plane and the hull structure is modelled over half the ship's breadth, non-symmetrical loads are to be broken down into symmetrical and anti-symmetrical loads and applied separately to the model with symmetry and anti-symmetry boundary conditions in way of the ship's centreline longitudinal plane (see [2.5.2]).

3.2 Load cases

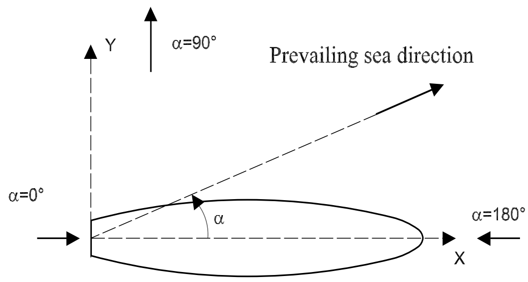
3.2.1 Equivalent waves

Wave loads are to be calculated for different load cases.

For each load case, the ship is considered to encounter a regular wave, defined by its parameters:

- wave length
- heading angle (see Fig 1)
- wave height
- phase.

Figure 1 : Wave heading



3.2.2 Load effects

The parameters listed in [3.2.1] are to be such that they maximise, and make equal to the target values specified in [3.2.3], the following load effects (one for each load case):

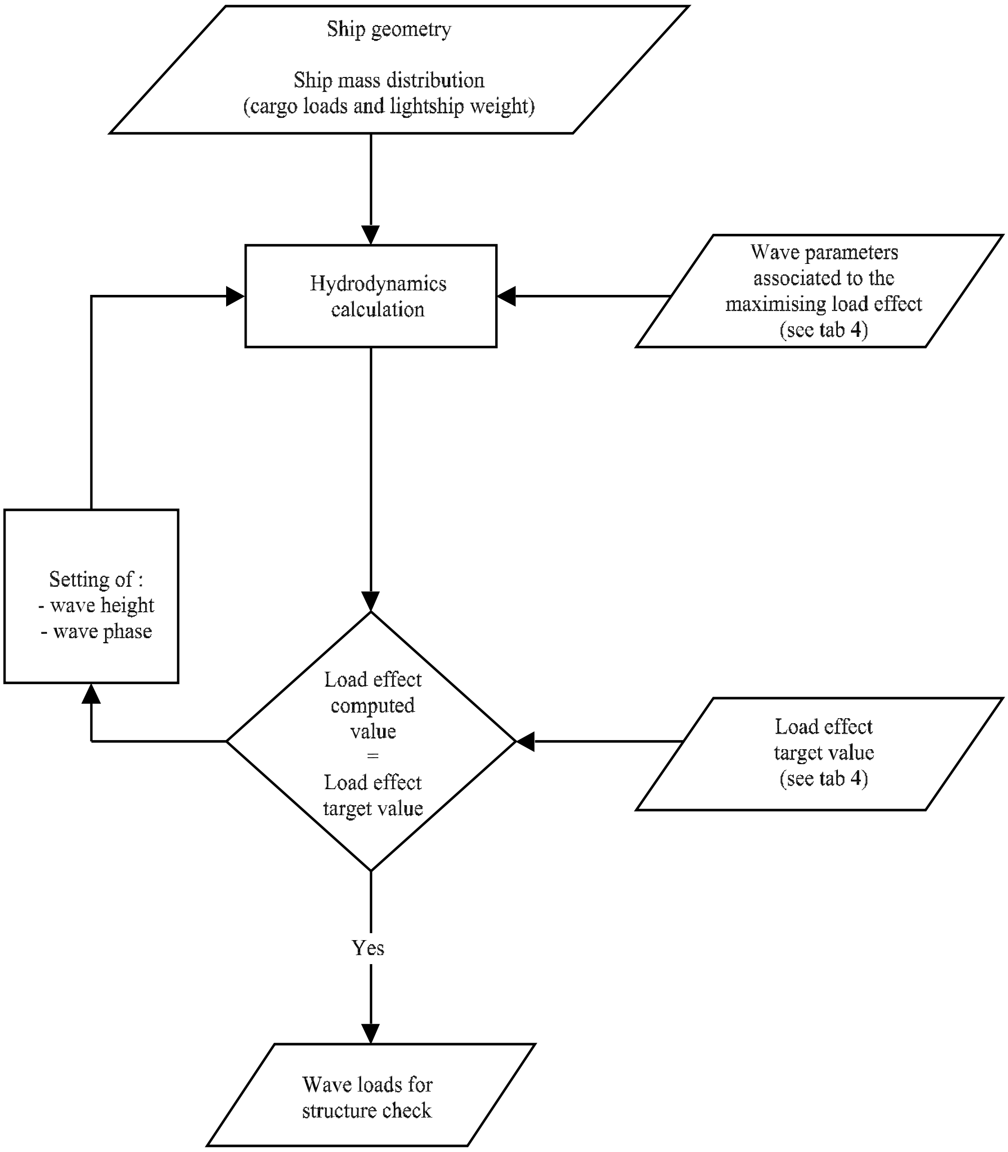
- vertical wave bending moment in hogging condition at midship section
- vertical wave bending moment in sagging condition at midship section
- vertical wave shear force on transverse bulkheads
- wave torque for ships with large deck openings at midship section
- transverse acceleration and roll angle
- vertical relative motion at sides in upright ship condition, at midship section.
- vertical relative motion at sides in inclined ship condition, at midship section

3.2.3 Value of loads effects

The wave lengths and headings which maximise each load effect are specified in Tab 3.

The wave amplitudes and phases are to be defined so that the target values in Tab 3 are attained by the maximised load effect, according to the procedure shown in Fig 2.

Figure 2 : Wave parameter calculations



4 Stress calculation

4.1 Stress components

4.1.1 Stress components are generally identified with respect to the element co-ordinate system, as shown, by way of example, in Fig 3. The orientation of the element co-ordinate system may or may not coincide with that of the reference co-ordinate system in Ch 1, Sec 2, [4].

Figure 3 : Reference and element co-ordinate

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:

$$\sigma_{VM} = \sqrt{\sigma_1^2 + \sigma_2^2 - \sigma_1\sigma_2 + 3\tau_{12}^2}$$

systems

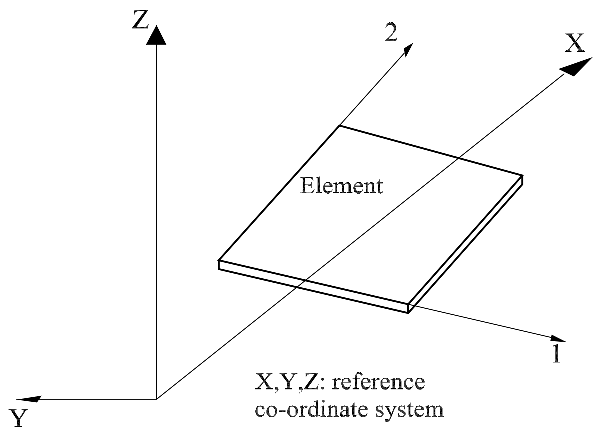


Table 3 : Load cases and load effect values

Load case	Maximised effect	Wave parameters **(2)**		Target		References
		λ/L	Heading angle	Value	Location(s)	
1	Vertical wave bending moment in hogging condition	1,0	180°	$0,625\gamma_{W1}M_{WV,H}$	Midship section	$M_{WV,H}$ defined in Ch 5, Sec 2, [3.1.1]
2	Vertical wave bending moment in sagging condition and vertical acceleration	1,0	180°	$0,625\gamma_{W1}M_{WV,S}$	Midship section	$M_{WV,S}$ defined in Ch 5, Sec 2, [3.1.1]
3	Vertical wave shear force	1,0	0° or 180°	$0,625\gamma_{W1}Q_{WV}$	Each transverse bulkhead	Q_{WV} defined in Ch 5, Sec 2, [3.4]
4	Wave torque **(1)**	0,5	60°	$0,625\gamma_{W1}M_{WT}$	Midship section	M_T defined in Ch 5, Sec 2, [3.3]
5	Transverse acceleration and roll angle	3,0	90°	$\gamma_{W2}A_{TY}$		A_{TY} defined in Ch 5, Sec 6, [1.2.2]
6	Vertical relative motion at sides in upright ship condition, at midship section	1,0	180°	$\gamma_{W2}h_1$	Midship section	h_1 defined in Ch 5, Sec 3, [3.3.1]
7	Vertical relative motion at sides in inclined ship condition, at midship section	0,7	90°	$\gamma_{W2}h_2$	Midship section	h_2 defined in Ch 5, Sec 3, [3.3.2]

(1) This load case is to be considered for ships with large deck openings only.
(2) The forward ship speed is to be taken equal to 0,6V.

Part B
Hull and Stability

Chapter 8
SHIPS LESS THAN 90 M IN LENGTH

Symbols used in chapter 8

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

- for steels in general:

  $E = 2,06.10^5 N/mm^2$
- for stainless steels:

  $E = 1,95.10^5 N/mm^2$
- for aluminium alloys:

  $E = 7,0.10^4 N/mm^2$

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

k : material factor, defined in:

- Pt B, Ch 4, Sec 1, [2.3], for steel,
- Pt B, Ch 4, Sec 1, [4.4], for aluminium alloys,

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

t_c : corrosion addition, in mm, defined in Pt B, Ch 4, Sec 2, Tab 2,

$M_{SW,H}$: Design still water bending moment, in kN.m, in hogging condition, at the hull transverse section considered, defined in Pt B, Ch 8, Sec 1, [2.2],

$M_{SW,S}$: Design still water bending moment, in kN.m, in sagging condition, at the hull transverse section considered, defined in Pt B, Ch 8, Sec 1, [2.2],

$M_{SW,Hmin}$: Minimum still water bending moment, in kN.m, in hogging condition, at the hull transverse section considered, without being taken greater than $0,3M_{WV,S}$,

$M_{WV,H}$: Vertical wave bending moment, in kN.m, in hogging condition, at the hull transverse section considered, defined in Pt B, Ch 8, Sec 1, [2.3],

$M_{WV,S}$: Vertical wave bending moment, in kN.m, in sagging condition, at the hull transverse section considered, defined in Pt B, Ch 8, Sec 1, [2.3],

g : Gravity acceleration, in m/s^2:

$g = 9,81 m/s^2$,

x, y, z : X, Y and Z co-ordinates, in m, of the calculation point with respect to the reference co-ordinate system defined in Pt B, Ch 1, Sec 2, [4].

SECTION 1 DESIGN LOADS

Symbols

For symbols not defined in this Section, refer to the list at the beginning of this Chapter.

n, n_1 : Navigation coefficients, defined in [1.5]

C : Wave parameter:

$$C = (118 - 0{,}36L)\frac{L}{1000}$$

F : Froude's number:

$$F = 0{,}164\frac{V}{\sqrt{L}}$$

V : Contractual service speed, in knots

a_B : Motion and acceleration parameter:

$$a_B = n\left(0{,}76F + 1{,}875\frac{h_W}{L}\right)$$

h_W : Wave parameter, in m:

$$h_W = 11{,}44 - \left|\frac{L-250}{110}\right|^3$$

h_1 : Reference value of the ship relative motion, in m, defined in [3.3.1]

a_{X1}, a_{Z1} : Reference values of the accelerations, in m/s², defined in [3.3.2].

1 General

1.1 Definitions

1.1.1 Still water loads

Still water loads are those acting on the ship at rest in calm water.

1.1.2 Wave loads

Wave loads are those due to wave pressures and ship motions, which can be assumed to have the same period as the inducing waves.

1.1.3 Local loads

Local loads are pressures and forces which are directly applied to the individual structural members: plating panels, ordinary stiffeners and primary supporting members.

- Still water local loads are constituted by the hydrostatic external sea pressures and the static pressures and forces induced by the weights carried in the ship spaces.
- Wave local loads are constituted by the external sea pressures due to waves and the inertial pressures and forces induced by the ship accelerations applied to the weights carried in the ship spaces.

For the structures which form the boundary of spaces not intended to carry liquids and which do not belong to the outer shell, the still water and wave pressures in flooding conditions are also to be considered.

1.1.4 Hull girder loads

Hull girder loads are still water and wave bending moments which result as effects of local loads acting on the ship as a whole and considered as a girder.

1.1.5 Loading condition

A loading condition is a distribution of weights carried in the ship spaces arranged for their storage.

1.1.6 Load case

A load case is a state of the ship structures subjected to a combination of hull girder and local loads.

1.2 Application criteria

1.2.1 Requirements applicable to all types of ships

The still water and wave loads defined in this Section are to be used for the determination of the hull girder strength and structural scantlings in the central part (see Ch 1, Sec 1) of ships less than 90 m in length, according to the requirements in Sec 2, Sec 3, Sec 4 and Sec 5.

1.2.2 Requirements applicable to specific ship types

The design loads applicable to specific ship types are to be defined in accordance with the requirements in Part E.

1.3 Hull girder loads

1.3.1 The still water and wave bending moment to be used for the determination of:

- the hull girder strength, according to the requirements of 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 [4] and [5], according to the requirements in Sec 3, Sec 4 and Sec 5,

are specified in [2].

1.4 Local loads

1.4.1 General

The local loads defined in [1.1.3] are to be calculated as specified in [1.4.2] for the elements of the outer shell and in [1.4.3] for the other elements.

1.4.2 Local loads for the elements of the outer shell

The local loads are to be calculated considering separately:

- the still water and wave external sea pressures, defined in [4]
- the still water and wave internal pressure, defined in [5], considering the compartment adjacent to the outer shell as being loaded.

1.4.3 Local loads for elements other than those of the outer shell

The local loads are to be calculated considering the still water and wave internal pressure, defined in [5].

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.

1.4.4 Flooding conditions

The still water and wave pressures in flooding conditions are specified in [5.8].

1.5 Navigation coefficients

1.5.1 The navigation coefficients, which appear in the formulae of this Section for the definition of wave hull girder and local loads, are:.

n : 0,90

n_1 : 0,95

2 Hull girder loads

2.1 General

2.1.1 Application

The requirements of this Article apply to ships having the following characteristics:

- $L < 90$ m
- $L / B > 5$
- $B / D < 2,5$
- $C_B \geq 0,6$

Ships not having one or more of the following characteristics, ships intended for the carriage of heated cargoes and ships of unusual type or design are considered by the Society on a case by case basis.

2.1.2 Hull girder load components

Hull girder loads include the still water and wave vertical bending moments.

In the case of ships with large openings in the strength deck, the Society may require longitudinal strength calculations to take into account also wave horizontal bending moments and torques, when deemed necessary on the basis of the ship's characteristics and intended service.

2.1.3 Sign conventions of bending moments

The hull girder bending moment is positive when it induces tensile stresses in the strength deck (hogging bending moment); it is negative in the opposite case (sagging bending moment).

2.2 Still water bending moments

2.2.1 For all ships, the longitudinal distributions of still water bending moment are to be calculated, for all the design loading conditions on which the approval of hull structural scantlings is based, on the basis of realistic data related to the amount of cargo, ballast, fuel, lubricating oil and fresh water. Except for docking condition afloat, departure and arrival conditions are to be considered. For conventional ships, these calculations may not be required when they are considered unnecessary by the Society on the basis of the ship's length and loading conditions.

The actual hull lines and lightweight distribution are to be taken into account in the calculations. The lightweight distribution may be replaced, if the actual values are not available, by a statistical distribution of weights accepted by the Society.

The Designer is to supply the data necessary to verify the calculations of still water loads.

2.2.2 The design still water bending moments $M_{SW,H}$ and $M_{SW,S}$ at any hull transverse section are the maximum still water bending moments calculated, in hogging and sagging conditions, respectively, at that hull transverse section for the loading conditions specified in [2.2.1].

Where no sagging bending moments act in the hull section considered, the value of $M_{SW,S}$ is to be taken as specified in Sec 3, Sec 4 and Sec 5.

2.2.3 If the design still water bending moments are not defined, at a preliminary design stage, their absolute values amidships are to be taken not less than the values obtained, in kN.m, from the following formulae:

- in hogging conditions:

$$M_{SWM,H} = 175 n_1 C L^2 B (C_B + 0,7) 10^{-3} - M_{WV,H}$$

- in sagging conditions:

$$M_{SWM,S} = 175 n_1 C L^2 B (C_B + 0,7) 10^{-3} + M_{WV,S}$$

where $M_{WV,H}$ and $M_{WV,S}$ are the vertical wave bending moments, in kN.m, defined in [2.3].

2.3 Vertical wave bending moments

2.3.1 The vertical wave bending moments at any hull transverse section are obtained, in kN.m, from the following formulae:

- hogging conditions

$$M_{WV,H} = 190 F_M n C L^2 B C_B 10^{-3}$$

- sagging conditions

$$M_{WV,S} = -110 F_M n C L^2 B (C_B + 0,7) 10^{-3}$$

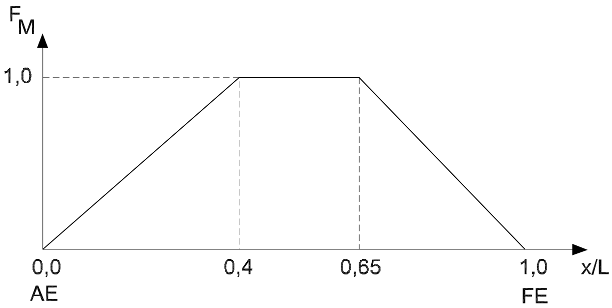
where:

F_M : Distribution factor defined in Tab 1 (see also Fig 1).

Table 1 : Distribution factor F_M

Hull transverse section location	Distribution factor F_M
$0 \le x < 0{,}4L$	$2{,}5\frac{x}{L}$
$0{,}4L \le x \le 0{,}65L$	1
$0{,}65L < x \le L$	$2{,}86\left(1 - \frac{x}{L}\right)$

Figure 1 : Distribution factor F_M



3 Ship motions and accelerations

3.1 General

3.1.1 Ship motions and accelerations are defined, with their sign, according to the reference co-ordinate system in Ch 1, Sec 2, [4].

3.1.2 Ship motions and accelerations are assumed to be periodic. The motion amplitudes, defined by the formulae of this Article, are half of the crest to through amplitudes.

3.2 Ship absolute motions and accelerations

3.2.1 Surge

The surge acceleration a_{SU} is to be taken equal to 0,5 m/s².

3.2.2 Heave

The heave acceleration is obtained, in m/s², from the following formula:

$$a_H = a_B g$$

3.2.3 Pitch

The pitch amplitude and acceleration are obtained from the formulae in Tab 2.

Table 2 : Pitch amplitude and acceleration

Amplitude A_P, in rad	Acceleration α_P, in rad/s²
$0{,}328 a_B\left(1{,}32 - \frac{h_W}{L}\right)\left(\frac{0{,}6}{C_B}\right)^{0{,}75}$	$A_P\left(\frac{2\pi}{0{,}575\sqrt{L}}\right)^2$

Table 3 : Reference values of the ship relative motion

Location	Reference value of the relative motion h_1, in m
$x = 0$	$0{,}7\left(\frac{4{,}35}{\sqrt{C_B}} - 3{,}25\right)h_{1,M}$ if $C_B < 0{,}875$ $h_{1,M}$ if $C_B \ge 0{,}875$
$0 < x < 0{,}3L$	$h_{1,AE} - \frac{h_{1,AE} - h_{1,M}}{0{,}3}\frac{x}{L}$
$0{,}3L \le x \le 0{,}7L$	$0{,}42nC(C_B + 0{,}7)$ without being taken greater than D - 0,9T
$0{,}7L < x < L$	$h_{1,M} + \frac{h_{1,FE} - h_{1,M}}{0{,}3}\left(\frac{x}{L} - 0{,}7\right)$
$x = L$	$\left(\frac{4{,}35}{\sqrt{C_B}} - 3{,}25\right)h_{1,M}$

Note 1:
$h_{1,AE}$: Reference value h_1 calculated for x = 0
$h_{1,M}$: Reference value h_1 calculated for x = 0,5L
$h_{1,FE}$: Reference value h_1 calculated for x = L

Table 4 : Reference value of the accelerations a_{X1} and a_{Z1}

Direction	Accelerations, in m/s²
X - Longitudinal	$a_{X1} = \sqrt{a_{SU}^2 + [A_P g + \alpha_p(z - T_1)]^2}$
Z - Vertical	$a_{Z1} = \sqrt{a_H^2 + \alpha_p^2 K_X L^2}$

Note 1:
a_{SU} : Surge acceleration, in m/s², defined in [3.2.1]
a_H : Heave acceleration, in m/s², defined in [3.2.2]
A_P, α_P : Pitch amplitude, in rad, and acceleration, in rad/s², defined in [3.2.3]

$$K_X = 1{,}2\left(\frac{x}{L}\right)^2 - 1{,}1\frac{x}{L} + 0{,}2$$

without being taken less than 0,018.

3.3 Ship relative motion and accelerations

3.3.1 Ship relative motion

The ship relative motion is the vertical oscillating translation of the sea waterline on the ship side. It is measured, with its sign, from the waterline at draught T and can be assumed as being symmetrical on the ship sides.

The reference value of the relative motion is obtained, at any hull transverse section, from the formulae in Tab 3.

3.3.2 Accelerations

The accelerations in X and Z direction are the acceleration components which result from the ship motions defined in

[3.2]. Their reference values at any point are obtained from the formulae in Tab 4.

4 Sea pressures

4.1 Still water and wave pressures

4.1.1 The still water and wave pressures are obtained, in kN/m², as specified in Tab 5 (see also Fig 2).

5 Internal pressures and forces

5.1 Liquids

5.1.1 Still water and inertial pressures

The still water and inertial pressures are obtained, in kN/m², as specified in Tab 7.

Table 5 : Still water and wave pressures

Location	Still water pressure p_S, in kN/m²	Wave pressure p_W, in kN/m²
Bottom and side below the waterline $z \le T$	$\rho g(T-z)$	$\rho g h_1 e^{\frac{-2\pi(T-z)}{L}}$
Side above the waterline $z > T$	0	$\rho g(T+h_1-z)$ without being taken less than 0,15L
Exposed decks	Pressure due to the load carried **(1)**	$17{,}5 n\varphi$ for $0 \le x \le 0{,}5L$ $\left\{17{,}5+\left[\frac{19{,}6\sqrt{H_F}-17{,}5}{0{,}25}\right]\left(\frac{x}{L}-0{,}5\right)\right\}n\varphi$ for $0{,}5L < x < 0{,}75L$ $19{,}6 n\varphi\sqrt{H}$ for $0{,}75L \le x \le L$

(1) The pressure due to the load carried is to be defined by the Designer and, in general, it may not be taken less than 10φ kN/m², where φ is defined in Tab 6.
The Society may accept pressure values lower than 10φ kN/m² when considered appropriate on the basis of the intended use of the deck.

Note 1:

ρ : Sea water density, in t/m³:
ρ = 1,025 t/m³,

H_F : Value of H calculated at x = 0,75L

V : Contractual service speed, in knots, to be taken not less than 13 knots

φ : Defined in Tab 6.

$$H = \left[2{,}66\left(\frac{x}{L}-0{,}7\right)^2+0{,}14\right]\sqrt{\frac{VL}{C_B}}-(z-T)$$

without being taken less than 0,8,

Figure 2 : Still water and wave pressures

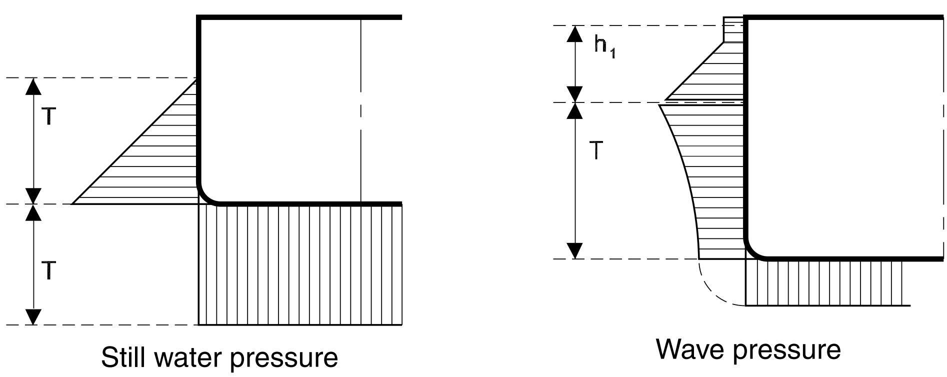


Table 6 : Coefficient for pressure on exposed decks

Exposed deck location	φ
Freeboard deck	1,00
Superstructure deck	0,75
1st tier of deckhouse	0,56
2nd tier of deckhouse and above	0,42

5.2 Dry bulk cargoes

5.2.1 Still water and inertial pressures

The still water and inertial pressures (excluding those acting on the sloping plates of wing tanks, which may be taken equal to zero) are obtained, in kN/m², as specified in Tab 8.

5.3 Dry uniform cargoes

5.3.1 Still water and inertial pressures

In ships with two or more decks, the pressure transmitted to the deck structures by the dry uniform cargoes in cargo compartments is to be considered.

The still water and inertial pressures transmitted to the deck structures are obtained, in kN/m², as specified in Tab 9.

Table 7 : Liquids
Still water and wave pressures

Still water pressure p_S, in kN/m²	Inertial pressure p_W, in kN/m²
The greater of the values obtained from the following formulae: $\rho_L g(z_L - z)$ $\rho_L g(z_{TOP} - z) + 100 p_{PV}$ to be taken not less than: $\rho_L g\left(\frac{0,8 L_1}{420 - L_1}\right)$	$\rho_L\left[a_{X1}\frac{\ell_C}{2} + a_{Z1}(z_{TOP} - z)\right]$

Note 1:

- ρ_L : Density, in t/m³, of the liquid cargo carried
- z_{TOP} : Z co-ordinate, in m, of the highest point of the tank in the z direction
- z_L : Z co-ordinate, in m, of the highest point of the liquid:

$$z_L = z_{TOP} + 0,5(z_{AP} - z_{TOP})$$

- z_{AP} : Z co-ordinate, in m, of the moulded deck line of the deck to which the air pipes extend, to be taken not less than z_{TOP}
- p_{PV} : Setting pressure, in bar, of safety valves
- ℓ_C : Longitudinal distance, in m, between the transverse tank boundaries.

Table 8 : Dry bulk cargoes - Still water and inertial pressures

Still water pressure p_S, in kN/m²	Inertial pressure p_W, in kN/m²
$\rho_B g(z_B - z)\left\{(\sin\alpha)^2\left[\tan\left(45^\circ - \frac{\varphi}{2}\right)\right]^2 + (\cos\alpha)^2\right\}$	$\rho_B a_{Z1}(z_B - z)\left\{(\sin\alpha)^2\left[\tan\left(45^\circ - \frac{\varphi}{2}\right)\right]^2 + (\cos\alpha)^2\right\}$

Note 1:

- ρ_B : Density, in t/m³, of the dry bulk cargo carried, to be taken equal to:

$$\rho_B = \frac{p_{DB}}{g(z_B - h_{DB})}$$

- p_{DB} : Design pressure, in kN/m², on the double bottom
- z_B : Z co-ordinate, in m, of the rated upper surface of the bulk cargo (horizontal ideal plane of the volume filled by the cargo), to be taken equal to:

$$z_B = 0,9(D - h_{DB}) + h_{DB}$$

- h_{DB} : Height, in m, of the double bottom, to be taken as the vertical distance from the baseline to the inner bottom
- α : Angle, in degrees, between the horizontal plane and the surface of the hull structure to which the calculation point belongs
- φ : Angle of repose, in degrees, of the dry bulk cargo carried (considered drained and removed); in the absence of more precise evaluation, the following values may be taken:
  - $\varphi = 30^\circ$ in general
  - $\varphi = 35^\circ$ for iron ore
  - $\varphi = 25^\circ$ for cement.

Table 9 : Dry uniform cargoes
Still water and inertial pressures

Still water pressure p_S, in kN/m²	Inertial pressure p_W, in kN/m²
The value of p_S is in general defined by the designer; in any case, it may not be taken less than 10 kN/m². When the value of p_S is not defined by the designer, it may be taken, in kN/m² equal to 6,9 h_{TD}, where h_{TD} is the compartment 'tweendeck height at side, in m	$p_S \frac{a_{Z1}}{g}$

5.4 Dry unit cargoes

5.4.1 Still water and inertial forces

The still water and inertial forces transmitted to the hull structures are to be determined on the basis of the forces obtained, in kN, as specified in Tab 10, taking into account the elastic characteristics of the lashing arrangement and/or the structure which contains the cargo.

Table 10 : Dry unit cargoes
Still water and inertial forces

Still water forces F_S, in kN	Inertial forces F_W, in kN
$F_S = Mg$	$F_{W,X} = Ma_{X1}$ in x direction $F_{W,Z} = Ma_{Z1}$ in z direction
Note 1: M : Mass, in t, of a dry unit cargo carried.	

5.5 Wheeled cargoes

5.5.1 Still water and inertial forces

Caterpillar trucks and unusual vehicles are considered by the Society on a case by case basis.

The load supported by the crutches of semi-trailers, handling machines and platforms is considered by the Society on a case by case basis.

The forces transmitted through the tyres are comparable to pressure uniformly distributed on the tyre print, whose dimensions are to be indicated by the Designer together with information concerning the arrangement of wheels on axles, the load per axles and the tyre pressures.

With the exception of dimensioning of plating, such forces may be considered as concentrated in the tyre print centre.

The still water and inertial forces transmitted to the hull structures are to be determined on the basis of the forces obtained, in kN, as specified in Tab 11.

In the case of tracked vehicles, the print to be considered is that below each wheel.

For vehicles on rails, all the forces transmitted are to be considered as concentrated.

5.6 Accommodation

5.6.1 Still water and inertial pressures

The still water and inertial pressures transmitted to the deck structures are obtained, in kN/m², as specified in Tab 12.

Table 11 : Wheeled cargoes
Still water and inertial forces

Still water forces F_S, in kN	Inertial forces F_W, in kN
$F_S = Mg$	$F_{W,Z} = Ma_{Z1}$ in z direction
Note 1: M : Force applied by one wheel, obtained, in t, from the following formula: $M = \frac{Q_A}{n_W}$ Q_A : Axle load, in t. For fork-lift trucks, the value of Q_A is to be taken equal to the total mass of the vehicle, including that of the cargo handled, applied to one axle only. n_W : Number of wheels for the axle considered.	

Table 12 : Accommodation
Still water and inertial pressures

Still water pressure p_S, in kN/m²	Inertial pressure p_W, in kN/m²
The value of p_S is defined in Tab 13 depending on the type of the accommodation compartment	$p_S \frac{a_{Z1}}{g}$

Table 13 : Still water deck pressure
in accommodation compartments

Type of accommodation compartment	p_S, in kN/m²
Large public spaces, such as: restaurants, halls, cinemas, lounges	5,0
Large rooms, such as: games and hobbies rooms, hospitals	3,0
Cabins	3,0
Other compartments	2,5

5.7 Machinery

5.7.1 Still water and inertial pressures

The still water and inertial pressures transmitted to the deck structures are obtained, in kN/m², from the formulae in Tab 14.

Table 14 : Machinery Still water and inertial pressures

Still water pressure p_S, in kN/m²	Inertial pressure p_W, in kN/m²
10	$p_S \frac{a_{Z1}}{g}$

5.8 Flooding

5.8.1 Still water and inertial pressures

The still water and inertial pressures to be considered as acting on bulkheads or inner sides which constitute boundaries of compartments not intended to carry liquids are obtained, in kN/m², from the formulae in Tab 15.

Table 15 : Flooding - Still water and inertial pressures

Still water pressure p_{SF}, in kN/m²	Inertial pressure p_{WF}, in kN/m²
$\rho_L g(z_F - z)$ without being taken less than 0,4 g d_0	$0{,}6 \rho_L a_{Z1}(z_F - z)$ without being taken less than 0,4 g d_0

Note 1:

z_F : Z co-ordinate, in m, of the freeboard deck at side in way of the transverse section considered. Where the results of damage stability calculations are available, the deepest equilibrium waterline may be considered in lieu of the freeboard deck; in this case, the Society may require transient conditions to be taken into account

d_0 : Distance, in m, to be taken equal to: $d_0 = 0{,}02L$

SECTION 2 HULL GIRDER STRENGTH

Symbols

For symbols not defined in this Section, refer to the list at the beginning of this Chapter.

M_{SW} : Still water bending moment, in kN·m:
- in hogging conditions:
  $M_{SW} = M_{SW,H}$
- in sagging conditions:
  $M_{SW} = M_{SW,S}$

M_{WV} : Vertical wave bending moment, in kN·m:
- in hogging conditions:
  $M_{WV} = M_{WV,H}$
- in sagging conditions:
  $M_{WV} = M_{WV,S}$

I_Y : Moment of inertia, in m^4, of the hull transverse section defined in [1.1] about its horizontal neutral axis

Z_A : Section modulus, in cm^3, at any point of the hull transverse section, to be calculated according to [1.3.1]

Z_{AB}, Z_{AD} : Section moduli, in cm^3, at bottom and deck, respectively, to be calculated according to [1.3.2]

n_1 : Navigation coefficient defined in Sec 1, [1.5.1]

C : Wave parameter, defined in Sec 1.

1 Basic criteria

1.1 Hull girder transverse sections

1.1.1 General

Hull girder transverse sections are constituted by the members contributing to the hull girder longitudinal strength, i.e. all continuous longitudinal members below the strength deck defined in [1.2], taking into account the requirements in [1.1.2] to [1.1.9].

These members are to be considered as having (see also Ch 4, Sec 2):

- gross scantlings, when the hull girder strength characteristics to be calculated are used for the yielding checks in [2]
- net scantlings, when the hull girder strength characteristics to be calculated are used for calculating the hull girder stresses for the strength checks of plating, ordinary stiffeners and primary supporting members in Sec 3, Sec 4 and Sec 5.

1.1.2 Continuous trunks and continuous longitudinal hatch coamings

Continuous trunks and continuous longitudinal hatch coamings may be included in the hull girder transverse sections, provided they are effectively supported by longitudinal bulkheads or primary supporting members.

1.1.3 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 [1.1.2]) may be included in the hull girder transverse sections.

1.1.4 Longitudinal girders between hatchways

Where longitudinal girders are fitted between hatchways, the sectional area that can be included in the hull girder transverse sections is obtained, in m^2, from the following formula:

$A_{EFF} = A_{LG}\, a$

where:

A_{LG} : Sectional area, in m^2, of longitudinal girders

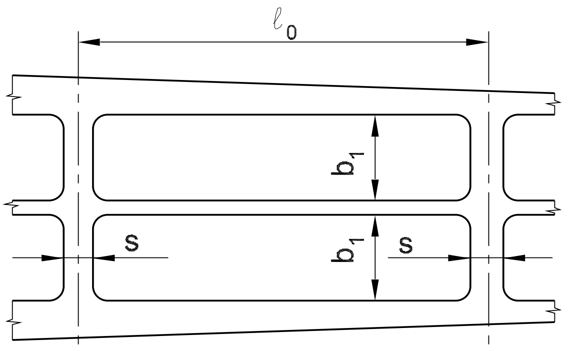
a : Coefficient:
- for longitudinal girders effectively supported by longitudinal bulkheads or primary supporting members:
  a = 1
- for longitudinal girders not effectively supported by longitudinal bulkheads or primary supporting members and having dimensions and scantlings such that $\ell_0/r \le 60$:
  $$a = 0{,}6\left(\frac{s}{b_1} + 0{,}15\right)^{0{,}5}$$
- for longitudinal girders not effectively supported by longitudinal bulkheads or primary supporting members and having dimensions and scantlings such that $\ell_0/r > 60$:
  a = 0

ℓ_0 : Span, in m, of longitudinal girders, to be taken as shown in Fig 1

r : Minimum radius of gyration, in m, of the longitudinal girder transverse section

s, b_1 : Dimensions, in m, defined in Fig 1.

Figure 1 : Longitudinal girders between hatchways



1.1.5 Longitudinal bulkheads with vertical corrugations

Longitudinal bulkheads with vertical corrugations may not be included in the hull girder transverse sections.

1.1.6 Members in materials other than steel

Where a member contributing to the longitudinal strength is made in material other than steel with a Young's modulus E equal to 2,06 10^5 N/mm², the steel equivalent sectional area that may be included in the hull girder transverse sections is obtained, in m², from the following formula:

$$A_{SE} = \frac{E}{2{,}06 \cdot 10^5} A_M$$

where:

A_M : Sectional area, in m², of the member under consideration.

1.1.7 Large openings

Large openings are:

- elliptical openings exceeding 2,5 m in length or 1,2 m in breadth
- circular openings exceeding 0,9 m in diameter.

Large openings and scallops, where scallop welding is applied, are always to be deducted from the sectional areas included in the hull girder transverse sections.

1.1.8 Small openings

Smaller openings than those in [1.1.7] in one transverse section in the strength deck or bottom area need not be deducted from the sectional areas included in the hull girder transverse sections, provided that:

$$\Sigma b_S \leq 0{,}06(B - \Sigma b)$$

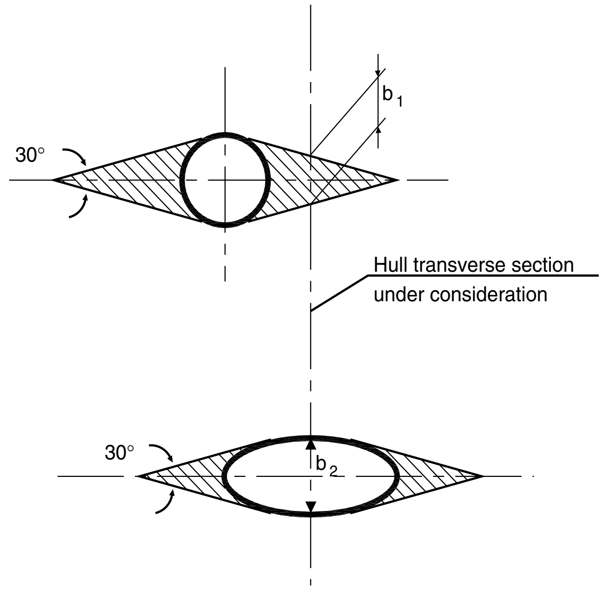
where:

Σb_S : Total breadth of small openings, in m, in the strength deck or bottom area at the transverse section considered, determined as indicated in Fig 2

Σb : Total breadth of large openings, in m, at the transverse section considered, determined as indicated in Fig 2

Where the total breadth of small openings Σb_S does not fulfil the above criteria, only the excess of breadth is to be deducted from the sectional areas included in the hull girder transverse sections.

Figure 2 : Calculation of Σb and Σb_S



b_1 and b_2 included in Σ b and Σ bs

1.1.9 Lightening holes, draining holes and single scallops

Lightening holes, draining holes and single scallops in longitudinals need not be deducted if their height is less than 0,25 h_W, without being greater than 75 mm, where h_W is the web height, in mm, defined in Ch 4, Sec 3.

Otherwise, the excess is to be deducted from the sectional area or compensated.

1.2 Strength deck

1.2.1 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.

1.2.2 A superstructure extending at least 0,15L within 0,4L 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:

$$t_{EQ} = 10^3 \left[\ell_P \left(\frac{Gh^2}{12 E I_J} + \frac{1}{A_J} \right) \right]^{-1}$$

where (see Fig 3):

ℓ_P : Longitudinal distance, in m, between the frames beside the opening

h : Height, in m, of openings

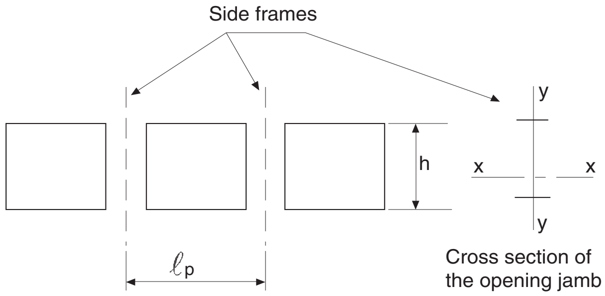
I_J : Moment of inertia, in m^4, of the opening jamb about the transverse axis y-y

A_J : Shear area, in m^2, of the opening jamb in the direction of the longitudinal axis x-x

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 3 : Side openings



1.3 Section modulus

1.3.1 The section modulus at any point of a hull transverse section is obtained, in m^3, from the following formula:

$$Z_A = \frac{I_Y}{|z - N|}$$

where:

z : Z co-ordinate, in m, of the calculation point with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [4]

N : Z co-ordinate, in m, of the centre of gravity of the hull transverse section defined in [1.1], with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [4].

1.3.2 The section moduli at bottom and at deck are obtained, in m^3, from the following formulae:

- at bottom:

$$Z_{AB} = \frac{I_Y}{N}$$

- at deck:

$$Z_{AD} = \frac{I_Y}{V_D}$$

where:

N : Defined in [1.3.1]

V_D : Vertical distance, in m:

- in general:
  $V_D = z_D - N$

  where:

  z_D : Z co-ordinate, in m, of strength deck, defined in [1.2] with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [4]

- if continuous trunks or hatch coamings are taken into account in the calculation of I_Y, as specified in [1.1.2]:

$$V_D = (z_T - N)\left(0{,}9 + 0{,}2\frac{y_T}{B}\right) \geq z_D - N$$

  where:

  y_T, z_T : Y and Z co-ordinates, in m, of the top of continuous trunk or hatch coaming with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [4]; y_T and z_T are to be measured for the point which maximises the value of V_D

- if longitudinal ordinary stiffeners or girders welded above the strength deck are taken into account in the calculation of I_Y, as specified in [1.1.3], V_D is to be obtained from the formula given above for continuous trunks or 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 ordinary stiffeners or girders with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [4].

2 Yielding check

2.1 Normal stresses induced by vertical bending moments

2.1.1 The normal stresses induced by vertical bending moments are obtained, in N/mm^2, from the following formulae:

- at any point of the hull transverse section:

$$\sigma_1 = \frac{M_{SW} + M_{WV}}{Z_A}$$

- at bottom:

$$\sigma_1 = \frac{M_{SW} + M_{WV}}{Z_{AB}}$$

- at deck:

$$\sigma_1 = \frac{M_{SW} + M_{WV}}{Z_{AD}}$$

2.1.2 The normal stresses in a member made in material other than han steel with a Young's modulus E equal to 2,06 10^5 N/mm^2, and included in the hull girder transverse sections as specified in [1.1.6], are obtained from the following formula:

$$\sigma_1 = \frac{E}{2{,}06{,}10^5}\sigma_{1S}$$

where:

σ_{1S} : Normal stress, in N/mm², in the member under consideration, calculated according to [2.1.1] considering this member as having the steel equivalent sectional area A_{SE} defined in [1.1.6].

2.2 Checking criteria

2.2.1 It is to be checked that the normal stresses σ_1 calculated according to [2.1] are in compliance with the following formula:

$\sigma_1 \leq \sigma_{1,ALL}$

where:

$\sigma_{1,ALL}$: Allowable normal stress, in N/mm²:

$\sigma_{1,ALL} = 175 / k$

3 Section modulus and moment of inertia

3.1 General

3.1.1 The requirements in [3.2] to [3.4] provide the minimum hull girder section modulus, complying with the checking criteria indicated in [2.2], and the midship section moment of inertia required to ensure sufficient hull girder rigidity.

3.2 Section modulus

3.2.1 For ships with C_B greater than 0,8,the gross section moduli Z_{AB} and Z_{AD} within 0,4L amidships are to be not less than the greater value obtained, in m³, from the following formulae:

- $Z_{R,MIN} = n_1 C L^2 B (C_B + 0{,}7) k 10^{-6}$
- $Z_R = \dfrac{M_{SW} + M_{WV}}{175/k} 10^{-3}$

3.2.2 For ships with C_B less than or equal to 0,8, the gross section moduli Z_{AB} and Z_{AD} at the midship section are to be not less than the value obtained, in m³, from the following formula:

$$Z_{R,MIN} = n_1 C L^2 B (C_B + 0{,}7) k 10^{-6}$$

In addition, the gross section moduli Z_{AB} and Z_{AD} within 0,4L amidships are to be not less than the value obtained, in m³, from the following formula:

$$Z_R = \frac{M_{SW} + M_{WV}}{175/k} 10^{-3}$$

3.2.3 The k material factors are to be defined with respect to the materials used for the bottom and deck members contributing to the hull girder longitudinal strength according to [1]. When factors for higher strength steels are used, the requirements in [3.4] apply.

3.2.4 Where the total breadth Σb_S of small openings, as defined in [1.1.8], is deducted from the sectional areas included in the hull girder transverse sections, the values Z_R and $Z_{R,MIN}$ defined in [4.2.1] may be reduced by 3%.

3.2.5 Scantlings of members contributing to the longitudinal strength (see [1]) are to be maintained within 0,4L amidships.

3.2.6 Scantlings of members contributing to the hull girder longitudinal strength (see [1]) may be gradually reduced, outside 0,4L amidships, to the minimum required for local strength purposes at fore and aft parts, as specified in Chapter 9.

3.3 Midship section moment of inertia

3.3.1 The gross midship section moment of inertia about its horizontal neutral axis is to be not less than the value obtained, in m⁴, from the following formula:

$$I_{YR} = 3 Z'_{R,MIN} L 10^{-2}$$

where $Z'_{R,MIN}$ is the required midship section modulus $Z_{R,MIN}$, in m³, calculated as specified in [3.2.1], but assuming k = 1.

3.4 Extent of higher strength steel

3.4.1 When a factor for higher strength steel is used in calculating the required section modulus at bottom or deck according to [3.2.1], the relevant higher strength steel is to be adopted for all members contributing to the longitudinal strength (see [1]), at least up to a vertical distance, in m, obtained from the following formulae:

- above the baseline (for section modulus at bottom):

$$V_{HB} = \frac{\sigma_{1B} - 175}{\sigma_{1B} + \sigma_{1D}} Z_D$$

- below a horizontal line located at a distance V_D (see [1.3.2]) above the neutral axis of the hull transverse section (for section modulus at deck):

$$V_{HD} = \frac{\sigma_{1D} - 175}{\sigma_{1B} + \sigma_{1D}} (N + V_D)$$

where:

σ_{1B}, σ_{1D} : Normal stresses, in N/mm², at bottom and deck, respectively, calculated according to [2.1.1]

z_D : Z co-ordinate, in m, of the strength deck, defined in [1.2], with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [4]

N : Z co-ordinate, in m, of the centre of gravity of the hull transverse section, defined in [1.1], with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [4]

V_D : Vertical distance, in m, defined in [1.3.2]

3.4.2 When a higher strength steel is adopted at deck, members not contributing to the longitudinal strength and welded on the strength deck (e.g. hatch coamings, strengthening of deck openings) are also generally to be made of the same higher strength steel.

3.4.3 The higher strength steel is to extend in length at least throughout the whole midship area where it is required for strength purposes according to the requirements of Part B.

4 Permissible still water bending moment

4.1 Permissible still water bending moment during navigation

4.1.1 The permissible still water bending moment at any hull transverse section during navigation, in hogging or sagging conditions, is the value M_{SW} considered in the hull girder section modulus calculation according to [3].

In the case of structural discontinuities in the hull transverse sections, the distribution of permissible still water bending moments is considered on a case by case basis.

4.2 Permissible still water bending moment in harbour conditions

4.2.1 The permissible still water bending moment at any hull transverse section in harbour conditions, in hogging or sagging conditions, is obtained, in kN.m, from the following formula:

$$M_{P,H} = \frac{130}{k} Z_{A,M} 10^3$$

where $Z_{A,M}$ is the lesser of Z_{AB} and Z_{AD} defined in [3.2.1].

SECTION 3 PLATING

Symbols

For symbols not defined in this Section, refer to the list at the beginning of this Chapter.

p_S : Still water pressure, in kN/m², see [3.2.2]

p_W : Wave pressure, in kN/m², see [3.2.2]

p_{SF}, p_{WF} : Still water and wave pressure, in kN/m², in flooding conditions, defined in Sec 1, [5.8]

F_S : Still water wheeled force, in kN, see [4.2.2]

$F_{W,Z}$: Inertial wheeled force, in kN, see [4.2.2]

σ_{X1} : In-plane hull girder normal stress, in N/mm², defined in:

- [3.2.4] for the strength check of plating subjected to lateral pressure
- [5.2.2] for the buckling check of plating for ships equal to or greater than 65 m in length

R_{eH} : Minimum yield stress, in N/mm², of the plating material, defined in Ch 4, Sec 1, [2]

I_Y : Net moment of inertia, in m⁴, of the hull transverse section around its horizontal neutral axis, to be calculated according to Sec 2 considering the members contributing to the hull girder longitudinal strength as having their net scantlings

N : Z co-ordinate, in m, with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [4], of the centre of gravity of the hull transverse section constituted by members contributing to the hull girder longitudinal strength considered as having their net scantlings (see Sec 1, [1])

ℓ : Length, in m, of the longer side of the plate panel

s : Length, in m, of the shorter side of the plate panel

c_a : Aspect ratio of the plate panel, equal to:

$$c_a = 1{,}21\sqrt{1 + 0{,}33\left(\frac{s}{\ell}\right)^2} - 0{,}69\frac{s}{\ell}$$

to be taken not greater than 1,0

c_r : Coefficient of curvature of the panel, equal to:

$$c_r = 1 - 0{,}5s/r$$

to be taken not less than 0,75

r : Radius of curvature, in m

t_{net} : Net thickness, in mm, of a plate panel

1 General

1.1 Application

1.1.1 For ships less than 65 m in length, the criteria in App 1 may be used for the strength check of plating, as an alternative to those contained in this Section.

1.2 Net thicknesses

1.2.1 As specified in Ch 4, Sec 2, [1], all thicknesses referred to in this Section are net, i.e. they do not include any margin for corrosion.

The gross thicknesses are obtained as specified in Ch 4, Sec 2.

1.3 Partial safety factors

1.3.1 The partial safety factors to be considered for the checking of the plating are specified in Tab 1.

Table 1 : Plating - Partial safety factors

Partial safety factors covering uncertainties regarding:	Symbol	Strength check of plating subjected to lateral pressure		Buckling check for L ≥ 65 m (see [5])
		General (see [3.2], [3.3.1], [3.4.1], [3.5.1] and [4])	Watertight bulkhead plating **(1)** (see [3.3.2], [3.4.2] and [3.5.2])	
Still water hull girder loads	γ_{S1}	Not applicable	Not applicable	1,00
Wave hull girder loads	γ_{W1}	Not applicable	Not applicable	1,15
Still water pressure	γ_{S2}	1,00	1,00	Not applicable
Wave pressure	γ_{W2}	1,20	1,20	Not applicable
Material	γ_m	1,02	1,02	1,02
Resistance	γ_R	1,20	1,05 **(2)**	1,10

(1) Applies also to plating of bulkheads or inner side which constitute boundary of compartments not intended to carry liquids.
(2) For plating of the collision bulkhead, γ_R =1,25.

1.4 Elementary plate panel

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

1.5 Load point

1.5.1 Unless otherwise specified, lateral pressure and hull girder stresses are to be calculated:

- for longitudinal framing, at the lower edge of the elementary plate panel or, in the case of horizontal plating, at the point of minimum y-value among those of the elementary plate panel considered
- for transverse framing, at the lower edge of the strake.

2 General requirements

2.1 General

2.1.1 The requirements in [2.2] and [2.3] are to be applied to plating in addition of those in [3] to [5].

2.2 Minimum net thicknesses

2.2.1 The net thickness of plating is to be not less than the values given in Tab 2.

2.3 Bilge plating

2.3.1 The bilge plating net thickness is to be not less than the net thickness obtained from:

- [3.3.1] for longitudinally framed bilges
- [3.4.1] for transversely framed bilges.

The net thickness of longitudinally framed bilge plating is to be not less than that required for the adjacent bottom or side plating, whichever is the greater.

The net thickness of transversely framed bilge plating may be taken not greater than that required for the adjacent bottom or side plating, whichever is the greater.

2.4 Sheerstrake

2.4.1 Welded sheerstrake

The net thickness of a welded sheerstrake is to be not less than that of the adjacent side plating, taking into account higher strength steel corrections if needed.

In general, the required net thickness of the adjacent side plating is to be taken as a reference. In specific case, depending on its actual net thickness, this latter may be required to be considered when deemed necessary by the Society.

2.4.2 Rounded sheerstrake

The net thickness of a rounded sheerstrake is to be not less than the actual net thickness of the adjacent deck plating.

2.4.3 Net thickness of the sheerstrake in way of breaks of long superstructures

The net thickness of the sheerstrake is to be increased in way of breaks of long superstructures occurring within 0,5L amidships, over a length of about one sixth of the ship's breadth on each side of the superstructure end.

This increase in net thickness is to be equal to 40%, without exceeding 4,5 mm.

Where the breaks of superstructures occur outside 0,5L amidships, the increase in net thickness may be reduced to 30%, without exceeding 2,5 mm.

2.4.4 Net thickness of the sheerstrake in way of breaks of short superstructures

The net thickness of the sheerstrake is to be increased in way of breaks of short superstructures occurring within 0,6L amidships, over a length of about one sixth of the ship's breadth on each side of the superstructure end.

This increase in net thickness is to be equal to 15%, without exceeding 4,5 mm.

Table 2 : Minimum net thickness of plating

Plating	Minimum net thickness, in mm
Keel	$5,1 + 0,026Lk^{1/2} + 4,5s$
Bottom	
• longitudinal framing	$3,2 + 0,018Lk^{1/2} + 4,5s$
• transverse framing	$4,1 + 0,018Lk^{1/2} + 4,5s$
Inner bottom	
• outside the engine room	$1,9 + 0,024Lk^{1/2} + 4,5s$
• engine room	$3,0 + 0,024Lk^{1/2} + 4,5s$
Side	
• below freeboard deck	$3,1 + 0,017Lk^{1/2} + 4,5s$
• between freeboard deck and strength deck	$3,0 + 0,004Lk^{1/2} + 4,5s$
Inner side	$1,7 + 0,013Lk^{1/2} + 4,5s$
Weather strength deck and trunk deck, if any	
• area within 0,4L amidships	
- longitudinal framing	$2,1 + 0,032Lk^{1/2} + 4,5s$
- transverse framing	$2,1 + 0,040Lk^{1/2} + 4,5s$
• area outside 0,4 L amidships	**(1)**
• between hatchways	$2,1 + 0,013Lk^{1/2} + 4,5s$
• at fore and aft part	$2,1 + 0,013Lk^{1/2} + 4,5s$
Cargo deck	
• general	$9,7sk^{1/2}$
• wheeled load only	4,5
Accommodation deck	$1,3 + 0,004Lk^{1/2} + 4,5s$
Platform in engine room	$1,7 + 0,013Lk^{1/2} + 4,5s$
Transverse watertight bulkhead	$1,3 + 0,004Lk^{1/2} + 4,5s$
Longitudinal watertight bulkhead	$1,7 + 0,013Lk^{1/2} + 4,5s$
Tank and wash bulkhead	$1,7 + 0,013Lk^{1/2} + 4,5s$

(1) The minimum net thickness is to be obtained by linearly interpolating between that required for the area within 0,4 L amidships and that at the fore and aft part.

2.5 Stringer plate

2.5.1 General

The net thickness of the stringer plate is to be not less than the actual net thickness of the adjacent deck plating.

2.5.2 Net thickness of the stringer plate in way of breaks of long superstructures

The net thickness of the stringer plate is to be increased in way of breaks of long superstructures occurring within 0,5L amidships, over a length of about one sixth of the ship's breadth on each side of the superstructure end.

This increase in net thickness is to be equal to 40%, without exceeding 4,5 mm.

Where the breaks of superstructures occur outside 0,5L amidships, the increase in net thickness may be reduced to 30%, without exceeding 2,5 mm.

2.5.3 Net thickness of the stringer plate in way of breaks of short superstructures

The net thickness of the stringer plate is to be increased in way of breaks of short superstructures occurring within 0,6L amidships, over a length of about one sixth of the ship's breadth on each side of the superstructure end.

This increase in net thickness is to be equal to 15%, without exceeding 4,5 mm.

3 Strength check of plating subjected to lateral pressure

3.1 General

3.1.1 The requirements of this Article apply for the strength check of plating subjected to lateral pressure and, for plating contributing to the longitudinal strength, to in-plane hull girder normal stresses.

3.2 Load model

3.2.1 General

The still water and wave lateral pressures induced by the sea and the various types of cargoes and ballast in intact conditions are to be considered, depending on the location of the plating under consideration and the type of the compartments adjacent to it, in accordance with Sec 1, [1.4].

The plating of bulkheads or inner side which constitute the boundary of compartments not intended to carry liquids is to be subjected to lateral pressure in flooding conditions.

3.2.2 Lateral pressure in intact conditions

The lateral pressure in intact conditions is constituted by still water pressure and wave pressure.

Still water pressure (p_S) includes:

- the still water sea pressure, defined in Sec 1, [4]
- the still water internal pressure, defined in Sec 1, [5.1] to Sec 1, [5.7] for the various types of cargoes and for ballast.

Wave pressure (p_W) includes:

- the wave pressure, defined in Sec 1, [4]
- the inertial pressure, defined in Sec 1, [5.1] to Sec 1, [5.7] for the various types of cargoes and for ballast.

3.2.3 Lateral pressure in flooding conditions

The lateral pressure in flooding conditions is constituted by the still water pressure p_{SF} and wave pressure p_{WF} defined in Sec 1, [5.8].

3.2.4 In-plane hull girder normal stresses

The in-plane hull girder normal stresses to be considered for the strength check of plating are obtained, at any hull transverse section, from the formulae in Tab 3.

3.3 Longitudinally framed plating contributing to the hull girder longitudinal strength

3.3.1 General

The net thickness of laterally loaded plate panels subjected to in-plane normal stress acting on the shorter sides is to be not less than the value obtained, in mm, from the following formula:

$$t = 14{,}9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{\lambda_L R_y}}$$

where:

$$\lambda_L = \sqrt{1 - 0{,}95\left(\gamma_m \frac{\sigma_{x1}}{R_y}\right)^2} - 0{,}225 \gamma_m \frac{\sigma_{x1}}{R_y}$$

3.3.2 Flooding conditions

The plating of bulkheads or inner side which constitute the boundary of compartments not intended to carry liquids is to be checked in flooding conditions. To this end, its net thickness is to be not less than the value obtained, in mm, from the following formula:

$$t = 14{,}9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{\lambda_L R_y}}$$

where λ_L is defined in [3.3.1].

Table 3 : Hull girder normal stresses

Condition		Hull girder normal stresses σ_{X1} , in N/mm²
Plating contributing to the hull girder longitudinal strength	$z = 0$	$\frac{[100 + 1{,}2(L_M - 65)]}{k_B} \frac{Z_{REQ}}{Z_{AB}} F_S$
	$0 < z < 0{,}25D$	$\sigma_{X1,B} - \frac{\sigma_{X1,B} - \sigma_{X1,N}}{0{,}25D} z$
	$0{,}25D \le z \le 0{,}75D$	$\frac{[50 + 0{,}6(L_M - 65)]}{k_N} F_S$
	$0{,}75D < z < D$	$\sigma_{X1,N} + \frac{\sigma_{X1,D} - \sigma_{X1,N}}{0{,}25D}(z - 0{,}75D)$
	$z \ge D$	$\frac{[100 + 1{,}2(L_M - 65)]}{k_D} \frac{Z_{REQ}}{Z_{AD}} F_S$
Plating not contributing to the hull girder longitudinal strength		0

Note 1:

- L_M : Ship's length, in m, defined in Ch 1, Sec 2, [3.1], but to be taken not less than 65 m
- Z_{REQ} : the greater of Z_R and $Z_{R,MIN}$, in m³, defined in Sec 2, [3.2]
- Z_{AB} ,Z_{AD} : Section moduli at bottom and deck, respectively, in m³, defined in Sec 2, [1.3], but to be taken not greater than $2Z_{REQ}$
- k_B, k_N, k_D: Material factor k for bottom, neutral axis area and deck, respectively
- F_S : Distribution factor defined in Tab 4 (see also Fig 1)
- $\sigma_{X1,B}$: Reference value σ_{X1} calculated for $z = 0$
- $\sigma_{X1,N}$: Reference value σ_{X1} calculated for $z = 0{,}5D$
- $\sigma_{X1,D}$: Reference value σ_{X1} calculated for $z = D$

Table 4 : Distribution factor F_S

Hull transverse section location	Distribution factor F_S
$0 \le x \le 0{,}1\ L$	0
$0{,}1\ L < x < 0{,}3\ L$	$5\frac{x}{L} - 0{,}5$
$0{,}3\ L \le x \le 0{,}7\ L$	1
$0{,}7\ L < x < 0{,}9\ L$	$4{,}5 - 5\frac{x}{L}$
$0{,}9\ L \le x \le L$	0

3.4 Transversely framed plating contributing to the hull girder longitudinal strength

3.4.1 General

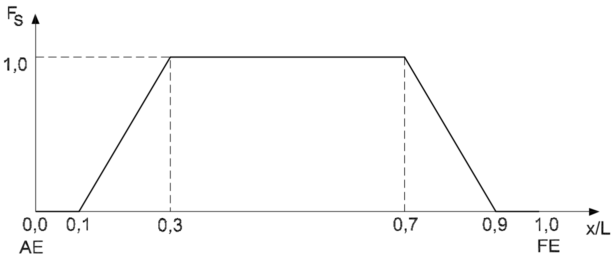
The net thickness of laterally loaded plate panels subjected to in-plane normal stress acting on the longer sides is to be not less than the value obtained, in mm, from the following formula:

$$t = 17{,}2 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{\lambda_T R_y}}$$

where:

$$\lambda_T = 1 - 0{,}89 \gamma_m \frac{\sigma_{x1}}{R_y}$$

Figure 1 : Distribution factor F_S



3.4.2 Flooding conditions

The plating of bulkheads or inner side which constitute the boundary of compartments not intended to carry liquids is to be checked in flooding conditions. To this end, its net thickness is to be not less than the value obtained, in mm, from the following formula:

$$t = 17{,}2 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{\lambda_T R_y}}$$

where λ_T is defined in [3.4.1].

3.5 Plating not contributing to the hull girder longitudinal strength

3.5.1 General

The net thickness of plate panels subjected to lateral pressure is to be not less than the value obtained, in mm, from the following formula:

$$t = 14{,}9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y}}$$

3.5.2 Flooding conditions

The plating of bulkheads or inner side which constitute the boundary of compartments not intended to carry liquids is to be checked in flooding conditions. To this end, its net thickness is to be not less than the value obtained, in mm, from the following formula:

$$t = 14,9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{R_y}}$$

4 Strength check of plating subjected to wheeled loads

4.1 General

4.1.1 The requirements of this Article apply for the strength check of plating subjected to wheeled loads.

4.2 Load model

4.2.1 General

The still water and inertial forces induced by the sea and the various types of wheeled vehicles are to be considered, depending on the location of the plating.

4.2.2 Wheeled forces

The wheeled force applied by one wheel is constituted by still water force and inertial force.

Still water force is the vertical force (F_S) defined in Sec 1, Tab 11.

Inertial force is the vertical force ($F_{W,Z}$) defined in Sec 1, Tab 11, for load case "b", with the acceleration a_{Z1} calculated at x = 0,5L.

4.3 Plating

4.3.1 The net thickness of plate panels subjected to wheeled loads is to be not less than the value obtained, in mm, from the following formula:

$$t = C_{WL}(n P_0 k)^{0,5} - t_c$$

where:

C_{WL} : Coefficient to be taken equal to:

$$C_{WL} = 2,15 - \frac{0,05\ell}{s} + 0,02\left(4 - \frac{\ell}{s}\right)\alpha^{0,5} - 1,75\alpha^{0,25}$$

where ℓ/s is to be taken not greater than 3

$\alpha = \frac{A_T}{\ell s}$ where ℓ is to be taken not greater than 5s

A_T : Tyre print area, in m² (see Fig 2). In the case of double or triple wheels, the area is that corresponding to the group of wheels.

n : Number of wheels on the plate panel, taken equal to:

- 1 in the case of a single wheel
- the number of wheels in a group of wheels in the case of double or triple wheels

P_0 : Wheeled force, in kN, taken equal to:

$$P_0 = \gamma_{S2} F_S + 0,4\gamma_{W2} F_{W,Z}$$

4.3.2 When the tyre print area is not known, it may be taken equal to:

$$A_T = \frac{n Q_A}{n_W p_T}$$

where:

n : Number of wheels on the plate panel, defined in [4.3.1]

Q_A : Axle load, in t

n_W : Number of wheels for the axle considered

p_T : Tyre pressure, in kN/m². When the tyre pressure is not indicated by the designer, it may be taken as defined in Tab 5.

Table 5 : Tyre pressures p_T for vehicles

Vehicle type	Tyre pressure p_T, in kN/m²	
	Pneumatic tyres	Solid rubber tyres
Private cars	250	Not applicable
Vans	600	Not applicable
Trucks and trailers	800	Not applicable
Handling machines	1100	1600

4.3.3 For vehicles with the four wheels of the axle located on a plate panel as shown in Fig 2, the net thickness of deck plating is to be not less than the greater of the values obtained, in mm, from the following formulae:

$$t = t_1$$

$$t = t_2(1 + \beta_2 + \beta_3 + \beta_4)^{0,5}$$

where:

t_1 : Net thickness obtained from [4.3.1] for n = 2, considering one group of two wheels located on the plate panel

t_2 : Net thickness obtained from [4.3.1] for n = 1, considering one wheel located on the plate panel

β_2, β_3, β_4: Coefficients obtained from the following formula, by replacing i by 2, 3 and 4, respectively (see Fig 2):

- for $x_i/b < 2$:

$$\beta_i = 0,8(1,2 - 2,02\alpha_i + 1,17\alpha_i^2 - 0,23\alpha_i^3)$$

- for $x_i/b \geq 2$:

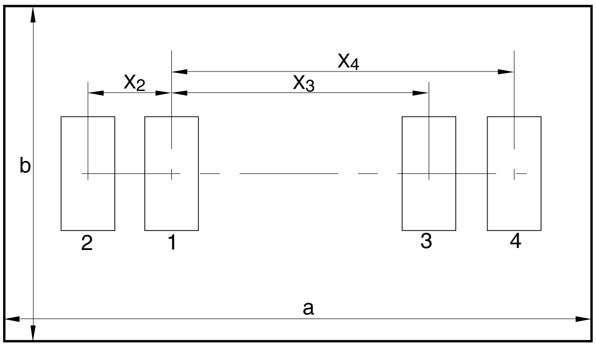
$$\beta_i = 0$$

x_i : Distance, in m, from the wheel considered to the reference wheel (see Fig 2)

b : Dimension, in m, of the plate panel side perpendicular to the axle

$$\alpha_i = \frac{x_i}{b}$$

Figure 2 : Four wheel axle located on a plate panel



5 Buckling check for ships equal to or greater than 65 m in length

5.1 General

5.1.1 Application

The requirements of this Article apply for the buckling check of plating subjected to in-plane hull girder compression stresses, in ships equal to or greater than 65m in length.

Rectangular plate panels are considered as being simply supported. For specific designs, other boundary conditions may be considered, at the Society's discretion, provided that the necessary information is submitted for review.

5.1.2 Compression and bending

For plate panels subjected to compression and bending along one side, as shown in Fig 3, side "b" is to be taken as the loaded side. In such case, the compression stress varies linearly from σ_1 to $\sigma_2 = \psi\, \sigma_1$ ($\psi \leq 1$) along edge "b".

5.2 Load model

5.2.1 Sign convention for normal stresses

The sign convention for normal stresses is as follows:

- tension: positive
- compression: negative.

5.2.2 In-plane hull girder compression normal stresses

The in-plane hull girder compression normal stresses to be considered for the buckling check of plating contributing to the longitudinal strength are obtained, in N/mm², from the following formula:

$$\sigma_{X1} = \gamma_{S1}\sigma_{S1} + \gamma_{W1}\sigma_{WV1}$$

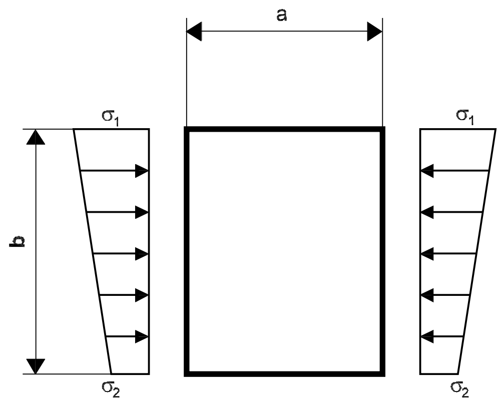
where σ_{S1} and σ_{WV1} are the hull girder normal stresses, in N/mm², defined in Tab 6.

σ_{X1} is to be taken as the maximum compression stress on the plate panel considered.

In no case may σ_{X1} be taken less than 30/k N/mm².

When the ship in still water is always in hogging condition, σ_{X1} may be evaluated by means of direct calculations when justified on the basis of the ship's characteristics and intended service. The calculations are to be submitted to the Society for approval.

Figure 3 : Buckling of a simply supported rectangular plate panel subjected to compression and bending



5.3 Critical stresses

5.3.1 Compression and bending for plane panel

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

$$\sigma_c = \sigma_E \qquad \text{for} \quad \sigma_E \leq \frac{R_{eH}}{2}$$

$$\sigma_c = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_E}\right) \qquad \text{for} \quad \sigma_E > \frac{R_{eH}}{2}$$

where:

σ_E : Euler buckling stress, to be obtained, in N/mm², from the following formula:

$$\sigma_E = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t_{net}}{b}\right)^2 K_1 \varepsilon$$

K_1 : Buckling factor defined in Tab 7

ε : Coefficient to be taken equal to:

- $\varepsilon = 1{,}00$ for $\alpha \geq 1$
- $\varepsilon = 1{,}05$ for $\alpha < 1$ and side "b" stiffened by flat bar
- $\varepsilon = 1{,}10$ for $\alpha < 1$ and side "b" stiffened by bulb section
- $\varepsilon = 1{,}21$ for $\alpha < 1$ and side "b" stiffened by angle or T-section
- $\varepsilon = 1{,}30$ for $\alpha < 1$ and side "b" stiffened by primary supporting members.

$\alpha = a/b$

Table 6 : Hull girder normal compression stresses

Condition	σ_{S1} , in N/mm² **(1)**	σ_{WV1} , in N/mm²
$z \geq N$	$\frac{M_{SW,S}}{I_Y}(z-N)10^{-3}$	$\frac{0,625 M_{WV,S}}{I_Y}(z-N)10^{-3}$
$z < N$	$\frac{M_{SW,H}}{I_Y}(z-N)10^{-3}$	$\frac{0,625 M_{WV,H}}{I_Y}(z-N)10^{-3}$
(1) When the ship in still water is always in hogging condition, σ_{S1} for $z \geq N$ is to be obtained, in N/mm², from the following formula, unless σ_{X1} is evaluated by means of direct calculations (see [5.2.2]): $\sigma_{S1} = \frac{M_{SW,Hmin}}{I_Y}(z-N)10^{-3}$		

5.3.2 Compression for corrugation flanges

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

$$\sigma_c = \sigma_E \qquad \text{for} \quad \sigma_E \leq \frac{R_{eH}}{2}$$

$$\sigma_c = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_E}\right) \qquad \text{for} \quad \sigma_E > \frac{R_{eH}}{2}$$

where:

σ_E : Euler buckling stress, to be obtained, in N/mm², from the following formula:

$$\sigma_E = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t_f}{V}\right)^2 K_5$$

K_5 : Buckling factor to be taken equal to:

$$K_5 = \left(1 + \frac{t_w}{t_f}\right)\left\{3 + 0,5\frac{V'}{V} - 0,33\left(\frac{V'}{V}\right)^2\right\}$$

t_f : Net thickness, in mm, of the corrugation flange

t_w : Net thickness, in mm, of the corrugation web

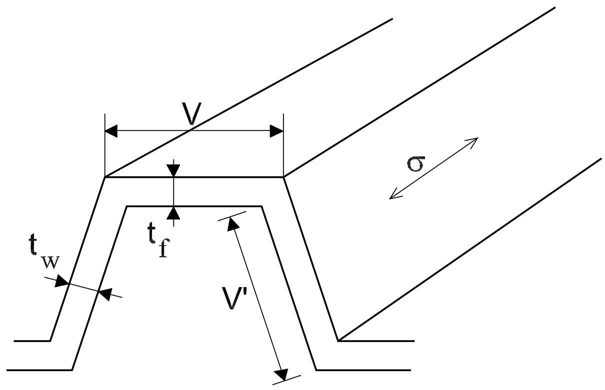
V, V′ : Dimensions of a corrugation, in mm, as shown in Fig 4.

5.4 Checking criteria

5.4.1 Acceptance of results

The net thickness of plate panels is to be such as to satisfy the buckling check, as indicated in [5.4.2]. When the buckling criteria is exceeded by less than 15 %, the scantlings may still be considered as acceptable, provided that the stiffeners located on the plate panel satisfy the buckling checks as specified in Sec 4, [4].

Figure 4 : Dimensions of a corrugation



5.4.2 Compression and bending

For plate panels subjected to compression and bending on one side, the critical buckling stress is to comply with the following formula:

$$\frac{\sigma_c}{\gamma_R \gamma_m} \geq |\sigma_b|$$

where:

σ_c : Critical buckling stress, in N/mm², defined in [5.3.1] or [5.3.2], as the case may be

σ_b : Compression stress, in N/mm², acting on side “b” of the plate panel, to be calculated as specified in [5.2.2].

Table 7 : Buckling factor K_1 for plate panels

Load pattern	Aspect ratio	Buckling factor K_1
$0 \le \psi \le 1$	$\alpha \ge 1$	$\dfrac{8,4}{\psi + 1,1}$
	$\alpha < 1$	$\left(\alpha + \dfrac{1}{\alpha}\right)^2 \dfrac{2,1}{\psi + 1,1}$
$-1 < \psi < 0$		$(1 + \psi)K_1' - \psi K_1'' + 10\psi(1 + \psi)$
$\psi \le -1$	$\alpha \dfrac{1-\psi}{2} \ge \dfrac{2}{3}$	$23,9\left(\dfrac{1-\psi}{2}\right)^2$
	$\alpha \dfrac{1-\psi}{2} < \dfrac{2}{3}$	$\left(15,87 + \dfrac{1,87}{\left(\alpha\dfrac{1-\psi}{2}\right)^2} + 8,6\left(\alpha\dfrac{1-\psi}{2}\right)^2\right)\left(\dfrac{1-\psi}{2}\right)^2$

Note 1:

$\psi = \dfrac{\sigma_2}{\sigma_1}$

K_1' : Value of K_1 calculated for $\psi = 0$

K_1'' : Value of K_1 calculated for $\psi = -1$

SECTION 4 ORDINARY STIFFENERS

Symbols

For symbols not defined in this Section, refer to the list at the beginning of this Chapter.

- p_S : Still water pressure, in kN/m², see [3.3.2]
- p_W : Wave pressure, in kN/m², see [3.3.2]
- p_{SF}, p_{WF} : Still water and wave pressure, in kN/m², in flooding conditions, defined in Sec 1, [5.8]
- F_S : Still water wheeled force, in kN, see [3.3.4]
- $F_{W,Z}$: Inertial wheeled force, in kN, see [3.3.4]
- σ_{X1} : Hull girder normal stress, in N/mm², defined in:
  - [3.3.5] for the yielding check of ordinary stiffeners
  - [4.2.2] for the buckling check of ordinary stiffeners for ships equal to or greater than 65 m in length
- R_{eH} : Minimum yield stress, in N/mm², of the stiffener material, defined in Ch 4, Sec 1, [2]
- s : Spacing, in m, of ordinary stiffeners
- ℓ : Span, in m, of ordinary stiffeners, measured between the supporting members, see Ch 4, Sec 3, [3.2]
- h_w : Stiffener web height, in mm
- t_w : Net web thickness, in mm
- b_f : Face plate width, in mm
- t_f : Net face plate thickness, in mm
- b_p : Width, in m, of the plating attached to the stiffener, for the yielding check, defined in Ch 4, Sec 3, [3.3.1]
- b_e : Width, in m, of the plating attached to the stiffener, for the buckling check, defined in [4.1]
- t_p : Net thickness, in mm, of the attached plating
- w : Net section modulus, in cm³, of the stiffener, with an attached plating of width b_p, to be calculated as specified in Ch 4, Sec 3, [3.4]
- A_e : Net sectional area, in cm², of the stiffener with attached plating of width b_e
- A_{Sh} : Net shear sectional area, in cm², of the stiffener, to be calculated as specified in Ch 4, Sec 3, [3.4]
- I_e : Net moment of inertia, in cm⁴, of the stiffener with attached shell plating of width b_e about its neutral axis parallel to the plating

$$\chi = \left(1 + 50\frac{\ell}{h_W}\right)^3$$

1 General

1.1 Application

1.1.1 For ships less than 65 m in length, the criteria in App 1 may be used for the strength check of ordinary stiffeners as an alternative to those contained in this Section.

1.2 Net scantlings

1.2.1 As specified in Ch 4, Sec 2, [1], all scantlings referred to in this section are net, i.e. they do not include any margin for corrosion.

The gross scantlings are obtained as specified in Ch 4, Sec 2.

1.3 Partial safety factors

1.3.1 The partial safety factors to be considered for the checking of the ordinary stiffeners are specified in Tab 1.

1.4 Load point

1.4.1 Lateral pressure

Unless otherwise specified, lateral pressure is to be calculated at mid-span of the ordinary stiffener considered.

1.4.2 Hull girder stresses

For longitudinal ordinary stiffeners contributing to the hull girder longitudinal strength, the hull girder bending stresses are to be calculated in way of the neutral axis of the stiffener considered.

1.5 Net dimensions of ordinary stiffeners

1.5.1 Flat bar

The net dimensions of a flat bar ordinary stiffener (see Fig 1) are to comply with the following requirements:

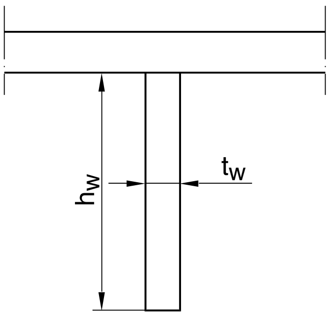
$$\frac{h_w}{t_w} \le 20\sqrt{k}$$

Table 1 : Ordinary stiffeners - Partial safety factors

Partial safety factors covering uncertainties regarding:	Symbol	Yielding check		Buckling check for L ≥ 65 m (see [4])
		General (see [3.3] to [3.5])	Watertight bulkhead ordinary stiffeners **(1)** (see [3.6])	
Still water hull girder loads	γ_{S1}	Not applicable	Not applicable	1,00
Wave hull girder loads	γ_{W1}	Not applicable	Not applicable	1,15
Still water pressure	γ_{S2}	1,00	1,00	Not applicable
Wave pressure	γ_{W2}	1,20	1,05	Not applicable
Material	γ_m	1,02	1,02	1,02
Resistance	γ_R	1,02	1,02 **(2)**	1,10

(1) Applies also to ordinary stiffeners of bulkheads or inner side which constitute boundary of compartments not intended to carry liquids.
(2) For ordinary stiffeners of the collision bulkhead, γ_R =1,25.

Figure 1 : Net dimensions of a flat bar



1.5.2 T-section

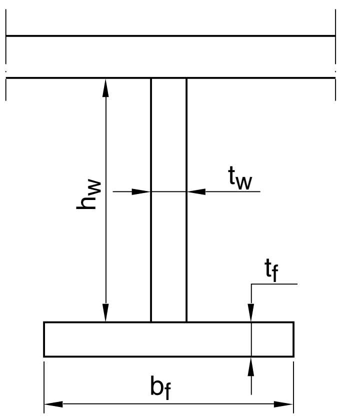
The net dimensions of a T-section ordinary stiffener (see Fig 2) are to comply with the following two requirements:

$$\frac{h_w}{t_w} \le 55\sqrt{k}$$

$$\frac{b_f}{t_f} \le 33\sqrt{k}$$

$$b_f t_f \ge \frac{h_w t_w}{6}$$

Figure 2 : Net dimensions of a T-section



1.5.3 Angle

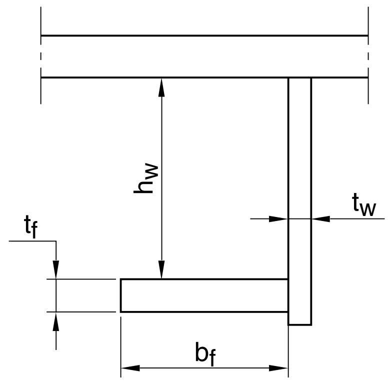
The net dimensions of an angle ordinary stiffener (see Fig 3) are to comply with the two following requirements:

$$\frac{h_w}{t_w} \le 55\sqrt{k}$$

$$\frac{b_f}{t_f} \le 16{,}5\sqrt{k}$$

$$b_f t_f \ge \frac{h_w t_w}{6}$$

Figure 3 : Net dimensions of an angle



2 General requirements

2.1 General

2.1.1 The requirements in [2.2] and [2.4] are to be applied to ordinary stiffeners in addition of those in [3] and [4].

2.2 Minimum net thicknesses

2.2.1 The net thickness of the web of ordinary stiffeners is to be not less than the lesser of:

- the value obtained, in mm, from the following formula:

  $t_{MIN} = (0{,}8 + 0{,}004Lk^{1/2} + 4{,}5s)\ c_T$
- the net as built thickness of the attached plating

where c_T is a coefficient equal to:

$$c_T = 0,7 + \frac{3T}{L} \quad \text{for} \quad L \le 25 m$$

$$c_T = 0,85 + \frac{2T}{L} \quad \text{for} \quad 25 m < L \le 40 m$$

$$c_T = 1,0 \quad \text{for} \quad L > 40 m$$

c_T may be taken not greater than 1,0.

2.3 Minimum net section modulus of side vertical ordinary stiffeners

2.3.1 The net section modulus of side vertical ordinary stiffeners is to be not less than the value obtained, in cm^3, from the following formula:

$$W_{MIN} = \alpha \cdot s \cdot \ell \cdot B^{1,5}$$

where:

α : Coefficient to be taken equal to:

- α = 0,75 for side vertical ordinary stiffeners located below the freeboard deck
- α = 0,65 for side vertical ordinary stiffeners located above the freeboard deck

In the area between 0,8 L from the aft end and the collision bulkhead, α is to be increased by 10%.

B : Breadth of the ship, in m, with:

- 6 m < B < 9 m for ships less than or equal to 50 m in length
- L/7 < B < L/6 for ships greater than 50 m in length.

2.4 Struts of open floors

2.4.1 The sectional area A_{ST}, in cm^2, and the moment of inertia I_{ST} about the main axes, in cm^4, of struts of open floors are to be not less than the values obtained from the following formulae:

$$A_{ST} = \frac{p_{ST} s \ell}{20}$$

$$I_{ST} = \frac{0,75 s \ell (p_{STB} + p_{STU}) A_{AST} \ell^2_{ST}}{47,2 A_{AST} - s \ell (p_{STB} + p_{STU})}$$

where:

p_{ST} : Pressure to be taken equal to the greater of the values obtained, in kN/m^2, from the following formulae:

$p_{ST} = 0,5 (p_{STB} + p_{STU})$

$p_{ST} = p_{STD}$

p_{STB} : Sea pressure, in kN/m^2, acting on the bottom in way of the strut equal to:

$p_{STB} = \gamma_{S2} p_S + \gamma_{W2} p_W$

p_{STU} : Pressure, in kN/m^2, acting on the inner bottom in way of the strut due to the load in the tank or hold above, equal to:

$p_{STU} = \gamma_{S2} p_S + \gamma_{W2} p_W$

p_{STD} : Pressure, in kN/m^2, in double bottom at mid-span of the strut equal to:

$p_{STD} = \gamma_{S2} p_S + \gamma_{W2} p_W$

ℓ : Span, in m, of transverse ordinary stiffeners constituting the open floor (see Ch 4, Sec 3, [3.2.2])

ℓ_{ST} : Length, in m, of the strut

A_{AST} : Actual net sectional area, in cm^2, of the strut.

3 Yielding check

3.1 General

3.1.1 The requirements of this Article apply for the yielding check of ordinary stiffeners subjected to lateral pressure or wheeled loads and, for ordinary stiffeners contributing to the hull girder longitudinal strength, to hull girder normal stresses.

3.1.2 The yielding check is also to be carried out for ordinary stiffeners subjected to specific loads, such as concentrated loads.

3.2 Structural model

3.2.1 Boundary conditions

The requirements in [3.4] and [3.6] apply to stiffeners considered as clamped at both ends, whose end connections comply with the requirements in [3.2.2].

The requirements in [3.5] apply to stiffeners considered as simply supported at both ends. Other boundary conditions may be considered by the Society on a case by case basis, depending on the distribution of wheeled loads.

For other boundary conditions, the yielding check will be considered on a case by case basis.

3.2.2 Bracket arrangement

The requirements of this Article apply to ordinary stiffeners without end brackets, with a 45° bracket at one end or with two 45° equal end brackets, where the bracket length is not less than 0,1ℓ.

In the case of ordinary stiffeners with two 45° end brackets of different length (in no case less than 0,1ℓ), the minimum section modulus and shear sectional area are considered by the Society on a case by case basis. In general, an acceptable solution consists in applying the criteria for equal brackets, considering both brackets as having length equal to 0,1ℓ.

In the case of significantly different bracket arrangement, the minimum section modulus and shear sectional area are considered by the Society on a case by case basis.

3.3 Load model

3.3.1 General

The still water and wave lateral loads induced by the sea and the various types of cargoes and ballast in intact conditions are to be considered, depending on the location of the ordinary stiffener under consideration and the type of the compartments adjacent to it, in accordance with Sec 1, [1.4].

Ordinary stiffeners of bulkheads or inner side which constitute the boundary of compartments not intended to carry liquids are to be subjected to the lateral pressure in flooding conditions.

3.3.2 Lateral pressure in intact conditions

Lateral pressure in intact conditions is constituted by still water pressure and wave pressure.

Still water pressure (p_S) includes:

- the still water sea pressure, defined in Sec 1, [4]
- the still water internal pressure, defined in Sec 1, [5.1] to Sec 1, [5.7] for the various types of cargoes and for ballast.

Wave pressure (p_W) includes:

- the wave pressure, defined in Sec 1, [4]
- the inertial pressure, defined in Sec 1, [5.1] to Sec 1, [5.7] for the various types of cargoes and for ballast.

3.3.3 Lateral pressure in flooding conditions

The lateral pressure in flooding conditions is constituted by the still water pressure p_{SF} and wave pressure p_{WF} defined in Sec 1, [5.8].

3.3.4 Wheeled forces

The wheeled force applied by one wheel is constituted by still water force and inertial force.

Still water force is the vertical force (F_S) defined in Sec 1, Tab 11.

Inertial force is the vertical force ($F_{W,Z}$) defined in Sec 1, Tab 11.

3.3.5 Hull girder normal stresses

The hull girder normal stresses to be considered for the yielding check of ordinary stiffeners are obtained, at any hull transverse section, from the formulae in Tab 2.

Table 2 : Hull girder normal stresses

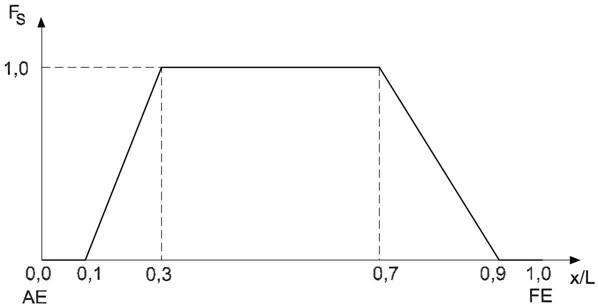
Condition		Hull girder normal stresses σ_{X1}, in N/mm²
Longitudinal ordinary stiffeners contributing to the hull girder longitudinal strength	$z = 0$	$\frac{[100 + 1{,}2(L_M - 65)]}{k_B} \frac{Z_{REQ}}{Z_{AB}} F_S$
	$0 < z < 0{,}25D$	$\sigma_{X1,B} - \frac{\sigma_{X1,B} - \sigma_{X1,N}}{0{,}25D} z$
	$0{,}25D \le z \le 0{,}75D$	$\frac{[50 + 0{,}6(L_M - 65)]}{k_N} F_S$
	$0{,}75D < z < D$	$\sigma_{X1,N} + \frac{\sigma_{X1,D} - \sigma_{X1,N}}{0{,}25D}(z - 0{,}75D)$
	$z \ge D$	$\frac{[100 + 1{,}2(L_M - 65)]}{k_D} \frac{Z_{REQ}}{Z_{AD}} F_S$
Longitudinal ordinary stiffeners not contributing to the hull girder longitudinal strength		0
Transverse ordinary stiffeners		0

Note 1:
L_M : Ship's length, in m, defined in Ch 1, Sec 2, [3.1], but to be taken not less than 65 m
Z_{REQ} : the greater of Z_R and $Z_{R,MIN}$, in m³, defined in Sec 2, [3.2]
Z_{AB},Z_{AD} : Section moduli at bottom and deck, respectively, in m³, defined in Sec 2, [1.3], but to be taken not less than $2Z_{REQ}$
k_B, k_N, k_D: Material factor k for bottom, neutral axis area and deck, respectively
F_S : Distribution factor defined in Tab 3 (see also Fig 4)
$\sigma_{X1,B}$: Reference value σ_{X1} calculated for $z = 0$
$\sigma_{X1,N}$: Reference value σ_{X1} calculated for $z = 0{,}5D$
$\sigma_{X1,D}$: Reference value σ_{X1} calculated for $z = D$

Table 3 : Distribution factor F_S

Hull transverse section location	Distribution factor F_S
$0 \le x \le 0,1\ L$	0
$0,1\ L < x < 0,3\ L$	$5\frac{x}{L} - 0,5$
$0,3\ L \le x \le 0,7\ L$	1
$0,7\ L < x < 0,9\ L$	$4,5 - 5\frac{x}{L}$
$0,9\ L \le x \le L$	0

Figure 4 : Distribution factor F_S



3.4 Net section modulus and net shear sectional area of ordinary stiffeners subjected to lateral pressure in intact condition

3.4.1 General

The requirements in [3.4.3] and [3.4.4] provide the required net section modulus and net shear sectional area of an ordinary stiffener subjected to lateral pressure in intact conditions.

3.4.2 Groups of equal ordinary stiffeners

Where a group of equal ordinary stiffeners is fitted, it is acceptable that the minimum net section modulus in [3.4.1] is calculated as the average of the values required for all the stiffeners of the same group, but this average is to be taken not less than 90% of the maximum required value.

The same applies for the minimum net shear sectional area.

3.4.3 Longitudinal and transverse ordinary stiffeners

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh}, in cm^2, of longitudinal or transverse ordinary stiffeners are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{12(R_y - \gamma_m \sigma_{X1})}\left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y}\left(1 - \frac{s}{2\ell}\right) s \ell$$

where β_b and β_s are the coefficients defined in Tab 4.

Table 4 : Coefficients β_b and β_s

End bracket arrangement	β_b	β_s
No bracket at ends	1,0	1,0
45° bracket of length not less than $0,1\ell$ at one end	$\frac{0,53\chi + 0,47}{0,65\chi + 0,34}$	$\frac{0,59\chi + 0,41}{0,65\chi + 0,34}$
45° equal brackets of length not less than $0,1\ell$ at both ends	$\frac{0,51\chi - 0,05}{0,8\chi + 0,2}$	0,8

3.4.4 Vertical ordinary stiffeners

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh}, in cm^2, of vertical ordinary stiffeners are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} \lambda_{bS} p_S + \gamma_{W2} \lambda_{bW} p_W}{12 R_y}\left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} \lambda_{sS} p_S + \gamma_{W2} \lambda_{sW} p_W}{R_y}\left(1 - \frac{s}{2\ell}\right) s \ell$$

where:

β_b, β_s : Coefficients defined in Tab 4

$$\lambda_{bS} = 1 + 0,2\frac{p_{Sd} - p_{Su}}{p_{Sd} + p_{Su}}$$

$$\lambda_{bW} = 1 + 0,2\frac{p_{Wd} - p_{Wu}}{p_{Wd} + p_{Wu}}$$

$$\lambda_{sS} = 1 + 0,4\frac{p_{Sd} - p_{Su}}{p_{Sd} + p_{Su}}$$

$$\lambda_{sW} = 1 + 0,4\frac{p_{Wd} - p_{Wu}}{p_{Wd} + p_{Wu}}$$

p_{Sd} : Still water pressure, in kN/m^2, at the lower end of the ordinary stiffener considered

p_{Su} : Still water pressure, in kN/m^2, at the upper end of the ordinary stiffener considered

p_{Wd} : Wave induced pressure, in kN/m^2, at the lower end of the ordinary stiffener considered.

p_{Wu} : Wave induced pressure, in kN/m^2, at the upper end of the ordinary stiffener considered

3.5 Net section modulus and net shear sectional area of ordinary stiffeners subjected to wheeled loads

3.5.1 The net section modulus w, in cm^3, and the net shear sectional area A_{Sh}, in cm^2, of ordinary stiffeners subjected to wheeled loads are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \frac{\alpha_S P_0 \ell}{4(R_y - \gamma_R \gamma_m \sigma_{X1})} 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \frac{\alpha_T P_0}{R_y}$$

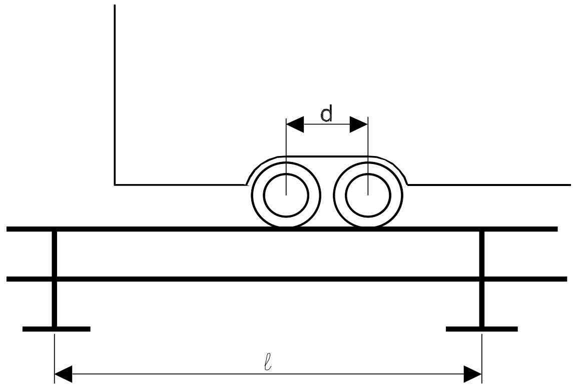
where:

P_0 : Wheeled force, in kN, taken equal to:

$$P_0 = \gamma_{S2} F_S + 0,4 \gamma_{W2} F_{W,Z}$$

α_S, α_T : Coefficients taking account of the number of axles and wheels per axle considered as acting on the stiffener, defined in Tab 5 (see Fig 5).

Figure 5 : Wheeled load on stiffeners - Double axles



3.6 Net section modulus and net shear sectional area of ordinary stiffeners subjected to lateral pressure in flooding conditions

3.6.1 General

The requirements in [3.6.1] to [3.6.4] apply to ordinary stiffeners of bulkheads or inner side which constitute boundary of compartments not intended to carry liquids.

These ordinary stiffeners are to be checked in flooding conditions as specified in [3.6.3] and [3.6.4], depending on the type of stiffener.

3.6.2 Groups of equal ordinary stiffeners

Where a group of equal ordinary stiffeners is fitted, it is acceptable that the minimum net section modulus in [3.6.1] is calculated as the average of the values required for all the stiffeners of the same group, but this average is to be taken not less than 90% of the maximum required value.

The same applies for the minimum net shear sectional area.

3.6.3 Longitudinal and transverse ordinary stiffeners

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh}, in cm^2, of longitudinal or transverse ordinary stiffeners are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{16 c_P (R_y - \gamma_m \sigma_{X1})} \left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{R_y} \left(1 - \frac{s}{2\ell}\right) s \ell$$

where:

β_b, β_s : Coefficients defined in [3.4.3]

c_P : Ratio of the plastic section modulus to the elastic section modulus of the ordinary stiffeners with an attached shell plating b_p, to be taken equal to 1,16 in the absence of more precise evaluation.

3.6.4 Vertical ordinary stiffeners

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh}, in cm^2, of vertical ordinary stiffeners are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} \lambda_{bS} p_{SF} + \gamma_{W2} \lambda_{bW} p_{WF}}{16 c_P R_y} \left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} \lambda_{sS} p_{SF} + \gamma_{W2} \lambda_{sW} p_{WF}}{R_y} \left(1 - \frac{s}{2\ell}\right) s \ell$$

where:

β_b, β_s : Coefficients defined in [3.4.3]

c_P : Ratio defined in [3.6.3]

$$\lambda_{bS} = 1 + 0{,}2 \frac{p_{SFd} - p_{SFu}}{p_{SFd} + p_{SFu}}$$

$$\lambda_{bW} = 1 + 0{,}2 \frac{p_{WFd} - p_{WFu}}{p_{WFd} + p_{WFu}}$$

$$\lambda_{sS} = 1 + 0{,}4 \frac{p_{SFd} - p_{SFu}}{p_{SFd} + p_{SFu}}$$

$$\lambda_{sW} = 1 + 0{,}4 \frac{p_{WFd} - p_{WFu}}{p_{WFd} + p_{WFu}}$$

p_{SFd} : Still water pressure, in kN/m^2, in flooding conditions, at the lower end of the ordinary stiffener considered

p_{SFu} : Still water pressure, in kN/m^2, in flooding conditions, at the upper end of the ordinary stiffener considered

p_{WFd} : Wave pressure, in kN/m^2, in flooding conditions, at the lower end of the ordinary stiffener considered.

p_{WFu} : Wave pressure, in kN/m^2, in flooding conditions, at the upper end of the ordinary stiffener considered

4 Buckling check for ships equal to or greater than 65 m in length

4.1 Width of attached plating

4.1.1 The width of the attached plating to be considered for the buckling check of the ordinary stiffeners is to be obtained, in m, from the following formulae:

- where no local buckling occurs on the attached plating (see Sec 3, [5.4.1]):

  $b_e = s$

- where local buckling occurs on the attached plating (see Sec 3, [5.4.1]):

  $$b_e = \left(\frac{2{,}25}{\beta_e} - \frac{1{,}25}{\beta_e^2}\right) s$$

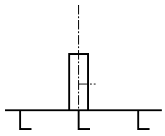
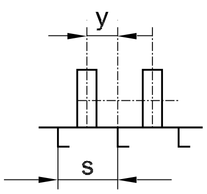
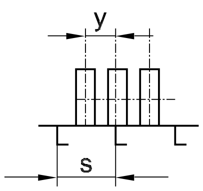
  to be taken not greater than s,

  where:

  $$\beta_e = \frac{s}{t_p} \sqrt{\frac{\sigma_b}{E}} 10^3$$

  σ_b : Compression stress σ_{X1}, in N/mm^2, acting on the plate panel, defined in Sec 3, [5.2.2].

Table 5 : Wheeled load on stiffeners - Coefficients α_S and α_T

Configuration	Single axle		Double axles	
	α_S	α_T	α_S	α_T
Single wheel 	1	1	$0,5\left(2-\frac{d}{\ell}\right)^2$	$2+\frac{d}{\ell}$
Double wheels 	$2\left(1-\frac{y}{s}\right)$	$2\left(1-\frac{y}{s}\right)$	$\left(1-\frac{y}{s}\right)\left(2-\frac{d}{\ell}\right)^2$	$2\left(1-\frac{y}{s}\right)\left(2+\frac{d}{\ell}\right)$
Triple wheels 	$3-2\frac{y}{s}$	$3-2\frac{y}{s}$	$0,5\left(3-2\frac{y}{s}\right)\left(2-\frac{d}{\ell}\right)^2$	$\left(3-2\frac{y}{s}\right)\left(2+\frac{d}{\ell}\right)$

Note 1:
d : Distance, in m, between two axles (see Fig 5)
y : Distance, in m, from the external wheel of a group of wheels to the stiffener under consideration, to be taken equal to the distance from the external wheel to the centre of the group of wheels.

4.2 Load model

4.2.1 Sign convention for normal stresses

The sign convention for normal stresses is as follows:

- tension: positive
- compression: negative.

4.2.2 Hull girder compression normal stresses

The hull girder compression normal stresses to be considered for the buckling check of ordinary stiffeners contributing to the hull girder longitudinal strength are obtained, in N/mm², from the following formula:

$$\sigma_{X1} = \gamma_{S1}\sigma_{S1} + \gamma_{W1}\sigma_{WV1}$$

where σ_{S1} and σ_{WV1} are the hull girder normal stresses, in N/mm², defined in Tab 6.

For longitudinal stiffeners, σ_{X1} is to be taken as the maximum compression stress on the stiffener considered.

In no case may σ_{X1} be taken less than 30/k N/mm².

When the ship in still water is always in hogging condition, σ_{X1} may be evaluated by means of direct calculations when justified on the basis of the ship's characteristics and intended service. The calculations are to be submitted to the Society for approval.

4.3 Critical stress

4.3.1 General

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

$$\sigma_c = \sigma_E \quad \text{for} \quad \sigma_E \le \frac{R_{eH}}{2}$$

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

where:

$\sigma_E = \min(\sigma_{E1}, \sigma_{E2})$

σ_{E1} : Euler column buckling stress, in N/mm², given in [4.3.2]

σ_{E2} : Euler web buckling stress, in N/mm², given in [4.3.3].

4.3.2 Column buckling of axially loaded stiffeners

The Euler column buckling stress is obtained, in N/mm², from the following formula:

$$\sigma_E = \pi^2 E \frac{I_e}{A_e \ell^2} 10^{-4}$$

4.3.3 Web buckling of axially loaded stiffeners

The Euler buckling stress of the stiffener web is obtained, in N/mm², from the following formulae:

- for flat bars:

$$\sigma_E = 16\left(\frac{t_W}{h_W}\right)^2 10^4$$

- for stiffeners with face plate:

$$\sigma_E = 78\left(\frac{t_W}{h_W}\right)^2 10^4$$

4.4 Checking criteria

4.4.1 Stiffeners parallel to the direction of compression

The critical buckling stress of the ordinary stiffener is to comply with the following formula:

$$\frac{\sigma_c}{\gamma_R \gamma_m} \geq |\sigma_b|$$

where:

σ_c : Critical buckling stress, in N/mm², as calculated in [4.3.1]

σ_b : Compression stress σ_{xb} or σ_{yb} , in N/mm², in the stiffener, as calculated in [4.2.2]].

4.4.2 Stiffeners perpendicular to the direction of compression

The net moment of inertia of stiffeners, in cm⁴, is to be not less than $400\ell^2$.

Table 6 : Hull girder normal compression stresses

Condition	σ_{S1} in N/mm² **(1)**	σ_{WV1} in N/mm²
$z \geq N$	$\frac{M_{SW,S}}{I_Y}(z-N)10^{-3}$	$\frac{0,625 M_{WV,S}}{I_Y}(z-N)10^{-3}$
$z < N$	$\frac{M_{SW,H}}{I_Y}(z-N)10^{-3}$	$\frac{0,625 M_{WV,H}}{I_Y}(z-N)10^{-3}$
(1) When the ship in still water is always in hogging condition, σ_{S1} for $z \geq N$ is to be obtained, in N/mm², from the following formula, unless σ_{X1} is evaluated by means of direct calculations (see [4.2.2]): $\sigma_{S1} = \frac{M_{SW,Hmin}}{I_Y}(z-N)10^{-3}$		

Figure 6 : Buckling of stiffeners perpendicular to the direction of compression

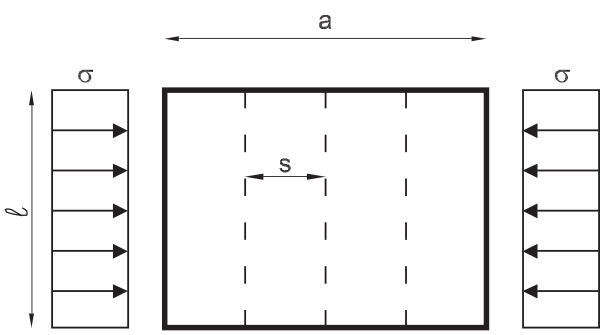
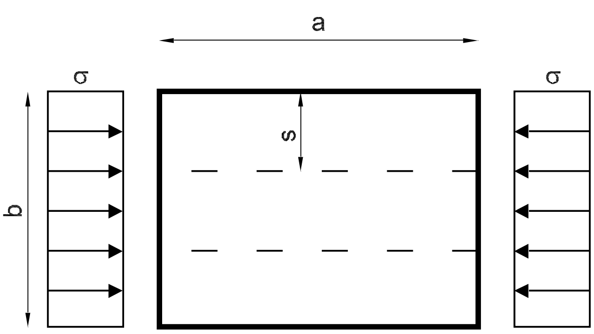


Figure 7 : Buckling of stiffeners parallel to the direction of compression



SECTION 5 PRIMARY SUPPORTING MEMBERS

Symbols

For symbols not defined in this Section, refer to the list at the beginning of this Chapter.

p_S : Still water pressure, in kN/m², see [3.4.2] and [3.4.4]

p_W : Wave pressure, in kN/m², see [3.4.2] and [3.4.4]

p_{SF}, p_{WF} : Still water and wave pressures, in kN/m², in flooding conditions, defined in Ch 8, Sec 1, [5.8]

σ_{X1} : Hull girder normal stress, in N/mm², defined in [3.4.5]

s : Spacing, in m, of primary supporting members

ℓ : Span, in m, of primary supporting members, measured between the supporting members, see Ch 4, Sec 3, [4.1]

h_W : Primary supporting member web height, in mm

b_p : Width, in m, of the plating attached to the primary supporting member, for the yielding check, as defined in Ch 4, Sec 3, [4.2]

w : Net section modulus, in cm³, of the primary supporting member, with an attached plating of width b_p, to be calculated as specified in Ch 4, Sec 3, [4.3]

A_{Sh} : Net shear sectional area, in cm², of the primary supporting member, to be calculated as specified in Ch 4, Sec 3, [4.3]

m : Boundary coefficient, to be taken equal to:

- m = 10 in general
- m = 12 for bottom and side girders

$$\chi = \left(1 + 50\frac{\ell}{h_W}\right)^3$$

1 General

1.1 Application

1.1.1 Ships less than 65 m in length

For ships less than 65 m in length, the criteria in App 1 may be used for the strength check of primary supporting members, as an alternative to those contained in this Section.

1.1.2 Analysis criteria

The requirements of this Section apply for the yielding and buckling checks of primary supporting members and analysed through an isolated beam structural model.

1.1.3 Direct calculations

Direct calculations may be required by the Society when deemed necessary on the basis of the ship's structural arrangement and load conditions. When required, these analyses are to be carried out according to the applicable requirements in Ch 7, Sec 3, Ch 7, App 1 or Ch 7, App 2.

1.2 Net scantlings

1.2.1 As specified in Ch 4, Sec 2, [1], all scantlings referred to in this section are net, i.e. they do not include any margin for corrosion.

The gross scantlings are obtained as specified in Ch 4, Sec 2.

1.3 Partial safety factors

1.3.1 The partial safety factors to be considered for checking primary supporting members are specified in Tab 1.

2 Minimum net thicknesses

2.1 General

2.1.1 The net thickness of plating which forms the webs of primary supporting members, with the exception of double bottom girders and floors for which specific requirements are given in [2.2], is to be not less than the lesser of:

- the value obtained, in mm, from the following formula:

  $t_{MIN} = (3,7 + 0,0015Lk^{1/2})\, c_T$
- the thickness of the attached plating

where c_T is a coefficient equal to:

$$c_T = 0,7 + \frac{3T}{L} \quad \text{for } L \le 25\,m$$

$$c_T = 0,85 + \frac{2T}{L} \quad \text{for } 25\,m < L \le 40\,m$$

$$c_T = 1,0 \quad \text{for } L > 40\,m$$

c_T may not be taken greater than 1,0.

Table 1 : Primary supporting members - Partial safety factors

Partial safety factors covering uncertainties regarding:	Symbol	Yielding check		Buckling check of pillars (see [4.1])
		General (see [3.4] and [3.5])	Watertight bulkhead primary supporting members **(1)** (see [3.6])	
Still water hull girder loads	γ_{S1}	Not applicable	Not applicable	1,00
Wave hull girder loads	γ_{W1}	Not applicable	Not applicable	1,15
Still water pressure	γ_{S2}	1,00	1,00	Not applicable
Wave pressure	γ_{W2}	1,20	1,05	Not applicable
Material	γ_m	1,02	1,02	1,02
Resistance	γ_R	1,02 in general 1,15 for bottom and side girders	1,02 **(2)**	2,00

(1) Applies also to primary supporting members of bulkheads or inner side which constitute boundary of compartments not intended to carry liquids.
(2) For primary supporting members of the collision bulkhead, γ_R =1,25

2.2 Double bottom

2.2.1 The net thickness of plating which forms primary supporting members of the double bottom is to be not less than the values given in Tab 2.

3 Yielding check

3.1 General

3.1.1 The requirements of this Article apply for the yielding check of primary supporting members subjected to lateral pressure or to wheeled loads and, for those contributing to the hull girder longitudinal strength, to hull girder normal stresses.

3.1.2 The yielding check is also to be carried out for primary supporting members subjected to specific loads, such as concentrated loads.

3.2 Bracket arrangement

3.2.1 The requirements of this Article apply to primary supporting members with 45° brackets at both ends of length not less than $0,1\ell$.

In the case of a significantly different bracket arrangement, the section modulus and shear sectional area are considered by the Society on a case by case basis.

3.3 Load point

3.3.1 Lateral pressure

Unless otherwise specified, lateral pressure is to be calculated at mid-span of the primary supporting member considered.

3.3.2 Hull girder normal stresses

For longitudinal primary supporting members contributing to the hull girder longitudinal strength, the hull girder normal stresses are to be calculated in way of the face plate of the primary supporting member considered.

For bottom and deck girders, it may generally be assumed that the hull girder normal stresses in the face plate are equal to 0,75 times those in the relevant plating.

3.4 Load model

3.4.1 General

The still water and wave lateral loads induced by the sea and the various types of cargoes and ballast in intact conditions are to be considered, depending on the location of the primary supporting member under consideration and the type of compartments adjacent to it, in accordance with Sec 1, [1.4].

Primary supporting members of bulkheads or inner side which constitute the boundary of compartments not intended to carry liquids are to be subjected to the lateral pressure in flooding conditions.

3.4.2 Lateral pressure in intact conditions

Lateral pressure in intact conditions is constituted by still water pressure and wave pressure.

Still water pressure (p_S) includes:

- the still water sea pressure, defined in Sec 1, [4]
- the still water internal pressure, defined in Sec 1, [5.1] to Sec 1, [5.7] for the various types of cargoes and for ballast.

Wave pressure (p_W) includes:

- the wave pressure, defined in Sec 1, [4]
- the inertial pressure, defined in Sec 1, [5.1] to Sec 1, [5.7] for the various types of cargoes and for ballast.

Table 2 : Minimum net thicknesses of double bottom primary supporting members

Primary supporting member	Minimum net thickness, in mm	
	Area within 0,4L amidships	Area outside 0,4L amidships
Centre girder	$2,1\ L^{1/3}\ k^{1/6}$	$1,7\ L^{1/3}\ k^{1/6}$
Side girders	$1,4\ L^{1/3}\ k^{1/6}$	$1,4\ L^{1/3}\ k^{1/6}$
Floors	$1,4\ L^{1/3}\ k^{1/6}$	$1,4\ L^{1/3}\ k^{1/6}$

3.4.3 Lateral pressure in flooding conditions

The lateral pressure in flooding conditions is constituted by the still water pressure p_{SF} and the wave pressure p_{WF} defined in Sec 1, [5.8].

3.4.4 Wheeled loads

For primary supporting members subjected to wheeled loads, the yielding check may be carried out according to [3.5] considering uniform pressures equivalent to the distribution of vertical concentrated forces, when such forces are closely located.

For the determination of the equivalent uniform pressures, the most unfavourable case, i.e. where the maximum number of axles are located on the same primary supporting member, according to Fig 1 to Fig 3, is to be considered.

The equivalent still water pressure and inertial pressure are indicated in Tab 2.

3.4.5 Hull girder normal stresses

The hull girder normal stresses to be considered for the yielding check of primary supporting members are obtained, at any hull transverse section, from the formulae in Tab 3.

Figure 1 : Wheeled loads - Distribution of vehicles on a primary supporting member

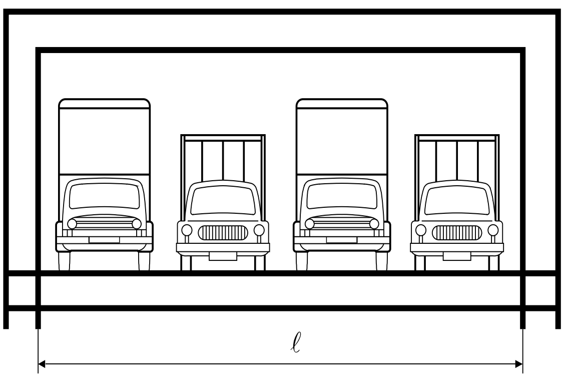


Figure 2 : Wheeled loads
Distance between two consecutive axles

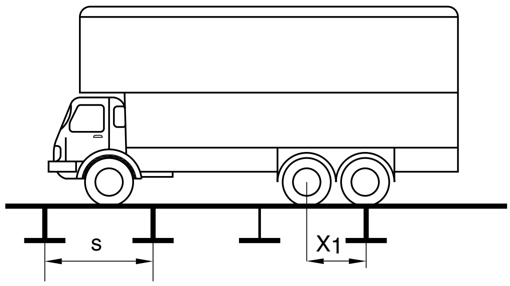


Figure 3 : Wheeled loads - Distance between axles of two consecutive vehicles

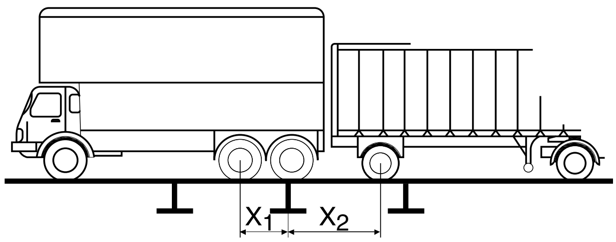


Table 3 : Wheeled loads
Equivalent uniform still water and inertial pressures

Still water pressure p_S , in kN/m²	Inertial pressure p_W , in kN/m²
$10\ p_{eq}$	$p_{eq}\ a_{Z1}$

Note 1:

$$p_{eq} = \frac{n_V Q_A}{\ell s}\left(3 - \frac{X_1 + X_2}{s}\right)$$

- n_V : Maximum number of vehicles possible located on the primary supporting member
- Q_A : Maximum axle load, in t, as defined in Sec 1, [5.5]
- X_1 : Minimum distance, in m, between 2 consecutive axles (see Fig 2 and Fig 3
- X_2 : Minimum distance, in m, between axles of 2 consecutive vehicles (see Fig 3).

Table 4 : Hull girder normal stresses

Condition		Hull girder normal stresses σ_{X1}, in N/mm²
Longitudinal primary supporting members contributing to the hull girder longitudinal strength	$z = 0$	$\frac{[100 + 1,2(L_M - 65)]}{k_B}\frac{Z_{REQ}}{Z_{AB}}F_S$
	$0 < z < 0,25D$	$\sigma_{X1,B} - \frac{\sigma_{X1,B} - \sigma_{X1,N}}{0,25D}z$
	$0,25D \le z \le 0,75D$	$\frac{[50 + 0,6(L_M - 65)]}{k_N}F_S$
	$0,75D < z < D$	$\sigma_{X1,N} + \frac{\sigma_{X1,D} - \sigma_{X1,N}}{0,25D}(z - 0,75D)$
	$z \ge D$	$\frac{[100 + 1,2(L_M - 65)]}{k_D}\frac{Z_{REQ}}{Z_{AD}}F_S$
Longitudinal primary supporting members not contributing to the hull girder longitudinal strength		0
Transverse primary supporting members		0

Note 1:
- L_M : Ship's length, in m, as defined in Ch 1, Sec 2, [3.1], but to be taken not less than 65 m
- Z_{REQ} : the greater of Z_R and $Z_{R,MIN}$, in m³, defined in Sec 2, [3.2]
- Z_{AB},Z_{AD} : Section moduli at bottom and deck, respectively, in m³, defined in Sec 2, [1.3], but to be taken not less than $2Z_{REQ}$
- k_B, k_N, k_D: Material factor k for bottom, neutral axis area and deck, respectively
- F_S : Distribution factor defined in Tab 5 (see also Fig 4)
- $\sigma_{X1,B}$: Reference value σ_{X1} calculated for z = 0
- $\sigma_{X1,N}$: Reference value σ_{X1} calculated for z = 0,5D
- $\sigma_{X1,D}$: Reference value σ_{X1} calculated for z = D

Table 5 : Distribution factor F_S

Hull transverse section location	Distribution factor F_S
$0 \le x \le 0,1$ L	0
0,1 L < x < 0,3 L	$5\frac{x}{L} - 0,5$
$0,3$ L $\le x \le 0,7$ L	1
0,7 L < x < 0,9 L	$4,5 - 5\frac{x}{L}$
$0,9$ L $\le x \le$ L	0

3.5 Net section modulus and net sectional shear area of primary supporting members subjected to lateral pressure in intact conditions

3.5.1 General

The requirements in [3.5.2] and [3.5.3] provide the minimum net section modulus and net shear sectional area of primary supporting members subjected to lateral pressure in intact conditions.

3.5.2 Longitudinal and transverse primary supporting members

The net section modulus w, in cm³, and the net shear sectional area A_{Sh}, in cm², of longitudinal or transverse primary supporting members are to be not less than the values obtained from the following formulae:

$$w = \gamma_R\gamma_m\beta_b\frac{\gamma_{S2}p_S + \gamma_{W2}p_W}{m(R_y - \gamma_R\gamma_m\sigma_{X1})}s\ell^2 10^3$$

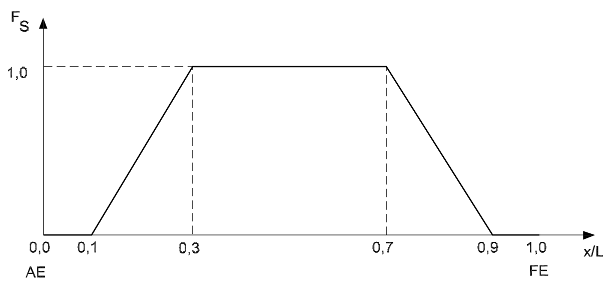
$$A_{Sh} = 10\gamma_R\gamma_m\beta_s\frac{\gamma_{S2}p_S + \gamma_{W2}p_W}{R_y}s\ell$$

where:

$$\beta_b = \frac{0,51\chi - 0,05}{0,8\chi + 0,2}$$

$$\beta_s = 0,8$$

Figure 4 : Distribution factor F_S



3.5.3 Vertical primary supporting members

The net section modulus w, in cm³, and the net shear sectional area A_{Sh}, in cm², of vertical primary supporting members are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2}\lambda_{bS} p_S + \gamma_{W2}\lambda_{bW} p_W}{m(R_y - \gamma_R \gamma_m \sigma_A)} s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2}\lambda_{sS} p_S + \gamma_{W2}\lambda_{sW} p_W}{R_y} s \ell$$

where:

β_b, β_s : Coefficients defined in [3.5.2]

$$\lambda_{bS} = 1 + 0{,}2 \frac{p_{Sd} - p_{Su}}{p_{Sd} + p_{Su}}$$

$$\lambda_{bW} = 1 + 0{,}2 \frac{p_{Wd} - p_{Wu}}{p_{Wd} + p_{Wu}}$$

$$\lambda_{sS} = 1 + 0{,}4 \frac{p_{Sd} - p_{Su}}{p_{Sd} + p_{Su}}$$

$$\lambda_{sW} = 1 + 0{,}4 \frac{p_{Wd} - p_{Wu}}{p_{Wd} + p_{Wu}}$$

p_{Sd} : Still water pressure, in kN/m², at the lower end of the primary supporting member considered

p_{Su} : Still water pressure, in kN/m², at the upper end of the primary supporting member considered

p_{Wd} : Wave pressure, in kN/m², at the lower end of the primary supporting member considered

p_{Wu} : Wave pressure, in kN/m², at the upper end of the primary supporting member considered

σ_A : Axial stress, to be obtained, in N/mm², from the following formula:

$$\sigma_A = 10 \frac{F_A}{A}$$

F_A : Axial load (still water and wave) transmitted to the vertical primary supporting members by the structures above. For multideck ships, the criteria in [4.1.1] for pillars are to be adopted.

A : Net sectional area, in cm², of the vertical primary supporting members with attached plating of width b_P.

3.6 Net section modulus and net shear sectional area of primary supporting members subjected to lateral pressure in flooding conditions

3.6.1 General

The requirements in [3.6.1] to [3.6.3] apply to primary supporting members of bulkheads or inner side which constitute the boundary of compartments not intended to carry liquids.

These primary supporting members are to be checked in flooding conditions as specified in [3.6.2] and [3.6.3], depending on the type of member.

3.6.2 Longitudinal and transverse primary supporting members

The net section modulus w, in cm³, and the net shear sectional area A_{Sh}, in cm², of longitudinal or transverse primary supporting members are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{16 c_P (R_y - \gamma_m \sigma_{X1})} s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{R_y} s \ell$$

where:

β_b, β_s : Coefficients defined in [3.5.2]

c_P : Ratio of the plastic section modulus to the elastic section modulus of the primary supporting members with an attached shell plating b_p, to be taken equal to 1,16 in the absence of more precise evaluation.

3.6.3 Vertical primary supporting members

The net section modulus w, in cm³, and the net shear sectional area A_{Sh}, in cm², of vertical primary supporting members are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2}\lambda_{bS} p_{SF} + \gamma_{W2}\lambda_{bW} p_{WF}}{16 c_P R_y} s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2}\lambda_{sS} p_{SF} + \gamma_{W2}\lambda_{sW} p_{WF}}{R_y} s \ell$$

where:

β_b, β_s : Coefficients defined in [3.5.2]

c_P : Ratio defined in [3.6.2]

$$\lambda_{bS} = 1 + 0{,}2 \frac{p_{SFd} - p_{SFu}}{p_{SFd} + p_{SFu}}$$

$$\lambda_{bW} = 1 + 0{,}2 \frac{p_{WFd} - p_{WFu}}{p_{WFd} + p_{WFu}}$$

$$\lambda_{sS} = 1 + 0{,}4 \frac{p_{SFd} - p_{SFu}}{p_{SFd} + p_{SFu}}$$

$$\lambda_{sW} = 1 + 0{,}4 \frac{p_{WFd} - p_{WFu}}{p_{WFd} + p_{WFu}}$$

p_{SFd} : Still water pressure, in kN/m², in flooding conditions, at the lower end of the primary supporting member considered

p_{SFu} : Still water pressure, in kN/m², in flooding conditions, at the upper end of the primary supporting member considered

p_{WFd} : Wave pressure, in kN/m², in flooding conditions, at the lower end of the primary supporting member considered.

p_{WFu} : Wave pressure, in kN/m², in flooding conditions, at the upper end of the primary supporting member considered

4 Buckling check

4.1 Buckling of pillars subjected to compression axial load

4.1.1 Compression axial load

The compression axial load in the pillar is to be obtained, in kN, from the following formula:

$$F_A = A_D(\gamma_S p_S + \gamma_W p_W) + \sum_i r(\gamma_S Q_{i,S} + \gamma_W Q_{i,W})$$

where:

A_D : Area, in m², of the portion of the deck or the platform supported by the pillar considered

r : Coefficient which depends on the relative position of each pillar above the one considered, to be taken equal to:

- r = 1,0 for the pillar considered
- r = 0,9 for the pillar immediately above that considered
- r = $0,9^i$ for the i^{th} pillar of the line above the pillar considered, to be taken not less than 0,478

$Q_{i,S}$,$Q_{i,W}$: Still water and wave load, respectively, in kN, from the i^{th} pillar of the line above the pillar considered, if any.

4.1.2 Critical column buckling stress of pillars

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

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

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

where:

σ_{E1} : Euler column buckling stress, to be obtained, in N/mm², from the following formula:

$$\sigma_{E1} = \pi^2 E \frac{I}{A(f\ell)^2} 10^{-4}$$

I : Minimum net moment of inertia, in cm⁴, of the pillar

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

ℓ : Span, in m, of the pillar

f : Coefficient, to be obtained from Tab 5.

4.1.3 Critical torsional buckling stress of built-up pillars

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

$$\sigma_{cT} = \sigma_{E2} \qquad \text{for} \quad \sigma_{E2} \le \frac{R_{eH}}{2}$$

$$\sigma_{cT} = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_{E2}}\right) \qquad \text{for} \quad \sigma_{E2} > \frac{R_{eH}}{2}$$

where:

σ_{E2} : Euler torsional buckling stress, to be obtained, in N/mm², from the following formula:

$$\sigma_{E2} = \frac{\pi^2 E I_w}{10^4 I_p \ell^2} + 0{,}41 E \frac{I_t}{I_p}$$

I_w : Net sectorial moment of inertia of the pillar, to be obtained, in cm⁶, from the following formula:

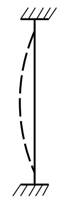
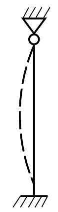
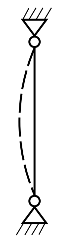
$$I_w = \frac{t_f b_f^3 h_w^2}{24} 10^{-6}$$

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

Table 6 : Coefficient f

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

t_F : Net face plate thickness of built-up section, in mm

I_p : Net polar moment of inertia of the pillar, to be obtained, in cm⁴, from the following formula:

$$I_P = I_{XX} + I_{YY}$$

I_{XX} : Net moment of inertia about the XX axis of the pillar section (see Fig 5)

I_{YY} : Net moment of inertia about the YY axis of the pillar section (see Fig 5)

I_t : St. Venant's net moment of inertia of the pillar, to be obtained, in cm⁴, from the following formula:

$$I_t = \frac{1}{3}[h_w t_w^3 + 2 b_f t_f^3] 10^{-4}$$

4.1.4 Critical local buckling stress of built-up pillars

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

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

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

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:

- $\sigma_{E3} = 78\left(\frac{t_W}{h_W}\right)^2 10^4$
- $\sigma_{E3} = 32\left(\frac{t_F}{b_F}\right)^2 10^4$

t_W, h_W, t_F, b_F : Dimensions, in mm, of the built-up section defined in [4.1.3].

4.1.5 Critical local buckling stress of pillars having hollow rectangular section

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

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

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

where:

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

- $\sigma_{E4} = 78\left(\frac{t_2}{b}\right)^2 10^4$
- $\sigma_{E4} = 78\left(\frac{t_1}{h}\right)^2 10^4$

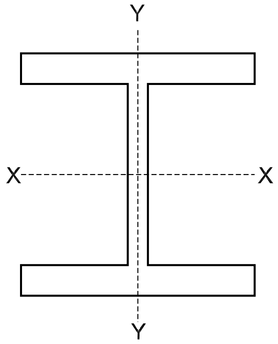
b : Length, in mm, of the shorter side of the section

t_2 : Net web thickness, in mm, of the shorter side of the section

h : Length, in mm, of the longer side of the section

t_1 : Net web thickness, in mm, of the longer side of the section.

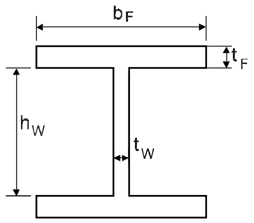
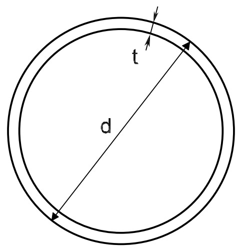
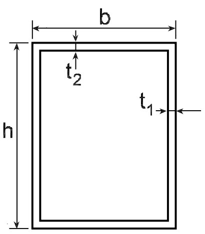
Figure 5 : Reference axes for the calculation of the moments of inertia of a built-up section



4.1.6 Checking criteria

The net scantlings of the pillar loaded by the compression axial stress F_A defined in [4.1.1] are to comply with the formulae in Tab 7.

Table 7 : Buckling check of pillars subjected to with compression axial stress

Pillar cross-section	Column buckling check	Torsional buckling check	Local buckling check	Geometric condition
Built-up 	$\frac{\sigma_{cB}}{\gamma_R\gamma_m} \ge 10\frac{F_A}{A}$	$\frac{\sigma_{cT}}{\gamma_R\gamma_m} \ge 10\frac{F_A}{A}$	$\frac{\sigma_{cL}}{\gamma_R\gamma_m} \ge 10\frac{F_A}{A}$	$\frac{b_F}{t_F} \le 40$
Hollow tubular 	$\frac{\sigma_{cB}}{\gamma_R\gamma_m} \ge 10\frac{F_A}{A}$	Not required	Not required	• $\frac{d}{t} \le 55$ • $t \ge 5{,}5$ mm
Hollow rectangular 	$\frac{\sigma_{cB}}{\gamma_R\gamma_m} \ge 10\frac{F_A}{A}$	Not required	$\frac{\sigma_{cL}}{\gamma_R\gamma_m} \ge 10\frac{F_A}{A}$	• $\frac{b}{t_2} \le 55$ • $\frac{h}{t_1} \le 55$ • t_1, $t_2 \ge 5{,}5$ mm

Note 1:

σ_{cB} : Critical column buckling stress, in N/mm^2, defined in [4.1.2]

σ_{cT} : Critical torsional buckling stress, in N/mm^2, defined in [4.1.3]

σ_{cL} : Critical local buckling stress, in N/mm^2, defined in [4.1.4] for built-up section or in [4.1.5] for hollow rectangular section

F_A : Compression axial load in the pillar, in kN, defined in [4.1.1]

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

Part B
Hull and Stability

Chapter 9
OTHER STRUCTURES

SECTION 1 FORE PART

Symbols

L_1, L_2 : Lengths, in m, defined in Ch 1, Sec 2, [2.1.1]

n : Navigation coefficient, defined in Ch 5, Sec 1, [2.6] or Ch 8, Sec 1, [1.5]

h_1 : Reference value of the ship relative motion, defined in Ch 5, Sec 3, [3.3] or Ch 8, Sec 1, [3.3]

a_{Z1} : Reference value of the vertical acceleration, defined in Ch 5, Sec 3, [3.4] or Ch 8, Sec 1, [3.3]

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

g : Gravity acceleration, in m/s^2:

$g = 9{,}81$ m/s^2

x, y, z : X, Y and Z co-ordinates, in m, of the calculation point with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [4]

p_S, p_W : Still water pressure and wave pressure defined in [2.3]

p_{BI} : Bottom impact pressure, defined in [3.2]

p_{FI} : Bow impact pressure, defined in [4.3]

k : Material factor, defined in Ch 4, Sec 1, [2.3]

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

s : Spacing, in m, of ordinary stiffeners or primary supporting members, as applicable

ℓ : Span, in m, of ordinary stiffeners or primary supporting members, as applicable

c_a : Aspect ratio of the plate panel, equal to:

$$c_a = 1{,}21\sqrt{1+0{,}33\left(\frac{s}{\ell}\right)^2} - 0{,}69\frac{s}{\ell}$$

to be taken not greater than 1,0

c_r : Coefficient of curvature of the panel, equal to:

$$c_r = 1 - 0{,}5\,s/r$$

to be taken not less than 0,75

r : Radius of curvature, in m

β_b, β_s : Coefficients defined in Ch 7, Sec 2, [3.7.3]

λ_{bS}, λ_{bW}, λ_{sS}, λ_{sW}: Coefficients defined in Ch 7, Sec 2, [3.4.5]

c_E : Coefficient to be taken equal to:

$c_E = 1$ for $L \le 65$ m

$c_E = 3 - L / 32{,}5$ for $65 \text{ m} < L < 90$ m

$c_E = 0$ for $L \ge 90$ m

c_F : Coefficient to be taken equal to:

$c_F = 0{,}9$ for forecastle sides

$c_F = 1{,}0$ in other cases.

1 General

1.1 Application

1.1.1 The requirements of this Section apply for the scantling of structures located forward of the collision bulkhead, i.e.:

- fore peak structures
- reinforcements of the flat bottom forward area
- reinforcements of the bow flare area
- stems.

1.1.2 Fore peak structures which form the boundary of spaces not intended to carry liquids, and which do not belong to the outer shell, are to be subjected to lateral pressure in flooding conditions. Their scantlings are to be determined according to the relevant criteria in Chapter 7 or Chapter 8, as applicable.

1.1.3 For ships less than 65 m in length, the criteria in Ch 8, App 1 may be used for the strength check of plating and ordinary stiffeners as an alternative to those in [2.4.1], [2.5.1], [2.6.1], [2.7.1] and [2.8.1].

1.2 Connections of the fore part with structures located aft of the collision bulkhead

1.2.1 Tapering

Adequate tapering is to be ensured between the scantlings in the fore part and those aft of the collision bulkhead. The tapering is to be such that the scantling requirements for both areas are fulfilled.

1.2.2 Supports of fore peak structures

Aft of the collision bulkhead, side girders are to be fitted as specified in Ch 4, Sec 5, [2.2] or Ch 4, Sec 5, [3.2], as applicable.

1.3 Net scantlings

1.3.1 As specified in Ch 4, Sec 2, [1], all scantlings referred to in this Section are net, i.e. they do not include any margin for corrosion.

Gross scantlings are obtained as specified in Ch 4, Sec 2.

2 Fore peak

2.1 Partial safety factors

2.1.1 The partial safety factors to be considered for checking fore peak structures are specified in Tab 1.

Table 1 : Fore peak structures - Partial safety factors

Partial safety factors covering uncertainties regarding:	Partial safety factors			
	Symbol	Plating	Ordinary stiffeners	Primary supporting members
Still water pressure	γ_{S2}	1,00	1,00	1,00
Wave induced pressure	γ_{W2}	1,20	1,20	1,20
Material	γ_m	1,02	1,02	1,02
Resistance	γ_R	1,20	1,40	1,60

2.2 Load point

2.2.1 Unless otherwise specified, lateral pressure is to be calculated at:

- the lower edge of the elementary plate panel considered, for plating
- mid-span, for stiffeners.

2.3 Load model

2.3.1 General

The still water and wave lateral pressures in intact conditions are to be considered. They are to be calculated as specified in [2.3.2] for the elements of the outer shell and in [2.3.3] for the other elements.

Still water pressure (p_S) includes:

- the still water sea pressure, defined in Tab 2
- the still water internal pressure due to liquids or ballast, defined in Tab 4
- for decks, the still water internal pressure due to uniform loads, defined in Tab 5.

Wave pressure (p_W) includes:

- the wave pressure, defined in Tab 2
- the inertial internal pressure due to liquids or ballast, defined in Tab 4
- for decks, the inertial internal pressure due to uniform loads, defined in Tab 5.

2.3.2 Lateral pressures for the elements of the outer shell

The still water and wave lateral pressures are to be calculated considering separately:

- the still water and wave external sea pressures
- the still water and wave internal pressures, considering the compartment adjacent to the outer shell as being loaded.

If the compartment adjacent to the outer shell is not intended to carry liquids, only the external sea pressures are to be considered.

Table 2 : Still water and wave pressures

Location	Still water sea pressure p_S, in kN/m²	Wave pressure p_W, in kN/m²
Bottom and side below the waterline: $z \le T$	$\rho g(T - z)$	$\rho g h_1 e^{\frac{-2\pi(T-z)}{L}}$
Side above the waterline: $z > T$	0	$\rho g(T + h_1 - z)$ without being taken less than 0,15L
Exposed deck	Pressure due to the load carried **(1)**	$19{,}6 n\varphi\sqrt{H}$

(1) The pressure due to the load carried is to be defined by the Designer and, in any case, it may not be taken less than 10φ kN/m², where φ is defined in Tab 3.
The Society may accept pressure values lower than 10φ kN/m² when considered appropriate on the basis of the intended use of the deck.

Note 1:

φ : Coefficient defined in Tab 3

$$H = \left[2{,}66\left(\frac{x}{L} - 0{,}7\right)^2 + 0{,}14\right]\sqrt{\frac{VL}{C_B}} - (z - T)$$

without being taken less than 0,8

V : Maximum ahead service speed, in knots, to be taken not less than 13 knots.

Table 3 : Coefficient for pressure on exposed deck

Exposed deck location	φ
Freeboard deck	1
Superstructure deck	0,75
1st tier of deckhouse	0,56
2nd tier of deckhouse	0,42
3rd tier of deckhouse	0,32
4th tier of deckhouse and above	0,25

Table 4 : Still water and inertial internal pressures due to liquids

Still water pressure p_S in kN/m²	Inertial pressure p_W in kN/m²
$\rho_L g(z_L - z)$	$\rho_L a_{Z1}(z_{TOP} - z)$

Note 1:

z_{TOP} : Z co-ordinate, in m, of the highest point of the tank

z_L : Z co-ordinate, in m, of the highest point of the liquid:
$z_L = z_{TOP} + 0{,}5\,(z_{AP} - z_{TOP})$

z_{AP} : Z co-ordinate, in m, of the moulded deck line of the deck to which the air pipes extend, to be taken not less than z_{TOP}.

Table 5 : Still water and inertial internal pressures due to uniform loads

Still water pressure p_S, in kN/m²	Inertial pressure p_W, in kN/m²
The value of p_S is, in general, defined by the Designer; in any case it may not be taken less than 10 kN/m². When the value of p_S is not defined by the Designer, it may be taken, in kN/m², equal to 6,9 h_{TD}, where h_{TD} is the compartment 'tweendeck height at side, in m	$p_S\dfrac{a_{Z1}}{g}$

2.3.3 Lateral pressures for elements other than those of the outer shell

The still water and wave lateral pressures to be considered as acting on an element which separates two adjacent compartments are those obtained considering the two compartments individually loaded.

2.4 Longitudinally framed bottom

2.4.1 Plating and ordinary stiffeners

The net scantlings of plating and ordinary stiffeners are to be not less than the values obtained from the formulae in Tab 6 and the minimum values in the same Table.

2.4.2 Floors

Floors are to be fitted at every four frame spacings and generally spaced no more than 2,5 m apart.

The floor dimensions and scantlings are to be not less than those specified in Tab 7.

In no case may the above scantlings be lower than those of the corresponding side transverses, as defined in [2.6.2].

2.4.3 Centre girder

Where no centreline bulkhead is to be fitted (see [2.10]), a centre bottom girder having the same dimensions and scantlings required in [2.4.2] for floors is to be provided.

The centre bottom girder is to be connected to the collision bulkhead by means of a large end bracket.

2.4.4 Side girders

Side girders, having the same dimensions and scantlings required in [2.4.2] for floors, are generally to be fitted every two longitudinals, in line with bottom longitudinals located aft of the collision bulkhead. Their extension is to be compatible in each case with the shape of the bottom.

2.5 Transversely framed bottom

2.5.1 Plating

The net scantling of plating is to be not less than the value obtained from the formulae in Tab 6 and the minimum values in the same table.

2.5.2 Floors

Solid floors are to be fitted at every frame spacing.

The solid floor dimensions and scantlings are to be not less than those specified in Tab 8.

2.5.3 Centre girder

Where no centreline bulkhead is to be fitted (see [2.10]), a centre bottom girder is to be fitted according to [2.4.3].

2.6 Longitudinally framed side

2.6.1 Plating and ordinary stiffeners

The net scantlings of plating and ordinary stiffeners are to be not less than the values obtained from the formulae in Tab 9 and the minimum values in the same table.

2.6.2 Side transverses

Side transverses are to be located in way of bottom transverse and are to extend to the upper deck. Their ends are to be amply faired in way of bottom and deck transverses.

Their net section modulus w, in cm³, and net shear sectional area A_{Sh}, in cm², are to be not less than the values obtained from the following formulae:

$$w = \gamma_R\gamma_m\beta_b\frac{\gamma_{S2}\lambda_{bS}p_S + \gamma_{W2}\lambda_{bW}p_W}{8R_y}s\ell^2 10^3$$

$$A_{Sh} = 10\gamma_R\gamma_m\beta_s\frac{\gamma_{S2}\lambda_{sS}p_S + \gamma_{W2}\lambda_{sW}p_W}{R_y}s\ell$$

Table 6 : Scantling of bottom plating and ordinary stiffeners

Element	Formula	Minimum value
Plating	Net thickness, in mm: • in general: $t = 14{,}9c_ac_rs\sqrt{\gamma_R\gamma_m\frac{\gamma_{S2}p_S+\gamma_{W2}p_W}{R_y}}$ • for inner bottom: $t = 14{,}9c_ac_rs\sqrt{\gamma_R\gamma_m\frac{\gamma_{S2}p_S+\gamma_{W2}p_W}{R_y}}$	Net minimum thickness, in mm: • in general: $t = c_F(0,038L+7,0)(sk)^{1/2}-c_E$ • for inner bottom: $t = 2+0{,}017Lk^{1/2}+4{,}5s$
Ordinary stiffeners	Net section modulus, in cm³: $w = \gamma_R\gamma_m\beta_b\frac{\gamma_{S2}p_S+\gamma_{W2}p_W}{8R_y}\left(1-\frac{s}{2\ell}\right)s\ell^2 10^3$	Web net minimum thickness, in mm, to be not less than the lesser of: • $t = 1{,}5L_2^{1/3}k^{1/6}$ • the thickness of the attached plating.
	Net shear sectional area, in cm²: $A_{Sh} = 10\gamma_R\gamma_m\beta_s\frac{\gamma_{S2}p_S+\gamma_{W2}p_W}{R_y}\left(1-\frac{s}{2\ell}\right)s\ell$	

Table 7 : Longitudinally framed bottom Floor dimensions and scantlings

Dimension or scantling	Specified value
Web height, in m	$h_M = 0{,}085\ D + 0{,}15$
Web net thickness, in mm	To be not less than that required for double bottom floors aft of the collision bulkhead; in any case, it may be taken not greater than 10 mm.
Floor face plate net sectional area, in cm²	$A_P = 3{,}15\ D$
Floor face plate net thickness, in mm	$t_P = 0{,}4\ D + 5$ May be assumed not greater than 14 mm.

Table 8 : Transversely framed bottom Floor dimensions and scantlings

Dimension or scantling	Specified value
Web height, in m	$h_M = 0{,}085\ D + 0{,}15$
Web net thickness, in mm	To be not less than that required for double bottom floors aft of the collision bulkhead; in any case, it may be taken not greater than 10 mm.
Floor face plate net sectional area, in cm²	$A_P = 1{,}67\ D$

2.7 Transversely framed side

2.7.1 Plating and ordinary stiffeners (side frames)

Side frames fitted at every frame space are to have the same vertical extension as the collision bulkhead.

The net scantlings of plating and side frames are to be not less than the values obtained from the formulae in Tab 9 and the minimum values in the table.

The value of the side frame section modulus is generally to be maintained for the full extension of the side frame.

2.7.2 Side girders

Depending on the hull body shape and structure aft of the collision bulkhead, one or more adequately spaced side girders per side are to be fitted.

Their net section modulus w, in cm³, and net shear sectional area A_{Sh}, in cm², are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{8 R_y} s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y} s \ell$$

Moreover, the depth b_A, in mm, and the net thickness t_A, in mm, of the side girder web are generally to be not less than the values obtained from the following formulae:

$b_A = 2{,}5\ (180 + L)$

$t_A = (6 + 0{,}018L)k^{1/2}$

2.7.3 Panting structures

In order to withstand the panting loads, horizontal structures are to be provided. These structures are to be fitted at a spacing generally not exceeding 2 m and consist of side girders supported by panting beams or side transverses whose ends are connected to deck transverses, located under the tank top, so as to form a strengthened ring structure.

Panting beams, which generally consist of sections having the greater side vertically arranged, are to be fitted every two frames.

2.7.4 Connection between panting beams, side frames and side girders

Each panting beam is to be connected to the side transverses by means of brackets whose arms are generally to be not less than twice the panting beam depth.

2.7.5 Connection between side frames and side girders

Side transverses not supporting panting beams are to be connected to side girders by means of brackets having the same thickness as that of the side girder and arms which are to be not less than one half of the depth of the side girder.

Table 9 : Scantling of side plating and ordinary stiffeners

Element	Formula	Minimum value
Plating	Net thickness, in mm: $t = 14{,}9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y}}$	Net minimum thickness, in mm: $t = c_F (0{,}038L + 7{,}0)(sk)^{1/2} - c_E$
Ordinary stiffeners	Net section modulus, in cm³: $w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{8 R_y} \left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$	Web net minimum thickness, in mm, to be not less than the lesser of: • $t = 1{,}5 L_2^{1/3} k^{1/6}$ • the thickness of the attached plating
	Net shear sectional area, in cm²: $A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y} \left(1 - \frac{s}{2\ell}\right) s \ell$	

Table 10 : Scantling of deck plating and ordinary stiffeners

Element	Formula	Minimum value
Plating	Net thickness, in mm: $t = 14{,}9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y}}$	Net minimum thickness, in mm: $t = 2{,}1 + 0{,}013 L k^{1/2} + 4{,}5 s$
Ordinary stiffeners	Net section modulus, in cm³: $w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{m R_y} \left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$	Web net minimum thickness, in mm, to be not less than the lesser of: • $t = 1{,}5 L_2^{1/3} k^{1/6}$ • the thickness of the attached plating.
	Net shear sectional area, in cm²: $A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y} \left(1 - \frac{s}{2\ell}\right) s \ell$	

Note 1:
m : Boundary coefficient, to be taken equal to:
- m = 12 for longitudinally framed decks
- m = 8 for transversely framed decks.

2.7.6 Panting beam scantlings

The net area A_B, in cm², and the net inertia J_B, in cm⁴, of the panting beam section are to be not less than the values obtained from the following formulae:

$A_B = 0{,}5\ L - 18$

$J_B = 0{,}34\ (0{,}5\ L - 18)\ b_B^2$

where:

b_B : Beam length, in m, measured between the internal edges of side girders or the internal edge of the side girder and any effective central or lateral support.

Where side girder spacing is other than 2 m, the values A_B and J_B are to be modified according to the relation between the actual spacing and 2 m.

2.7.7 Panting beams of considerable length

Panting beams of considerable length are generally to be supported at the centreline by a wash bulkhead or pillars arranged both horizontally and vertically.

2.7.8 Non-tight platforms

Non-tight platforms may be fitted in lieu of side girders and panting beams. Their openings and scantlings are to be in accordance with [2.9.1].

Their spacing is to be not greater than 2,5 m.

If the peak exceeds 10 m in depth, a non-tight platform is to be arranged at approximately mid-depth.

2.7.9 Additional transverse bulkheads

Where the peak exceeds 10 m in length and the frames are supported by panting beams or non-tight platforms, additional transverse wash bulkheads or side transverses are to be fitted.

2.8 Decks

2.8.1 Plating and ordinary stiffeners

The net scantlings of plating and ordinary stiffeners are to be not less than the values obtained from the formulae in Tab 10 and the minimum values in the same table.

2.8.2 Primary supporting members

Scantlings of primary supporting members are to be in accordance with Ch 7, Sec 3, considering the loads in [2.3].

The partial safety factors to be used are those defined in Ch 7, Sec 3, [1.3].

2.9 Platforms

2.9.1 Non-tight platforms

Non-tight platforms located inside the peak are to be provided with openings having a total area not less than 10% of that of the platforms. Moreover, the thickness of the plating and the section modulus of ordinary stiffeners are to be not less than those required in [2.10] for the non-tight central longitudinal bulkhead.

The number and depth of non-tight platforms within the peak is considered by the Society on a case by case basis.

The platforms may be replaced by equivalent horizontal structures whose scantlings are to be supported by direct calculations.

2.9.2 Platform transverses

The net sectional area of platform transverses, calculated considering a width of attached plating whose net sectional area is equal to that of the transverse flange, is to be not less than the value obtained, in cm², from the following formula:

$$A = 10 \gamma_R \gamma_m \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{C_P R_y} d_S h_S$$

where:

p_S, p_W : Still water pressure and wave pressure, defined in Tab 2, acting at the ends of the platform transverse in the direction of its axis

d_S : Half of the longitudinal distance, in m, between the two transverses longitudinally adjacent to that under consideration

h_S : Half of the vertical distance, in m, between the two transverses vertically adjacent to that under consideration

C_P : Coefficient, to be taken equal to:

$$C_P = 1 \quad \text{for} \quad \frac{d_P}{r_P} \le 70$$

$$C_P = 1{,}7 - 0{,}01\frac{d_P}{r_P} \quad \text{for} \quad 70 < \frac{d_P}{r_P} \le 140$$

When $d_P / r_P > 140$, the scantlings of the struts are considered by the Society on a case by case basis

d_P : Distance, in cm, from the face plate of the side transverse and that of the bulkhead vertical web, connected by the strut, measured at the level of the platform transverse

r_P : Radius of gyration of the strut, to be obtained, in cm, from the following formula:

$$r_P = \sqrt{\frac{J}{A_E}}$$

J : Minimum net moment of inertia, in cm^4, of the strut considered

A_E : Actual net sectional area, in cm^2, of the transverse section of the strut considered.

2.9.3 Breasthooks

Breasthooks are to have the same thickness of that required for platforms. They are to be arranged on the stem, in way of every side longitudinal, or at equivalent spacing in the case of transverse framing, extending aft for a length equal to approximately twice the breasthook spacing.

2.10 Central longitudinal bulkhead

2.10.1 General

Unless otherwise agreed by the Society on the basis of the ship's dimensions and fore peak arrangement, a centreline non-tight longitudinal bulkhead is to be fitted.

2.10.2 Extension

In the case of a bulbous bow, such bulkhead is generally to extend for the whole length and depth of the fore peak.

Where hull structures are flared, such as those situated above the bulb and in the fore part of the peak, the bulkhead may be locally omitted.

Similarly, the extension of the bulkhead may be limited for bows without a bulb, depending on the shape of the hull. However, the bulkhead is to be fitted in the higher part of the peak.

2.10.3 Plating thickness

The net plating thickness of the lower part of the longitudinal bulkhead over a height at least equal to h_M defined in [2.4.2] is to be not less than that required for the centre girder in [2.4.3].

Elsewhere, the net thickness of the longitudinal bulkhead plating is to be not less than the value obtained, in mm, from the following formula:

$$t = 6{,}5 + 0{,}013\ L_1$$

2.10.4 Ordinary stiffeners

The net section modulus of ordinary stiffeners is to be not less than the value obtained, in cm^3, from the following formula:

$$w = 3{,}5 s \ell^2 k (z_{TOP} - z_M)$$

where:

z_{TOP} : Z co-ordinate, in m, of the highest point of the tank

z_M : Z co-ordinate, in m, of the stiffener mid-span.

2.10.5 Primary supporting members

Vertical and longitudinal primary supporting members, to be made preferably with symmetrical type sections, are to have a section modulus not less than 50% of that required for the corresponding side or longitudinal webs.

The vertical and longitudinal webs are to be provided with adequate fairing end brackets and to be securely connected to the struts, if any.

2.10.6 Openings

Bulkhead openings are to be limited in the zone corresponding to the centre girder to approximately 2% of the area, and, in the zone above, to not less than 10% of the area. Openings are to be located such as to affect as little as possible the plating sections adjacent to primary supporting members.

2.11 Bulbous bow

2.11.1 General

Where a bulbous bow is fitted, fore peak structures are to effectively support the bulb and are to be adequately connected to its structures.

2.11.2 Shell plating

The thickness of the shell plating of the fore end of the bulb and the first strake above the keel is generally to be not less than that required in [5.2.1] for plate stems. This thickness is to be extended to the bulbous zone, which, depending on its shape, may be damaged by anchors and chains during handling.

2.11.3 Connection with the fore peak

Fore peak structures are to be extended inside the bulb as far as permitted by the size and shape of the latter.

2.11.4 Horizontal diaphragms

At the fore end of the bulb, the structure is generally to be supported by means of horizontal diaphragms, spaced not more than 1 m apart, and a centreline vertical diaphragm.

2.11.5 Longitudinal stiffeners

Bottom and side longitudinals are to extend inside the bulb, forward of the fore end by at least 30% of the bulb length measured from the perpendicular to the fore end of the bulb.

The fore end of longitudinals is to be located in way of a reinforced transverse ring; forward of such ring, longitudinals are to be replaced by ordinary transverse rings.

2.11.6 Floors

Solid floors are to be part of reinforced transverse rings generally arranged not more than 3 frame spaces apart.

2.11.7 Breasthooks

Breasthooks, to be placed in line with longitudinals, are to be extended on sides aft of the stem, so as to form longitudinal side girders.

2.11.8 Longitudinal centreline wash bulkhead

For a bulb of considerable width, a longitudinal centreline wash bulkhead may be required by the Society in certain cases.

2.11.9 Transverse wash bulkhead

In way of a long bulb, transverse wash bulkheads or side transverses of adequate strength arranged not more than 5 frame spaces apart may be required by the Society in certain cases.

3 Reinforcements of the flat bottom forward area

3.1 Area to be reinforced

3.1.1 In addition to the requirements in [2], the structures of the flat bottom forward area are to be able to sustain the dynamic pressures due to the bottom impact. The flat bottom forward area is:

- longitudinally, over the bottom located between ξL and 0,05L aft of the fore end, where the coefficient ξ is obtained from the following formula:

  $$\xi = 0{,}25(1{,}6 - C_B)$$

  without being taken less than 0,2 or greater than 0,25
- transversely, over the whole flat bottom and the adjacent zones up to a height, from the base line, not less than 2L, in mm. In any case, it is not necessary that such height is greater than 300 mm.

3.1.2 The bottom dynamic impact pressure is to be considered if:

T_F < min (0,04L; 8,6 m)

where T_F is the minimum forward draught, in m, among those foreseen in operation in ballast conditions or conditions of partial loading.

3.1.3 The value of the minimum forward draught T_F adopted for the calculations is to be specified in the loading manual.

3.1.4 An alternative arrangement and extension of strengthening with respect to the above may also be required where the minimum forward draught exceeds 0,04 L, depending on the shape of the forward hull body and the ship's length and service speed.

3.2 Bottom impact pressure

3.2.1 The bottom impact pressure p_{BI} is to be obtained, in kN/m², from the following formula:

$$p_{BI} = 25n\left[0{,}004 - \left(\frac{T_F}{L}\right)^2\right]\frac{L_1 L}{T_F}$$

where T_F is the draught defined in [3.1.2].

3.3 Partial safety factors

3.3.1 The partial safety factors to be considered for checking the reinforcements of the flat bottom forward area are specified in Tab 11.

Table 11 : Reinforcements of the flat bottom forward area - Partial safety factors

Partial safety factors covering uncertainties regarding:	Partial safety factors		
	Symbol	Plating	Ordinary stiffeners
Still water pressure	γ_{S2}	1,00	1,00
Wave pressure	γ_{W2}	1,10	1,10
Material	γ_m	1,02	1,02
Resistance	γ_R	1,30	1,15

Table 12 : Reinforcements of plating and ordinary stiffeners of the flat bottom forward area

Element	Formula	Minimum value
Plating	Net thickness, in mm: $t = 13{,}9c_a c_r s\sqrt{\gamma_R\gamma_m\frac{\gamma_{W2}p_{BI}}{R_y}}$	Net minimum thickness, in mm: $t = c_F(0,038L + 7,0)(sk)^{1/2} - c_E$
Ordinary stiffeners	Net section modulus, in cm³: $w = \gamma_R\gamma_m\beta_b\frac{\gamma_{W2}p_{BI}}{16c_P R_y}\left(1-\frac{s}{2\ell}\right)s\ell^2 10^3$	Web net minimum thickness, in mm, to be not less than the lesser of: • $t = 1{,}5L_2^{1/3}k^{1/6}$ • the thickness of the attached plating
	Net shear sectional area, in cm²: $A_{Sh} = 10\gamma_R\gamma_m\beta_s\frac{\gamma_{W2}p_{BI}}{R_y}\left(1-\frac{s}{2\ell}\right)s\ell$	
Note 1: c_P : Ratio of the plastic section modulus to the elastic section modulus of the ordinary stiffeners with attached shell plating, to be taken equal to 1,16 in the absence of more precise evaluation.		

3.4 Scantlings

3.4.1 Plating and ordinary stiffeners

In addition to the requirements in [2.4.1] and [2.5.1], the net scantlings of plating and ordinary stiffeners of the flat bottom forward area, defined in [3.1], are to be not less than the values obtained from the formulae in Tab 12 and the minimum values in the same Table.

The span of ordinary stiffeners to be considered for the calculation of net section modulus and net shear sectional area is to be taken as the distance between the adjacent primary supporting members; the effect of local supports (e.g. additional vertical brackets located between primary supporting members) is considered by the Society on a case-by-case basis.

3.4.2 Tapering

Outside the flat bottom forward area, scantlings are to be gradually tapered so as to reach the values required for the areas considered.

3.5 Arrangement of primary supporting members and ordinary stiffeners: longitudinally framed bottom

3.5.1 The requirements in [3.5.2] to [3.5.4] apply to the structures of the flat bottom forward area, defined in [3.1], in addition to the requirements of [2.4].

3.5.2 Bottom longitudinals and side girders, if any, are to extend as far forward as practicable, and their spacing may not exceed that adopted aft of the collision bulkhead.

3.5.3 The spacing of solid floors in a single or double bottom is to be not greater than either that required for the midship section in Ch 4, Sec 4 or (1,35 + 0,007 L) m, whichever is the lesser.

However, where the minimum forward draught T_F is less than 0,02 L, the spacing of floors forward of 0,2 L from the stem is to be not greater than (0,9 + 0,0045 L) m.

3.5.4 The Society may require adequately spaced side girders having a depth equal to that of the floors. As an alternative to the above, girders with increased scantlings may be fitted.

3.6 Arrangement of primary supporting members and ordinary stiffeners: transversely framed double bottom

3.6.1 The requirements in [3.6.2] to [3.6.4] apply to the structures of the flat bottom forward area, defined in [3.1], in addition to the requirements of [2.5].

3.6.2 Solid floors are to be fitted:

- at every second frame between 0,75L and 0,8L from the aft end
- at every frame space forward of 0,8L from the aft end.

3.6.3 Side girders with a depth equal to that of the floors are to be fitted at a spacing generally not exceeding 2,4 m. In addition, the Society may require intermediate half height girders, half the depth of the side girders, or other equivalent stiffeners.

3.6.4 Intercostal longitudinal ordinary stiffeners are to be fitted at a spacing generally not exceeding 1,2 m. Their section modulus is to be not less than 250 cm³.

4 Reinforcements of the bow flare area

4.1 Application

4.1.1 The requirements in [4.2] to [4.5] apply to ships with any service notations.

4.2 Area to be reinforced

4.2.1 In addition to the requirements in [2], the structures of the bow flare area are to be able to sustain the dynamic pressures due to the bow impact pressure.

4.2.2 The bow area is that extending forward of 0,9 L from the aft end of L and above the summer load waterline.

4.3 Bow impact pressure

4.3.1 The bow impact pressure p_{FI} is to be obtained, in kN/m², from the following formula:

$$p_{FI} = nC_SC_LC_Z(0,22 + 0,15\tan\alpha)(0,4V\sin\beta + 0,6\sqrt{L})^2$$

where:

C_S : Coefficient depending on the type of structures on which the bow impact pressure is considered to be acting:

- $C_S = 1,8$ for plating and ordinary stiffeners
- $C_S = 0,5$ for primary supporting members

C_L : Coefficient depending on the ship's length:

- $C_L = 0,0125\ L$ for $L < 80$ m
- $C_L = 1,0$ for $L \geq 80$ m

C_Z : Coefficient depending on the distance between the summer load waterline and the calculation point:

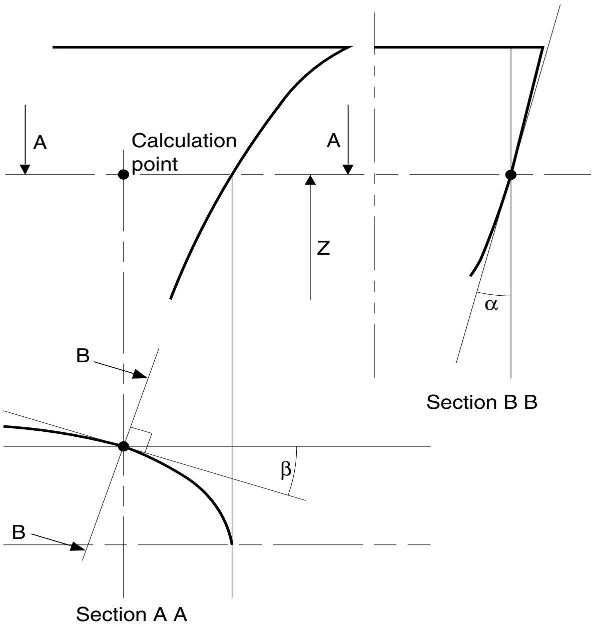
- $C_Z = C - 0,5\ (z-T)$ for $z \geq 2\ C + T - 11$
- $C_Z = 5,5$ for $z < 2\ C + T - 11$

C : Wave parameter, defined in Ch 5, Sec 2

α : Flare angle at the calculation point, defined as the angle between a vertical line and the tangent to the side plating, measured in a vertical plane normal to the horizontal tangent to the shell plating (see Fig 1)

β : Entry angle at the calculation point, defined as the angle between a longitudinal line parallel to the centreline and the tangent to the shell plating in a horizontal plane (see Fig 1).

Figure 1 : Definition of angles α and β



4.4 Partial safety factors

4.4.1 The partial safety factors to be considered for checking the reinforcements of the bow flare area are specified in Tab 13.

Table 13 : Reinforcements of the bow flare area Partial safety factors

Partial safety factors covering uncertainties regarding:	Partial safety factors		
	Symbol	Plating	Ordinary stiffeners
Still water pressure	γ_{S2}	1,00	1,00
Wave pressure	γ_{W2}	1,10	1,10
Material	γ_m	1,02	1,02
Resistance	γ_R	1,30	1,02

4.5 Scantlings

4.5.1 Plating and ordinary stiffeners

In addition to the requirements in [2.6.1] and [2.7.1], the net scantlings of plating and ordinary stiffeners of the bow flare area, defined in [4.2], are to be not less than the values obtained from the formulae in Tab 14 and the minimum values in the same table.

The span of ordinary stiffeners to be considered for the calculation of net section modulus and net shear sectional area is to be taken as the distance between the adjacent primary supporting members; the effect of local supports (e.g. additional vertical brackets located between primary supporting members) is considered by the Society on a case-by-case basis.

4.5.2 Tapering

Outside the bow flare area, scantlings are to be gradually tapered so as to reach the values required for the areas considered.

4.5.3 Intercostal stiffeners

Intercostal stiffeners are to be fitted at mid-span where the angle between the stiffener web and the attached plating is less than 70°.

4.5.4 Primary supporting members

In addition to the requirements in [2.6] and [2.7], primary supporting members are generally to be verified through direct calculations carried out according to Ch 7, Sec 3, considering the bow impact pressures defined in [4.3] and the partial safety factors in Tab 1.

5 Stems

5.1 General

5.1.1 Arrangement

Adequate continuity of strength is to be ensured at the connection of stems to the surrounding structure.

Abrupt changes in sections are to be avoided.

Table 14 : Reinforcements of plating and ordinary stiffeners of the bow flare area

Element	Formula	Minimum value
Plating	Net thickness, in mm: $t = 11 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{W2} p_{FI}}{R_y}}$	Net minimum thickness, in mm: $t = c_F(0,038L + 7,0)(sk)^{1/2} - c_E$
Ordinary stiffeners	Net section modulus, in cm³: $w = \gamma_R \gamma_m \beta_b \frac{\gamma_{W2} p_{FI}}{18 c_P R_y}\left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$	Web net minimum thickness, in mm, to be not less than the lesser of: • $t = 1,5 L_2^{1/3} k^{1/6}$ • the thickness of the attached plating.
	Net shear sectional area, in cm²: $A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{W2} p_{FI}}{R_y}\left(1 - \frac{s}{2\ell}\right) s \ell$	

Note 1:

c_P : Ratio of the plastic section modulus to the elastic section modulus of the ordinary stiffeners with attached shell plating, to be taken equal to 1,16 in the absence of more precise evaluation.

5.1.2 Gross scantlings

With reference to Ch 4, Sec 2, [1], all scantlings and dimensions referred to in [5.2] and [5.3] are gross, i.e. they include the margins for corrosion.

5.2 Plate stems

5.2.1 Where the stem is constructed of shaped plates, the gross thickness of the plates below the load waterline is to be not less than the value obtained, in mm, from the following formula:

$$t_S = 1{,}37(0{,}95 + \sqrt{L_3})\sqrt{k}$$

where:

L_3 : Ship's length L, in m, but to be taken not greater than 300.

Above the load waterline this thickness may be gradually tapered towards the stem head, where it is to be not less than that required for side plating at ends.

5.2.2 The plating forming the stems is to be supported by horizontal diaphragms spaced not more than 1200 mm apart and connected, as far as practicable, to the adjacent frames and side stringers.

5.2.3 If considered necessary, and particularly where the stem radius is large, a centreline stiffener or web of suitable scantlings is to be fitted.

5.3 Bar stems

5.3.1 The gross area of bar stems constructed of forged or rolled steel is to be not less than the value obtained, in cm^2, from the following formulae:

$$A_P = \left(0{,}40 + \frac{10T}{L}\right)(0{,}009L^2 + 20)\sqrt{k} \quad \text{for } L \le 90$$

$$A_P = \left(0{,}40 + \frac{10T}{L}\right)(1{,}8L - 69)\sqrt{k} \quad \text{for } 90 < L \le 200$$

where the ratio T/L in the above formulae is to be taken not less than 0,05 or greater than 0,075.

5.3.2 The gross thickness t_B of the bar stem is to be not less than the value obtained, in mm, from the following formula:

$$t_B = (0{,}4L + 13)\sqrt{k}$$

5.3.3 The cross-sectional area of the stem may be gradually tapered from the load waterline to the upper end, where it may be equal to the two thirds of the value as calculated above.

5.3.4 The lower part of the stem may be constructed of cast steel subject to the examination by the Society; where necessary, a vertical web is to be fitted for welding of the centre keelson.

5.3.5 Welding of the bar stem with the bar keel and the shell plating is to be in accordance with Ch 12, Sec 1, [3.4].

6 Transverse thrusters

6.1 Scantlings of the thruster tunnel and connection with the hull

6.1.1 The thickness of the tunnel is to be not less than that of the adjacent hull plating.

6.1.2 When the tunnel is not welded to the hull, the connection devices are examined by the Society on a case by case basis.

SECTION 2 AFT PART

Symbols

L_1, L_2 : Lengths, in m, defined in Ch 1, Sec 2, [2.1.1]

h_1 : Reference value of the ship relative motion, defined in Ch 5, Sec 3, [3.3] or Ch 8, Sec 1, [3.3]

a_{Z1} : Reference value of the vertical acceleration, defined in Ch 5, Sec 3, [3.4] or Ch 8, Sec 1, [3.3]

ρ : Sea water density, in t/m^3

g : Gravity acceleration, in m/s^2:

$g = 9,81$ m/s^2

x, y, z : X, Y and Z co-ordinates, in m, of the calculation point with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [4]

p_S, p_W : Still water pressure and wave pressure defined in [2.3]

k : Material factor, defined in Ch 4, Sec 1, [2.3]

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

s : Spacing, in m, of ordinary stiffeners or primary supporting members, as applicable

ℓ : Span, in m, of ordinary stiffeners or primary supporting members, as applicable

c_a : Aspect ratio of the plate panel, equal to:

$$c_a = 1,21\sqrt{1 + 0,33\left(\frac{s}{\ell}\right)^2} - 0,69\frac{s}{\ell}$$

to be taken not greater than 1,0

c_r : Coefficient of curvature of the panel, equal to:

$c_r = 1 - 0,5\ s/r$

to be taken not less than 0,75

r : Radius of curvature, in m

β_b, β_s : Coefficients defined in Ch 7, Sec 2, [3.7.3]

λ_{bS}, λ_{bW}, λ_{sS}, λ_{sW}: Coefficients defined in Ch 7, Sec 2, [3.4.5]

c_E : Coefficient to be taken equal to:

$c_E = 1$ for $L \leq 65$ m

$c_E = 3 - L/30$ for $65\ m < L < 90$ m

$c_E = 0$ for $L \geq 90$ m

c_F : Coefficient:

$c_F = 0,8$ for poop sides

$c_F = 1,0$ in other cases.

1 General

1.1 Application

1.1.1 The requirements of this Section apply for the scantlings of structures located aft of the after peak bulkhead and for the reinforcements of the flat bottom aft area.

1.1.2 Aft peak structures which form the boundary of spaces not intended to carry liquids, and which do not belong to the outer shell, are to be subjected to lateral pressure in flooding conditions. Their scantlings are to be determined according to the relevant criteria in Chapter 7 or Chapter 8, as applicable.

1.1.3 For ships less than 65 m in length, the criteria in Ch 8, App 1 may be used for the strength check of plating and ordinary stiffeners as an alternative to those in [3.2.1].

1.2 Connections of the aft part with structures located fore of the after peak bulkhead

1.2.1 Tapering

Adequate tapering is to be ensured between the scantlings in the aft part and those fore of the after peak bulkhead. The tapering is to be such that the scantling requirements for both areas are fulfilled.

1.3 Net scantlings

1.3.1 As specified in Ch 4, Sec 2, [1], all scantlings referred to in this Section are net, i.e. they do not include any margin for corrosion.

Gross scantlings are obtained as specified in Ch 4, Sec 2.

2 Aft peak

2.1 Partial safety factors

2.1.1 The partial safety factors to be considered for checking aft peak structures are specified in Tab 1.

Table 1 : Aft peak structures - Partial safety factors

Partial safety factors covering uncertainties regarding:	Partial safety factors			
	Symbol	Plating	Ordinary stiffeners	Primary supporting members
Still water pressure	γ_{S2}	1,00	1,00	1,00
Wave pressure	γ_{W2}	1,20	1,20	1,20
Material	γ_m	1,02	1,02	1,02
Resistance	γ_R	1,20	1,40	1,60

2.2 Load point

2.2.1 Unless otherwise specified, lateral pressure is to be calculated at:

- the lower edge of the elementary load panel considered, for plating
- mid-span, for stiffeners.

2.3 Load model

2.3.1 General

The still water and wave lateral pressures in intact conditions are to be considered. They are to be calculated as specified in [2.3.2] for the elements of the outer shell and in [2.3.3] for the other elements.

Still water pressure (p_S) includes:

- the still water sea pressure, defined in Tab 2
- the still water internal pressure due to liquid or ballast, defined in Tab 4
- for decks, the still water internal pressure due to dry uniform weights, defined in Tab 5

Wave pressure (p_W) includes:

- the wave pressure, defined in Tab 2
- the inertial pressure due to liquids or ballast, defined in Tab 4
- for decks, the inertial pressure due to uniform loads, defined in Tab 5.

2.3.2 Lateral pressures for the elements of the outer shell

The still water and wave lateral pressures are to be calculated considering separately:

- the still water and wave external sea pressures
- the still water and wave internal pressure, considering the compartment adjacent to the outer shell as being loaded

If the compartment adjacent to the outer shell is not intended to carry liquids, only the external sea pressures are to be considered.

2.3.3 Lateral pressures for elements other than those of the outer shell

The still water and wave lateral pressures to be considered as acting on an element which separates two adjacent compartments are those obtained considering the two compartments individually loaded.

3 After peak

3.1 Arrangement

3.1.1 General

The after peak is, in general, to be transversely framed.

3.1.2 Floors

Solid floors are to be fitted at every frame spacing.

The floor height is to be adequate in relation to the shape of the hull. Where a sterntube is fitted, the floor height is to extend at least above the sterntube. Where the hull lines do not allow such extension, plates of suitable height with upper and lower edges stiffened and securely fastened to the frames are to be fitted above the sterntube.

Table 2 : Still water and wave pressures

Location	Still water sea pressure p, in kN/m²	Wave pressure p_W, in kN/m²
Bottom and side below the waterline: $z \le T$	$\rho g(T - z)$	$\rho g h_1 e^{\frac{-2\pi(T-z)}{L}}$
Side above the waterline: $z > T$	0	$\rho g(T + h_1 - z)$ without being taken less than 0,15L
Exposed deck	Pressure due to the load carried **(1)**	$17{,}5n\varphi$

(1) The pressure due to the load carried is to be defined by the Designer and, in any case, it may not be taken less than 10φ kN/m², where φ is defined in Tab 3.
The Society may accept pressure values lower than 10φ kN/m² when considered appropriate on the basis of the intended use of the deck.

Note 1:

φ : Coefficient defined in Tab 3.

Table 3 : Coefficient for pressure on exposed deck

Exposed deck location	φ
Freeboard deck	1
Superstructure deck	0,75
1st tier of deckhouse	0,56
2nd tier of deckhouse	0,42
3rd tier of deckhouse	0,32
4th tier of deckhouse and above	0,25

Table 4 : Still water and wave internal pressures due to liquids

Still water pressure p_S, in kN/m²	Inertial pressure p_W, in kN/m²
$\rho g(z_L - z)$	$\rho a_{Z1}(z_{TOP} - z)$

Note 1:
z_{TOP} : Z co-ordinate, in m, of the highest point of the tank
z_L : Z co-ordinate, in m, of the highest point of the liquid:
$$z_L = z_{TOP} + 0{,}5(z_{AP} - z_{TOP})$$
z_{AP} : Z co-ordinate, in m, of the moulded deck line of the deck to which the air pipes extend, to be taken not less than z_{TOP}.

Table 5 : Still water and inertial internal pressures due to uniform loads

Still water pressure p_S, in kN/m²	Inertial pressure p_W, in kN/m²
The value of p_S is, in general, defined by the Designer: in any case it may not be taken less than 10 kN/m². When the value of p_S is not defined by the Designer, it may be taken, in kN/m², equal to 6,9 h_{TD}, where h_{TD} is the compartment 'tweendeck height at side, in m	$p_S \frac{a_{Z1}}{g}$

In way of and near the rudder post, propeller post and rudder horn, floors are to be extended up to the peak tank top and are to be increased in thickness; the increase will be considered by the Society on a case by case basis, depending on the arrangement proposed.

Floors are to be fitted with stiffeners having spacing not greater than 800 mm.

3.1.3 Side frames

Side frames are to be extended up to a deck located above the full load waterline.

Side frames are to be supported by one of the following types of structure:

- non-tight platforms, to be fitted with openings having a total area not less than 10% of the area of the platforms
- side girders supported by side primary supporting members connected to deck transverses.

The distance between the above side frame supports is to be not greater than 2,5 m.

3.1.4 Platforms and side girders

Platforms and side girders within the peak are to be arranged in line with those located in the area immediately forward.

Where this arrangement is not possible due to the shape of the hull and access needs, structural continuity between the peak and the structures of the area immediately forward is to be ensured by adopting wide tapering brackets.

Where the after peak is adjacent to a machinery space whose side is longitudinally framed, the side girders in the after peak are to be fitted with tapering brackets.

3.1.5 Longitudinal bulkheads

A longitudinal non-tight bulkhead is to be fitted on the centreline of the ship, in general in the upper part of the peak, and stiffened at each frame spacing.

Where either the stern overhang is very large or the maximum breadth of the peak is greater than 20 m, additional longitudinal wash bulkheads may be required.

3.2 Scantlings

3.2.1 Plating and ordinary stiffeners (side frames)

The net scantlings of plating and ordinary stiffeners are to be not less than those obtained from the formulae in:

- Tab 6 for plating
- Tab 7 for ordinary stiffeners

and not less than the minimum values in the same tables.

3.2.2 Floors

The net thickness of floors is to be not less than that obtained, in mm, from the following formula:

$t_M = 6{,}5 + 0{,}023\ L_1\ k^{1/2}$

3.2.3 Side transverses

The net section modulus w, in cm³, and the net shear sectional area A_{SH}, in cm², of side transverses are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2}\lambda_{bS}p_S + \gamma_{W2}\lambda_{bW}p_W}{8R_y} s\ell^2 10^3$$

$$A_{Sh} = 10\gamma_R \gamma_m \beta_s \frac{\gamma_{S2}\lambda_{sS}p_S + \gamma_{W2}\lambda_{sW}p_W}{R_y} s\ell$$

3.2.4 Side girders

The net section modulus w, in cm³, and the net shear sectional area A_{Sh}, in cm², of side girders are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2}p_S + \gamma_{W2}p_W}{8R_y} s\ell^2 10^3$$

$$A_{Sh} = 10\gamma_R \gamma_m \beta_s \frac{\gamma_{S2}p_S + \gamma_{W2}p_W}{R_y} s\ell$$

3.2.5 Deck primary supporting members

Scantlings of deck primary supporting members are to be in accordance with Ch 7, Sec 3, considering the loads in [2.3].

The partial safety factors to be used are those defined in Ch 7, Sec 3, [1.3].

Table 6 : Net thickness of plating

Plating location	Net thickness, in mm	Net minimum thickness, in mm
Bottom, side and transom	$14{,}9c_a c_r s\sqrt{\gamma_R\gamma_m\frac{\gamma_{S2}p_S+\gamma_{W2}p_W}{R_y}}$	$t = c_F(0{,}038L+7{,}0)(sk)^{1/2}-c_E$
Inner bottom		$2 + 0{,}017\ L\ k^{1/2} + 4{,}5\ s$
Deck		For strength deck: $2{,}1 + 0{,}013\ L\ k^{1/2} + 4{,}5\ s$
Platform and wash bulkhead		$1{,}3 + 0{,}004\ L\ k^{1/2} + 4{,}5\ s$ for $L < 120$ m $2{,}1 + 2{,}2\ k^{1/2} + s$ for $L \geq 120$ m

Table 7 : Net scantlings of ordinary stiffeners

Ordinary stiffener location	Formulae	Minimum value
Bottom and side	Net section modulus, in cm^3: $w = \gamma_R\gamma_m\beta_b\frac{\gamma_{S2}p_S+\gamma_{W2}p_W}{8R_y}\left(1-\frac{s}{2\ell}\right)s\ell^2 10^3$	Web net minimum thickness, in mm, to be not less than the lesser of: • $t = 1{,}5L_2^{1/3}k^{1/6}$ • the thickness of the attached plating.
	Net shear sectional area, in cm^2: $A_{Sh} = 10\gamma_R\gamma_m\beta_s\frac{\gamma_{S2}p_S+\gamma_{W2}p_W}{R_y}\left(1-\frac{s}{2\ell}\right)s\ell$	
Deck	Net section modulus, in cm^3: $w = \gamma_R\gamma_m\beta_b\frac{\gamma_{S2}p_S+\gamma_{W2}p_W}{mR_y}\left(1-\frac{s}{2\ell}\right)s\ell^2 10^3$	
	Net shear sectional area, in cm^2: $A_{Sh} = 10\gamma_R\gamma_m\beta_s\frac{\gamma_{S2}p_S+\gamma_{W2}p_W}{R_y}\left(1-\frac{s}{2\ell}\right)s\ell$	
Platform and wash bulkhead	Net section modulus, in cm^3: $w = 3{,}5s\ell^2 k(z_{TOP}-z_M)$	

Note 1:

m : Boundary coefficient, to be taken equal to:
- m = 12 for longitudinally framed decks
- m = 8 for transversely framed decks

Z_{TOP} : Z co-ordinate, in m, of the highest point of the peak tank

Z_M : Z co-ordinate, in m, of the stiffener mid-span.

4 Reinforcements of the flat area of the bottom aft

4.1 General

4.1.1 In the flat area of the bottom aft, if any, increased bottom plating thickness as well as additional bottom stiffeners may be considered by the Society on a case by case basis.

5 Connection of hull structures with the rudder horn

5.1 Connection of after peak structures with the rudder horn

5.1.1 General

The requirement of this sub-article apply to the connection between peak structure and rudder horn where the sternframe is of an open type and is fitted with the rudder horn.

5.1.2 Rudder horn

Horn design is to be such as to enable sufficient access for welding and inspection.

The scantlings of the rudder horn, which are to comply with Ch 10, Sec 1, [9.2], may be gradually tapered inside the hull.

Connections by slot welds are not acceptable.

5.1.3 Hull structures

Between the horn intersection with the shell and the peak tank top, the vertical extension of the hull structures is to be not less than the horn height, defined as the distance from the horn intersection with the shell to the mid-point of the lower horn gudgeon.

The thickness of the structures adjacent to the rudder horn, such as shell plating, floors, platforms and side girders, the centreline bulkhead and any other structures, is to be adequately increased in relation to the horn scantlings.

5.2 Structural arrangement above the after peak

5.2.1 Side transverses

Where a rudder horn is fitted, side transverses, connected to deck beams, are to be arranged between the platform forming the peak tank top and the weather deck.

The side transverse spacing is to be not greater than:

- 2 frame spacings in way of the horn
- 4 frame spacings for and aft of the rudder horn
- 6 frame spacings in the area close to the after peak bulkhead.

The side transverses are to be fitted with end brackets and located within the poop. Where there is no poop, the scantlings of side transverses below the weather deck are to be adequately increased with respect to those obtained from the formulae in [3.2.3].

5.2.2 Side girders

Where the depth from the peak tank top to the weather deck is greater than 2,6 m and the side is transversely framed, one or more side girders are to be fitted, preferably in line with similar structures existing forward.

6 Sternframes

6.1 General

6.1.1 Sternframes may be made of cast or forged steel, with a hollow section, or fabricated from plate.

6.1.2 Cast steel and fabricated sternframes are to be strengthened by adequately spaced horizontal plates.

Abrupt changes of section are to be avoided in castings; all sections are to have adequate tapering radius.

6.2 Connections

6.2.1 Connection with hull structure

Sternframes are to be effectively attached to the aft structure and the lower part of the sternframe is to be extended forward of the propeller post to a length not less than 1500 + 6L mm, in order to provide an effective connection with the keel. However, the sternframe need not extend beyond the after peak bulkhead.

The net thickness of shell plating connected with the sternframe is to be not less than that obtained, in mm, from the following formula:

$$t = 0,045\ L\ k^{1/2} + 8,5$$

6.2.2 Connection with the keel

The thickness of the lower part of the sternframes is to be gradually tapered to that of the solid bar keel or keel plate.

Where a keel plate is fitted, the lower part of the sternframe is to be so designed as to ensure an effective connection with the keel.

6.2.3 Connection with transom floors

Rudder posts and, in the case of ships greater than 90 m in length, propeller posts are to be connected with transom floors having height not less than that of the double bottom and net thickness not less than that obtained, in mm, from the following formula:

$$t = 9 + 0,023\ L_1\ k^{1/2}$$

6.2.4 Connection with centre keelson

Where the sternframe is made of cast steel, the lower part of the sternframe is to be fitted, as far as practicable, with a longitudinal web for connection with the centre keelson.

6.3 Propeller posts

6.3.1 Gross scantlings

With reference to Ch 4, Sec 2, [1], all scantlings and dimensions referred to in [6.3.2] to [6.3.4] are gross, i.e. they include the margins for corrosion.

6.3.2 Gross scantlings of propeller posts

The gross scantlings of propeller posts are to be not less than those obtained from the formulae in Tab 8 for single screw ships and Tab 9 for twin screw ships.

Scantlings and proportions of the propeller post which differ from those above may be considered acceptable provided that the section modulus of the propeller post section about its longitudinal axis is not less than that calculated with the propeller post scantlings in Tab 8 or Tab 9, as applicable.

6.3.3 Section modulus below the propeller shaft bossing

In the case of a propeller post without a sole piece, the section modulus of the propeller post may be gradually reduced below the propeller shaft bossing down to 85% of the value calculated with the scantlings in Tab 8 or Tab 9, as applicable.

In any case, the thicknesses of the propeller posts are to be not less than those obtained from the formulae in the tables.

6.3.4 Welding of fabricated propeller post with the propeller shaft bossing

Welding of a fabricated propeller post with the propeller shaft bossing is to be in accordance with Ch 12, Sec 1, [3.3].

6.4 Integral rudder posts

6.4.1 Net section modulus of integral rudder post

The net section modulus around the horizontal axis X (see Fig 1) of an integral rudder post is to be not less than that obtained, in cm^3, from the following formula:

$$w_{RP} = 14{,}4\, C_R\, L_D\, 10^{-6}$$

where:

C_R : Rudder force, in N, acting on the rudder blade, defined in Ch 10, Sec 1, [2.1.2] and Ch 10, Sec 1, [2.2.2], as the case may be

L_D : Length of rudder post, in m.

6.5 Propeller shaft bossing

6.5.1 In single screw ships, the thickness of the propeller shaft bossing, included in the propeller post, is to be not less than 60% of the dimension "b" required in [6.3.2] for bar propeller posts with a rectangular section.

Table 8 : Single screw ships - Gross scantlings of propeller posts

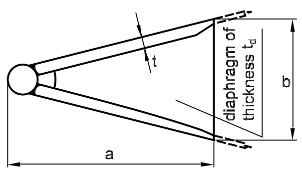
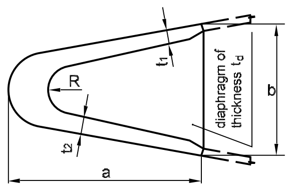
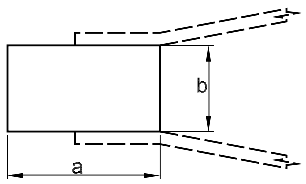
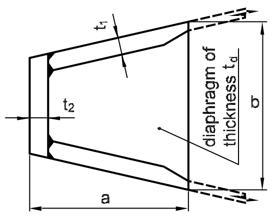
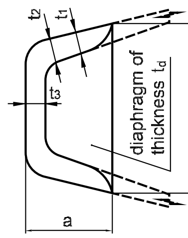
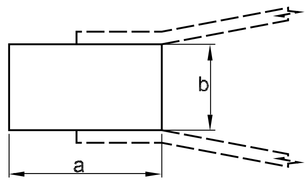
Gross scantlings of propeller posts, in mm	**Fabricated propeller post** 	**Cast propeller post** 	**Bar propeller post, cast or forged, having rectangular section** 
a	$50\,L^{1/2}$	$33\,L^{1/2}$	$10 \cdot \sqrt{2{,}5(L+10)}$ for $L \le 60$ $10 \cdot \sqrt{7{,}2L-256}$ for $L > 60$
b	$35\,L^{1/2}$	$23\,L^{1/2}$	$10 \cdot \sqrt{1{,}6(L+10)}$ for $L \le 60$ $10 \cdot \sqrt{4{,}6L-164}$ for $L > 60$
t_1 **(1)**	$2{,}5\,L^{1/2}$	$3{,}2\,L^{1/2}$ to be taken not less than 19 mm	ϕ
t_2 **(1)**	ϕ	$4{,}4\,L^{1/2}$ to be taken not less than 19 mm	ϕ
t_D	$1{,}3\,L^{1/2}$	$2{,}0\,L^{1/2}$	ϕ
R	ϕ	50	ϕ
(1) Propeller post thicknesses t_1 and t_2 are, in any case, to be not less than (0,05 L + 9,5) mm. **Note 1:** ϕ = not applicable.			

Table 9 : Twin screw ships - Gross scantlings of propeller posts

Gross scant-lings of pro-pellerposts, in mm	**Fabricated propeller post** 	**Cast propeller post** 	**Bar propeller post, cast or forged, having rectangular section** 
a	25 $L^{1/2}$	12,5 $L^{1/2}$	0,72 L + 90 for $L \le 50$ 2,40 L + 6 for $L > 50$
b	25 $L^{1/2}$	25 $L^{1/2}$	0,24 L + 30 for $L \le 50$ 0,80 L + 2 for $L > 50$
t_1 **(1)**	2,5 $L^{1/2}$	2,5 $L^{1/2}$	ϕ
t_2 **(1)**	3,2 $L^{1/2}$	3,2 $L^{1/2}$	ϕ
t_3 **(1)**	ϕ	4,4 $L^{1/2}$	ϕ
t_D	1,3 $L^{1/2}$	2 $L^{1/2}$	ϕ

(1) Propeller post thicknesses t_1, t_2 and t_3 are, in any case, to be not less than (0,05 L + 9,5) mm.
Note 1: ϕ = not applicable.

6.6 Rudder gudgeon

6.6.1 Rudder gudgeons

In general, gudgeons are to be solidly forged or cast with the sternframe.

The height of the gudgeon is to be not greater than 1,2 times the pintle diameter. In any case, the height and diameter of the gudgeons are to be suitable to house the rudder pintle.

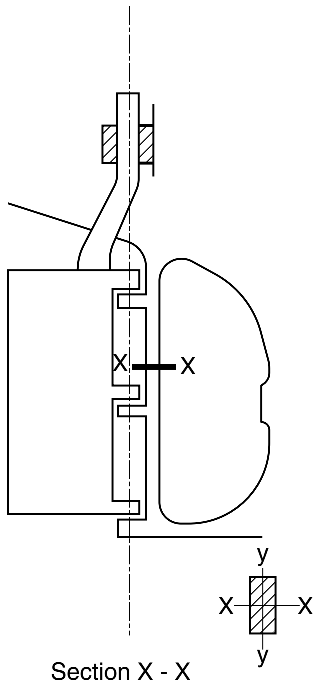
The thickness of the metal around the finished bore of the gudgeons is to be not less than half the diameter of the pintle.

6.7 Sterntubes

6.7.1 The sterntube thickness is considered by the Society on a case by case basis. In no case, however, may it be less than the thickness of the side plating adjacent to the sternframe.

Where the materials adopted for the sterntube and the plating adjacent to the sternframe are different, the sterntube thickness is to be at least equivalent to that of the plating.

Figure 1 : Integral rudder post



SECTION 3 MACHINERY SPACE

Symbols

L_2 : Length, in m, defined in Ch 1, Sec 2, [2.1.1]

k : Material factor, defined in Ch 4, Sec 1, [2.3]

s : Spacing, in m, of ordinary stiffeners

P : Maximum power, in kW, of the engine

n_r : Number of revolutions per minute of the engine shaft at power equal to P

L_E : Effective length, in m, of the engine foundation plate required for bolting the engine to the seating, as specified by the engine manufacturer.

1 General

1.1 Application

1.1.1 The requirements of this Section apply for the arrangement and scantling of machinery space structures as regards general strength. It is no substitute to machinery manufacturer's requirements which have to be dealt with at Shipyard diligence.

1.2 Scantlings

1.2.1 Net scantlings

As specified in Ch 4, Sec 2, [1], all scantlings referred to in this Section are net, i.e. they do not include any margin for corrosion.

The gross scantlings are obtained as specified in Ch 4, Sec 2.

1.2.2 General

Unless otherwise specified in this Section, the scantlings of plating, ordinary stiffeners and primary supporting members in the machinery space are to be determined according to the relevant criteria in Chapter 7 or Chapter 8, as applicable. In addition, the minimum thickness requirements specified in this Section apply.

1.2.3 Primary supporting members

The Designer may propose arrangements and scantlings alternative to the requirements of this Section, on the basis of direct calculations which are to be submitted to the Society for examination on a case by case basis.

The Society may also require such direct calculations to be carried out whenever deemed necessary.

1.3 Connections of the machinery space with structures located aft and forward

1.3.1 Tapering

Adequate tapering is to be ensured between the scantlings in the machinery space and those aft and forward. The tapering is to be such that the scantling requirements for all areas are fulfilled.

1.3.2 Deck discontinuities

Decks which are interrupted in the machinery space are to be tapered on the side by means of horizontal brackets.

2 Double bottom

2.1 Arrangement

2.1.1 General

Where the machinery space is immediately forward of the after peak, the double bottom is to be transversely framed. In all other cases it may be transversely or longitudinally framed.

2.1.2 Double bottom height

The double bottom height at the centreline, irrespective of the location of the machinery space, is to be not less than the value defined in Ch 4, Sec 4, [4.2.1]. This depth may need to be considerably increased in relation to the type and depth of main machinery seatings.

The above height is to be increased by the Shipyard where the machinery space is very large and where there is a considerable variation in draught between light ballast and full load conditions.

Where the double bottom height in the machinery space differs from that in adjacent spaces, structural continuity of longitudinal members is to be ensured by sloping the inner bottom over an adequate longitudinal extent. The knuckles in the sloped inner bottom are to be located in way of floors.

2.1.3 Centre bottom girder

In general, the centre bottom girder may not be provided with holes. In any case, in way of any openings for manholes on the centre girder, permitted only where absolutely necessary for double bottom access and maintenance, local strengthening is to be arranged.

2.1.4 Side bottom girders

In the machinery space the number of side bottom girders is to be adequately increased, with respect to the adjacent areas, to ensure adequate rigidity of the structure.

The side bottom girders are to be a continuation of any bottom longitudinals in the areas adjacent to the machinery space and are generally to have a spacing not greater than 3 times that of longitudinals and in no case greater than 3 m.

2.1.5 Side bottom girders in way of machinery seatings

Additional side bottom girders are to be fitted in way of machinery seatings.

Side bottom girders arranged in way of main machinery seatings are to extend for the full length of the machinery space.

Where the machinery space is situated amidships, the bottom girders are to extend aft of the after bulkhead of such space for at least three frame spaces, and beyond to be connected to the hull structure by tapering.

Where the machinery space is situated aft, the bottom girders are to extend as far aft as practicable in relation to the shape of the bottom and to be supported by floors and side primary supporting members at the ends.

Forward of the machinery space forward bulkhead, the bottom girders are to be tapered for at least three frame spaces and are to be effectively connected to the hull structure.

2.1.6 Floors in longitudinally framed double bottom

Where the double bottom is longitudinally framed, the floor spacing is to be not greater than:

- 1 frame spacing in way of the main engine and thrust bearing
- 2 frame spacings in other areas of the machinery space.

Additional floors are to be fitted in way of other important machinery.

2.1.7 Floors in transversely framed double bottom

Where the double bottom in the machinery space is transversely framed, floors are to be arranged at every frame.

Furthermore, additional floors are to be fitted in way of boiler foundations or other important machinery.

2.1.8 Floors stiffeners

In addition to the requirements in Ch 4, Sec 3, [4.7], floors are to have web stiffeners sniped at the ends and spaced not more than approximately 1 m apart.

The section modulus of web stiffeners is to be not less than 1,2 times that required in Ch 4, Sec 3, [4.7].

2.1.9 Manholes and wells

The number and size of manholes in floors located in way of seatings and adjacent areas are to be kept to the minimum necessary for double bottom access and maintenance.

The depth of manholes is generally to be not greater than 40% of the floor local depth, and in no case greater than 750 mm, and their width is to be equal to approximately 400 mm.

In general, manhole edges are to be stiffened with flanges; failing this, the floor plate is to be adequately stiffened with flat bars at manhole sides.

Manholes with perforated portable plates are to be fitted in the inner bottom in the vicinity of wells arranged close to the aft bulkhead of the engine room.

Drainage of the tunnel is to be arranged through a well located at the aft end of the tunnel.

2.2 Minimum thicknesses

2.2.1 The net thicknesses of inner bottom, floor and girder webs are to be not less than the values given in Tab 1.

3 Single bottom

3.1 Arrangement

3.1.1 Bottom girder

For single bottom girder arrangement, the requirements of Ch 4, Sec 4, [4.1] and Ch 4, Sec 4, [4.4] for double bottom apply.

3.1.2 Floors in longitudinally framed single bottom

Where the single bottom is longitudinally framed, the floor spacing is to be not greater than:

- 1 frame spacing in way of the main engine and thrust bearing
- 2 frame spacings in other areas of the machinery spaces.

Additional floors are to be fitted in way of other important machinery.

Table 1 : Double bottom - Minimum net thicknesses of inner bottom, floor and girder webs

Element	Minimum net thickness, in mm	
	Machinery space within 0,4L amidships	Machinery space outside 0,4L amidships
Inner bottom	$[0,75L^{1/2} + 1,35 + 4,5(s - 0,23L^{1/4})]k^{1/2}$ The Society may require the thickness of the inner bottom in way of the main machinery seatings and on the main thrust blocks to be increased, on a case by case basis.	
Margin plate	$L^{1/2}\,k^{1/4} + 1$	$0,9\,L^{1/2}\,k^{1/4} + 1$
Centre girder	$1,8\,L^{1/3}\,k^{1/6} + 4$	$1,55\,L^{1/3}\,k^{1/6} + 3,5$
Floors and side girders	$1,7\,L^{1/3}\,k^{1/6} + 1$	
Girder bounding a duct keel	$0,8\,L^{1/2}\,k^{1/4} + 2,5$ to be taken not less than that required for the centre girder	

3.1.3 Floors in transversely framed single bottom

Where the single bottom is transversely framed, the floors are to be arranged at every frame.

Furthermore, additional floors are to be fitted in way of boiler foundations or other important machinery.

3.1.4 Floor height

The height of floors in way of machinery spaces located amidships is to be not less than B/14,5. Where the top of the floors is recessed in way of main machinery, the height of the floors in way of this recess is generally to be not less than B/16. Lower values will be considered by the Society on a case by case basis.

Where the machinery space is situated aft or where there is considerable rise of floor, the depth of the floors will be considered by the Society on a case by case basis.

3.1.5 Floor flanging

Floors are to be fitted with welded face plates in way of:

- engine bed plates
- thrust blocks
- auxiliary seatings.

3.2 Minimum thicknesses

3.2.1 The net thicknesses of inner bottom, floor and girder webs are to be not less than the values given in Tab 2.

Table 2 : Single bottom - Minimum net thicknesses of inner bottom, floor and girder webs

Element	Minimum net thickness, in mm	
	Machinery space within 0,4L amidships	Machinery space outside 0,4L amidships
Centre girder	$7 + 0{,}05\ L_2\ k^{1/2}$	$6 + 0{,}05\ L_2\ k^{1/2}$
Floors and side girder	$6{,}5 + 0{,}05\ L_2\ k^{1/2}$	$5 + 0{,}05\ L_2\ k^{1/2}$

4 Side

4.1 Arrangement

4.1.1 General

The type of side framing in machinery spaces is generally to be the same as that adopted in the adjacent areas.

4.1.2 Extension of the hull longitudinal structure within the machinery space

In ships where the machinery space is located aft and where the side is longitudinally framed, the longitudinal structure is preferably to extend for the full length of the machinery space.

In any event, the longitudinal structure is to be maintained for at least 0,3 times the length of the machinery space, calculated from the forward bulkhead of the latter, and abrupt structural discontinuities between longitudinally and transversely framed structures are to be avoided.

4.1.3 Side transverses

Side transverses are to be aligned with floors. One is preferably to be located in way of the forward end and another in way of the after end of the machinery casing.

For a longitudinally framed side, the side transverse spacing is to be not greater than 4 frame spacings.

For a transversely framed side, the side transverse spacing is to be not greater than 5 frame spaces. The web height is to be not less than twice that of adjacent frames and the section modulus is to be not less than four times that of adjacent frames.

Side transverse spacing greater than that above may be accepted provided that the scantlings of ordinary frames are increased, according to the Society's requirements to be defined on a case by case basis.

5 Platforms

5.1 Arrangement

5.1.1 General

The location and extension of platforms in machinery spaces are to be arranged so as to be a continuation of the structure of side longitudinals, as well as of platforms and side girders located in the adjacent hull areas.

5.1.2 Platform transverses

In general, platform transverses are to be arranged in way of side or longitudinal bulkhead transverses.

For longitudinally framed platforms, the spacing of platform transverses is to be not greater than 4 frame spacings.

5.2 Minimum thicknesses

5.2.1 The net thickness of platforms is to be not less than that obtained, in mm, from the following formula:

$$t = 0{,}018 L_2 k^{1/2} + 4{,}5$$

6 Pillaring

6.1 Arrangement

6.1.1 General

The pillaring arrangement in machinery spaces is to account both for the concentrated loads transmitted by machinery and superstructures and for the position of main machinery and auxiliary engines.

6.1.2 Pillars

Pillars are generally to be arranged in the following positions:

- in way of machinery casing corners and corners of large openings on platforms; alternatively, two pillars may be fitted on the centreline (one at each end of the opening)
- in way of the intersection of platform transverses and girders
- in way of transverse and longitudinal bulkheads of the superstructure.

In general, pillars are to be fitted with brackets at their ends.

6.1.3 Pillar bulkheads

In general, pillar bulkheads, fitted ‘tweendecks below the upper deck, are to be located in way of load-bearing bulkheads in the superstructures.

Longitudinal pillar bulkheads are to be a continuation of main longitudinal hull structures in the adjacent spaces forward and aft of the machinery space.

Pillar bulkhead scantlings are to be not less than those required in [7.3] for machinery casing bulkheads.

7 Machinery casing

7.1 Arrangement

7.1.1 Ordinary stiffener spacing

Ordinary stiffeners are to be located:

- at each frame, in longitudinal bulkheads
- at a distance of about 750 mm, in transverse bulkheads.

The ordinary stiffener spacing in portions of casings which are particularly exposed to wave action is considered by the Society on a case by case basis.

7.2 Openings

7.2.1 General

All machinery space openings, which are to comply with the requirements in Sec 9, [6], are to be enclosed in a steel casing leading to the highest open deck. Casings are to be reinforced at the ends by deck beams and girders associated to pillars.

In the case of large openings, the arrangement of cross-ties as a continuation of deck beams may be required.

Skylights, where fitted with openings for light and air, are to have coamings of a height not less than:

- 900 mm, if in position 1
- 760 mm, if in position 2.

7.2.2 Access doors

Access doors to casings are to comply with Sec 9, [6.2].

7.3 Scantlings

7.3.1 Plating and ordinary stiffeners

The net scantlings of plating and ordinary stiffeners are to be not less than those obtained according to the applicable requirements in Sec 4.

7.3.2 Minimum thicknesses

The net thickness of bulkheads is to be not less than:

- 5,5 mm for bulkheads in way of cargo holds
- 4 mm for bulkheads in way of accommodation spaces.

8 Main machinery seatings

8.1 Arrangement

8.1.1 General

The scantlings of main machinery seatings and thrust bearings are to be adequate in relation to the weight and power of engines and the static and dynamic forces transmitted by the propulsive installation.

8.1.2 Seating supporting structure

Transverse and longitudinal members supporting the seatings are to be located in line with floors and double or single bottom girders, respectively.

They are to be so arranged as to avoid discontinuity and ensure sufficient accessibility for welding of joints and for surveys and maintenance.

8.1.3 Seatings included in the double bottom structure

Where high-power internal combustion engines or turbines are fitted, seatings are to be integral with the double bottom structure. Girders supporting the bedplates in way of seatings are to be aligned with double bottom girders and are to be extended aft in order to form girders for thrust blocks.

The girders in way of seatings are to be continuous from the bedplates to the bottom shell.

8.1.4 Seatings above the double bottom plating

Where the seatings are situated above the double bottom plating, the girders in way of seatings are to be fitted with flanged brackets, generally located at each frame and extending towards both the centre of the ship and the sides.

The extension of the seatings above the double bottom plating is to be limited as far as practicable while ensuring adequate spaces for the fitting of bedplate bolts. Bolt holes are to be located such that they do not interfere with seating structures.

8.1.5 Seatings in a single bottom structure

For ships having a single bottom structure within the machinery space, seatings are to be located above the floors and to be adequately connected to the latter and to the girders located below.

8.1.6 Number of girders in way of machinery seatings

In general, at least two girders are to be fitted in way of main machinery seatings.

One girder may be fitted only where the following three formulae are complied with:

$$L < 150\,m$$
$$P < 7100\,kW$$
$$P < 2{,}3\,n_R L_E$$

8.2 Minimum scantlings

8.2.1 As a guidance, the net scantlings of the structural elements in way of the internal combustion engine seatings may be obtained from the formulae in Tab 3.

Table 3 : Minimum scantlings of the structural elements in way of machinery seatings

Scantling	Minimum value
Net cross-sectional area, in cm^2, of each bedplate of the seatings	$40 + 70\frac{P}{n_r L_E}$
Bedplate net thickness, in mm	• Bedplates supported by two or more girders: $\sqrt{240 + 175\frac{P}{n_r L_E}}$ • Bedplates supported by one girder: $5 + \sqrt{240 + 175\frac{P}{n_r L_E}}$
Total web net thickness, in mm, of girders fitted in way of machinery seatings	• Bedplates supported by two or more girders: $\sqrt{320 + 215\frac{P}{n_r L_E}}$ • Bedplates supported by one girder: $\sqrt{95 + 65\frac{P}{n_r L_E}}$
Web net thickness, in mm, of floors fitted in way of machinery seatings	$\sqrt{55 + 40\frac{P}{n_r L_E}}$

SECTION 4 SUPERSTRUCTURES AND DECKHOUSES

Symbols

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, [4]

s : Spacing, in m, of ordinary stiffeners

k : Material factor, defined in:

- Ch 4, Sec 1, [2.3], for steel
- Ch 4, Sec 1, [4.4], for aluminium alloys

t_c : Corrosion addition, in mm, defined in Ch 4, Sec 2, Tab 2.

1 General

1.1 Application

1.1.1 The requirements of this Section apply for the scantling of plating and associated structures of front, side and aft bulkheads and decks of superstructures and deckhouses, which may or may not contribute to the longitudinal strength.

1.1.2 The requirements of this Section comply with the applicable regulations of the 1966 International Convention on Load Lines, with regard to the strength of enclosed superstructures.

1.2 Net scantlings

1.2.1 As specified in Ch 4, Sec 2, [1], all scantlings referred to in this Section are net, i.e. they do not include any margin for corrosion.

The gross scantlings are obtained as specified in Ch 4, Sec 2.

1.3 Definitions

1.3.1 Superstructures and deckhouses contributing to the longitudinal strength

Superstructures and deckhouses contributing to the longitudinal strength are defined in Ch 6, Sec 1, [2.2].

1.3.2 Tiers of superstructures and deckhouses

The lowest tier is normally that which is directly situated above the freeboard deck.

Where the freeboard exceeds one standard superstructure height, defined in Ch 1, Sec 2, Tab 2 for "all other superstructures", the lowest tier may be considered as an upper tier when calculating the scantlings of superstructures and deckhouses.

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

1.4 Connections of superstructures and deckhouses with the hull structure

1.4.1 Superstructure and deckhouse frames are to be fitted as far as practicable as extensions of those underlying and are to be effectively connected to both the latter and the deck beams above.

Ends of superstructures and deckhouses are to be efficiently supported by bulkheads, diaphragms, webs or pillars.

Where hatchways are fitted close to the ends of superstructures, additional strengthening may be required.

1.4.2 Connection to the deck of corners of superstructures and deckhouses is considered by the Society on a case by case basis. Where necessary, doublers or reinforced welding may be required.

1.4.3 As a rule, the frames of sides of superstructures and deckhouses are to have the same spacing as the beams of the supporting deck.

Web frames are to be arranged to support the sides and ends of superstructures and deckhouses.

1.4.4 The side plating at ends of superstructures is to be tapered into the bulwark or sheerstrake of the strength deck.

Where a raised deck is fitted, this arrangement is to extend over at least 3 frame spacings.

1.5 Structural arrangement of superstructures and deckhouses

1.5.1 Strengthening in way of superstructures and deckhouses

Web frames, transverse partial bulkheads or other equivalent strengthening are to be fitted inside deckhouses of at least 0,5B in breadth extending more than 0,15L in length within 0,4L amidships. These transverse strengthening reinforcements are to be spaced approximately 9 m apart and are to be arranged, where practicable, in line with the transverse bulkheads below.

Web frames are also to be arranged in way of large openings, boats davits and other areas subjected to point loads.

Web frames, pillars, partial bulkheads and similar strengthening are to be arranged, in conjunction with deck transverses, at ends of superstructures and deckhouses.

1.5.2 Strenghtening of the raised quarter deck stringer plate

When a superstructure is located above a raised quarter deck, the thickness of the raised quarter deck stringer plate is to be increased by 30% and is to be extended within the superstructure.

The increase above may be reduced when the raised quarter deck terminates outside 0,5 L amidships.

1.5.3 Openings

Openings are to be in accordance with Sec 9.

Continuous coamings are to be fitted above and below doors or similar openings.

1.5.4 Access and doors

Access openings cut in sides of enclosed superstructures are to be fitted with doors made of steel or other equivalent material, and permanently attached.

Special consideration is to be given to the connection of doors to the surrounding structure.

Securing devices which ensure watertightness are to include tight gaskets, clamping dogs or other similar appliances, and are to be permanently attached to the bulkheads and doors. These doors are to be operable from both sides.

Doors are to open outwards, to provide additional security against the impact of the sea, unless otherwise permitted by the Society.

1.5.5 Strengthening of deckhouses in way of lifeboats and rescue boats

Sides of deckhouses are to be strengthened in way of lifeboats and rescue boats and the top plating is to be reinforced in way of their lifting appliances.

1.5.6 Constructional details

Lower tier stiffeners are to be welded to the decks at their ends.

Brackets are to be fitted at the upper and preferably also the lower ends of vertical stiffeners of exposed front bulkheads of engine casings and superstructures or deckhouses protecting pump room openings.

1.5.7 Use of aluminium alloys

Unprotected front bulkheads of first tier superstructures or deckhouses are generally to be built of steel and not of aluminium alloy.

Aluminium alloys may be adopted for front bulkheads of superstructures or deckhouses above the first tier.

2 Design loads

2.1 Sides contributing to the longitudinal strength

2.1.1 Load point

Lateral pressure is to be calculated at:

- the lower edge of the elementary plate panel, for plating
- mid-span, for stiffeners.

2.1.2 Lateral pressure

The lateral pressure is constituted by the still water sea pressure (p_S) and the wave pressure (p_W), defined in Ch 5, Sec 5.

Moreover, when the side is a tank boundary, the lateral pressure constituted by the still water internal pressure (p_S) and the inertial pressure (p_W), defined in Ch 5, Sec 6, [1] is also to be considered.

2.2 Front, side and aft bulkheads not contributing to the longitudinal strength

2.2.1 Load point

Lateral pressure is to be calculated at:

- mid-height of the bulkhead, for plating
- mid-span, for stiffeners.

2.2.2 Lateral pressure

The lateral pressure to be used for the determination of scantlings of the structure of front, side and aft bulkheads of superstructures and deckhouses is to be obtained, in kN/m², from the following formula:

$$p = 10ac[bf-(z-T)]$$

without being less than p_{min}

where:

a : Coefficient defined in Tab 1

c : Coefficient taken equal to:

$$c = 0,3 + 0,7\frac{b_1}{B_1}$$

For exposed parts of machinery casings, c is to be taken equal to 1

b_1 : Breadth of deckhouse, in m, at the position considered, to be taken not less than $0,25B_1$

B_1 : Actual maximum breadth of ship on the exposed weather deck, in m, at the position considered

b : Coefficient defined in Tab 2

f : Coefficient defined in Tab 3

p_{min} : Minimum lateral pressure defined in Tab 4.

2.3 Decks

2.3.1 The lateral pressure for decks which may or may not contribute to the longitudinal strength is constituted by the still water internal pressure (p_S) and the inertial pressure (p_W), defined in Ch 5, Sec 6, [7].

Moreover, when the deck is a tank boundary, the lateral pressure constituted by the still water internal pressure (p_S) and the inertial pressure (p_W), defined in Ch 5, Sec 6, [1] is also to be considered.

Table 1 : Lateral pressure for superstructures and deckhouses - Coefficient a

Type of bulkhead	Location	a	a maximum
Unprotected front	Lowest tier	$2 + \frac{L}{120}$	4,5
	Second tier	$1 + \frac{L}{120}$	3,5
	Third tier	$0,5 + \frac{L}{150}$	2,5
	Fourth tier	$0,9\left(0,5 + \frac{L}{150}\right)$	2,25
	Fifth tier and above	$0,8\left(0,5 + \frac{L}{150}\right)$	2,0
Protected front	Lowest, second and third tiers	$0,5 + \frac{L}{150}$	2,5
	Fourth tier	$0,9\left(0,5 + \frac{L}{150}\right)$	2,25
	Fifth tier and above	$0,8\left(0,5 + \frac{L}{150}\right)$	2,0
Side	Lowest, second and third tiers	$0,5 + \frac{L}{150}$	2,5
	Fourth tier	$0,9\left(0,5 + \frac{L}{150}\right)$	2,25
	Fifth tier and above	$0,8\left(0,5 + \frac{L}{150}\right)$	2,0
Aft end	All tiers, when: x/L ≤ 0,5	$0,7 + \frac{L}{1000} - 0,8\frac{x}{L}$	$1 - 0,8\frac{x}{L}$
	All tiers, when: x/L > 0,5	$0,5 + \frac{L}{1000} - 0,4\frac{x}{L}$	$0,8 - 0,4\frac{x}{L}$

Table 2 : Lateral pressure for superstructures and deckhouses - Coefficient b

Location of bulkhead **(1)**	b
$\frac{x}{L} \le 0,45$	$1 + \left(\frac{\frac{x}{L} - 0,45}{C_B + 0,2}\right)^2$
$\frac{x}{L} > 0,45$	$1 + 1,5\left(\frac{\frac{x}{L} - 0,45}{C_B + 0,2}\right)^2$

(1) For deckhouse sides, the deckhouse is to be subdivided into parts of approximately equal length, not exceeding 0,15L each, and x is to be taken as the co-ordinate of the centre of each part considered.

Note 1:

C_B : Block coefficient, with $0,6 \le C_B \le 0,8$

Table 3 : Lateral pressure for superstructures and deckhouses - Coefficient f

Length L of ship, in m	f
L < 150	$\frac{L}{10}e^{-L/300} - \left[1 - \left(\frac{L}{150}\right)^2\right]$
150 ≤ L < 300	$\frac{L}{10}e^{-L/300}$
L ≥ 300	11,03

Table 4 : Lateral minimum pressure for superstructures and deckhouses

Type of bulkhead	Location	p_{min}, in kN/m²
Unprotected front	Lowest tier	$30 \le 25,0 + 0,10L \le 50$
	Second and third tiers	$15 \le 12,5 + 0,05L \le 25$
	Fourth tier and above	$12 \le 10,0 + 0,04L \le 20$
Protected front, side and aft end	Lowest, second and third tiers	$15 \le 12,5 + 0,05L \le 25$
	Fourth tier and above	$12 \le 10,0 + 0,04L \le 20$

3 Plating

3.1 Front, side and aft bulkheads

3.1.1 Plating contributing to the longitudinal strength

The net thickness of side plate panels contributing to the longitudinal strength is to be determined in accordance with the applicable requirements of Ch 7, Sec 1 or Ch 8, Sec 3, as applicable, considering the lateral pressure defined in [2.1.2].

3.1.2 Plating not contributing to the longitudinal strength

The net thickness of plating of front, side and aft bulkheads not contributing to the longitudinal strength is to be not less than the value obtained, in mm, from the following formula:

$$t = 0,95s\sqrt{kp} - t_c$$

without being less than the values indicated in Tab 5, where p is the lateral pressure, in kN/m², defined in [2.2].

For plating which forms tank boundaries, the net thickness is to be determined in accordance with [3.1.1], considering the hull girder stress equal to 0.

3.2 Decks

3.2.1 The net thickness of plate panels of decks which may or may not contribute to the longitudinal strength is to be determined in accordance with the applicable requirements of Ch 7, Sec 1 or Ch 8, Sec 3, as applicable.

Table 5 : Superstructures and deckhouses Minimum thicknesses

Location	Minimum thickness, in mm
Lowest tier	$(5 + 0,01\ L)\ k^{1/2} - t_C$
Second tier and above	$(4 + 0,01\ L)\ k^{1/2} - t_C$
Note 1: L is to be taken not less than 100m and not greater than 300m.	

3.2.2 For decks sheathed with wood, the net thickness obtained from [3.2.1] may be reduced by 10 percent.

4 Ordinary stiffeners

4.1 Front, side and aft bulkheads

4.1.1 Ordinary stiffeners of plating contributing to the longitudinal strength

The net scantlings of ordinary stiffeners of plating contributing to the longitudinal strength are to be determined in accordance with the applicable requirements of Ch 7, Sec 2 or Ch 8, Sec 4, as applicable.

4.1.2 Ordinary stiffeners of plating not contributing to the longitudinal strength

The net section modulus w of ordinary stiffeners of plating not contributing to the longitudinal strength is to be not less than the value obtained, in cm^3, from the following formula:

$$w = 0,35\varphi k s \ell^2 p(1 - \alpha t_c) - \beta t_c$$

where:

ℓ : Span of the ordinary stiffener, in m, equal to the 'tweendeck height and to be taken not less than 2 m

p : Lateral pressure, in kN/m^2, defined in [2.2]

φ : Coefficient depending on the stiffener end connections, and taken equal to:

- 1 for lower tier stiffeners
- value defined in Tab 6 for stiffeners of upper tiers

α, β : Parameters defined in Ch 4, Sec 2, Tab 1.

The section modulus of side ordinary stiffeners need not be greater than that of the side ordinary stiffeners of the tier situated directly below taking account of spacing and span.

For ordinary stiffeners of plating forming tank boundaries, the net scantlings are to be determined in accordance with [4.1.1], considering the hull girder stress equal to 0.

Table 6 : Stiffeners of superstructures and deckhouses - Coefficient φ for end connections

Coefficient φ	Upper end welded to deck	Bracketed upper end	Sniped upper end
Lower end welded to deck	1,00	0,85	1,15
Bracketed lower end	0,85	0,85	1,00
Sniped lower end	1,15	1,00	1,15

4.2 Decks

4.2.1 The net scantlings of ordinary stiffeners of decks which may or may not contribute to the longitudinal strength are to be determined in accordance with the applicable requirements of Ch 7, Sec 2.

5 Primary supporting members

5.1 Front, side and aft bulkheads

5.1.1 Primary supporting members of plating contributing to the longitudinal strength

The net scantlings of side primary supporting members of plating contributing to the longitudinal strength are to be determined in accordance with the applicable requirements of Ch 7, Sec 3 or Ch 8, Sec 5, as applicable.

5.1.2 Primary supporting members of plating not contributing to the longitudinal strength

The net scantlings of side primary supporting members of plating not contributing to the longitudinal strength are to be determined in accordance with the applicable requirements of Ch 7, Sec 3 or Ch 8, Sec 5, as applicable, using the lateral pressure defined in [2.2].

5.2 Decks

5.2.1 The net scantlings of primary supporting members of decks which may or may not contribute to the longitudinal strength are to be determined in accordance with the applicable requirements of Ch 7, Sec 3.

6 Additional requirements applicable to movable wheelhouses

6.1 General

6.1.1 The requirements of this Article apply in addition of those in [1] to [5].

6.1.2 The structures of movable wheelhouses are to be checked in low and in high position.

6.1.3 Mechanical locking devices are to be fitted in addition to hydraulic systems.

6.2 Supports and guides, connections with the deck, under deck reinforcements, locking devices

6.2.1 Still water and inertial forces

The supports or guides of movable wheelhouses, connections with the deck, under deck reinforcements and locking devices are to be checked considering the sum of the following forces:

- still water and inertial forces, determined according to Ch 5, Sec 6, [5]
- wind forces, corresponding to a lateral pressure of 1,2kN/m².

6.2.2 Checking criteria

It is to be checked that the equivalent stress σ_{VM}, calculated according to Ch 7, App 1, [5.1.2] or Ch 7, App 1, [5.2.2], as applicable, is in compliance with the following formula:

$$\frac{R_y}{\gamma_R \gamma_m} \geq \sigma_{VM}$$

where:

R_y : Minimum yield stress, in N/mm², of the material, to be taken equal to 235/k, unless otherwise specified

γ_R : Partial safety factor covering uncertainties regarding resistance, to be taken equal to:

- 1,10 in general
- 1,40 for checking locking devices

γ_m : Partial safety factor covering uncertainties regarding material, to be taken equal to 1,02.

SECTION 5 BOW DOORS AND INNER DOORS

Symbols

L_1 : Length, in m, defined in Ch 1, Sec 2, [2.1.1].

1 General

1.1 Application

1.1.1 The requirements of this Section apply to the arrangement, strength and securing of bow doors and inner doors leading to a complete or long forward enclosed superstructure or to a long non-enclosed superstructure, when this is fitted to attain minimum bow height equivalence.

1.1.2 Two types of bow door are provided for:

- visor doors opened by rotating upwards and outwards about a horizontal axis through two or more hinges located near the top of the door and connected to the primary supporting members of the door by longitudinally arranged lifting arms
- side-opening doors opened either by rotating outwards about a vertical axis through two or more hinges located near the outboard edges or by horizontal translation by means of linking arms arranged with pivoted attachments to the door and the ship. It is anticipated that side-opening bow doors are arranged in pairs.

Other types of bow door are considered by the Society on a case by case basis in association with the applicable requirements of this Section.

1.2 Gross scantlings

1.2.1 With reference to Ch 4, Sec 2, [1], all scantlings and dimensions referred to in this Section are gross, i.e. they include the margins for corrosion.

1.3 Arrangement

1.3.1 Bow doors are to be situated above the freeboard deck. A watertight recess in the freeboard deck located forward of the collision bulkhead and above the deepest waterline fitted for arrangement of ramps or other related mechanical devices may be regarded as a part of the freeboard deck for the purpose of this requirement.

1.3.2 An inner door is to be fitted as part of the collision bulkhead. The inner door need not be fitted directly above the bulkhead below, provided it is located within the limits specified for the position of the collision bulkhead, as per Ch 2, Sec 1, [2.1].

A vehicle ramp may be arranged for this purpose, provided its position complies with Ch 2, Sec 1, [2.1].

If this is not possible, a separate inner weathertight door is to be installed, as far as practicable within the limits specified for the position of the collision bulkhead.

1.3.3 Bow doors are to be so fitted as to ensure tightness consistent with operational conditions and to give effective protection to inner doors.

Inner doors forming part of the collision bulkhead are to be weathertight over the full height of the cargo space and arranged with fixed sealing supports on the aft side of the doors.

1.3.4 Bow doors and inner doors are to be arranged so as to preclude the possibility of the bow door causing structural damage to the inner door or to the collision bulkhead in the case of damage to or detachment of the bow door. If this is not possible, a separate inner weathertight door is to be installed, as indicated in [1.3.2].

1.3.5 The requirements for inner doors are based on the assumption that vehicles are effectively lashed and secured against movement in stowed position.

1.4 Definitions

1.4.1 Securing device

A securing device is a device used to keep the door closed by preventing it from rotating about its hinges.

1.4.2 Supporting device

A supporting device is a device used to transmit external or internal loads from the door to a securing device and from the securing device to the ship's structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, which transmits loads from the door to the ship's structure.

1.4.3 Locking device

A locking device is a device that locks a securing device in the closed position.

2 Design loads

2.1 Bow doors

2.1.1 Design external pressure

The design external pressure to be considered for the scantlings of primary supporting members and securing and supporting devices of bow doors is to be not less than that obtained, in kN/m², from the following formula:

$$p_E = 0,5 n_D C_L C_Z (0,22 + 0,15 \tan\alpha)(0,4 V \sin\beta + 0,6 \sqrt{L_1})^2$$

where:

n_D : Navigation coefficient, defined in Tab 1

V : Maximum ahead service speed, in knots

C_L : Coefficient depending on the ship's length:

$C_L = 0,0125\ L$ for $L < 80$ m

$C_L = 1,0$ for $L \geq 80$ m

C_Z : Coefficient defined in Sec 1, [4.3.1], to be taken equal to 5,5

α : Flare angle at the calculation point, defined as the angle between a vertical line and the tangent to the side plating, measured in a vertical plane normal to the horizontal tangent to the shell plating (see Fig 1)

β : Entry angle at the calculation point, defined as the angle between a longitudinal line parallel to the centreline and the tangent to the shell plating in a horizontal plane (see Fig 1).

Table 1 : Navigation coefficient

Navigation notation	Navigation coefficient n_D
Unrestricted navigation	1,00
Summer zone	1,00
Tropical zone	0,80
Coastal area	0,80
Sheltered area	0,50

2.1.2 Design external forces

The design external forces F_X, F_Y, F_Z to be considered for the scantlings of securing and supporting devices of bow doors are to be not less than those obtained, in kN, from the following formulae:

$F_X = p_E A_X$

$F_Y = p_E A_Y$

$F_Z = p_E A_Z$

where:

p_E : External pressure, in kN/m², to be calculated according to [2.1.1], assuming the angles α and β measured at the point on the bow door located $\ell/2$ aft of the stem line on the plane h/2 above the bottom of the door, as shown in Fig 1

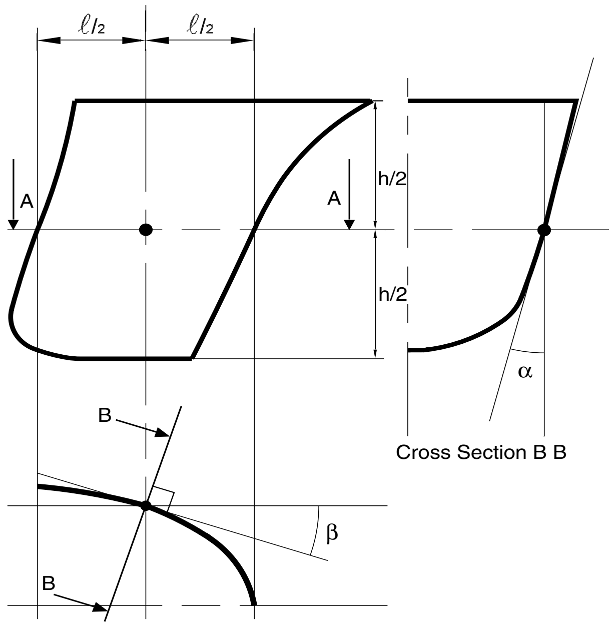
h : Height, in m, to be taken as the lesser of h_1 and h_2

h_1 : Height, in m, of the door between the levels of its bottom and the upper deck

h_2 : Height, in m, of the door between its bottom and top

ℓ : Length, in m, of the door at a height h/2 above the bottom of the door

Figure 1 : Definition of angles α and β



A_X : Area, in m², of the transverse vertical projection of the door between the levels of the bottom of the door and the top of the upper deck bulwark, or between the bottom of the door and the top of the door, including the bulwark, where it is part of the door, whichever is lesser. Where the flare angle of the bulwark is at least 15 degrees less than the flare angle of the adjacent shell plating, the height from the bottom of the door may be measured to the upper deck or to the top of the door, whichever is lesser. In determining the height from the bottom of the door to the upper deck or to the top of the door, the bulwark is to be excluded

A_Y : Area, in m², of the longitudinal vertical projection of the door between the levels of the bottom of the door and the top of the upper deck bulwark, or between the bottom of the door and the top of the door, including the bulwark, where it is part of the door, whichever is lesser. Where the flare angle of the bulwark is at least 15 degrees less than the flare angle of the adjacent shell plating, the height from the bottom of the door may be measured to the upper deck or to the top of the door, whichever is lesser

A_Z : Area, in m², of the horizontal projection of the door between the bottom of the door and the top of the upper deck bulwark, or between the bottom of the door and the top of the door, including the bulwark, where it is part of the door, whichever is the lesser. Where the flare angle of the bulwark is at least 15 degrees less than the flare angle of the adjacent shell plating, the height from the bottom of the door may be measured to the upper deck or to the top of the door, whichever is lesser

For bow doors, including bulwark, of unusual form or proportions, e.g. ships with a rounded nose and large stem angles, the areas and angles used for determination of the design values of external forces will be considered on a case by case basis.

2.1.3 Closing moment

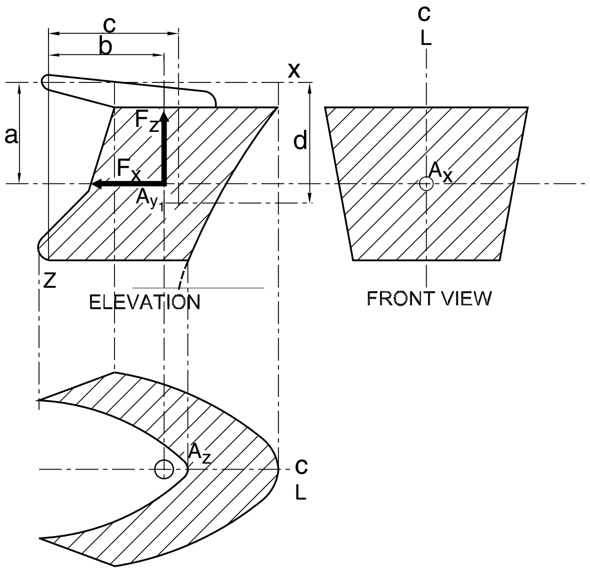
For visor doors, the closing moment under external loads is to be obtained, in kN.m, from the following formula:

$M_Y = F_X\, a + 10\, W\, c - F_Z\, b$

where:

- W : Mass of the visor door, in t
- a : Vertical distance, in m, from visor pivot to the centroid of the transverse vertical projected area of the visor door, as shown in Fig 2
- b : Horizontal distance, in m, from visor pivot to the centroid of the horizontal projected area of the visor door, as shown in Fig 2
- c : Horizontal distance, in m, from visor pivot to the centre of gravity of visor mass, as shown in Fig 2.

Figure 2 : Bow doors of visor type



2.1.4 Forces acting on the lifting arms

The lifting arms of a visor door and its supports are to be dimensioned for the static and dynamic forces applied during the lifting and lowering operations, and a minimum wind pressure of 1,5 kN/m² is to be taken into account.

2.2 Inner doors

2.2.1 Design external pressure

The design external pressure to be considered for the scantlings of primary supporting members, securing and supporting devices and surrounding structure of inner doors is to be taken as the greater of the values obtained, in kN/m², from the following formulae:

$p_E = 0{,}45\, L_1$

$p_E = 10\, h$

where:

- h : Distance, in m, from the calculation point to the top of the cargo space.

2.2.2 Design internal pressure

The design internal pressure p_I to be considered for the scantlings of securing devices of inner doors is to be not less than 25 kN/m².

3 Scantlings of bow doors

3.1 General

3.1.1 The strength of bow doors is to be commensurate with that of the surrounding structure.

3.1.2 Bow doors are to be adequately stiffened and means are to be provided to prevent lateral or vertical movement of the doors when closed.

For visor doors, adequate strength for opening and closing operations is to be provided in the connections of the lifting arms to the door structure and to the ship's structure.

3.2 Plating and ordinary stiffeners

3.2.1 Plating

The thickness of the bow door plating is to be not less than that obtained according to the requirements in Sec 1 for the fore part, using the bow door stiffener spacing. In no case may it be less than the minimum required thickness of fore part shell plating.

3.2.2 Ordinary stiffeners

The section modulus of bow door ordinary stiffeners is to be not less than that obtained according to the requirements in Sec 1 for the fore part, using the bow door stiffener spacing.

Consideration is to be given, where necessary, to differences in conditions of fixity between the ends of ordinary stiffeners of bow doors and those of the fore part shell.

3.3 Primary supporting members

3.3.1 Bow door ordinary stiffeners are to be supported by primary supporting members constituting the main stiffening of the door.

3.3.2 The primary supporting members of the bow door and the hull structure in way are to have sufficient stiffness to ensure integrity of the boundary support of the door.

3.3.3 Scantlings of primary supporting members are generally to be verified through direct calculations on the basis of the external pressure pE in [2.1.1] and the strength criteria in [6.1.1] and [6.1.2].

In general, isolated beam models may be used to calculate the loads and stresses in primary supporting members, which are to be considered as having simply supported end connections.

4 Scantlings of inner doors

4.1 General

4.1.1 The gross scantlings of the primary supporting members are generally to be verified through direct calculations on the basis of the external pressure p_E in [2.1.1] and the strength criteria in [6.1.1] and [6.1.2].

In general, isolated beam models may be used to calculate the loads and stresses in primary supporting members.

4.1.2 Where inner doors also serve as vehicle ramps, their scantlings are to be not less than those obtained according to Sec 8.

4.1.3 The distribution of the forces acting on the securing and supporting devices is generally to be supported by direct calculations taking into account the flexibility of the structure and the actual position and stiffness of the supports.

5 Securing and supporting of bow doors

5.1 General

5.1.1 Bow doors are to be fitted with adequate means of securing and supporting so as to be commensurate with the strength and stiffness of the surrounding structure.

The hull supporting structure in way of the bow doors is to be suitable for the same design loads and design stresses as the securing and supporting devices.

Where packing is required, the packing material is to be of a comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered by the Society on a case by case basis.

The maximum design clearance between securing and supporting devices is generally not to exceed 3 mm.

A means is to be provided for mechanically fixing the door in the open position.

5.1.2 Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be included and considered to calculate the reaction forces acting on the devices. Small and/or flexible devices such as cleats intended to provide local compression of the packing material may generally not be included in the calculation in [5.2.5].

The number of securing and supporting devices is generally to be the minimum practical while taking into account the requirements for redundant provision given in [5.2.6] and [5.2.7] and the available space for adequate support in the hull structure.

5.1.3 For visor doors which open outwards, the pivot arrangement is generally to be such that the visor is self-closing under external loads, i.e. it is to be checked that the closing moment M_Y, defined in [2.1.3], is in compliance with the following formula:

$$M_Y > 0$$

Moreover, the closing moment M_Y is to be not less than the value M_{Y0}, in kN.m, obtained from the following formula:

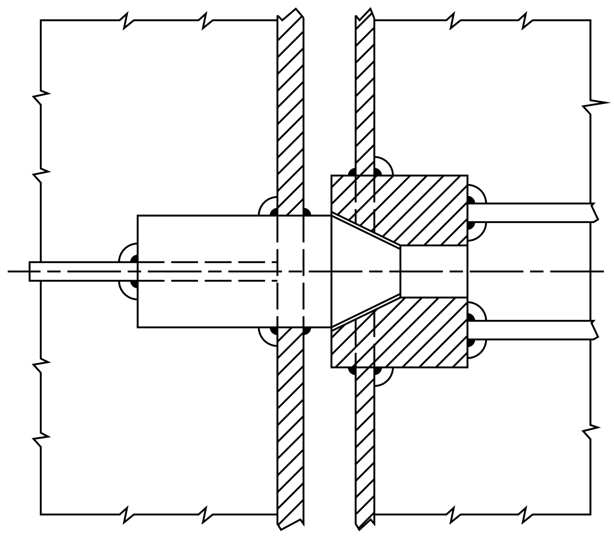
$$M_{Y0} = 10Wc + 0,1\sqrt{a^2+b^2}\sqrt{F_X^2+F_Z^2}$$

5.1.4 For side-opening doors, a thrust bearing is to be provided in way of girder ends at the closing of the two leaves to prevent one leaf from shifting towards the other under the effect of unsymmetrical pressure (see example in Fig 3).

The parts of the thrust bearing are to be kept secured to each other by means of securing devices.

The Society may consider any other arrangement serving the same purpose.

Figure 3 : Thrust bearing



5.2 Scantlings

5.2.1 Securing and supporting devices are to be adequately designed so that they can withstand the reaction forces within the allowable stresses defined in [6.1.1].

5.2.2 For visor doors, the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously together with the self weight of the door:

- Case 1: F_X and F_Z
- Case 2: $0,7F_Y$ acting on each side separately together with $0,7F_X$ and $0,7F_Z$

where F_X, F_Y and F_Z are to be calculated as indicated in [2.1.2] and applied at the centroid of projected areas.

5.2.3 For side-opening doors, the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously together with the self weight of the door:

- Case 1: F_X , F_Y and F_Z acting on both doors
- Case 2: $0,7F_X$ and $0,7F_Z$ acting on both doors and $0,7F_Y$ acting on each door separately

where F_X, F_Y and F_Z are to be calculated as indicated in [2.1.2] and applied at the centroid of projected areas.

5.2.4 The support forces as calculated according to Case 1 in [5.2.2] and Case 1 in [5.2.3] are to generally give rise to a zero moment about the transverse axis through the centroid of the area A_X.

For visor doors, longitudinal reaction forces of pin and/or wedge supports at the door base contributing to this moment are not to be in the forward direction.

5.2.5 The distribution of the reaction forces acting on the securing and supporting devices may need to be supported by direct calculations taking into account the flexibility of the hull structure and the actual position and stiffness of the supports.

5.2.6 The arrangement of securing and supporting devices in way of these securing devices is to be designed with redundancy so that, in the event of failure of any single securing or supporting device, the remaining devices are capable of withstanding the reaction forces without exceeding by more than 20% the allowable stresses defined in [6.1.1].

5.2.7 For visor doors, two securing devices are to be provided at the lower part of the door, each capable of providing the full reaction force required to prevent opening of the door within the allowable stresses defined in [6.1.1].

The opening moment M_0 to be balanced by this reaction force is to be taken not less than that obtained, in kN.m, from the following formula:

$$M_0 = 10\ W\ d + 5\ A_X\ a$$

where:

d : Vertical distance, in m, from the hinge axis to the centre of gravity of the door, as shown in Fig 2

a : Vertical distance, in m, defined in [2.1.3].

5.2.8 For visor doors, the securing and supporting devices excluding the hinges are to be capable of resisting the vertical design force (F_Z-10W), in kN, within the allowable stresses defined in [6.1.1].

5.2.9 All load transmitting elements in the design load path, from the door through securing and supporting devices into the ship's structure, including welded connections, are to be of the same strength standard as required for the securing and supporting devices. These elements include pins, supporting brackets and back-up brackets.

6 Strength Criteria

6.1 Primary supporting members and securing and supporting devices

6.1.1 Yielding check

It is to be checked that the normal stresses σ, the shear stress τ and the equivalent stress σ_{VM}, induced in the primary supporting members and in the securing and supporting devices of bow doors by the design load defined in [2], are in compliance with the following formulae:

$$\sigma \le \sigma_{ALL}$$

$$\tau \le \tau_{ALL}$$

$$\sigma_{VM} = (\sigma^2 + \tau^2)^{0,5} \le \sigma_{VM,ALL}$$

where:

σ_{ALL} : Allowable normal stress, in N/mm², equal to:
$\sigma_{ALL} = 120 / k$

τ_{ALL} : Allowable shear stress, in N/mm², equal to:
$\tau_{ALL} = 80 / k$

$\sigma_{VM,ALL}$: Allowable equivalent stress, in N/mm², equal to:
$\sigma_{VM,ALL} = 150 / k$

k : Material factor, defined in Ch 4, Sec 1, [2.3], but to be taken not less than 0,72 unless a fatigue analysis is carried out.

6.1.2 Buckling check

The buckling check of primary supporting members is to be carried out according to Ch 7, Sec 3, [6].

6.1.3 Bearings

For steel to steel bearings in securing and supporting devices, it is to be checked that the nominal bearing pressure σ_B, in N/mm², is in compliance with the following formula:

$$\sigma_B \le 0,8\ R_{e,HB}$$

where:

$$\sigma_B = 10\frac{F}{A_B}$$

F : Design force, in kN, defined in [2.1.2]

A_B : Projected bearing area, in cm²

$R_{e,HB}$: Yield stress, in N/mm², of the bearing material.

For other bearing materials, the allowable bearing pressure is to be determined according to the manufacturer's specification.

6.1.4 Bolts

The arrangement of securing and supporting devices is to be such that threaded bolts do not carry support forces.

It is to be checked that the tension σ_T in way of threads of bolts not carrying support forces is in compliance with the following formula:

$$\sigma_T \le \sigma_{T,ALL}$$

where:

$\sigma_{T,ALL}$: Allowable tension in way of threads of bolts, in N/mm², equal to:
$\sigma_{T,ALL} = 125 / k$

k : Material coefficient defined in [6.1.1].

7 Securing and locking arrangement

7.1 Systems for operation

7.1.1 Securing devices are to be simple to operate and easily accessible.

Securing devices are to be equipped with mechanical locking arrangement (self-locking or separate arrangement), or to be of the gravity type.

The opening and closing systems as well as securing and locking devices are to be interlocked in such a way that they can only operate in the proper sequence.

7.1.2 Bow doors and inner doors giving access to vehicle decks are to be provided with an arrangement for remote control, from a position above the freeboard deck, of:

- the closing and opening of the doors, and
- associated securing and locking devices for every door.

Indication of the open/closed position of every door and every securing and locking device is to be provided at the remote control stations.

The operating panels for operation of doors are to be inaccessible to unauthorised persons.

A notice plate, giving instructions to the effect that all securing devices are to be closed and locked before leaving harbour, is to be placed at each operating panel and is to be supplemented by warning indicator lights.

7.1.3 Where hydraulic securing devices are applied, the system is to be mechanically lockable in closed position. This means that, in the event of loss of hydraulic fluid, the securing devices remain locked.

The hydraulic system for securing and locking devices is to be isolated from other hydraulic circuits, when in closed position.

7.2 Systems for indication/monitoring

7.2.1 Separate indicator lights and audible alarms are to be provided on the navigation bridge and on the operating panel to show that the bow door and inner door are closed and that their securing and locking devices are properly positioned.

The indication panel is to be provided with a lamp test function. It is not to be possible to turn off the indicator light.

7.2.2 The indicator system is to be designed on the fail-safe principle and is to show by visual alarms if the door is not fully closed and not fully locked and by audible alarms if securing devices become open or locking devices become unsecured.

The power supply for the indicator system for operating and closing doors is to be independent of the power supply for operating and closing the doors and is to be provided with a back-up power supply from the emergency source of power or other secure power supply e.g. UPS.

The sensors of the indicator system are to be protected from water, ice formation and mechanical damage.

Note 1: The indicator system is considered designed on the fail-safe principle when the following conditions occur.

- The indication panel is provided with:
  - a power failure alarm
  - an earth failure alarm
  - a lamp test
  - separate indication for door closed, door locked, door not closed and door unlocked.
- Limit switches are electrically closed when the door is closed (when several limit switches are provided they may be connected in series).
- Limit switches are electrically closed when securing arrangements are in place (when several limit switches are provided they may be connected in series).
- Two electrical circuits (also in one multicore cable) are fitted, one for the indication of door closed / not closed and the other for door locked / unlocked.
- In the case of dislocation of limit switches, indication to show: not closed / unlocked / securing arrangement not in place - as appropriate.

7.2.3 The indication panel on the navigation bridge is to be equipped with a mode selection function "harbour/sea voyage", so arranged that an audible alarm is given on the navigation bridge if the ship leaves harbour with the bow door or inner door not closed or with any of the securing devices not in the correct position.

7.2.4 A water leakage detection system with an audible alarm and television surveillance is to be arranged to provide an indication to the navigation bridge and to the engine control room of leakage through the inner door.

7.2.5 Between the bow door and the inner door a television surveillance system is to be fitted with a monitor on the navigation bridge and in the engine control room.

The system is to monitor the position of doors and a sufficient number of their securing devices.

Special consideration is to be given to the lighting and contrasting colour of the objects under surveillance.

7.2.6 The indicator system for the closure of the doors and the television surveillance systems for the doors and water leakage detection, and for special category and ro-ro spaces are to be suitable to operate correctly in the ambient conditions on board and to be type approved on the basis of the applicable tests required in Part E, Chapter 1 and/or Part E, Chapter 12.

7.2.7 A drainage system is to be arranged in the area between bow door and ramp, or, where no ramp is fitted, between bow door and inner door. The system is to be equipped with an audible alarm providing an indication on the navigation bridge, which is to be activated when the water levels in these areas exceed 0,5 m or the high water level alarm, whichever is the lesser.

8 Operating and maintenance manual

8.1 General

8.1.1 An Operating and Maintenance Manual (OMM) for the bow door and inner door is to be provided on board and contain necessary information on:

a) main particulars and design drawings
- special safety precautions
- details of vessel, class, statutory certificates
- equipment and design loading (for ramps)
- key plan of equipment (doors and ramps)
- Manufacturer's recommended testing for equipment
- description of equipment (bow doors, inner bow doors, bow ramp/doors, side doors, stern doors, central power pack, bridge panel, engine control room panel)

b) service conditions
- limiting heel and trim of ship for loading/unloading
- limiting heel and trim for door operations
- door/ramp operating instructions
- door/ramp emergency operating instructions

c) maintenance
- schedule and extent of maintenance
- trouble-shooting and acceptable clearances
- Manufacturer's maintenance procedures

d) register of inspections, including inspection of locking, securing and supporting devices, repairs and renewals.

This manual is to be submitted in duplicate to the Society for approval that the above-mentioned items are contained in the OMM and that the maintenance part includes the necessary information with regard to inspections, trouble-shooting and acceptance / rejection criteria.

Note 1: It is recommended that inspections of the doors and supporting and securing devices be carried out by ship's personnel at monthly intervals or following any incidents which could result in damage, including heavy weather or contact in the region of the shell doors. A record is to be kept and any damage found during such inspections is to be reported to the Society.

8.1.2 Documented operating procedures for closing and securing the bow door and inner door are to be kept on board and posted at an appropriate place.

SECTION 6 SIDE DOORS AND STERN DOORS

Symbols

L_1 : Length, in m, defined in Ch 1, Sec 2, [2.1.1].

1 General

1.1 Application

1.1.1 The requirements of this Section apply to the arrangement, strength and securing of side doors, abaft the collision bulkhead, and of stern doors leading to enclosed spaces.

1.2 Gross scantlings

1.2.1 With reference to Ch 4, Sec 2, [1], all scantlings and dimensions referred to in this Section are gross, i.e. they include the margins for corrosion.

1.3 Arrangement

1.3.1 Side doors and stern doors are to be so fitted as to ensure tightness and structural integrity commensurate with their location and the surrounding structure.

1.3.2 Where the sill of any side door is below the uppermost load line, the arrangement is considered by the Society on a case by case basis.

1.3.3 Doors are preferably to open outwards.

1.4 Definitions

1.4.1 Securing device

A securing device is a device used to keep the door closed by preventing it from rotating about its hinges or about pivoted attachments to the ship.

1.4.2 Supporting device

A supporting device is a device used to transmit external or internal loads from the door to a securing device and from the securing device to the ship's structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, which transmits loads from the door to the ship's structure.

1.4.3 Locking device

A locking device is a device that locks a securing device in the closed position.

2 Design loads

2.1 Side and stern doors

2.1.1 Design forces

The design external forces F_E and the design internal forces F_I to be considered for the scantlings of primary supporting members and securing and supporting devices of side doors and stern doors are to be obtained, in kN, from the formulae in Tab 1.

3 Scantlings of side doors and stern doors

3.1 General

3.1.1 The strength of side doors and stern doors is to be commensurate with that of the surrounding structure.

3.1.2 Side doors and stern doors are to be adequately stiffened and means are to be provided to prevent any lateral or vertical movement of the doors when closed.

Adequate strength is to be provided in the connections of the lifting/manoeuvring arms and hinges to the door structure and to the ship's structure.

3.1.3 Where doors also serve as vehicle ramps, the design of the hinges is to take into account the ship angle of trim and heel which may result in uneven loading on the hinges.

3.1.4 Shell door openings are to have well rounded corners and adequate compensation is to be arranged with web frames at sides and stringers or equivalent above and below.

3.2 Plating and ordinary stiffeners

3.2.1 Plating

The thickness of the door plating is to be not less than that obtained according to the requirements in Ch 7, Sec 1 for side plating, using the door stiffener spacing. In no case may it be less than the minimum required thickness of side plating.

Where doors also serve as vehicle ramps, the thickness of the door plating is to be not less than that obtained according to Sec 8.

3.2.2 Ordinary stiffeners

The scantling of door ordinary stiffeners is to be not less than that obtained according to the requirements in Ch 7, Sec 2 for the side, using the door stiffener spacing.

Table 1 : Design forces

Structural elements	External force F_E, in kN	Internal force F_I, in kN
Securing and supporting devices of doors opening inwards	$A\ p_E + F_P$	$F_0 + 10\ W$
Securing and supporting devices of doors opening outwards	$A\ p_E$	$F_0 + 10\ W + F_P$
Primary supporting members **(1)**	$A\ p_E$	$F_0 + 10\ W$

(1) The design force to be considered for the scantlings of the primary supporting members is the greater of F_E and F_I.

Note 1:

- A : Area, in m², of the door opening
- W : Mass of the door, in t
- F_P : Total packing force, in kN; the packing line pressure is normally to be taken not less than 5 N/mm
- F_0 : the greater of F_C and 5A, in kN
- F_C : Accidental force, in kN, due to loose cargoes etc., to be uniformly distributed over the area A and to be taken not less than 300 kN. For small doors such as bunker doors and pilot doors, the value of F_C may be appropriately reduced. However, the value of F_C may be taken as zero, provided an additional structure such as an inner ramp is fitted, which is capable of protecting the door from accidental forces due to loose cargoes.
- p_E : External design pressure determined at the centre of gravity of the door opening and to be taken not less than that obtained, in kN/m², from the following formulae:
  $p_E = 10\ (T - Z_G) + 25$ for $Z_G < T$
  $p_E = 25$ for $Z_G \geq T$
  Moreover, for stern doors of ships fitted with bow doors, p_E is to be taken not less than that obtained, in kN/m², from the following formula:
  $$p_E = 0{,}6 n_D C_L (0{,}8 + 0{,}6\sqrt{L_1})^2$$
- T : Draught, in m, at the highest subdivision load line
- Z_G : Height of the centre of the area of the door, in m, above the baseline
- n_D : Navigation coefficient, defined in Tab 2
- C_L : Coefficient depending on the ship's length:
  $C_L = 0{,}0125\ L$ for $L < 80$ m
  $C_L = 1{,}0$ for $L \geq 80$ m.

Consideration is to be given, where necessary, to differences in conditions of fixity between the ends of ordinary stiffeners of doors and those of the side.

Where doors also serve as vehicle ramps, the scantling of ordinary stiffeners is to be not less than that obtained according to Sec 8.

3.3 Primary supporting members

3.3.1 The door ordinary stiffeners are to be supported by primary supporting members constituting the main stiffening of the door.

3.3.2 The primary supporting members and the hull structure in way are to have sufficient stiffness to ensure structural integrity of the boundary of the door.

3.3.3 Scantlings of primary supporting members are generally to be verified through direct calculations on the basis of the design forces in [2.1.1] and the strength criteria in Sec 5, [6.1.1] and Sec 5, [6.1.2].

In general, isolated beam models may be used to calculate the loads and stresses in primary supporting members, which are to be considered as having simply supported end connections.

Table 2 : Navigation coefficient

Navigation notation	Navigation coefficient n_D
Unrestricted navigation	1,00
Summer zone	1,00
Tropical zone	0,80
Coastal area	0,80
Sheltered area	0,50

4 Securing and supporting of doors

4.1 General

4.1.1 Side doors and stern doors are to be fitted with adequate means of securing and supporting so as to be commensurate with the strength and stiffness of the surrounding structure.

The hull supporting structure in way of the doors is to be suitable for the same design loads and design stresses as the securing and supporting devices.

Where packing is required, the packing material is to be of a comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered by the Society on a case by case basis.

The maximum design clearance between securing and supporting devices is generally not to exceed 3 mm.

A means is to be provided for mechanically fixing the door in the open position.

4.1.2 Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be included and considered to calculate the reaction forces acting on the devices. Small and/or flexible devices such as cleats intended to provide local compression of the packing material may generally not be included in the calculation in [4.2.2].

The number of securing and supporting devices is generally to be the minimum practical while taking into account the requirements for redundant provision given in [4.2.3] and the available space for adequate support in the hull structure.

4.2 Scantlings

4.2.1 Securing and supporting devices are to be adequately designed so that they can withstand the reaction forces within the allowable stresses defined in Sec 5, [6.1.1].

4.2.2 The distribution of the reaction forces acting on the securing and supporting devices may need to be supported by direct calculations taking into account the flexibility of the hull structure and the actual position of the supports.

4.2.3 The arrangement of securing and supporting devices in way of these securing devices is to be designed with redundancy so that, in the event of failure of any single securing or supporting device, the remaining devices are capable of withstanding the reaction forces without exceeding by more than 20% the allowable stresses defined in Sec 5, [6.1.1].

4.2.4 All load transmitting elements in the design load path, from the door through securing and supporting devices into the ship's structure, including welded connections, are to be of the same strength standard as required for the securing and supporting devices. These elements include pins, supporting brackets and back-up brackets.

5 Strength criteria

5.1 Primary supporting members and securing and supporting devices

5.1.1 Yielding check

It is to be checked that the normal stress σ, the shear stress τ and the equivalent stress σ_{VM}, induced in the primary supporting members and in the securing and supporting devices of doors by the design load defined in [2], are in compliance with the following formulae:

$\sigma \le \sigma_{ALL}$

$\tau \le \tau_{ALL}$

$\sigma_{VM} = (\sigma^2 + \tau^2)^{0,5} \le \sigma_{VM,ALL}$

where:

σ_{ALL} : Allowable normal stress, in N/mm^2:
$\sigma_{ALL} = 120 / k$

τ_{ALL} : Allowable shear stress, in N/mm^2:
$\tau_{ALL} = 80 / k$

$\sigma_{VM,ALL}$: Allowable equivalent stress, in N/mm^2:
$\sigma_{VM,ALL} = 150 / k$

k : Material factor, defined in Ch 4, Sec 1, [2.3], but to be taken not less than 0,72 unless a fatigue analysis is carried out.

5.1.2 Buckling check

The buckling check of primary supporting members is to be carried out according to Ch 7, Sec 3, [6].

5.1.3 Bearings

For steel to steel bearings in securing and supporting devices, it is to be checked that the nominal bearing pressure σ_B, in N/mm^2, is in compliance with the following formula:

$\sigma_B \le 0,8\ R_{eH,B}$

where:

$$\sigma_B = 10\frac{F}{A_B}$$

with:

F : Design force, in KN, defined in [2.1.1]

A_B : Projected bearing area, in cm^2

$R_{eH,B}$: Yield stress, in N/mm^2, of the bearing material.

For other bearing materials, the allowable bearing pressure is to be determined according to the manufacturer's specification.

5.1.4 Bolts

The arrangement of securing and supporting devices is to be such that threaded bolts do not carry support forces.

It is to be checked that the tension σ_T in way of threads of bolts not carrying support forces is in compliance with the following formula:

$\sigma_T \le \sigma_{T,ALL}$

where:

$\sigma_{T,ALL}$: Allowable tension in way of threads of bolts, in N/mm^2:
$\sigma_{T,ALL} = 125 / k$

k : Material factor, defined in Sec 5, [6.1.1].

6 Securing and locking arrangement

6.1 Systems for operation

6.1.1 Securing devices are to be simple to operate and easily accessible.

Securing devices are to be equipped with mechanical locking arrangement (self-locking or separate arrangement), or to be of the gravity type.

The opening and closing systems as well as securing and locking devices are to be interlocked in such a way that they can only operate in the proper sequence.

6.1.2 Doors which are located partly or totally below the freeboard deck with a clear opening area greater than 6 m^2 are to be provided with an arrangement for remote control, from a position above the freeboard deck, of:

- the closing and opening of the doors
- associated securing and locking devices.

For doors which are required to be equipped with a remote control arrangement, indication of the open/closed position of the door and the securing and locking device is to be provided at the remote control stations.

The operating panels for operation of doors are to be inaccessible to unauthorised persons.

A notice plate, giving instructions to the effect that all securing devices are to be closed and locked before leaving harbour, is to be placed at each operating panel and is to be supplemented by warning indicator lights.

6.1.3 Where hydraulic securing devices are applied, the system is to be mechanically lockable in closed position. This means that, in the event of loss of hydraulic fluid, the securing devices remain locked.

The hydraulic system for securing and locking devices is to be isolated from other hydraulic circuits, when in closed position.

7 Operating and Maintenance Manual

7.1 General

7.1.1

An Operating and Maintenance Manual (OMM) for the side doors and stern doors is to be provided on board and contain necessary information on:

a) main particulars and design drawings
   - special safety precautions
   - details of vessel
   - equipment and design loading (for ramps)
   - key plan of equipment (doors and ramps)
   - Manufacturer's recommended testing for equipment
   - description of equipment for bow doors, inner bow doors, bow ramp/doors, side doors, stern doors, central power pack, bridge panel, engine control room panel

b) service conditions
   - limiting heel and trim of ship for loading/unloading
   - limiting heel and trim for door operations
   - door/ramp operating instructions
   - door/ramp emergency operating instructions

c) maintenance
   - schedule and extent of maintenance
   - trouble-shooting and acceptable clearances
   - Manufacturer's maintenance procedures

d) register of inspections, including inspection of locking, securing and supporting devices, repairs and renewals.

This manual is to be submitted in duplicate to the Society for approval that the above-mentioned items are contained in the OMM and that the maintenance part includes the necessary information with regard to inspections, trouble-shooting and acceptance / rejection criteria.

Note 1: It is recommended that inspections of the door and supporting and securing devices be carried out by ship's personnel at monthly intervals or following any incidents which could result in damage, including heavy weather or contact in the region of the shell doors. A record is to be kept and any damage recorded during such inspections is to be reported to the Society.

7.1.2 Documented operating procedures for closing and securing the side and stern doors are to be kept on board and posted at an appropriate place.

SECTION 7 HATCH COVERS

Symbols

p_S : Still water pressure, in kN/m^2 (see [4.1]

p_W : Wave pressure, in kN/m^2 (see [4.1])

s : Length, in m, of the shorter side of the plate panel

ℓ : Length, in m, of the longer side of the plate panel

b_P : Width, in m, of the plating attached to the ordinary stiffener or primary supporting member, defined in [3]

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

A_{Sh} : Net shear sectional area, in cm^2, of the ordinary stiffener or primary supporting member, to be calculated as specified in Ch 4, Sec 3, [3.4], for ordinary stiffeners, and Ch 4, Sec 3, [4.3], for primary supporting members

m : Boundary coefficient for ordinary stiffeners and primary supporting members, taken equal to:

- m = 8 in the case of ordinary stiffeners and primary supporting members simply supported at both ends or supported at one end and clamped at the other
- m = 12 in the case of ordinary stiffeners and primary supporting members clamped at both ends

t_C : Corrosion additions, in mm, defined in [1.5]

R_{eH} : Minimum yield stress, in N/mm^2, of the material, defined in Ch 4, Sec 1, [2]

R_m : Minimum ultimate tensile strength, in N/mm^2, of the material, defined in Ch 4, Sec 1, [2]

R_y : Yield stress, in N/mm^2, of the material, to be taken equal to 235/k N/mm^2, unless otherwise specified

k : Material factor, defined in Ch 4, Sec 1, [2.3]

c_S : Coefficient, taken equal to:

- $c_S = 1-(s/2\ell)$ for ordinary stiffeners
- $c_S = 1$ for primary supporting members

g : Gravity acceleration, in m/s^2:

$g = 9{,}81$ m/s^2.

1 General

1.1 Application

1.1.1 The requirements in [1] to [8] apply to steel hatch covers in positions 1 and 2 on weather decks, defined in Ch 1, Sec 2, [3.16].

The requirements in [9] apply to steel covers of small hatches fitted on the exposed fore deck over the forward 0,25L.

1.2 Materials

1.2.1 Steel

The formulae for scantlings given in the requirements in [5] are applicable to steel hatch covers.

Materials used for the construction of steel hatch covers are to comply with the applicable requirements of Part D, Chapter 2.

1.2.2 Other materials

The use of materials other than steel is considered by the Society on a case by case basis, by checking that criteria adopted for scantlings are such as to ensure strength and stiffness equivalent to those of steel hatch covers.

1.3 Net scantlings

1.3.1 As specified in Ch 4, Sec 2, [1], all scantlings referred to in this Section are net, i.e. they do not include any margin for corrosion.

The gross scantlings are obtained as specified in Ch 4, Sec 2.

1.4 Partial safety factors

1.4.1 The partial safety factors to be considered for checking hatch cover structures are specified in Tab 1.

Table 1 : Hatch covers - Partial safety factors

Partial safety factors covering uncertainties regarding:	Partial safety factors		
	Symbol	Plating	Ordinary stiffeners and primary supporting members
Still water pressure	γ_{S2}	1,00	1,00
Wave pressure	γ_{W2}	1,20	1,20
Material	γ_m	1,02	1,02
Resistance	γ_R	1,22	1,22

1.5 Corrosion additions

1.5.1 Corrosion additions for hatch covers

The corrosion addition to be considered for the plating and internal members of hatch covers is the value specified in Tab 2 for the total thickness of the member under consideration.

1.5.2 Corrosion additions for hatch coamings

The corrosion addition to be considered for the hatch coaming structures and coaming stays is equal to 1,5 mm.

Table 2 : Corrosion additions t_c for steel hatch covers

Corrosion addition t_c , in mm	
Plating and stiffeners of single skin hatch cover	2,0
Top and bottom plating of double skin hatch cover	2,0
Internal structures of double skin hatch cover	1,5

1.5.3 Corrosion additions for stainless steel

For structural members made of stainless steel, the corrosion addition t_c is to be taken equal to 0.

1.5.4 Corrosion additions for aluminium alloys

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

2 Arrangements

2.1 Height of hatch coamings

2.1.1 The height above the deck of hatch coamings closed by portable covers is to be not less than:

- 600 mm in position 1
- 450 mm in position 2.

2.1.2 The height of hatch coamings in positions 1 and 2 closed by steel covers provided with gaskets and securing devices may be reduced with respect to the above values or the coamings may be omitted entirely.

In such cases the scantlings of the covers, their gasketing, their securing arrangements and the drainage of recesses in the deck are considered by the Society on a case by case basis.

2.1.3 Regardless of the type of closing arrangement adopted, the coamings may have reduced height or be omitted in way of openings in closed superstructures or decks below the freeboard deck.

2.2 Hatch covers

2.2.1 Hatch covers on exposed decks are to be weathertight.

Hatch covers in closed superstructures need not be weathertight.

However, hatch covers fitted in way of ballast tanks, fuel oil tanks or other tanks are to be watertight.

2.2.2 The ordinary stiffeners and primary supporting members of the hatch covers are to be continuous over the breadth and length of the hatch covers, as far as practical. When this is impractical, sniped end connections are not to be used and appropriate arrangements are to be adopted to ensure sufficient load carrying capacity.

2.2.3 The spacing of primary supporting members parallel to the direction of ordinary stiffeners is to be not greater than 1/3 of the span of primary supporting members.

2.2.4 The breadth of the primary supporting member flange is to be not less than 40% of its depth for laterally unsupported spans greater than 3,0 m. Tripping brackets attached to the flange may be considered as a lateral support for primary supporting members.

2.2.5 The covers used in 'tweendecks are to be fitted with an appropriate system ensuring an efficient stowing when the ship is sailing with open 'tweendecks.

2.2.6 The ends of hatch covers are normally to be protected by efficiently secured galvanised steel strips.

2.2.7 Efficient retaining arrangements are to be provided to prevent translation of the hatch cover under the action of the longitudinal and transverse forces exerted by the stacks of containers on the cover. These retaining arrangements are to be located in way of the hatch coaming side brackets.

Solid fittings are to be welded on the hatch cover where the corners of the containers are resting. These parts are intended to transmit the loads of the container stacks onto the hatch cover on which they are resting and also to prevent horizontal translation of the stacks by means of special intermediate parts arranged between the supports of the corners and the container corners.

Longitudinal stiffeners are to stiffen the hatch cover plate in way of these supports and connect at least the nearest three transverse stiffeners.

2.2.8 The width of each bearing surface for hatch covers is to be at least 65 mm.

2.3 Hatch coamings

2.3.1 Coamings, stiffeners and brackets are to be capable of withstanding the local forces in way of the clamping devices and handling facilities necessary for securing and moving the hatch covers as well as those due to cargo stowed on the latter.

2.3.2 Special attention is to be paid to the strength of the fore transverse coaming of the forward hatch and to the scantlings of the closing devices of the hatch cover on this coaming.

2.3.3 Longitudinal coamings are to be extended at least to the lower edge of deck beams.

Where they are not part of continuous deck girders, longitudinal coamings are to extend for at least two frame spaces beyond the end of the openings.

Where longitudinal coamings are part of deck girders, their scantlings are to be as required in Ch 7, Sec 3.

2.3.4 Transverse coamings are to extend below the deck at least to the lower edge of longitudinals.

Transverse coamings not in line with ordinary deck beams below are to extend below the deck at least three longitudinal frame spaces beyond the side coamings.

2.4 Small hatchways

2.4.1 The height of small hatchway coamings is to be not less than 600 mm if located in position 1, and 450 mm if located in position 2.

Where the closing appliances are in the form of hinged steel covers secured weathertight by gaskets and swing bolts, the height of the coamings may be reduced or the coamings may be omitted altogether.

2.4.2 Small hatch covers are to have strength equivalent to that required for main hatchways and are to be of steel, weathertight and generally hinged.

Securing arrangements and stiffening of hatch cover edges are to be such that weathertightness can be maintained in any sea condition.

At least one securing device is to be fitted at each side. Circular hole hinges are considered equivalent to securing devices.

2.4.3 Hold accesses located on the weather deck are to be provided with watertight metallic hatch covers, unless they are protected by a closed superstructure. The same applies to accesses located on the forecastle deck and leading directly to a dry cargo hold through a trunk.

2.4.4 Accesses to cofferdams and ballast tanks are to be manholes fitted with watertight covers fixed with bolts which are sufficiently closely spaced.

2.4.5 Hatchways of special design are considered by the Society on a case by case basis.

3 Width of attached plating

3.1 Ordinary stiffeners

3.1.1 The width of the attached plating to be considered for the check of ordinary stiffeners is to be obtained, in m, from the following formulae:

- where the attached plating extends on both sides of the stiffener:

  $b_P = s$

- where the attached plating extends on one side of the stiffener:

  $b_P = 0,5\ s$

3.2 Primary supporting members

3.2.1 Primary supporting members parallel to ordinary stiffeners

The width of the attached plating to be considered for the yielding and buckling checks of primary supporting members analysed through beam or grillage models is to be obtained, in m, from the following formulae:

- where the plating extends on both sides of the primary supporting member:

  $b_p = b_{p,1} + b_{p,2}$

- where the plating extends on one side of the primary supporting member:

  $b_p = b_{p,1}$

where:

$b_{p,1} = \min(0,165\ \ell_P, S_{p,1})$

$b_{p,2} = \min(0,165\ \ell_P, S_{p,2})$

ℓ_P : span, in m, of the primary supporting member considered

$S_{p,1}$, $S_{p,2}$: half distance, in m, between the primary supporting member considered and those adjacent, on the two sides.

4 Load model

4.1 Lateral pressures and concentrated loads

4.1.1 General

The still water and wave lateral pressures and concentrated loads, to be considered as acting on hatch covers, are those in [4.1.2] to [4.1.7].

Each case in [4.1.2] to [4.1.7] is not necessarily exhaustive for any specific hatch cover; however, depending on the location of each cover and its intended use, the pressures and loads to be considered as acting on it are to be calculated for one or more of these cases. For example, for a hatch cover located on an exposed deck and covering a ballast tank, the pressures in [4.1.2] and [4.1.3] are to be separately considered. If the same hatch cover is also intended to carry uniform cargoes, the pressures in [4.1.4] are to be individually considered, in addition to the two above.

4.1.2 Hatch covers on exposed decks

The still water lateral pressure and loads are to be considered when the hatch cover is intended to carry uniform cargoes, wheeled cargoes or containers. In these cases, the still water lateral pressures and loads are to be calculated according to [4.1.4] to [4.1.5], as applicable.

The wave lateral pressure is to be considered and is defined in [4.2].

4.1.3 Hatch covers in way of liquid cargo or ballast tanks

The still water and wave lateral pressures are to be considered and are defined in Ch 5, Sec 6, [1].

4.1.4 Hatch covers carrying uniform cargoes

The still water and wave lateral pressures are to be considered and are defined in Ch 5, Sec 6, [4].

4.1.5 Hatch covers carrying containers

The still water and wave loads are to be considered and are defined in Ch 5, Sec 6, [5].

4.1.6 Hatch covers carrying wheeled cargoes

The still water and wave loads are to be considered and are defined in Ch 5, Sec 6, [6].

4.1.7 Hatch covers carrying special cargoes

In the case of carriage on the hatch covers of special cargoes (e.g. pipes, etc.) which may temporarily retain water during navigation, the lateral pressure to be applied is considered by the Society on a case by case basis.

4.2 Wave pressure for hatch covers on exposed decks

4.2.1 The wave pressure pW is defined in Tab 3 according to the hatch cover position.

4.2.2 Where two or more panels are connected by hinges, each individual panel is to be considered separately.

4.3 Load point

4.3.1 Wave lateral pressure for hatch covers on exposed decks

The wave lateral pressure to be considered as acting on each hatch cover is to be calculated at a point located:

- longitudinally, at the hatch cover mid-length
- transversely, on the longitudinal plane of symmetry of the ship
- vertically, at the top of the hatch coaming.

4.3.2 Lateral pressures other than the wave pressure

The lateral pressure is to be calculated:

- in way of the geometrical centre of gravity of the plate panel, for plating
- at mid-span, for ordinary stiffeners and primary supporting members.

5 Strength check

5.1 General

5.1.1 Application

The strength check is applicable to rectangular hatch covers subjected to a uniform pressure, designed with primary supporting members arranged in one direction or as a grillage of longitudinal and transverse primary supporting members.

In the latter case, the stresses in the primary supporting members are to be determined by a grillage or a Finite Element analysis. It is to be checked that stresses induced by concentrated loads are in accordance with the criteria in [5.3.4].

5.1.2 Hatch covers supporting wheeled loads

The scantlings of hatch covers supporting wheeled loads are to be obtained in accordance with:

- the applicable requirements of Ch 7, Sec 1 for plating
- the applicable requirements of Ch 7, Sec 2 for ordinary stiffeners
- the applicable requirements of Ch 7, Sec 3 for primary supporting members.

5.1.3 Hatch covers subjected to concentrated loads

For hatch covers supporting concentrated loads, ordinary stiffeners and primary supporting members are generally to be checked by direct calculations, taking into account the stiffener arrangements and their relative inertia. It is to be checked that stresses induced by concentrated loads are in accordance with the criteria in [5.3.4].

Table 3 : Wave pressure on hatch covers

Wave pressure p_W, in kN/m²			
Freeboard length L_{LL}, in m	Hatchway location	Position 1	Position 2
$L_{LL} \le 100$ m	$0 \le x \le 0,75\, L_{LL}$	$14,9 + 0,195 L_{LL}$	$11,3 + 0,142 L_{LL}$
	$0,75 L_{LL} \le x \le L_{LL}$	$15,8 + \frac{L_{LL}}{3}\left(1 - \frac{5}{3}\frac{x}{L_{LL}}\right) - 3,6\frac{x}{L_{LL}}$	
$L_{LL} \ge 100$ m	$0 \le x \le 0,75 L_{LL}$	34,3	25,5
	$0,75 L_{LL} < x \le L_{LL}$	$34,3 + \frac{p_{FP} - 34,3}{0,25}\left(\frac{x}{L_{LL}} - 0,75\right)$ **(1)**	

(1) Where a position 1 hatchway is located at least one superstructure standard height, as specified in Ch 1, Sec 2, Tab 2, higher than the freeboard deck, where the pressure p_W may be taken equal to 34,3 kN/m².

Note 1:

p_{FP} : pressure, in kN/m², at the forward perpendicular, to be taken equal to:

- p_{FP} = 49,1 + 0,0726 (L_{LL} - 100) for Type B ships
- p_{FP} = 49,1 + 0,356 (L_{LL} - 100) for Type B-60 or Type B-100 ships

5.1.4 Covers of small hatchways

The thickness of covers is to be not less than 8 mm. This thickness is to be increased or an efficient stiffening fitted to the Society's satisfaction where the greatest horizontal dimension of the cover exceeds 0,6 m.

5.2 Plating

5.2.1 Net thickness

The net thickness of steel hatch cover top plating is to be not less than the value obtained, in mm, from the following formula:

$$t = F_p 15{,}8s\sqrt{\frac{p_S + p_W}{0{,}95R_{eH}}}$$

where:

F_p : factor for combined membrane and bending response, equal to:

- $F_P = 1{,}50$ in general
- $F_P = 2{,}375\ \sigma/R_{eH}$ for $\sigma/R_{eH} \geq 0{,}64$, for the attached plating of primary supporting members.

p_S : still water pressure, in kN/m², to be calculated according to [4.1].

p_W : wave pressure, in kN/m², defined in [4.2].

σ : normal stress, in N/mm², in the attached plating of primary supporting members, calculated according to [5.3.3] b) or determined through a grillage analysis or a Finite Element analysis, as the case may be.

5.2.2 Minimum net thickness

In addition to [5.2.1], the net thickness, in mm, of hatch cover plating is to be not less than 1% of s or 6 mm, whichever is the greater.

5.2.3 Critical buckling stress check

The compressive stress s in the hatch cover plating, induced by the bending of primary supporting members, either parallel and perpendicular to the direction of ordinary stiffeners, calculated according to [5.3.3] or determined through a grillage analysis or a Finite Element analysis, as the case may be, is to comply with the following formula:

$$\frac{\sigma_{Cp}}{\gamma_R\gamma_m} \geq \sigma$$

where σ_{Cp} is critical buckling stress, defined in Ch 7, Sec 1, [5.3.1].

In addition, the bi-axial compression stress in the hatch cover plating, when calculated by means of Finite Element analysis, is to comply with the requirements in Ch 7, Sec 1, [5.4.5].

5.3 Ordinary stiffeners and primary supporting members

5.3.1 General

a) The flange outstand of the primary supporting members is to be not greater than 15 times the flange thickness.

b) The net dimensions of the flat bar ordinary stiffeners and buckling stiffeners are to comply with the following requirement:

$$\frac{h_W}{t_W} \leq 15\sqrt{k}$$

where h_w and t_w are the height and thickness, in mm, of the ordinary stiffener, respectively.

5.3.2 Application

The requirements in [5.3.3] to [5.3.7] apply to:

- ordinary stiffeners
- primary supporting members which may be analysed through isolated beam models.

Primary supporting members whose arrangement is of a grillage type and which cannot be analysed through isolated beam models are to be checked by direct calculations, using the checking criteria in [5.3.4].

5.3.3 Normal and shear stress

a) Where the grillage analysis or Finite Element analysis is not carried out according to the requirements in [5.1.1], the maximum normal stress σ and shear stress τ in the ordinary stiffeners are to be obtained, in N/mm², from the following formulae:

$$\sigma = \frac{s(p_S + p_W)\ell_S^{\,2}10^3}{12w}$$

$$\tau = \frac{5s(p_S + p_W)\ell_S}{A_{sh}}$$

where:

ℓ_S : ordinary stiffener span, in m, to be taken as the spacing, in m, of primary supporting members or the distance between a primary supporting member and the edge support, as applicable. When brackets are fitted at both ends of all ordinary stiffener spans, the ordinary stiffener span may be reduced by an amount equal to 2/3 of the minimum bracket arm length, but not greater than 10% of the gross span, for each bracket.

p_W : wave pressure, as defined in [4.2].

b) Where the grillage analysis or Finite Element analysis is not carried out according to the requirements in [5.1.1], the maximum normal stress σ and shear stress τ in the primary supporting members are to be obtained, in N/mm², from the following formulae:

$$\sigma = \frac{s(p_S + p_W)\ell_m^{\,2}10^3}{mw}$$

$$\tau = \frac{5s(p_S + p_W)\ell_m}{A_{sh}}$$

where p_w is the wave pressure, as defined in [4.2], and ℓ_m is the span of the primary supporting member.

5.3.4 Checking criteria

a) Strength check

The normal stress σ and the shear stress τ, calculated according to [5.3.3] or determined through a grillage analysis or Finite Element analysis, as the case may be, are to comply with the following formulae:

$$\frac{R_{eH}}{\gamma_R \gamma_m} \geq \sigma$$

$$0,57\frac{R_{eH}}{\gamma_m \gamma_R} \geq \tau$$

b) Critical buckling stress check of the ordinary stiffeners

The compressive stress σ in the top flange of ordinary stiffeners, induced by the bending of primary supporting members, parallel to the direction of ordinary stiffeners, calculated according to [5.3.3] or determined through a grillage analysis or a Finite Element analysis, as the case may be, is to comply with the following formula:

$$\frac{\sigma_{Cs}}{\gamma_m \gamma_R} \geq \sigma$$

where:

$\sigma_{CS} = \sigma_{ES}$ for $\sigma_{ES} \leq R_{eH}/2$

$\sigma_{CS} = \sigma_{ES}\ [1 - R_{eH} / (4\ \sigma_{ES})]$ for $\sigma_{ES} \leq R_{eH}/2$

$\sigma_{ES} = \min\ (\sigma_{E1}, \sigma_{E2})$

σ_{E1} and σ_{E2} are defined in Ch 7, Sec 2, [4.3.1].

In calculating σ_{E2}, C_0 is to be taken equal to:

$$C_0 = \frac{k_p E t_p^{\ 3}}{3s\left(1 + \dfrac{1,33 k_p k_W t_p^{\ 3}}{1000 s t_W^{\ 3}}\right)} 10^{-3}$$

where:

t_p = net thickness, in mm, of the attached plating

h_w, t_w = height and thickness, in mm, of the ordinary stiffener, respectively

$k_p = 1 - \eta_p$ to be taken not less than zero; for flanged ordinary stiffeners, k_p need not be taken less than 0,1

$$\eta_p = \frac{\sigma}{\sigma_{Ep}}$$

σ is calculated according to [5.3.3] or determined through a grillage analysis

$$\sigma_{Ep} = 3,6E\left(\frac{t_p}{1000s}\right)^2$$

c) Critical buckling stress check of the web panels of the primary supporting members

The shear stress τ in the web panels of the primary supporting members, calculated according to [5.3.3] or determined through a grillage analysis or a Finite Element analysis, as the case may be, is to comply with the following formula:

$$\frac{\tau_C}{\gamma_m \gamma_R} \geq \tau$$

where τ_C is critical shear buckling stress, defined in Ch 7, Sec 1, [5.3.2].

For primary supporting members parallel to the direction of ordinary stiffeners, τ_C is to be calculated considering the actual dimensions of the panels taken for the determination of the stress τ_C.

For primary supporting members perpendicular to the direction of ordinary stiffeners or for hatch covers built without ordinary stiffeners, a presumed square panel of dimension d is to be taken for the determination of the stress τ_C. In such case, the average shear stress τ of the values calculated at the ends of this panel is to be considered.

d) Deflection limit

The vertical deflection of primary supporting members is to be not more than 0,0056 ℓ_{max}, where ℓ_{max} is the greatest span of primary supporting members.

5.3.5 Net section modulus and net shear sectional area

This requirement provides the minimum net section modulus and net shear sectional area of an ordinary stiffener or a primary supporting member subjected to lateral pressure, complying with the checking criteria indicated in [5.3.4].

The net section modulus w, in cm³, and the net shear sectional area A_{Sh}, in cm², of an ordinary stiffener subjected to lateral pressure are to be not less than the values obtained from the following formulae:

$$w = \gamma_m \gamma_R \frac{s(p_S + p_W) l_S^{\ 2} 10^3}{12 R_{eH}}$$

$$A_{Sh} = \gamma_m \gamma_R \frac{5s(p_S + p_W) l_S}{0,57 R_{eH}}$$

The net section modulus w, in cm³, and the net shear sectional area A_{sh}, in cm², of a primary supporting member subject to lateral pressure are to be not less than the values obtained from the following formulae:

$$w = \gamma_m \gamma_R \frac{s(p_S + p_W) l_m^{\ 2} 10^3}{m R_{eH}}$$

$$A_{Sh} = \gamma_m \gamma_R \frac{5s(p_S + p_W) l_m}{0,57 R_{eH}}$$

5.3.6 Minimum net thickness of web

The net thickness of the ordinary stiffeners and primary supporting members, in mm, is to be not less than the minimum values given in [5.2.2].

5.3.7 Ordinary stiffeners and primary supporting members of variable cross-section

The section modulus of ordinary stiffeners and primary supporting members with a variable cross-section is to be not less than the greater of the values obtained, in cm³, from the following formulae:

$$w = w_{CS}$$

$$w = \left(1 + \frac{3,2\alpha - \psi - 0,8}{7\psi + 0,4}\right) w_{CS}$$

where:

w_{CS} : Section modulus, in cm³, for a constant cross-section, obtained according to [5.3.5]

$$\alpha = \frac{\ell_1}{\ell_0}$$

$$\psi = \frac{w_1}{w_0}$$

ℓ_1 : Length of the variable section part, in m, (see Fig 1)

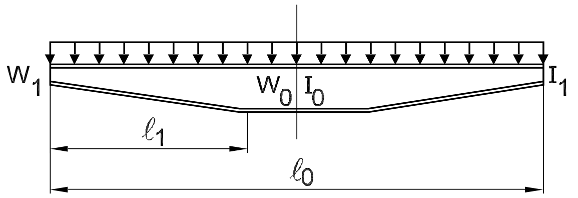
ℓ_0 : Span measured, in m, between end supports (see Fig 1)

w_1 : Section modulus at end, in cm^3 (see Fig 1)

w_0 : Section modulus at mid-span, in cm^3 (see Fig 1).

The use of this formula is limited to the determination of the strength of ordinary stiffeners and primary supporting members in which abrupt changes in the cross-section do not occur along their length.

Figure 1 : Variable cross-section stiffener



6 Hatch coamings

6.1 Stiffening

6.1.1 The ordinary stiffeners of the hatch coamings are to be continuous over the breadth and length of the hatch coamings.

6.1.2 Coamings are to be stiffened on their upper edges with a stiffener suitably shaped to fit the hatch cover closing appliances.

Moreover, when covers are fitted with tarpaulins, an angle or a bulb section is to be fitted all around coamings of more than 3 m in length or 600 mm in height; this stiffener is to be fitted at approximately 250 mm below the upper edge. The width of the horizontal flange of the angle is not to be less than 180 mm.

6.1.3 Where hatch covers are fitted with tarpaulins, coamings are to be strengthened by brackets or stays with a spacing not greater than 3 m.

Where the height of the coaming exceeds 900 mm, additional strengthening may be required.

However, reductions may be granted for transverse coamings in protected areas.

6.1.4 When two hatches are close to each other, underdeck stiffeners are to be fitted to connect the longitudinal coamings with a view to maintaining the continuity of their strength.

Similar stiffening is to be provided over 2 frame spacings at ends of hatches exceeding 9 frame spacings in length.

In some cases, the Society may require the continuity of coamings to be maintained above the deck.

6.1.5 Where watertight metallic hatch covers are fitted, other arrangements of equivalent strength may be adopted.

6.2 Load model

6.2.1 The wave lateral pressure to be considered as acting on the hatch coamings is that specified in [6.2.2] and [6.2.3].

6.2.2 The wave lateral pressure pWC, in kN/m2, on the No. 1 forward transverse hatch coaming is to be taken equal to:

p_{WC} = 290 kN/m^2.

6.2.3 The wave lateral pressure pWC, in kN/m2, on the hatch coamings other than the No. 1 forward transverse hatch coaming is to be taken equal to:

p_{WC} = 220 kN/m^2.

6.3 Scantlings

6.3.1 Plating

In ships intended for the carriage of liquid cargoes, the plate thickness of coamings is also to be checked under liquid internal pressures.

a) Net thickness

The net thickness of the hatch comaing plate is to be not less than the value obtained, in mm, from the following formula:

$$t = 16,4s\sqrt{\frac{p_{WC}}{R_{eH}}}$$

b) Minimum net thickness

In addition to the requirements in a), the net thickness of the hatch coaming plate is to be not less than 9,5 mm.

6.3.2 Ordinary stiffeners

The net section modulus w of the longitudinal or transverse ordinary stiffeners of hatch coamings is to be not less than the value obtained, in cm^3, from the following formula:

$$w = \frac{1,2sp_{WC}l^2 10^3}{mc_pR_{eH}}$$

where:

m = 16 in general

m = 12 for the end span of stiffeners sniped at the coaming corners

c_p = ratio of the plastic section modulus to the elastic section modulus of the secondary stiffeners with an attached plate breadth, in mm, equal to 40 t, where t is the plate net thickness

c_p = 1,16 in the absence of more precise evaluation.

6.3.3 Coaming stays

The net section modulus w, in cm^3, and the thickness t_w, in mm, of the coaming stays are to be not less than the values obtained from the following formulae:

$$w = \frac{1,05H_C^2 s_c p_{WC} 10^3}{2R_{eH}}$$

$$t_w = \frac{H_C s_c p_{WC} 10^3}{0,5hR_{eH}}$$

where:

H_C = stay height, in m

s_c = stay spacing, in m

h = stay depth, in mm, at the connection with deck

For calculating the section modulus of coaming stays, their face plate area is to be taken into account only when it is welded with full penetration welds to the deck plating and adequate underdeck structure is fitted to support the stresses transmitted by it.

6.3.4 Local details

The design of local details is to comply with the requirements in this Section for the purpose of transferring the pressures on the hatch covers to the hatch coamings and, through them, to the deck structures below. Hatch coamings and supporting structures are to be adequately stiffened to accommodate the loading from hatch covers in longitudinal, transverse and vertical directions.

The normal stress s and the shear stress t, in N/mm², induced in the underdeck structures by the loads transmitted by stays are to comply with the following formulae:

$\sigma \leq \sigma_{ALL}$

$\tau \leq \tau_{ALL}$

σ_{ALL} : allowable normal stress, in N/mm², equal to 0,95 R_{eH}

τ_{ALL} : allowable shear stress, in N/mm², equal to 0,5 R_{eH}

Unless otherwise stated, weld connections and materials are to be dimensioned and selected in accordance with the requirements in Ch 12, Sec 1 and Part D, respectively.

Double continuous fillet welding is to be adopted for the connections of stay webs with deck plating and the weld throat thickness is to be not less than 0,44 t_W, where t_W is the gross thickness of the stay web.

Toes of stay webs are to be connected to the deck plating with full penetration double bevel welds extending over a distance not less than 15% of the stay width.

6.3.5 Coamings of small hatchways

The coaming plate thickness is to be not less than the lesser of the following values:

- the thickness for the deck inside line of openings calculated for that position, assuming as spacing of stiffeners the lesser of the values of the height of the coaming and the distance between its stiffeners, if any, or
- 10 mm.

Coamings are to be suitably strengthened where their height exceeds 0,80 m or their greatest horizontal dimension exceeds 1,20 m, unless their shape ensures an adequate rigidity.

7 Weathertightness, closing arrangement and securing devices

7.1 Weathertightness

7.1.1 Where the hatchway is exposed and closed with a single panel, the weathertightness is to be ensured by gaskets and clamping devices sufficient in number and quality.

Weathertightness may also be ensured means of tarpaulins.

7.1.2 The mean spacing of swing bolts or equivalent devices is, in general, to be not greater than:

- 2,0 m for dry cargo holds
- 1,5 m for ballast compartments
- 1,0 m for liquid cargo holds.

7.2 Gaskets

7.2.1 The weight of hatch covers and any cargo stowed thereon, together with inertia forces generated by ship motions, are to be transmitted to the ship's structure through steel to steel contact.

This may be achieved by continuous steel to steel contact of the hatch cover skirt plate with the ship's structure or by means of defined bearing pads.

7.2.2 The sealing is to be obtained by a continuous gasket of relatively soft elastic material compressed to achieve the necessary weathertightness. Similar sealing is to be arranged between cross-joint elements.

Where fitted, compression flat bars or angles are to be well rounded where in contact with the gasket and to be made of a corrosion-resistant material.

7.2.3 The gasket and the securing arrangements are to maintain their efficiency when subjected to large relative movements between the hatch cover and the ship's structure or between hatch cover elements.

If necessary, suitable devices are to be fitted to limit such movements.

7.2.4 The gasket material is to be of a quality suitable for all environmental conditions likely to be encountered by the ship, and is to be compatible with the cargoes transported.

The material and form of gasket selected are to be considered in conjunction with the type of hatch cover, the securing arrangement and the expected relative movement between the hatch cover and the ship's structure.

The gasket is to be effectively secured to the hatch cover.

7.2.5 Coamings and steel parts of hatch covers in contact with gaskets are to have no sharp edges.

7.2.6 Metallic contact is required for an earthing connection between the hatch cover and the hull structures. If necessary, this is to be achieved by means of a special connection for the purpose.

7.3 Closing arrangement, securing devices and stoppers

7.3.1 General

Panel hatch covers are to be secured by appropriate devices (bolts, wedges or similar) suitably spaced alongside the coamings and between cover elements.

The securing and stop arrangements are to be fitted using appropriate means which cannot be easily removed.

In addition to the requirements above, all hatch covers, and in particular those carrying deck cargo, are to be effectively secured against horizontal shifting due to the horizontal forces resulting from ship motions.

Towards the ends of the ship, vertical acceleration forces may exceed the gravity force. The resulting lifting forces are to be considered when dimensioning the securing devices according to [7.3.5] to [7.3.7]. Lifting forces from cargo secured on the hatch cover during rolling are also to be taken into account.

Hatch coamings and supporting structure are to be adequately stiffened to accommodate the loading from hatch covers.

Hatch covers provided with special sealing devices, insulated hatch covers, flush hatch covers and those having coamings of a reduced height (see [2.1]) are considered by the Society on a case by case basis.

In the case of hatch covers carrying containers, the scantlings of the closing devices are to take into account the possible upward vertical forces transmitted by the containers.

7.3.2 Arrangements

The securing and stopping devices are to be arranged so as to ensure sufficient compression on gaskets between hatch covers and coamings and between adjacent hatch covers.

Arrangement and spacing are to be determined with due attention to the effectiveness for weathertightness, depending on the type and the size of the hatch cover, as well as on the stiffness of the hatch cover edges between the securing devices.

At cross-joints of multipanel covers, (male/female) vertical guides are to be fitted to prevent excessive relative vertical deflections between loaded/unloaded panels.

The location of stoppers is to be compatible with the relative movements between hatch covers and the ship's structure in order to prevent damage to them. The number of stoppers is to be as small as possible.

7.3.3 Spacing

The spacing of the securing arrangements is to be generally not greater than 6 m.

The spacing of securing arrangements of tank hatch covers in 'tweendecks is to be not greater than 600 mm.

7.3.4 Construction

Securing arrangements with reduced scantlings may be accepted provided it can be demonstrated that the possibility of water reaching the deck is negligible.

Securing devices are to be of reliable construction and securely attached to the hatchway coamings, decks or hatch covers.

Individual securing devices on each hatch cover are to have approximately the same stiffness characteristics.

7.3.5 Area of securing devices

The net cross area of each securing device is to be not less than the value obtained, in cm², from the following formula:

$$A = 1{,}4 S_S \left(\frac{235}{R_{eH}}\right)^f$$

where:

S_S : Spacing, in m, of securing devices

f : Coefficient taken equal to:

- 0,75 for $R_{eH} > 235$ N/mm²,
- 1,00 for $R_{eH} \le 235$ N/mm².

In the above calculations, R_{eH} may not be taken greater than 0,7 R_m.

Between hatch cover and coaming and at cross-joints, a packing line pressure sufficient to obtain weathertightness is to be maintained by securing devices. For packing line pressures exceeding 5 N/mm, the net cross area A is to be increased in direct proportion. The packing line pressure is to be specified.

In the case of securing arrangements which are particularly stressed due to the unusual width of the hatchway, the net cross area A of the above securing arrangements is to be determined through direct calculations.

7.3.6 Inertia of edges elements

The hatch cover edge stiffness is to be sufficient to maintain adequate sealing pressure between securing devices.

The moment of inertia of edge elements is to be not less than the value obtained, in cm⁴, from the following formula:

$$I = 6 p_L S_S^4$$

where:

p_L : Packing line pressure, in N/mm, to be taken not less than 5 N/mm

S_S : Spacing, in m, of securing devices.

7.3.7 Diameter of rods or bolts

Rods or bolts are to have a net diameter not less than 19 mm for hatchways exceeding 5 m² in area.

7.3.8 Stoppers

Hatch covers are to be effectively secured, by means of stoppers, against the transverse forces arising from a pressure of 175 kN/m².

With the exclusion of No. 1 hatch cover, hatch covers are to be effectively secured, by means of stoppers, against the longitudinal forces acting on the forward end arising from a pressure of 175 kN/m².

No. 1 hatch cover is to be effectively secured, by means of stoppers, against the longitudinal forces acting on the forward end arising from a pressure of 230 kN/m².

The equivalent stress in stoppers, their supporting structures and in the throat of the stopper welds is to be equal to or less than the allowable value, equal to 0,8 R_{eH}.

7.4 Tarpaulins

7.4.1 Where weathertightness of hatch covers is ensured by means of tarpaulins, at least two layers of tarpaulins are to be fitted.

Tarpaulins are to be free from jute and waterproof and are to have adequate characteristics of strength and resistance to atmospheric agents and high and low temperatures.

The mass per unit surface of tarpaulins made of vegetable fibres, before the waterproofing treatment, is to be not less than:

- 0,65 kg/m² for waterproofing by tarring
- 0,60 kg/m² for waterproofing by chemical dressing
- 0,55 kg/m² for waterproofing by dressing with black oil.

In addition to tarpaulins made of vegetable fibres, those of synthetic fabrics or plastic laminates may be accepted by the Society provided their qualities, as regards strength, waterproofing and resistance to high and low temperatures, are equivalent to those of tarpaulins made of vegetable fibres.

7.5 Cleats

7.5.1 The arrangements for securing the tarpaulins to hatch coamings are to incorporate cleats of a suitable pattern giving support to battens and wedges and with edges rounded so as to minimise damage to the wedges.

7.5.2 Cleats are to be spaced not more than 600 mm from centre to centre and are to be not more than 150 mm from the hatch corners.

7.5.3 The thickness of cleats is to be not less than 9,5 mm for angle cleats and 11 mm for forged cleats.

7.5.4 Where rod cleats are fitted, resilient washers or cushions are to be incorporated.

7.5.5 Where hydraulic cleating is adopted, a positive means is to be provided to ensure that it remains mechanically locked in the closed position in the event of failure of the hydraulic system.

7.6 Wedges, battens and locking bars

7.6.1 Wedges

Wedges are to be of tough wood, generally not more than 200 mm in length and 50 mm in width.

They are generally to be tapered not more than 1 in 6 and their thickness is to be not less than 13 mm.

7.6.2 Battens and locking bars

For all hatchways in exposed positions, battens or transverse bars in steel or other equivalent means are to be provided in order to efficiently secure the portable covers after the tarpaulins are battened down.

Portable covers of more than 1,5 m in length are to be secured by at least two such securing appliances.

8 Drainage

8.1 Arrangement

8.1.1 Drainage is to be arranged inside the line of gaskets by means of a gutter bar or vertical extension of the hatch side and end coaming.

8.1.2 Drain openings are to be arranged at the ends of drain channels and are to be provided with efficient means for preventing ingress of water from outside, such as non-return valves or equivalent.

8.1.3 Cross-joints of multipanel hatch covers are to be arranged with drainage of water from the space above the gasket and a drainage channel below the gasket.

8.1.4 If a continuous outer steel contact is arranged between the cover and the ship's structure, drainage from the space between the steel contact and the gasket is also to be provided.

9 Small hatches fitted on the exposed fore deck

9.1 Application

9.1.1 General

The requirements in [9] apply to steel covers of small hatches fitted on the exposed fore deck over the forward 0,25L, for ships of equal to or greater than 80 m in length, where the height of the exposed deck in way of the hatch is less than 0,1L or 22 m above the summer load waterline, whichever is the lesser.

Small hatches are hatches designed for access to spaces below the deck and are capable of being closed weathertight or watertight, as applicable. Their opening is generally equal to or less than 2,5 m^2.

9.1.2 Small hatches designed for emergency escape

Small hatches designed for emergency escape are not required to comply with the requirements in [9.4.1] a) and b), in [9.4.3] and in [9.5].

Securing devices of hatches designed for emergency escape are to be of a quick-acting type (e.g. one action wheel handles are provided as central locking devices for latching/unlatching of hatch cover) operable from both sides of the hatch cover.

9.2 Strength

9.2.1 For small rectangular steel hatch covers, the plate thickness, stiffener arrangement and scantlings are to be not less than those obtained, in mm, from Tab 4 and Fig 2.

Ordinary stiffeners, where fitted, are to be aligned with the metal-to-metal contact points, required in [9.3.1] (see also Fig 2). Primary supporting members are to be continuous. All stiffeners are to be welded to the inner edge stiffener (see also Fig 3).

9.2.2 The upper edge of the hatchway coamings is to be suitably reinforced by a horizontal section, normally not more than 170 to 190 mm from the upper edge of the coamings.

9.2.3 For small hatch covers of circular or similar shape, the cover plate thickness and reinforcement are to comply with the requirements in [5].

9.2.4 For small hatch covers constructed of materials other than steel, the required scantlings are to provide equivalent strength.

Table 4 : Structural scantlings of small rectangular steel hatch covers

Hatch nominal size (mm x mm)	Cover plate thickness (mm)	Primary supporting members	Ordinary stiffeners
		Flat Bar (mm x mm); number	
630 x 630	8	-	-

Hatch nominal size (mm x mm)	Cover plate thickness (mm)	Primary supporting members	Ordinary stiffeners
630 x 830	8	100 x 8 ; 1	-
830 x 630	8	100 x 8 ; 1	-
830 x 830	8	100 x 10 ; 1	-
1030 x 1030	8	120 x 12 ; 1	80 x 8 ; 2
1330 x 1330	8	150 x 12 ; 2	100 x 10 ; 2

9.3 Weathertightness

9.3.1 The hatch cover is to be fitted with a gasket of elastic material. This is to be designed to allow a metal-to-metal contact at a designed compression and to prevent over compression of the gasket by green sea forces that may cause the securing devices to be loosened or dislodged. The metal-to-metal contacts are to be arranged close to each securing device in accordance with Fig 2, and to be of sufficient capacity to withstand the bearing force.

9.4 Primary securing devices

9.4.1 Small hatches located on the exposed fore deck are to be fitted with primary securing devices such that their hatch covers can be secured in place and weathertight by means of a mechanism employing any one of the following methods:

a) Butterfly nuts tightening onto forks (clamps),

b) Quick acting cleats, or

c) Central locking device.

Dogs (twist tightening handles) with wedges are deemed unacceptable by the Society.

9.4.2 The primary securing method is to be designed and manufactured such that the designed compression pressure is achieved by one person without the need for any tools.

9.4.3 For a primary securing method using butterfly nuts, the forks (clamps) are to be of robust design. They are to be designed to minimise the risk of butterfly nuts being dislodged while in use, by means of curving the forks upward, a raised surface on the free end, or a similar method. The plate thickness of unstiffened steel forks is to be not less than 16 mm. An example of arrangement is shown in Fig 3.

9.4.4 For small hatch covers located on the exposed deck forward of the foremost cargo hatch, the hinges are to be fitted such that the predominant direction of green sea will cause the cover to close, which means that the hinges are normally to be located on the fore edge.

9.4.5 On small hatches located between the main hatches, for example between hatches No. 1 and No. 2, the hinges are to be placed on the fore edge or outboard edge, whichever is practicable for protection from green water in beam sea and bow quartering conditions.

9.5 Secondary Securing Device

9.5.1 Small hatches on the fore deck are to be fitted with an independent secondary securing device e.g. by means of a sliding bolt, a hasp or a backing bar of slack fit, which is capable of keeping the hatch cover in place, even in the event that the primary securing device became loosened or dislodged. It is to be fitted on the side opposite to the hatch cover hinges.

Figure 2 : Structural arrangement of small rectangular steel hatch covers

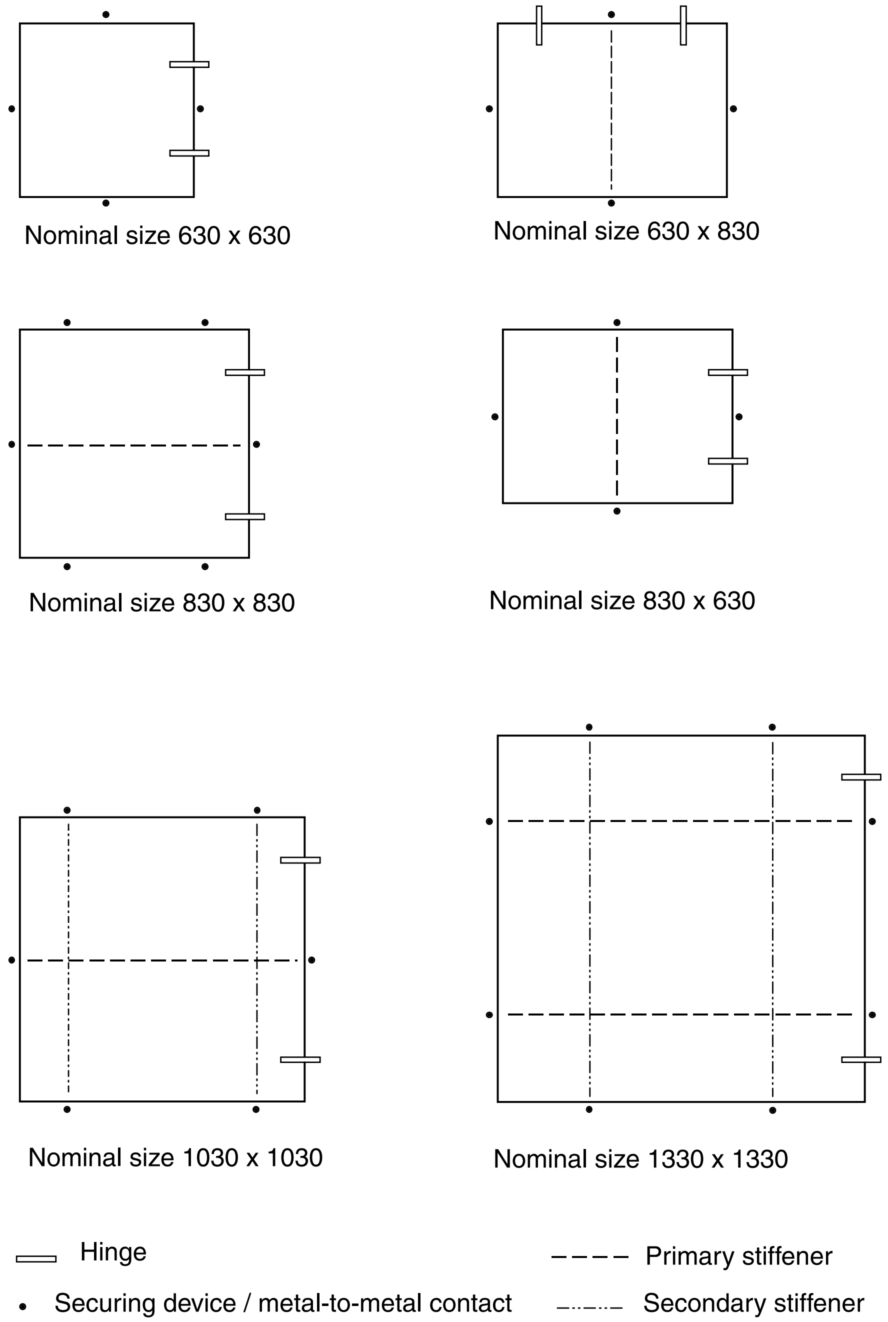
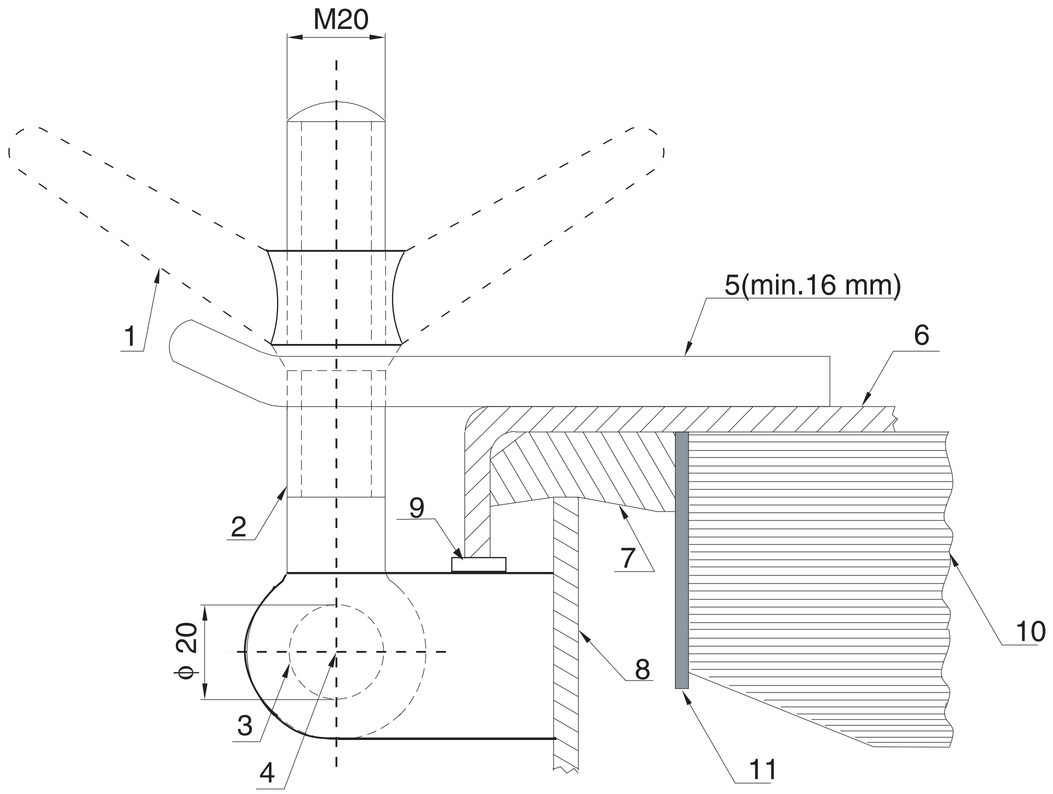


Figure 3 : Example of a primary securing method



Legend:

1: butterfly nut

2: bolt

3: pin

4: centre of pin

5: fork (clamp) plate

6: hatch cover

7: gasket

8: hatch coaming

9: bearing pad welded on the bracket of a toggle bolt for metal-to-metal contact

10: stiffener

11: inner edge stiffener

***Note**: Dimensions in mm*

SECTION 8 MOVABLE DECKS AND INNER RAMPS - EXTERNAL RAMPS

1 Movable decks and inner ramps

1.1 Application

1.1.1 The requirements of this Article apply to movable decks and inner ramps.

1.2 Materials

1.2.1 The decks and inner ramps are to be made of steel or aluminium alloys complying with the requirements of Part D. Other materials of equivalent strength may be used, subject to a case by case examination by the Society.

1.3 Net scantlings

1.3.1 As specified in Ch 4, Sec 2, [1], all scantlings referred to in this Section are net, i.e. they do not include any margin for corrosion.

The gross scantlings are obtained as specified in Ch 4, Sec 2.

1.4 Plating

1.4.1 The net thickness of plate panels subjected to wheeled loads is to be not less than the value obtained from Ch 7, Sec 1, [4.3], where nP_0 is not to be taken less than 50 kN.

1.5 Supporting structure

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, at sea
- movable deck in service, loaded, in lower position, resting on supports or supporting legs and locked, at sea
- movable inner ramp in sloped position, supported by hinges at one end and by a deck at the other, with possible intermediate supports, loaded, at harbour
- movable inner ramp in horizontal position, loaded and locked, at sea.

1.5.2 Loading cases

The scantlings of the structure are to be verified in both sea and harbour conditions for the following cases:

- loaded movable deck or inner ramp under loads according to the vehicle distribution indicated by the Designer
- loaded movable deck or inner ramp under uniformly distributed loads corresponding to a pressure, in kN/m², taken equal to:

$$p = \frac{n_V P_V + P_P}{A_P}$$

- empty movable deck under uniformly distributed masses corresponding to a pressure, in kN/m², taken equal to:

$$p = \frac{P_P}{A_P}$$

where:

n_V : Maximum number of vehicles loaded on the movable deck

P_V : Mass of a vehicle, in kN

P_P : Mass of the movable deck, in kN

A_P : Effective area of the movable deck, in m².

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		$p_S = p$
Upright sea condition	"a"	No inertial pressure
	"b"	$p_{W,X} = p\frac{a_{X1}}{g}$ in x direction $p_{W,Z} = p\frac{a_{Z1}}{g}$ in z direction
Inclined sea condition (negative roll angle)	"c" "d"	$p_{W,Y} = p\frac{C_{FA}a_{Y2}}{g}$ in y direction $p_{W,Z} = p\frac{C_{FA}a_{Z2}}{g}$ in z direction
Harbour condition **(1)**	during lifting	$p_{W,X} = 0{,}035p$ in x direction $p_{W,Y} = 0{,}087p$ in y direction $p_{W,Z} = 0{,}2p$ in z direction
	at rest	$p_{W,X} = 0{,}035p$ in x direction $p_{W,Y} = 0{,}087p$ in y direction $p_{W,Z} = 0$ in z direction

(1) For harbour conditions, a heel angle of 5° and a trim angle of 2° are taken into account.

Note 1:

p : Pressure, in kN/m², to be calculated according to [1.5.2] for the condition considered.

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"

1.5.3 Still water and inertial pressures

The still water and inertial pressures transmitted to the movable deck or inner ramp structures are obtained, in kN/m^2, as specified in Tab 1.

1.5.4 Checking criteria

It is to be checked that the combined stress σ_{VM} is in accordance with the criteria defined in Ch 7, Sec 3, [4.3.1].

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 rigid supports and locking devices is in accordance with the criteria defined in Ch 7, Sec 3, [4.3.1].

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 external ramps are to be examined for their watertightness, if applicable, and as a support of vehicles at harbour.

2.1.3 The locking of external ramps in stowage position at sea is examined by the Society on a case by case basis.

2.1.4 The ship's structure under the reactions due to the ramp is examined by the Society on a case by case basis.

SECTION 9 ARRANGEMENT OF HULL AND SUPERSTRUCTURE OPENINGS

1 General

1.1 Application

1.1.1 The requirements of this Section apply to the arrangement of hull and superstructure openings excluding hatchways, for which the requirements in Sec 7 apply.

1.2 Definitions

1.2.1 Standard height of superstructure

The standard height of superstructure is that defined in Ch 1, Sec 2, Tab 2.

1.2.2 Standard sheer

The standard sheer is that defined according to regulation 38 of the International Load Line Convention 1966, as amended.

1.2.3 Exposed zones

Exposed zones are the boundaries of superstructures or deckhouses set in from the ship's side at a distance less than or equal to 0,04 B.

1.2.4 Unexposed zones

Unexposed zones are the boundaries of deckhouses set in from the ship's side at a distance greater than 0,04 B.

2 External openings

2.1 General

2.1.1 All external openings leading to compartments assumed intact in the damage analysis, which are below the final damage waterline, are required to be watertight.

2.1.2 External openings required to be watertight in accordance with [2.1.1] are to be of sufficient strength and, except for cargo hatch covers, are to be fitted with indicators on the bridge.

2.1.3 Openings in the shell plating below the deck limiting the vertical extent of damage are to be kept permanently closed while at sea. Should any of these openings be accessible during the voyage, they are to be fitted with a device which prevents unauthorised opening.

2.1.4 Notwithstanding the requirements of [2.1.3], the Society may authorise that particular doors may be opened at the discretion of the Master, if necessary for the operation of the ship and provided that the safety of the ship is not impaired.

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

3 Sidescuttles, windows and skylights

3.1 General

3.1.1 Application

The requirements in [3.1] to [3.4] apply to sidescuttles and rectangular windows providing light and air, located in positions which are exposed to the action of sea and/or bad weather.

3.1.2 Sidescuttle definition

Sidescuttles are round or oval openings with an area not exceeding 0,16 m^2. Round or oval openings having areas exceeding 0,16 m^2 are to be treated as windows.

3.1.3 Window definition

Windows are rectangular openings generally, having a radius at each corner relative to the window size in accordance with recognised national or international standards, and round or oval openings with an area exceeding 0,16 m^2.

3.1.4 Number of openings in the shell plating

The number of openings in the shell plating are to be reduced to the minimum compatible with the design and proper working of the ship.

3.1.5 Material and scantlings

Sidescuttles and windows together with their glasses, deadlights and storm covers, if fitted, are to be of approved design and substantial construction in accordance with, or equivalent to, recognised national or international standards.

Non-metallic frames are not acceptable. The use of ordinary cast iron is prohibited for sidescuttles below the freeboard deck.

3.1.6 Means of closing and opening

The arrangement and efficiency of the means for closing any opening in the shell plating are to be consistent with its intended purpose and the position in which it is fitted is to be generally to the satisfaction of the Society.

3.1.7 Opening of sidescuttles

All sidescuttles, the sills of which are below the freeboard deck for cargo ships, are to be of such construction as to prevent effectively any person opening them without the consent of the Master of the ship.

Sidescuttles and their deadlights which are not accessible during navigation are to be closed and secured before the ship leaves port.

The Society, at its discretion, may prescribe that the time of opening such sidescuttles in port and of closing and locking them before the ship leaves port is to be recorded in a log book.

3.2 Opening arrangement

3.2.1 General

Sidescuttles may not be fitted in such a position that their sills are below a line drawn parallel to the freeboard deck at side and having its lowest point 0,025B or 0,5 m, whichever is the greater distance, above the summer load waterline (or timber summer load waterline if assigned).

3.2.2 Sidescuttles below 1,4+0,025B m above the water

Where in 'tweendecks the sills of any of the sidescuttles are below a line drawn parallel to the bulkhead deck at side and having its lowest point 1,4+0,025B m above the water when the ship departs from any port, all the sidescuttles in that 'tweendecks are to be closed watertight and locked before the ship leaves port, and they may not be opened before the ship arrives at the next port. In the application of this requirement, the appropriate allowance for fresh water may be made when applicable.

For any ship that has one or more sidescuttles so placed that the above requirements apply when it is floating at its deepest subdivision load line, the Society may indicate the limiting mean draught at which these sidescuttles are to have their sills above the line drawn parallel to the bulkhead deck at side, and having its lowest point 1,4+0,025B above the waterline corresponding to the limiting mean draught, and at which it is therefore permissible to depart from port without previously closing and locking them and to open them at sea under the responsibility of the Master during the voyage to the next port. In tropical zones as defined in the International Convention on Load Lines in force, this limiting draught may be increased by 0,3 m.

3.2.3 Cargo spaces

No sidescuttles may be fitted in any spaces which are appropriated exclusively for the carriage of cargo or coal.

Sidescuttles may, however, be fitted in spaces appropriated alternatively for the carriage of cargo or passengers, but they are to be of such construction as to prevent effectively any person opening them or their deadlights without the consent of the Master.

If cargo is carried in such spaces, the sidescuttles and their deadlights are to be closed watertight and locked before the cargo is shipped. The Society, at its discretion, may prescribe that the time of closing and locking is to be recorded in a log book.

3.2.4 Non-opening type sidescuttles

Sidescuttles are to be of the non-opening type in the following cases:

- where they become immersed by any intermediate stage of flooding or the final equilibrium waterplane in any required damage case for ships subject to damage stability regulations
- where they are fitted outside the space considered flooded and are below the final waterline for those ships where the freeboard is reduced on account of subdivision characteristics.

3.2.5 Manholes and flush scuttles

Manholes and flush scuttles in positions 1 or 2, or within superstructures other than enclosed superstructures, are to be closed by substantial covers capable of being made watertight. Unless secured by closely spaced bolts, the covers are to be permanently attached.

3.2.6 Ships with several decks

In ships having several decks above the bulkhead deck, the arrangement of sidescuttles and rectangular windows is considered by the Society on a case by case basis.

Particular consideration is to be given to the ship side up to the upper deck and the front bulkhead of the superstructure.

3.2.7 Automatic ventilating scuttles

Automatic ventilating sidescuttles, fitted in the shell plating below the freeboard deck for cargo ships, are considered by the Society on a case by case basis.

3.2.8 Window arrangement

Windows may not be fitted below the freeboard deck, in first tier end bulkheads or sides of enclosed superstructures and in first tier deckhouses considered as being buoyant in the stability calculations or protecting openings leading below.

In the front bulkhead of a superstructure situated on the upper deck, in the case of substantially increased freeboard, rectangular windows with permanently fitted storm covers are acceptable.

3.2.9 Skylights

Fixed or opening skylights are to have glass thickness appropriate to their size and position as required for sidescuttles and windows. Skylight glasses in any position are to be protected from mechanical damage and, where fitted in positions 1 or 2, to be provided with permanently attached robust deadlights or storm covers.

3.2.10 Gangway, cargo and coaling ports

Cargo ports and other similar openings in the sides of ships below the freeboard deck of cargo ships are to be fitted with doors so designed as to ensure the same watertightness and structural integrity as the surrounding shell plating. They are to be effectively closed and secured watertight before the ship leaves port and to be kept closed during navigation. Unless otherwise granted by the Society, these opening are to open outwards.

The number of such openings is to be the minimum compatible with the design and proper working of the ship.

Unless otherwise permitted by the Society, the lower edge of the openings may not be fitted below a line drawn parallel to the freeboard deck at side, which is at its lowest point at least 230 mm above the upper edge of the uppermost load line.

Where it is permitted to arrange cargo ports and other similar openings with their lower edge below the line specified above, additional features are to be fitted to maintain the watertight integrity.

The fitting of a second door of equivalent strength and watertightness is one acceptable arrangement. A leakage detection device is to be provided in the compartment between the two doors. Drainage of this compartment to the bilges, controlled by a readily accessible screw-down valve, is to be arranged. The outer door is to open outwards.

Arrangements for bow doors and their inner doors, side doors and stern doors and their securing are to be in compliance with the requirements specified in Sec 5 and in Sec 6, respectively.

3.3 Glasses

3.3.1 General

In general, toughened glasses with frames of special type are to be used in compliance with, or equivalent to, recognised national or international standards.

The use of clear plate glasses is considered by the Society on a case by case basis.

3.3.2 Thickness of toughened glasses in sidescuttles

The thickness of toughened glasses in sidescuttles is to be not less than that obtained, in mm, from Tab 1.

Type A, B or C sidescuttles are to be adopted according to the requirements of Tab 2, where:

- Zone 1 is the zone comprised between a line, parallel to the sheer profile, with its lowest points at a distance above the summer load waterline equal to 0,025B m, or 0,5 m, whichever is the greater, and a line parallel to the previous one and located 1,4 m above it
- Zone 2 is the zone located above Zone A and bounded at the top by the freeboard deck
- Zone 3 is the first tier of superstructures or deckhouses
- Zone 4 is the second tier of deckhouses
- Zone 5 is the third and higher tiers of deckhouses.

3.3.3 Thickness of toughened glasses in rectangular windows

The thickness of toughened glasses in rectangular windows is to be not less than that obtained, in mm, from Tab 3.

Dimensions of rectangular windows other than those in Tab 3 are considered by the Society on a case by case basis.

Table 1 : Thickness of toughened glasses in sidescuttles

Clear light diameter of sidescuttle, in mm	Thickness, in mm		
	Type A Heavy series	Type B Medium series	Type C Light series
200	10	8	6
250	12	8	6
300	15	10	8
350	15	12	8
400	19	12	10
450	Not applicable	15	10

Table 2 : Types of sidescuttles

<table>
<tr><th>Zone</th><th colspan="2">Aft of 0,875 L from the aft end</th><th>Fwd of 0,875 L from the aft end</th></tr>
<tr><td>5</td><td colspan="2">Type C</td><td>Type B</td></tr>
<tr><td rowspan="2">4</td><td colspan="2">Protecting openings giving direct access to spaces below the freeboard deck: Type B</td><td rowspan="2">Type B</td></tr>
<tr><td colspan="2">Not protecting openings giving direct access to spaces below the freeboard deck: Type C</td></tr>
<tr><td rowspan="3">3</td><td colspan="2">Exposed zones: Type B</td><td rowspan="3">Type B</td></tr>
<tr><td rowspan="2">Unexposed zones</td><td>Protecting openings giving direct access to spaces below the freeboard deck: Type B</td></tr>
<tr><td>Not protecting openings giving direct access to spaces below the freeboard deck: Type C</td></tr>
<tr><td>2</td><td colspan="2">Type B</td><td>Type A</td></tr>
<tr><td>1</td><td colspan="2">Type A</td><td>Type A</td></tr>
</table>

Table 3 : Thickness of toughened glasses in rectangular windows

Nominal size (clear light) of rectangular window, in mm²	Thickness, in mm		Total minimum of closing appliances of openingtype rectangular windows **(1)**
	Unexposed zone of first tier, exposed zone of second tier	Unexposed zone of second tier, exposed zone of third tier and above	
300 x 425	10	8	4
355 x 500	10	8	4
400 x 560	12	8	4
450 x 630	12	8	4
500 x 710	15	10	6
560 x 800	15	10	6
900 x 630	19	12	6
1000 x 710	19	12	8
1100 x 800	Not applicable	15	8

(1) Swing bolts and circular hole hinges of glass holders of opening type rectangular windows are considered as closing appliances.

3.3.4 Thickness of glasses forming screen bulkheads or internal boundaries of deckhouses

The thickness of glasses forming screen bulkheads on the side of enclosed promenade spaces and that for rectangular windows in the internal boundaries of deckhouses which are protected by such screen bulkheads are considered by the Society on a case by case basis.

The Society may require both limitations on the size of rectangular windows and the use of glasses of increased thickness in way of front bulkheads which are particularly exposed to heavy sea.

3.3.5

For windows and sidescuttles with dimensions different from those indicated in Table 1 and Table 3, the thickness calculation of the glasses is to be obtained according to Standard ISO 21005, considering the pressure indicated in Sec 4, [2.2.2].

3.4 Deadlight arrangement

3.4.1 General

Sidescuttles to the following spaces are to be fitted with efficient, hinged inside deadlights:

- spaces below the freeboard deck
- spaces within the first tier of enclosed superstructures
- first tier deckhouses on the freeboard deck protecting openings leading below or considered buoyant in stability calculations.

Deadlights are to be capable of being closed and secured watertight if fitted below the freeboard deck and weathertight if fitted above.

3.4.2 Watertight deadlights

Efficient, hinged inside deadlights so arranged that they can be easily and effectively closed and secured watertight, are to be fitted to all sidescuttles except that abaft one eighth of the ship's length from the forward perpendicular and above a line drawn parallel to the bulkhead deck at side and having its lowest point at a height of 3,7+0,025B m above the deepest subdivision load line. The deadlights may be portable in passenger accommodation other than that for steerage passengers, unless the deadlights are required by the International Convention on Load Lines in force to be permanently attached in their proper positions. Such portable deadlights are to be stowed adjacent to the sidescuttles they serve.

3.4.3 Openings at the side shell in the second tier

Sidescuttles and windows at the side shell in the second tier superstructure, protecting direct access to an opening leading below or considered buoyant in the stability calculations, are to be provided with efficient, hinged inside deadlights capable of being effectively closed and secured weathertight.

3.4.4 Openings set inboard in the second tier

Sidescuttles and windows set inboard from the side shell in the second tier, protecting direct access below to spaces listed in [3.4.1], are to be provided with either efficient, hinged inside deadlights or, where they are accessible, permanently attached external storm covers of approved design and substantial construction capable of being effectively closed and secured weathertight.

Cabin bulkheads and doors in the second tier and above separating sidescuttles and windows from a direct access leading below or in the second tier considered buoyant in the stability calculations may be accepted in place of fitted deadlights or storm covers fitted to the sidescuttles and windows.

Note 1: Deadlights in accordance with recognised standards are fitted to the inside of windows and sidescuttles, while storm covers of comparable specifications to deadlights are fitted to the outside of windows, where accessible, and may be hinged or portable.

3.4.5 Deckhouses on superstructures of less than standard height

Deckhouses situated on a raised quarterdeck or on the deck of a superstructure of less than standard height may be treated as being in the second tier as far as the provision of deadlights is concerned, provided the height of the raised quarterdeck or superstructure is not less than the standard quarterdeck height.

3.4.6 Openings protected by a deckhouse

Where an opening in a superstructure deck or in the top of a deckhouse on the freeboard deck which gives access to a space below the freeboard deck or to a space within an enclosed superstructure is protected by a deckhouse, then it is considered that only those sidescuttles fitted in spaces which give direct access to an open stairway need to be fitted with deadlights.

4 Discharges

4.1 Arrangement of discharges

4.1.1 Inlets and discharges

All inlets and discharges in the shell plating are to be fitted with efficient and accessible arrangements for preventing the accidental admission of water into the ship.

4.1.2 Inboard opening of ash-shoot, rubbish-shoot, etc.

The inboard opening of each ash-shoot, rubbish-shoot, etc. is to be fitted with an efficient cover.

If the inboard opening is situated below the freeboard deck for cargo ships, the cover is to be watertight, and in addition an automatic non-return valve is to be fitted in the shoot in an easily accessible position above the deepest subdivision load line. When the shoot is not in use, both the cover and the valve are to be kept closed and secured.

4.2 Arrangement of garbage chutes

4.2.1 Inboard end above the waterline

The inboard end is to be located above the waterline formed by an 8,5 °heel, to port or starboard, at a draft corresponding to the assigned summer freeboard, but not less than 1000 mm above the summer load waterline.

Where the inboard end of the garbage chute exceeds 0,01L above the summer load waterline, valve control from the freeboard deck is not required, provided the inboard gate valve is always accessible under service conditions.

4.2.2 Inboard end below the waterline

Where the inboard end of a garbage chute is below the equilibrium waterlines of a cargo ship to which damage stability requirements apply then:

- the inboard end hinged cover/valve is to be watertight;
- the valve is to be a screw-down non-return valve fitted in an easily accessible position above the deepest load line; and
- the screw-down non-return valve is to be controlled from a position above the bulkhead deck and provided with open/closed indicators. The valve control is to be clearly marked: “Keep closed when not in use”.

4.2.3 Gate valves

For garbage chutes, two gate valves controlled from the working deck of the chute may be accepted instead of a non-return valve with a positive means of closing it from a position above the freeboard deck. In addition, the lower gate valve is to be controlled from a position above the freeboard deck. An interlock system between the two valves is to be arranged.

The distance between the two gate valves is to be adequate to allow the smooth operation of the interlock system.

4.2.4 Hinged cover and discharge flap

The upper gate valve, as required in [4.2.3], may be replaced by a hinged weathertight cover at the inboard end of the chute together with a discharge flap which replaces the lower gate valve.

The cover and discharge flap are to be arranged with an interlock so that the flap cannot be operated until the hopper cover is closed.

4.2.5 Marking of valve and hinged cover

The gate valve controls and/or hinged cover are to be clearly marked: “Keep closed when not in use”.

4.3 Scantlings of garbage chutes

4.3.1 Material

The chute is to be constructed of steel. Other equivalent materials are considered by the Society on a case by case basis.

4.3.2 Wall thickness

The wall thickness of the chute up to and including the cover is to be not less than that obtained, in mm, from Tab 4.

Table 4 : Wall thickness of garbage chutes

External diameter d, in mm	Thickness, in mm
$d \leq 80$	7,0
$80 < d < 180$	7,0 + 0,03 (d - 80)
$180 \leq d \leq 220$	10,0 + 0,063 (d - 180)

5 Freeing ports

5.1 General provisions

5.1.1 General

Where bulwarks on the weather portions of freeboard or superstructure decks form wells, ample provision is to be made for rapidly freeing the decks of water and for draining them.

A well is any area on the deck exposed to the weather, where water may be entrapped. Wells are considered to be deck areas bounded on four sides by deck structures; however, depending on their configuration, deck areas bounded on three or even two sides by deck structures may be deemed wells.

5.1.2 Freeing port areas

The minimum required freeing port areas in bulwarks on the freeboard deck are specified in Tab 5.

5.1.3 Freeing port arrangement

Where a sheer is provided, two thirds of the freeing port area required is to be provided in the half of the well nearer the lowest point of the sheer curve.

One third of the freeing port area required is to be evenly spread along the remaining length of the well.

Where the exposed freeboard deck or an exposed superstructure deck has little or no sheer, the freeing port area is to be evenly spread along the length of the well.

However, bulwarks may not have substantial openings or accesses near the breaks of superstructures, unless they are effectively detached from the superstructure sides.

Table 5 : Freeing port area in bulwark located on freeboard deck

Ship types or ship particulars	Area A of freeing ports, in m²	Applicable requirement
Type A	$0,33\ \ell_B\ h_B$	[5.5.2]
Type B-100	$0,33\ \ell_B\ h_B$	[5.5.2]
Type B-60	$0,25\ \ell_B\ h_B$	[5.5.1]
Ships fitted with a trunk included in freeboard calculation and/or breadth ≥ 0,6B	$0,33\ \ell_B\ h_B$	[5.3.1]
Ships fitted with continuous or substantially continuous trunk and/or hatch coamings	A_2	[5.3.1]
Ships fitted with non-continuous trunk and/or hatch coamings	A_3	[5.3.2]
Ships fitted with open superstructure	A_S for superstructures A_W for wells	[5.4.2] [5.4.3]
Other ships	A_1	[5.2.1]

Note 1:

ℓ_B : Length, in m, of bulwark in a well at one side of the ship

h_B : Mean height, in m, of bulwark in a well of length ℓ_B.

5.1.4 Freeing port positioning

The lower edge of freeing ports is to be as near the deck as practicable, at not more than 100 mm above the deck.

All the openings in the bulwark are to be protected by rails or bars spaced approximately 230 mm apart.

5.1.5 Freeing port closures

If shutters or closures are fitted to freeing ports, ample clearance is to be provided to prevent jamming. Hinges are to have pins or bearings of non-corrodible material. Shutters may not be fitted with securing appliances.

5.1.6 Gutter bars

Gutter bars greater than 300 mm in height fitted around the weather decks of tankers, in way of cargo manifolds and cargo piping, are to be treated as bulwarks. The freeing port area is to be calculated in accordance with the applicable requirements of this Section. Closures attached to the freeing ports for use during loading and discharge operations are to be arranged in such a way that jamming cannot occur while at sea.

5.2 Freeing port area in a well not adjacent to a trunk or hatchways

5.2.1 Freeing port area

Where the sheer in way of the well is standard or greater than the standard, the freeing port area on each side of the ship for each well is to be not less than that obtained, in m², in Tab 6.

In ships with no sheer, the above area is to be increased by 50%. Where the sheer is less than the standard, the percentage of increase is to be obtained by linear interpolation.

Wells on raised quarterdecks are to be treated as being on freeboard decks.

Table 6 : Freeing port area in a well not adjacent to a trunk or hatchways

Location	Area A_1 of freeing ports, in m²	
	$\ell_B \le 20$	$\ell_B > 20$
Freeboard deck and raised quarterdecks	$0,7 + 0,035\ell_B + A_C$	$0,07\ell_B + A_C$
Superstructure decks	$0,35 + 0,0175\ell_B + 0,5A_C$	$0,035\ell_B + 0,5A_C$

Note 1:

ℓ_B : Length, in m, of bulwark in the well, to be taken not greater than 0,7 L

A_C : Area, in m², to be taken, with its sign, equal to:

$$A_C = \frac{\ell_W}{25}(h_B - 1,2) \quad \text{for } h_B > 1,2$$

$$A_C = 0 \quad \text{for } 0,9 \le h_B \le 1,2$$

$$A_C = \frac{\ell_W}{25}(h_B - 0,9) \quad \text{for } h_B < 0,9$$

h_B : Mean height, in m, of the bulwark in a well of length ℓ_B.

5.2.2 Minimum freeing port area for a deckhouse having breadth not less than 0,8 B

Where a flush deck ship is fitted amidships with a deckhouse having breadth not less than 0,8 B and the width of the passageways along the side of the ship not greater than 1,5 m, the freeing port area is to be calculated for two separate wells, before and abaft the deckhouse. For each of these wells, the freeing port area is to be obtained from Tab 6, where ℓ_B is to be taken equal to the actual length of the well considered (in this case the limitation $\ell_B \le 0,7$ L may not be applied).

5.2.3 Minimum freeing port area for screen bulkhead

Where a screen bulkhead is fitted across the full breadth of the ship at the fore end of a midship deckhouse, the weather deck is to be considered as divided into two wells, irrespective of the width of the deckhouse, and the freeing port area is to be obtained in accordance with [4.1.2].

5.3 Freeing port area in a well contiguous to a trunk or hatchways

5.3.1 Freeing area for continuous trunk or continuous hatchway coaming

Where the ship is fitted with a continuous trunk not included in the calculation of freeboard or where continuous or substantially continuous hatchway side coamings are fitted between detached superstructures, the freeing port area is to be not less than that obtained, in m², from Tab 7.

Where the ship is fitted with a continuous trunk having breadth not less than 0,6 B, included in the calculation of freeboard, and where open rails on the weather parts of the freeboard deck in way of the trunk for at least half the length of these exposed parts are not fitted, the freeing port area in the well contiguous to the trunk is to be not less than 33% of the total area of the bulwarks.

Table 7 : Freeing port area in a well contiguous to a continuous trunk or hatchways

Breadth B_H, in m, of hatchway or trunk	Area A_2 of freeing ports, in m²
$B_H \leq 0{,}4B$	$0{,}2\ \ell_B\ h_B$
$0{,}4B < B_H < 0{,}75B$	$\left[0{,}2 - 0{,}286\left(\frac{B_H}{B} - 0{,}4\right)\right]\ell_B h_B$
$B_H \geq 0{,}75B$	$0{,}1\ \ell_B\ h_B$

Note 1:
- ℓ_B : Length, in m, of bulwark in a well at one side of the ship
- h_B : Mean height, in m, of bulwark in a well of length ℓ_B.

5.3.2 Freeing area for non-continuous trunk or hatchway coaming

Where the free flow of water across the deck of the ship is impeded due to the presence of a non-continuous trunk, hatchway coaming or deckhouse in the whole length of the well considered, the freeing port area in the bulwark of this well is to be not less than that obtained, in m², from Tab 8.

Table 8 : Freeing port area in a well contiguous to non-continuous trunk or hatchways

Free flow area f_P, in m²	Freeing port area A_3, in m²
$f_p \leq A_1$	A_2
$A_1 < f_P < A_2$	$A_1 + A_2 - f_P$
$f_P \geq A_2$	A_1

Note 1:
- f_P : Free flow area on deck, equal to the net area of gaps between hatchways, and between hatchways and superstructures and deckhouses up to the actual height of the bulwark
- A_1 : Area of freeing ports, in m², to be obtained from Tab 6
- A_2 : Area of freeing ports, in m², to be obtained from Tab 7.

5.4 Freeing port area in an open space within superstructures

5.4.1 General

In ships having superstructures on the freeboard or superstructure decks, which are open at either or both ends to wells formed by bulwarks on the open decks, adequate provision for freeing the open spaces within the superstructures is to be provided.

5.4.2 Freeing port area for open superstructures

The freeing port area on each side of the ship for the open superstructure is to be not less than that obtained, in m², from the following formula:

$$A_S = A_1 c_{SH}\left[1 - \left(\frac{\ell_W}{\ell_T}\right)^2\right]\left(\frac{b_0 h_S}{2\ell_T h_W}\right)$$

where:

- ℓ_T : Total well length, in m, to be taken equal to:
  $\ell_T = \ell_W + \ell_S$
- ℓ_W : Length, in m, of the open deck enclosed by bulwarks
- ℓ_S : Length, in m, of the common space within the open superstructures
- A_1 : Freeing port area, in m², required for an open well of length ℓ_T, in accordance with Tab 6, where A_C is to be taken equal to zero
- c_{SH} : Coefficient which accounts for the absence of sheer, if applicable, to be taken equal to:
  c_{SH} = 1,0 in the case of standard sheer or sheer greater than standard sheer
  c_{SH} = 1,5 in the case of no sheer
- b_0 : Breadth, in m, of the openings in the end bulkhead of enclosed superstructures
- h_S : Standard superstructure height, in m, defined in [1.2.1]
- h_W : Distance, in m, of the well deck above the freeboard deck.

5.4.3 Freeing port area for open well

The freeing port area on each side of the ship for the open well is to be not less than that obtained, in m², from the following formula:

$$A_W = A_1 c_{SH}\left(\frac{h_S}{2h_W}\right)$$

A_1 : Freeing port area, in m², required for an open well of length ℓ_W, in accordance with Tab 6

c_{SH}, h_S, h_W, ℓ_W:Defined in [5.4.2].

The resulting freeing port areas for the open superstructure A_S and for the open well A_W are to be provided along each side of the open space covered by the open superstructure and each side of the open well, respectively.

5.5 Freeing port area in bulwarks of the freeboard deck for ships of types A, B-100 and B-60

5.5.1 Freeing arrangement for type B ships

For type B-60 ships, the freeing port area in the lower part of the bulwarks of the freeboard deck is to be not less than 25% of the total area of the bulwarks in the well considered.

Type B-100 ships with bulwarks are to have open rails fitted for at least half the length of the weather deck or other equivalent freeing arrangements. A freeing port area, in the lower part of the bulwarks, of 33% of the total area of the bulwarks, is an acceptable equivalent freeing arrangement.

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

The upper edge of the sheer strake is to be kept as low as possible.

5.5.2 Freeing arrangement for type A ships

Type A ships with bulwarks are to have open rails fitted for at least half the length of the weather deck or other equivalent freeing arrangements. A freeing port area, in the lower part of the bulwarks, of 33% of the total area of the bulwarks, is an acceptable equivalent freeing arrangement.

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

The upper edge of the sheer strake is to be kept as low as possible.

6 Machinery space openings

6.1 Engine room skylights

6.1.1 Engine room skylights in positions 1 or 2 are to be properly framed, securely attached to the deck and efficiently enclosed by steel casings of suitable strength. Where the casings are not protected by other structures, their strength will be considered by the Society on a case by case basis.

6.2 Closing devices

6.2.1 Machinery casings

Openings in machinery space casings in positions 1 or 2 are to be fitted with doors of steel or other equivalent materials, permanently and strongly attached to the bulkhead, and framed, stiffened and fitted so that the whole structure is of equivalent strength to the unpierced bulkhead and weathertight when closed. The doors are to be capable of being operated from both sides and, unless otherwise permitted by the Society, to open outwards to give additional protection against wave impact.

Other openings in such casings are to be fitted with equivalent covers, permanently attached in their proper position.

6.2.2 Machinery casings on Type A ships

Machinery casings on Type A ships are to be protected by an enclosed poop or bridge of at least standard height, or by a deckhouse of equal height and equivalent strength, provided that machinery casings may be exposed if there are no openings giving direct access from the freeboard deck to the machinery spaces.

However, a weathertight door is permitted in the machinery casing, provided that it leads to a space or passageway which is as strongly constructed as the casing and is separated from the stairway to the engine room by a second weathertight door of steel or other equivalent material.

6.2.3 Height of the sill of the door

The height of the sill of the door is to be not less than:

- 600 mm above the deck if in position 1
- 380 mm above the deck if in position 2
- 230 mm in all other cases.

6.2.4 Double doors

Where casings are not protected by other structures, double doors (i.e. inner and outer doors) are required for ships assigned freeboard less than that based on Table 28.2 of Regulation 28 of the International Convention on Load Lines in force. An inner sill of 230 mm in conjunction with the outer sill of 600 mm is to be provided.

6.2.5 Fiddley openings

Fiddley openings are to be fitted with strong covers of steel or other equivalent material permanently attached in their proper positions and capable of being secured weathertight.

6.3 Coamings

6.3.1

Coamings of any fiddley, funnel or machinery space ventilator in an exposed position on the freeboard deck or superstructure deck are to be as high above the deck as is reasonable and practicable.

In general, ventilators necessary to continuously supply the machinery space are to have coamings whose height is in compliance with [8.1.2], but need not be fitted with weathertight closing appliances.

Ventilators necessary to continuously supply the emergency generator room, if this is considered buoyant in the stability calculations or protecting an opening leading below, are to have coamings of sufficient height to comply with [8.1.2], without having to fit weathertight closing appliances.

Where, due to the ship's size and arrangement, this is not practicable, lesser heights for machinery space and emergency generator room ventilator coamings, fitted with weathertight closing appliances in accordance with [8.1.3] or [8.1.4], may be permitted by the Society in combination with other suitable arrangements to ensure an uninterrupted, adequate supply of ventilation to these spaces.

7 Companionway

7.1 General

7.1.1 Openings in freeboard deck

Openings in freeboard deck other than hatchways, machinery space openings, manholes and flush scuttles are to be protected by an enclosed superstructure or by a deckhouse or companionway of equivalent strength and weathertightness.

7.1.2 Openings in superstructures

Openings in an exposed superstructure deck, in the top of a deckhouse on the freeboard deck which gives access to a space below the freeboard deck or a space within an enclosed superstructure, are to be protected by an efficient deckhouse or companionway.

7.1.3 Openings in superstructures having height less than standard height

Openings in the top of a deckhouse on a raised quarterdeck or superstructure of less than standard height, having a height equal to or greater than the standard quarterdeck height are to be provided with an acceptable means of closing but need not be protected by an efficient deckhouse or companionway provided the height of the deckhouse is at least the height of the superstructure.

7.2 Scantlings

7.2.1 Companionways on exposed decks protecting openings leading into enclosed spaces are to be of steel and strongly attached to the deck and are to have adequate scantlings.

7.3 Closing devices

7.3.1 Doors

Doorways in deckhouses or companionways leading to or giving access to spaces below the freeboard deck or to enclosed superstructures are to be fitted with weathertight doors. The doors are to be made of steel, to be capable of being operated from both sides and, unless otherwise permitted by the Society, to open outwards to give additional protection against wave impact.

Alternatively, if stairways within a deckhouse are enclosed within properly constructed companionways fitted with weathertight doors, the external door need not be watertight.

Where the closing appliances of access openings in superstructures and deckhouses are not weathertight, interior deck openings are to be considered exposed, i.e. situated in the open deck.

7.3.2 Height of sills

The height above the deck of sills to the doorways in companionways is to be not less than:

- 600 mm in position 1
- 380 mm in position 2.

Where access is not provided from above, the height of the sills to doorways in deckhouses on the freeboard deck is to be 600 mm.

Where access is provided to spaces inside a bridge or poop from the deck above as an alternative to access from the freeboard deck, the height of the sills into the bridge or poop is to be 380 mm. This also applies to deckhouses on the freeboard deck.

8 Ventilators

8.1 Closing appliances

8.1.1 General

Ventilator openings are to be provided with efficient weathertight closing appliances of steel or other equivalent material.

8.1.2 Closing appliance exemption

Ventilators need not be fitted with closing appliances, unless specifically required by the Society, if the coamings extend for more than:

- 4,5 m above the deck in position 1
- 2,3 m above the deck in position 2.

8.1.3 Closing appliances for ships of not more than 100 m in length

In ships of not more than 100 m in length, the closing appliances are to be permanently attached to the ventilator coamings.

8.1.4 Closing appliances for ships of more than 100 m in length

Where, in ships of more than 100 m in length, the closing appliances are not permanently attached, they are to be conveniently stowed near the ventilators to which they are to be fitted.

8.1.5 Ventilation of machinery spaces and emergency generator room

In order to satisfactorily ensure, in all weather conditions:

- the continuous ventilation of machinery spaces,
- and, when necessary, the immediate ventilation of the emergency generator room,

the ventilators serving such spaces are to comply with [8.1.2], i.e. their openings are to be so located that they do not require closing appliances.

8.1.6 Reduced height of ventilator coamings for machinery spaces and emergency generator room

Where, due to the ship's size and arrangement, the requirements in [8.1.5] are not practicable, lesser heights may be accepted for machinery space and emergency generator room ventilator coamings fitted with weathertight closing appliances in accordance with [8.1.1], [8.1.3] and [8.1.4] in combination with other suitable arrangements, such as separators fitted with drains, to ensure an uninterrupted, adequate supply of ventilation to these spaces.

8.1.7 Closing arrangements of ventilators led overboard or through enclosed superstructures

Closing arrangements of ventilators led overboard to the ship side or through enclosed superstructures are considered by the Society on a case by case basis. If such ventilators are led overboard more than 4,5 m above the freeboard deck, closing appliances may be omitted provided that satisfactory baffles and drainage arrangements are fitted.

8.2 Coamings

8.2.1 General

Ventilators in positions 1 or 2 to spaces below freeboard decks or decks of enclosed superstructures are to have coamings of steel or other equivalent material, substantially constructed and efficiently connected to the deck.

Ventilators passing through superstructures other than enclosed superstructures are to have substantially constructed coamings of steel or other equivalent material at the freeboard deck.

8.2.2 Scantlings

The scantlings of ventilator coamings exposed to the weather are to be not less than those obtained fromTab 9 .

In exposed locations or for the purpose of compliance with buoyancy calculations, the height of coamings may be required to be increased to the satisfaction of the Society.

Table 9 : Scantlings of ventilator coamings

Feature	Scantlings
Height of the coaming, in mm, above the deck	h = 900 in position 1 h = 760 in position 2
Thickness of the coaming, in mm **(1)**	$t = 5,5 + 0,01\ d_V$ with $7,5 \le t \le 10,0$
Support	If h > 900 mm, the coaming is to be suitably stiffened or supported by stays.

(1) Where the height of the ventilator exceeds the height h, the thickness of the coaming may be gradually reduced, above that height, to a minimum of 6,5 mm.

Note 1:

d_V : Internal diameter of the ventilator, in mm.

8.3 Strength check of ventilators subject to green sea loads

8.3.1 Application

The requirements in [8.3] apply to strength checks of the ventilator pipes and their closing devices located within the forward quarter length of the ship, for ships of length 80 m or more, where the height of the exposed deck in way of the item is less than 0,1L or 22 m above the summer load waterline, whichever is the lesser.

8.3.2 Green sea loads

The green sea pressure ρ acting on ventilator pipes and their closing devices is to be obtained, in kN/m², from the following formula:

$$p = 0,5\ \rho\ V^2\ C_d\ C_s\ C_p$$

where:

ρ : density, t/m³, of sea water, to be taken equal to 1,025 t/m³

V : velocity, in m/s, of water over the fore deck, to be taken equal to 13,5 m/sec

C_d : shape coefficient:

- $C_d = 0,5$ for pipes
- $C_d = 1,3$ for ventilator heads in general
- $C_d = 0,8$ for a ventilator head of cylindrical form with its axis in the vertical direction

C_s : slamming coefficient, to be taken equal to 3,2

C_p : protection coefficient:

$C_p = 0,7$ for pipes and ventilator heads located immediately behind a breakwater or forecastle,

$C_p = 1,0$ elsewhere and immediately behind a bulwark.

8.3.3 Green sea forces

Forces acting in the horizontal direction on the ventilator and its closing device are to be calculated from [8.3.2] using the largest projected area of each component.

8.3.4 Strength Requirements

Bending moments and stresses in ventilator pipes are to be calculated at the following critical positions:

- at penetration pieces
- at weld or flange connections
- at toes of supporting brackets.

Bending stresses in the net section are to be equal to or less than $0,8\ R_{eH}$, where R_{eH} is the minimum yield stress or 0,2% proof stress, in N/mm², of the steel at room temperature, defined in Ch 4, Sec 1, [2]. Irrespective of corrosion protection, a corrosion addition equal to 2,0 mm is then to be applied to the net scantlings.

Pipe thicknesses and bracket heights are to be obtained from Tab 10, for standard ventilators of 900 mm height closed by heads having projected area not greater than the one specified in Tab 10.

Where brackets are required, three or more radial brackets are to be fitted. Bracket thickness is to be not less than 8 mm, bracket length is to be not less than 100 mm and bracket height is to be obtained from Tab 10, but need not extend over the joint flange for the head. Bracket toes at the deck are to be suitably supported.

For ventilators of height greater than 900 mm, brackets or alternative means of support are to be fitted. Pipe thickness is not to be taken less than that specified in Pt C, Ch 1, Sec 10, [9.1.8] a).

All component parts and connections of ventilators are to be capable of withstanding the loads defined in [8.3.2].

Rotating type mushroom ventilator heads are deemed not suitable for application in the areas defined in [8.3.1].

9 Tank cleaning openings

9.1 General

9.1.1 Ullage plugs, sighting ports and tank cleaning openings may not be arranged in enclosed spaces.

10 Closure of chain lockers

10.1 General

10.1.1

Spurling pipes and chain lockers are to be watertight up to the weather deck.

Bulkheads between separate chain lockers (see Fig 1), or which form a common boundary of chain lockers (see Fig 2), need not however be watertight.

Where means of access is provided, it is to be closed by a substantial cover and secured by closely spaced bolts.

Where a means of access to spurling pipes or cable lockers is located below the weather deck, the access cover and its securing arrangements are to be in accordance with recognised standards (e.g. ISO 5894-1999 or equivalent) for watertight manhole covers. Butterfly nuts and/or hinged bolts are prohibited as the securing mechanism for the access cover.

Spurling pipes through which anchor chains are led are to be provided with permanently attached closing appliances to minimise water ingress.

Figure 1 : Separate chain lockers

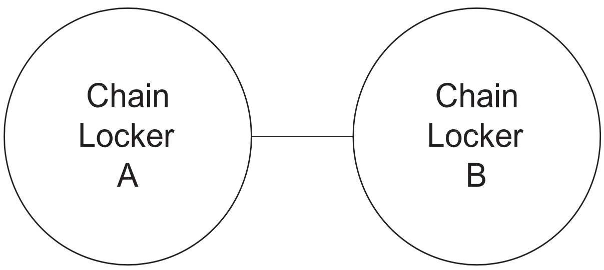


Figure 2 : Chain locker with a common boundary

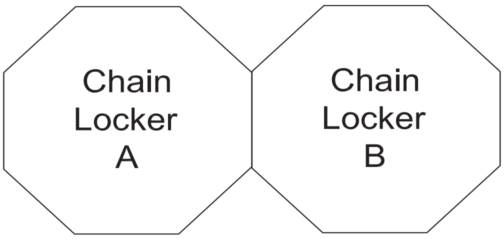


Table 10 : 900 mm Ventilator Pipe Thickness and Bracket Standards

Nominal pipe diameter (mm)	Minimum fitted gross thickness LL 36(c) (mm)	Maximum projected area of head (cm^2)	Height of brackets (mm)
80A	6,3	-	460
100A	7,0	-	380
150A	8,5	-	300
200A	8,5	550	-
250A	8,5	880	-
300A	8,5	1200	-
350A	8,5	2000	-
400A	8,5	2700	-
450A	8,5	3300	-
500A	8,5	4000	-
Note 1: For other ventilator heights, the relevant requirements in [8.3.4] are to be applied.			

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

11.1 Requirements for Type B-60 ships

11.1.1 Any Type B ships of over 100 metres, may be assigned freeboards less than those required for Type B, provided that, in relation to the amount of reduction granted, the requirements in [11.1.2] to [11.1.4] are considered satisfactory by the Society.

In addition, the requirements stated in Regulation 27 of Part 3, Annex I, Chapter III of the International Convention on Load Lines, 1966 and Protocol of 1988, as amended, are to be complied with.

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

11.1.3 The freeing arrangements are to comply with the provisions of this Sec 9.

11.1.4 The hatchway covers in positions 1 and 2 comply with the provisions of Sec 7.

11.2 Requirements for Type B-100 ships

11.2.1 The requirements in [11.2.2] to [11.2.4] are to be complied with.

In addition, the provisions of Regulation 27 of Part 3, Annex I, Chapter III of the International Convention on Load Lines, 1966 and Protocol of 1988, as amended, are to be complied with.

11.2.2 Machinery casings

Machinery casings are to be protected by an enclosed poop or bridge of at least standard height, or by a deckhouse of equal height and equivalent strength, provided that machinery casings may be exposed if there are no openings giving direct access from the freeboard deck to the machinery space. A door complying with the requirements of this Sec 9 may, however, be permitted in the machinery casing, provided that it leads to a space or passageway which is as strongly constructed as the casing and is separated from the stairway to the engine room by a second weathertight door of steel or other equivalent material.

11.2.3 Gangway and access

An efficiently constructed fore and aft permanent gangway of sufficient strength is to be fitted at the level of the superstructure deck between the poop and the midship bridge or deckhouse where fitted, or equivalent means of access is to be provided such as a well lighted and ventilated underdeck passageway (with a clear opening of at least 0,8 m in width and 2 m in height), as close as practicable to the freeboard deck.

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

11.2.4 Freeing arrangements

Ships with bulwarks are to be provided with open rails fitted for at least half the length of the weather deck or other effective freeing arrangements.

A freeing port area, in the lower part of the bulkwarks, of 33% of the total area of the bulkwarks, is an acceptable equivalent freeing arrangement.

The upper edge of the sheer strake is to be kept as low as practicable.

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

SECTION 10 HELICOPTER DECKS

1 General

1.1 Application

1.1.1 In the case of ships for which the additional class notation **Helideck** or **Helideck-H** is not assigned, but having areas equipped for the landing and take-off of helicopters, and located on a weather deck or on a platform permanently connected to the hull structure, the requirements of Pt F, Ch 10, Sec 13, [3] are to be complied with.

Part B
Hull and Stability

Chapter 10
HULL OUTFITTING

SECTION 1 RUDDERS

Symbols

V_{AV} : maximum ahead service speed, in knots, with the ship on summer load waterline; if V_{AV} is less than 10 knots, the maximum service speed is to be taken not less than the value obtained from the following formula:

$$V_{MIN} = \frac{V_{AV} + 20}{3}$$

V_{AD} : maximum astern speed, in knots, to be taken not less than 0,5 V_{AV}

A : total area of the rudder blade, in m^2, bounded by the blade external contour, including the mainpiece and the part forward of the centreline of the rudder pintles, if any

k_1 : material factor, defined in [1.4.3]

k : material factor, defined in Ch 4, Sec 1, [2.3] (see also [1.4.5]

C_R : rudder force, in N, acting on the rudder blade, defined in [2.1.1] and [2.2.1]

M_{TR} : rudder torque, in N.m, acting on the rudder blade, defined in [2.1.2] and [2.2.2]

M_B : bending moment, in N.m, in the rudder stock, defined in [4.1].

1 General

1.1 Application

1.1.1 Ordinary profile rudders

The requirements of this Section apply to ordinary profile rudders, without any special arrangement for increasing the rudder force, whose maximum orientation at maximum ship speed is limited to 35° on each side.

In general, an orientation greater than 35° is accepted for manoeuvres or navigation at very low speed.

1.1.2 High lift profiles

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 less 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 ship speed. These calculations are to be considered by the Society on a case-by-case basis.

The rudder scantlings are to be designed so as to be able to sustain possible failures of the orientation control system, or, alternatively, redundancy of the system itself may be required.

1.1.3 Steering nozzles

The requirements for steering nozzles are given in [10].

1.1.4 Special rudder types

Rudders others than those in [1.1.1], [1.1.2] and [1.1.3] will be considered by the Society on a case-by- case basis.

1.2 Gross scantlings

1.2.1 With reference to Ch 4, Sec 2, [1], all scantlings and dimensions referred to in this Section are gross, i.e. they include the margins for corrosion.

1.3 Arrangements

1.3.1 Effective means are to be provided for supporting the weight of the rudder without excessive bearing pressure, e.g. by means of a rudder carrier attached to the upper part of the rudder stock. The hull structure in way of the rudder carrier is to be suitably strengthened.

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

In addition, structural rudder stops of suitable strength are to be provided, except where the steering gear is provided with its own rudder stopping devices, as detailed in Pt C, Ch 1, Sec 9.

1.3.3 In rudder trunks which are open to the sea, a seal or stuffing box is to be fitted above the deepest load waterline, to prevent water from entering the steering gear compartment and the lubricant from being washed away from the rudder carrier. If the top of the rudder trunk is below the deepest waterline two separate stuffing boxes are to be provided.

1.4 Materials

1.4.1 Rudder stocks, pintles, coupling bolts, keys and cast parts of rudders are to be made of rolled steel, steel forgings or steel castings according to the applicable requirements in Part D, Chapter 2.

1.4.2 The material used for rudder stocks, pintles, keys and bolts is to have a minimum yield stress not less than 200 N/mm^2.

1.4.3 The requirements relevant to the determination of scantlings contained in this Section apply to steels having a minimum yield stress equal to 235 N/mm^2.

Where the material used for rudder stocks, pintles, coupling bolts, keys and cast parts of rudders has a yield stress different from 235 N/mm^2, the scantlings calculated with the formulae contained in the requirements of this Section are to be modified, as indicated, depending on the material factor k_1, to be obtained from the following formula:

$$k_1 = \left(\frac{235}{R_{eH}}\right)^n$$

where:

R_{eH} : yield stress, in N/mm^2, of the steel used, and not exceeding the lower of 0,7 R_m and 450 N/mm^2,

R_m : minimum ultimate tensile strength, in N/mm^2, of the steel used,

n : coefficient to be taken equal to:

- n = 0,75 for $R_{eH} > 235$ N/mm^2,
- n = 1,00 for $R_{eH} \le 235$ N/mm^2.

1.4.4 Significant reductions in rudder stock diameter due to the application of steels with yield stresses greater than 235 N/mm^2 may be accepted by the Society subject to the results of a check calculation of the rudder stock deformations.

Large rudder stock deformations are to be avoided in order to avoid excessive edge pressures in way of bearings.

1.4.5 Welded parts of rudders are to be made of approved rolled hull materials. For these members, the material factor k defined in Ch 4, Sec 1, [2.3] is to be used.

2 Force and torque acting on the rudder

2.1 Rudder blade without cut-outs

2.1.1 Rudder blade description

A rudder blade without cut-outs may have trapezoidal or rectangular contour.

2.1.2 Rudder force

The rudder force C_R is to be obtained, in N, from the following formula:

$$C_R = 132\, n_R\, A\, V^2\, r_1\, r_2\, r_3$$

where:

n_R : navigation coefficient, defined in Tab 1,

V : V_{AV}, or V_{AD}, depending on the condition under consideration (for high lift profiles see [1.1.2]),

r_1 : shape factor, to be taken equal to:

$$r_1 = \frac{\lambda + 2}{3}$$

λ : coefficient, to be taken equal to:

$$\lambda = \frac{h^2}{A_T}$$

and not greater than 2,

h : mean height, in m, of the rudder area to be taken equal to (see Fig 1):

$$h = \frac{z_3 + z_4 - z_2}{2}$$

A_T : area, in m^2, to be calculated by adding the rudder blade area A to the area of the rudder post or rudder horn, if any, up to the height h,

r_2 : coefficient to be obtained from Tab 2,

r_3 : coefficient to be taken equal to:

- r_3 = 0,8 for rudders outside the propeller jet (centre rudders on twin screw ships, or similar cases),
- r_3 = 1,15 for rudders behind a fixed propeller nozzle,
- r_3 = 1,0 in other cases.

Table 1 : Navigation coefficient

Navigation notation	Navigation coefficient n_R
Summer zone	0,95
Caspian Sea	0,85

Table 2 : Values of coefficient r_2

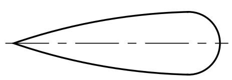
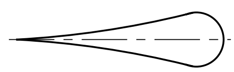
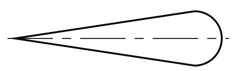
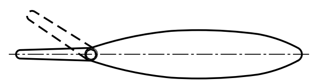
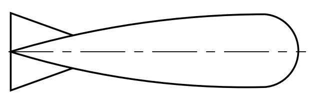
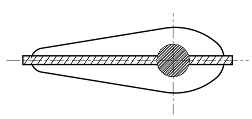
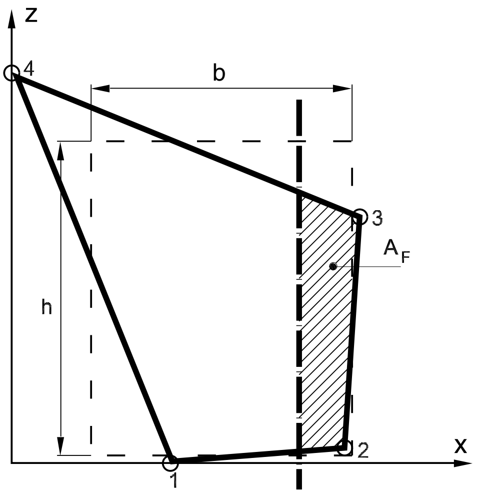
Rudder profile type	r_2 for ahead condition	r_2 for astern condition
NACA 00 - Goettingen 	1,10	0,80
Hollow 	1,35	0,90
Flat side 	1,10	0,90
High lift 	1,70	1,30
Fish tail 	1,40	0,80
Single plate 	1,00	1,00

Figure 1 : Geometry of rudder blade without cut-outs



2.1.3 Rudder torque

The rudder torque M_{TR}, for both ahead and astern conditions, is to be obtained, in N.m, from the following formula:

$M_{TR} = C_R\, r$

where:

r : lever of the force C_R, in m, equal to:

$$r = b\left(\alpha - \frac{A_F}{A}\right)$$

and to be taken not less than 0,1 b for the ahead condition,

b : mean breadth, in m, of rudder area to be taken equal to (see Fig 1):

$$b = \frac{x_2 + x_3 - x_1}{2}$$

α : coefficient to be taken equal to:
- $\alpha = 0{,}33$ for ahead condition,
- $\alpha = 0{,}66$ for astern condition,

A_F : area, in m², of the rudder blade portion afore the centreline of rudder stock (see Fig 1).

2.2 Rudder blade with cut-outs (semi-spade rudders)

2.2.1 Rudder blade description

A rudder blade with cut-outs may have trapezoidal or rectangular contour, as indicated in Fig 2.

2.2.2 Rudder force

The rudder force C_R, in N, acting on the blade is to be calculated in accordance with [2.1.2].

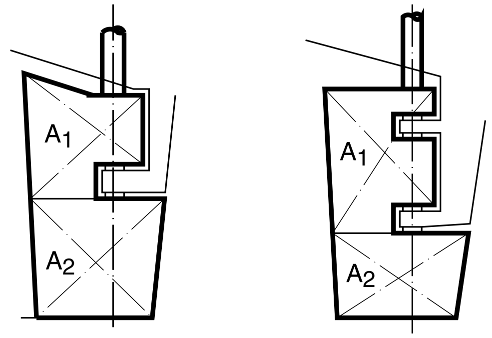
2.2.3 Rudder torque

The rudder torque M_{TR}, in N.m, is to be calculated in accordance with the following procedure.

The rudder blade area A is to be divided into two rectangular or trapezoidal parts having areas A_1 and A_2, defined in Fig 2, so that:

$A = A_1 + A_2$

Figure 2 : Rudder blades with cut-outs



Trapezoidal rudder blade Semi-spade rudder with rudder horn - 2 bearings

Trapezoidal rudder blade Semi-spade rudder with rudder horn - 3 bearings

The rudder forces C_{R1} and C_{R2}, acting on each part A_1 and A_2 of the rudder blade, respectively, are to be obtained, in N, from the following formulae:

$$C_{R1} = C_R\frac{A_1}{A}$$

$$C_{R2} = C_R\frac{A_2}{A}$$

The levers r_1 and r_2 of the forces C_{R1} and C_{R2}, respectively, are to be obtained, in m, from the following formulae:

$$r_1 = b_1\left(\alpha - \frac{A_{1F}}{A_1}\right)$$

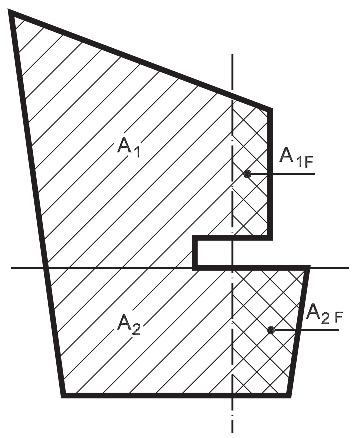
$$r_2 = b_2\left(\alpha - \frac{A_{2F}}{A_2}\right)$$

where:

b_1, b_2 : mean breadths of the rudder blade parts having areas A_1 and A_2, respectively, to be determined according to [2.1.3],

A_{1F}, A_{2F} : areas, in m², of the rudder blade parts, defined in Fig 3,

Figure 3 : Geometry of rudder blade with cut-outs



α : coefficient to be taken equal to:
- $\alpha = 0{,}33$ for ahead condition,
- $\alpha = 0{,}66$ for astern condition.

For rudder parts located behind a fixed structure such as a rudder horn, α is to be taken equal to:

- $\alpha = 0,25$ for ahead condition,
- $\alpha = 0,55$ for astern condition.

The torques M_{TR1} and M_{TR2} , relevant to the rudder blade parts A_1 and A_2 respectively, are to be obtained, in N.m, from the following formulae:

$$M_{TR1} = C_{R1}\, r_1$$

$$M_{TR2} = C_{R2}\, r_2$$

The total torque M_{TR} acting on the rudder stock, for both ahead and astern conditions, is to be obtained, in N.m, from the following formula:

$$M_{TR} = M_{TR1} + M_{TR2}$$

For the ahead condition only, M_{TR} is to be taken not less than the value obtained, in N.m, from the following formula:

$$M_{TR,MIN} = 0,1\, C_R \frac{A_1 b_1 + A_2 b_2}{A}$$

3 Loads acting on the rudder structure

3.1 General

3.1.1 Loads

The force and torque acting on the rudder, defined in [2], induce in the rudder structure the following loads:

- bending moment and torque in the rudder stock,
- support forces,
- bending moment, shear force and torque in the rudder body,
- bending moment, shear force and torque in rudder horns and solepieces.

3.1.2 Direct load calculations

The bending moment in the rudder stock, the support forces, and the bending moment and shear force in the rudder body are to be determined through direct calculations to be performed in accordance to the static schemes and the load conditions specified in App 1.

For rudders with solepiece or rudder horns these structures are to be included in the calculation model in order to account for the elastic support of the rudder body.

The other loads (i.e. the torque in the rudder stock and in the rudder body and the loads in rudder horns and solepieces) are to be calculated as indicated in the relevant requirements of this Section.

3.1.3 Simplified methods for load calculation

For ordinary rudder types, the bending moment in the rudder stock, the support forces, and the bending moment and shear force in the rudder body may be determined through approximate methods specified in the relevant requirements of this Section.

The other loads (i.e. the torque in the rudder stock and in the rudder body and the loads in rudder horns and solepieces) are to be calculated as indicated in the relevant requirements of this Section.

4 Rudder stock scantlings

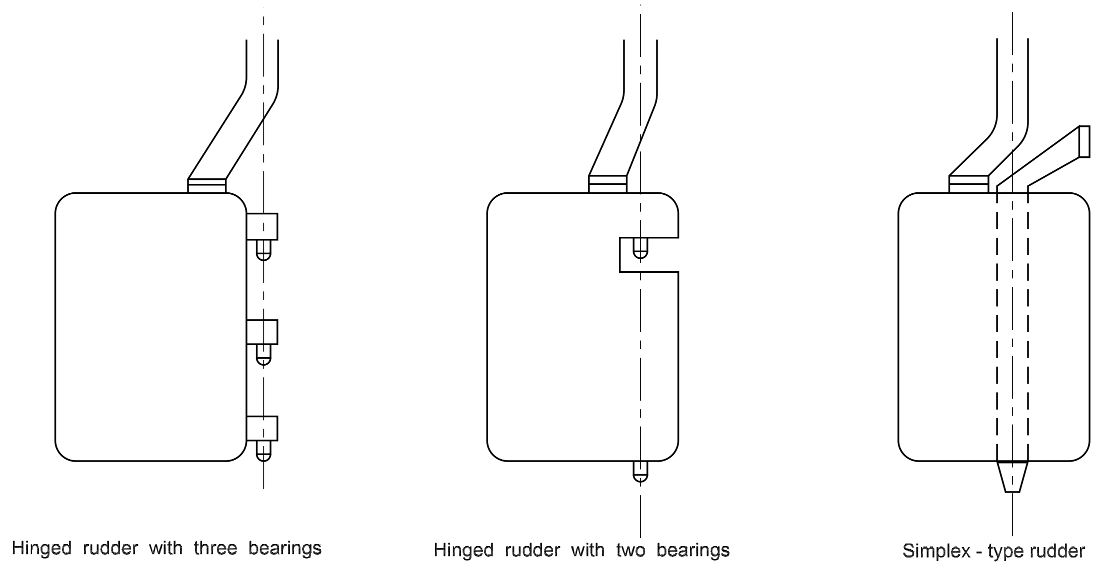
4.1 Bending moment

4.1.1 General

The bending moment M_B in the rudder stock is to be obtained as follows:

- for spade rudders M_B is to be determined according to [4.1.2] through a direct calculation,
- for 2 bearing rudders with solepiece and 2 bearing semi-spade rudders with rudder horn, M_B is to be calculated according to:
  - [4.1.2] through a direct calculation, or
  - [4.1.3] through a simplified method,
- for 3 bearing semi-spade rudders with rudder horn and for the rudder types shown in Fig 4, M_B may be taken equal to zero.

Figure 4 : Rudder types



4.1.2 Bending moment calculated through a direct calculation

For spade rudders, 2 bearing rudders with solepiece and 2 bearing semi-spade rudders with rudder horn, where a direct calculation according to the static schemes and the load conditions specified in App 1 is carried out, the bending moment in the rudder stock is to be obtained as specified in App 1.

4.1.3 Bending moment calculated through a simplified method

For 2 bearing rudders with solepiece and 2 bearing semi-spade rudders with rudder horn, where a direct calculation according to the static schemes and the load conditions specified in App 1 is not carried out, the bending moment M_B in the rudder stock is to be obtained, in N.m, from the following formula:

$$M_B = 0{,}866\frac{HC_R}{A}$$

where H is defined, in m^3, in Tab 3.

4.2 Scantlings

4.2.1 Rudder stock subjected to torque only

For rudder stocks subjected to torque only (3 bearing semi-spade rudders with rudder horn in Fig 2 and the rudder types shown in Fig 4), it is to be checked that the torsional shear stress τ, in N/mm^2, induced by the torque M_{TR} is in compliance with the following formula:

$\tau \leq \tau_{ALL}$

where:

τ_{ALL} : allowable torsional shear stress, in N/mm^2:

$\tau_{ALL} = 68/k_1$

For this purpose, the rudder stock diameter is to be not less than the value obtained, in mm, from the following formula:

$d_T = 4{,}2\ (M_{TR}\ k_1)^{1/3}$

4.2.2 Rudder stock subjected to combined torque and bending

For rudder stocks subjected to combined torque and bending (spade rudders, 2 bearing rudders with solepiece and 2 bearing semi-spade rudders with rudder horn in Tab 3), it is to be checked that the equivalent stress σ_E induced by the bending moment M_B and the torque M_{TR} is in compliance with the following formula:

$\sigma_E \leq \sigma_{E,ALL}$

where:

σ_E : equivalent stress to be obtained, in N/mm^2, from the following formula:

$$\sigma_E = \sqrt{\sigma_B^2 + 3\tau_T^2}$$

σ_B : bending stress to be obtained, in N/mm^2, from the following formula:

$$\sigma_B = 10^3\frac{10{,}2M_B}{d_{TF}^3}$$

τ_T : torsional stress to be obtained, in N/mm^2, from the following formula:

$$\tau_T = 10^3\frac{5{,}1M_{TR}}{d_{TF}^3}$$

$\sigma_{E,ALL}$: allowable equivalent stress, in N/mm^2, equal to:

$\sigma_{E,ALL} = 118/k_1\ N/mm^2$

Table 3 : Factor H

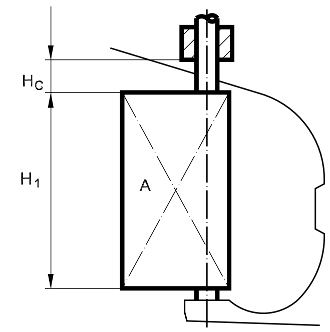
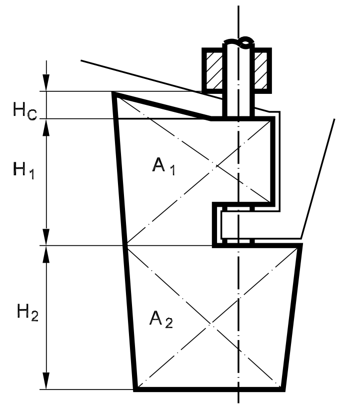
Rudder type	H, in m^3
	**2 bearing rudders with solepiece** Aa_1uH_1
	**2 bearing semi-spade rudders with rudder horn** 0,83 B **(1)**
(1) B is the greater of the absolute values obtained from the following formulae: • $B = A_1uH_1 + A_2(vH_1 + wH_2)$ • $B = A_1a_2H_1 - A_2(a_3H_1 + 0{,}5H_2)$ where a_1, a_2, a_3, u, v, w are defined in Tab 4.	

Table 4 : Coefficients for calculating the bending moment in the rudder stock

Coefficient	Value
a_1	2,55 - 1,75c
a_2	$1{,}75c^2 - 3{,}9c + 2{,}35$
a_3	$2{,}65c^2 - 5{,}9c + 3{,}25$
u	$1{,}1c^2 - 2{,}05c + 1{,}175$
v	$1{,}15c^2 - 1{,}85c + 1{,}025$
w	$-3{,}05c^4 + 8{,}14c^3 - 8{,}15c^2 + 3{,}81c - 0{,}735$
Note 1: $c = \frac{H_1}{H_1 + H_C}$ H_1, H_C : as defined in Tab 3, as applicable.	

For this purpose, the rudder stock diameter is to be not less than the value obtained, in mm, from the following formula:

$$d_{TF} = 4,2(M_{TR}k_1)^{1/3}\left(1+\frac{4}{3}\left(\frac{M_B}{M_{TR}}\right)^2\right)^{1/6}$$

In general, the diameter of a rudder stock subjected to torque and bending may be gradually tapered above the upper stock bearing so as to reach the value of d_T in way of the quadrant or tiller.

5 Rudder stock couplings

5.1 Horizontal flange couplings

5.1.1 General

In general, the coupling flange and the rudder stock are to be forged from a solid piece. A shoulder radius as large as practicable is to be provided for between the rudder stock and the coupling flange. This radius is to be not less than 0,13 d_1, where d_1 is the greater of the rudder stock diameters d_T and d_{TF}, in mm, to be calculated in compliance with the requirements in [4.2.1] and [4.2.2], respectively.

Where the rudder stock diameter does not exceed 350 mm, the coupling flange may be welded onto the stock provided that its thickness is increased by 10%, and that the weld extends through the full thickness of the coupling flange and that the assembly obtained is subjected to heat treatment. This heat treatment is not required if the diameter of the rudder stock is less than 75 mm.

Where the coupling flange is welded, the grade of the steel used is to be of weldable quality, particularly with a carbon content not greater than 0,25% and 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 0,13 d_1, where d_1 is defined above.

5.1.2 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 [5.1.1],
- k_{1S} : material factor k_1 for the steel used for the rudder stock,
- k_{1B} : material factor k_1 for the steel used for the bolts,
- e_M : mean distance, in mm, from the bolt axes to the longitudinal axis through the coupling centre (i.e. the centre of the bolt system),
- n_B : total number of bolts, which is to be not less than 6.

Non-fitted bolts may be used provided that, in way of the mating plane of the coupling flanges, a key is fitted having a section of (0,25d_T x 0,10d_T) mm^2 and keyways in both the coupling flanges, and provided that at least two of the coupling bolts are fitted bolts.

The distance from the bolt axes to the external edge of the coupling flange is to be not less than 1,2 d_B.

5.1.3 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, calculated in accordance with [5.1.2], where the number of bolts n_B is to be taken not greater than 8,
- k_{1F} : material factor k_1 for the steel used for the flange,
- k_{1B} : material factor k_1 for the steel used for the bolts.

In any case, the thickness t_P is to be not less than 0,9 d_B.

5.1.4 Locking device

A suitable locking device is to be provided to prevent the accidental loosening of nuts.

5.2 Couplings between rudder stocks and tillers

5.2.1 Application

The requirements in Pt C, Ch 1, Sec 9 apply.

5.2.2 General

The entrance edge of the tiller bore and that of the rudder stock cone are to be rounded or bevelled.

The right fit of the tapered bearing is to be checked before final fit up, to ascertain that the actual bearing is evenly distributed and at least equal to 80% of the theoretical bearing area; push-up length is measured from the relative positioning of the two parts corresponding to this case.

The required push-up length is to be checked after releasing of hydraulic pressures applied in the hydraulic nut and in the assembly

5.2.3 Keyless couplings through special devices

The use of special devices for frictional connections, such as expansible rings, may be accepted by the Society on a case-by-case basis provided that the following conditions are complied with:

- evidence that the device is efficient (theoretical calculations and results of experimental tests, references of behaviour during service, etc.) are to be submitted to the Society
- the torque transmissible by friction is to be not less than 2 M_{TR}
- design conditions and strength criteria are to comply with [5.2.1]
- instructions provided by the manufacturer are to be complied with, notably concerning the pre-stressing of the tightening screws.

5.3 Cone couplings between rudder stocks and rudder blades

5.3.1 Taper on diameter

The taper on diameter of the cone couplings is to be in compliance with the following formulae:

- for cone couplings without hydraulic arrangements for assembling and disassembling the coupling:

$$\frac{1}{12} \le \frac{d_U - d_0}{t_S} \le \frac{1}{8}$$

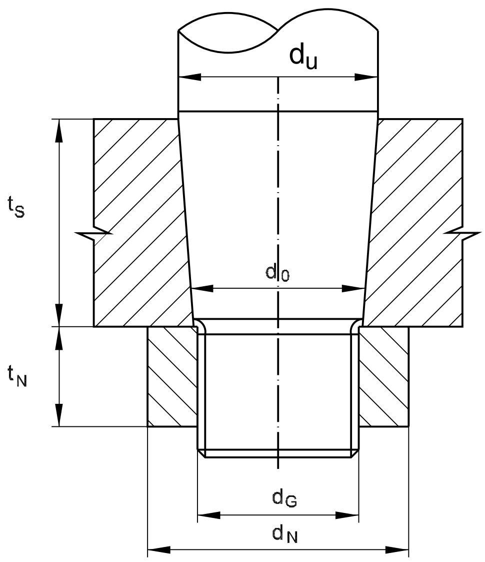
- for cone couplings with hydraulic arrangements for assembling and disassembling the coupling (assembling with oil injection and hydraulic nut):

$$\frac{1}{20} \le \frac{d_U - d_0}{t_S} \le \frac{1}{12}$$

where:

d_U, t_S, d_0,: geometrical parameters of the coupling, defined in Fig 5.

Figure 5 : Geometry of cone coupling



5.3.2 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 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 Δ_0 and Δ_1 are to be obtained from the formulae in Tab 5.

5.3.3 Slogging nut

The coupling is to be secured by a slugging nut, whose dimensions are to be in accordance with the following formulae:

$t_S \ge 1,5\ d_1$

$d_G \ge 0,65\ d_1$

$t_N \ge 0,60\ d_G$

$d_N \ge 1,2\ d_0$ and, in any case, $d_N \ge 1,5\ d_G$

where:

t_S, d_G, t_N, d_N, d_1, d_0:geometrical parameters of the coupling, defined in Fig 5.

The above minimum dimensions of the locking nut are only given for guidance, the determination of adequate scantlings being left to the Designer.

5.3.4 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 0,13 d_G and an outer diameter not less than 0,13 d_0 or 1,6 d_G, whichever is the greater.

5.3.5 Key

For cone couplings without hydraulic arrangements for assembling and disassembling the coupling, a key is to be fitted having a section of $(0,25d_T \times 0,10d_T)$ mm^2 and keyways in both the tapered part and the rudder gudgeon.

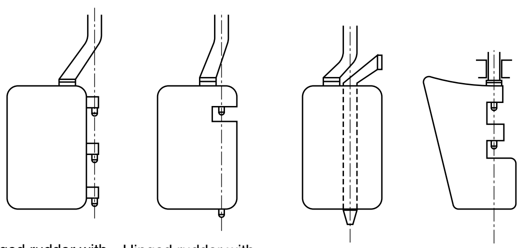
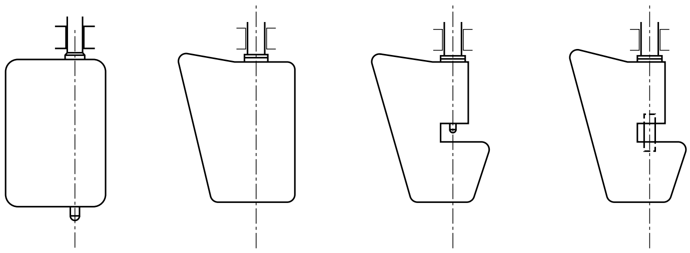
The key is to be machined and located on the fore or aft part of the rudder. The key is to be inserted at half-thickness into stock and into the solid part of the rudder.

For cone couplings with hydraulic arrangements for assembling and disassembling the coupling, the key may be omitted. In this case the designer is to submit to the Society shrinkage calculations supplying all data necessary for the relevant check.

5.3.6 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.

Table 5 : Push up length values

Rudder type	Δ_0	Δ_1
 Hinged rudder with three bearings; Hinged rudder with two bearings; Simplex - type; 3 bearings semi-spade rudders with rudder horn	$6,2\frac{M_{TR}\eta\gamma}{c d_M t_S \mu_A \beta}10^{-3}$	$\frac{2\eta+5}{1,8}\frac{\gamma d_0 R_{eH}}{10^6 c}$
 Spade rudder; Simple pintle; Inserted pintle	The greater of: • $6,2\frac{M_{TR}\eta\gamma}{c d_M t_S \mu_A \beta}10^{-3}$ • $16\frac{M_{TR}\eta\gamma}{c t_S^2 \beta}\sqrt{\frac{d_{1L}^6-d_{1S}^6}{d_{1S}^6}}10^{-3}$	$\frac{2\eta+5}{1,8}\frac{\gamma d_0 R_{eH}}{10^6 c(1+\rho_1)}$
High lift profile and special rudder types	The greater of: • $6,2\frac{M_{TR}\eta\gamma}{c d_M t_S \mu_A \beta}10^{-3}$ • $6\frac{M_{TR}\eta\gamma}{c t_S^2 \beta}\sqrt{\frac{d_{1L}^6-d_{1S}^6}{d_{1S}^6}}10^{-3}$ • $6,2\frac{M_T\eta\gamma}{c d_M t_S \mu_A \beta}$ • $18,4\frac{M_F\eta\gamma}{c t_S^2 \beta}$	The greater of: • $\frac{2\eta+5}{1,8}\frac{\gamma d_0 R_{eH}}{10^6 c(1+\rho_1)}$ • $\frac{2\eta+5}{1,8}\frac{\gamma d_0 R_{eH}}{10^6 c(1+\rho_2)}$

Note 1:

$$\rho_1 = \frac{80\sqrt{d_{1L}^6-d_{1S}^6}}{R_{eH} d_M t_S^2\left[1-\left(\frac{d_0}{d_E}\right)^2\right]}$$

$$\rho_2 = \frac{7,4 M_F \cdot 10^6}{R_{eH} d_M t_S^2\left[1-\left(\frac{d_0}{d_E}\right)^2\right]}10^6$$

R_{eH} : defined in [1.4.3]

M_F, M_T : bending moment and torsional moment, respectively, in kN.m, provided by the manufacturer

d_{1S} : the greater of the rudder stock diameters d_T and d_{TF}, in mm, calculated in way of the upper part of the rudder stock (at tiller level) in compliance with the the requirements in [4.2.1] and [4.2.2], respectively, considering k_1=1

d_{1L} : the greater of the rudder stock diameters d_T and d_{TF}, in mm, calculated in way of the lower part of the rudder stock (between the top of the rudder plate and the lower bearing of the rudder stock) in compliance with the the requirements in [4.2.1] and [4.2.2], respectively, considering k_1=1

η : coefficient to be taken equal to: η = 1 for keyed connections; η = 2 for keyless connections

c : taper of conical coupling measured on diameter, to be obtained from the following formula: $c = (d_U - d_0) / t_S$

β : coefficient to be taken equal to: $\beta = 1 - (d_M / d_E)^2$

d_M : mean diameter, in mm, of the conical bore, to be obtained from the following formula: $d_M = d_U - 0,5\ c\ t_S$

d_E : external boss diameter, in mm

μ_A : coefficient to be taken equal to: $(\mu^2 - 0,25\ c^2)^{1/2}$

μ, γ : coefficients to be taken equal to:

- for rudder stocks and bosses made of steel: μ = 0,15; γ = 1
- for rudder stocks made of steel and bosses made of SG iron: μ = 0,13; $\gamma = 1,24 - 0,1\ \beta$

t_S, d_U, d_0 : defined in Fig 5

5.4 Vertical flange couplings

5.4.1 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 [5.1.1],

k_{1S}, k_{1B} : material factors, defined in [5.1.2],

n_B : total number of bolts, which is to be not less than 8.

5.4.2 The first moment of area of the sectional area of bolts about the vertical axis through the centre of the coupling is to be not less than the value obtained, in cm³, from the following formula:

$$M_S = 0,43\, d_1^3 10^{-6}$$

where:

d_1 : rudder stock diameter, in mm, defined in [5.1.1].

5.4.3 The thickness of the coupling flange, in mm, is to be not less than d_B , defined in [5.4.1].

5.4.4 The distance, in mm, from the bolt axes to the external edge of the coupling flange is to be not less than 1,2 d_B , where d_B is defined in [5.4.1].

5.4.5 A suitable locking device is to be provided to prevent the accidental loosening of nuts.

5.5 Couplings by continuous rudder stock welded to the rudder blade

5.5.1 When the rudder stock extends through the upper plate of the rudder blade and is welded to it, the thickness of this plate in the vicinity of the rudder stock is to be not less than 0,20 d_1, where d_1 is defined in [5.1.1].

5.5.2 The welding of the upper plate of the rudder blade with the rudder stock is to be made with a full penetration weld and is to be subjected to non-destructive inspection through dye penetrant or magnetic particle test and ultrasonic testing.

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 0,20 d_1, where d_1 is defined in [5.1.1].

5.6 Skeg connected with rudder trunk

5.6.1 In case of a rudder trunk connected with the bottom of a skeg, the throat weld is to be concave shaped to give a fillet shoulder radius as large as practicable. This radius is considered by the Society on a case by case basis.

6 Rudder stock and pintle bearings

6.1 Forces on rudder stock and pintle bearings

6.1.1 Where a direct calculation according to the static schemes and the load conditions specified in App 1 is carried out, the support forces are to be obtained as specified in App 1.

Where such a direct calculation is not carried out, the support forces F_{A1} and F_{A2} acting on the rudder stock bearing and on the pintle bearing, respectively, are to be obtained, in N, from the following formulae:

$$F_{A1} = \left(\frac{A_{G1}}{A} + 0,87\frac{h_0}{H_0}\right) C_R$$

$$F_{A2} = \frac{A_{G2}}{A} C_R$$

where:

A_{G1} ,A_{G2} : portions of the rudder blade area A, in m², supported by the rudder stock bearing and by the pintle bearing respectively, to be not less than the value obtained from Tab 6,

h_0 : coefficient defined in Tab 6,

H_0 : distance, in m, between the points at mid-height of the upper and lower rudder stock bearings.

6.2 Rudder stock bearing

6.2.1 The mean bearing pressure acting on the rudder stock bearing is to be in compliance with the following formula:

$$p_F \le p_{F,ALL}$$

where:

p_F : mean bearing pressure acting on the rudder stock bearings, in N/mm², equal to:

$$p_F = \frac{F_{A1}}{d_m h_m}$$

F_{A1} : force acting on the rudder stock bearing, in N, calculated as specified in [6.1.1],

d_m : actual inner diameter, in mm, of the rudder stock bearings,

h_m : bearing length, in mm. For the purpose of this calculation it is to be taken not greater than:

- 1,2d_m, for spade rudders,
- d_m, for rudder of other types,

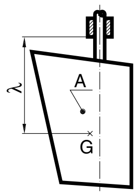
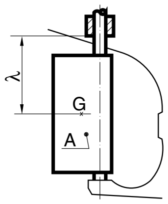
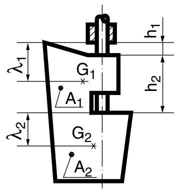
where d_m is defined in [6.2.1].

$p_{F,ALL}$: allowable bearing pressure, in N/mm², defined in Tab 7.

Values greater than those given in Tab 7 may be accepted by the Society in accordance with the Manufacturer's specifications if they are verified by tests.

6.2.2 An adequate lubrication of the bearing surface is to be ensured.

Table 6 : Areas A_{G1} , A_{G2} and h_0

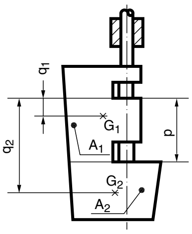
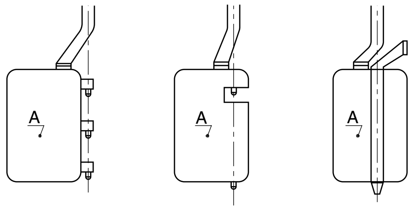
Rudder type	A_{G1}, in m²	A_{G2}, in m²	h_0 , in m
spade rudders 	A	0	$1{,}15\lambda$
2 bearing rudders with solepiece 	Rudder blade area above a horizontal line equally spaced from the upper and the lower edges	Rudder blade area below a horizontal line equally spaced from the upper and the lower edges	$0{,}3\lambda$
2 bearing semi-spade rudders with rudder horn 	$\dfrac{A_1\lambda_1 h_2^2}{(h_1+h_2)^3}$	The greater of **(1)**: • $\dfrac{\lambda A}{h_1+h_2}$ • A	The greater of: • $0{,}19\dfrac{A_1\lambda_1}{A}$ • $\left\lvert 0{,}3\dfrac{A_1\lambda_1-2A_2\lambda_2}{A}\right\rvert$

(1) $\lambda = \dfrac{(\lambda_2+h_2+h_1)A_2+\lambda_1\cdot A_1}{A}$

Note 1:

G, G_1, G_2 : centres of gravity of area A, A_1 and A_2 respectively,

n : number of pintles.

Rudder type	A_{G1}, in m²	A_{G2}, in m²	h_0 , in m
3 bearing semi-spade rudders with rudder horn 	0	• lower pintle: $\dfrac{A_1 q_1 + A_2 q_2}{p}$ • upper pintle, the greater of: $A_1 + A_2 - \dfrac{A_1 q_1 + A_2 q_2}{p}$ $0{,}5 \dfrac{A_1 q_1 + A_2 q_2}{p}$	0
Hinged rudders and Simplex type rudders 	0	$\dfrac{A}{n}$	0

(1) $\lambda = \dfrac{(\lambda_2 + h_2 + h_1)A_2 + \lambda_1 \cdot A_1}{A}$

Note 1:

G, G_1, G_2 : centres of gravity of area A, A_1 and A_2 respectively,

n : number of pintles.

6.3 Pintle bearings

6.3.1 The mean bearing pressure acting on the gudgeons is to be in compliance with the following formula:

$p_F \leq p_{F,ALL}$

where:

p_F : mean bearing pressure acting on the gudgeons, in N/mm², equal to:

$$p_F = \frac{F_{A2}}{d_A h_L}$$

F_{A2} : force acting on the pintle, in N, calculated as specified in [6.1.1],

d_A : actual diameter, in mm, of the rudder pintles,

h_L : bearing length, in mm (see [6.3.3]),

$p_{F,ALL}$: allowable bearing pressure, in N/mm², defined in Tab 7.

Values greater than those given in Tab 7 may be accepted by the Society in accordance with the Manufacturer's specifications if they are verified by tests.

6.3.2 An adequate lubrication of the bearing surface is to be ensured.

6.3.3 The bearing length, in mm, is to be not less than d_A, where d_A is defined in [6.4.1]. For the purpose of the calculation in [6.3.1], the bearing length is to be taken not greater than 1,2 d_A.

Table 7 : Allowable bearing pressure

Bearing material	$p_{F,ALL}$, in N/mm²
Lignum vitae	2,5
White metal, oil lubricated	4,5
Synthetic material with hardness between 60 and 70 Shore D **(1)**	5,5
Steel, bronze and hot-pressed bronze-graphite materials **(2)**	7,0

(1) Indentation hardness test at 23°C and with 50% moisture to be performed according to a recognised standard. Type of synthetic bearing materials is to be approved by the Society.

(2) Stainless and wear-resistant steel in combination with stock liner approved by the Society.

6.3.4 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:

$$t_0 = \frac{d_A}{1000} + 1$$

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, the tolerance on support diameter is to be not less than 1,5 mm.

6.4 Pintles

6.4.1 Rudder pintles are to have a diameter not less than the value obtained, in mm, from the following formula:

$$d_A = \frac{0{,}38V_{AV}}{V_{AV}+3}\sqrt{F_{A2}k_1} + f_C$$

where:

F_{A2} : force, in N, acting on the pintle, calculated as specified in [6.1.1],

f_C : coefficient depending on corrosion, whose value may generally be obtained from the following formula:

$$f_C = 30\sqrt{k_1}$$

The Society may accept lower values of f_C, considering the ship's dimensions and satisfactory service experience of corrosion control systems adopted.

6.4.2 Provision is to be made for a suitable locking device to prevent the accidental loosening of pintles.

6.4.3 The pintles are to have a conical coupling with a taper on diameter in accordance with [5.3.1].

The conical coupling is to be secured by a nut, whose dimension are to be in accordance with [5.3.3].

6.4.4 The length of the pintle housing in the gudgeon is to be not less than the value obtained, in mm, from the following formula:

$$h_L = 0{,}35\sqrt{F_{A2}k_1}$$

where:

F_{A2} : force, in N, acting on the pintle, calculated as specified in [6.1.1].

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 [6.4.1].

7 Rudder blade scantlings

7.1 General

7.1.1 Application

The requirements in [7.1] to [7.6] apply to streamlined rudders and, when applicable, to rudder blades of single plate rudders.

7.1.2 Rudder blade structure

The structure of the rudder blade is to be such that stresses are correctly transmitted to the rudder stock and pintles. To this end, horizontal and vertical web plates are to be provided.

Horizontal and vertical webs acting as main bending girders of the rudder blade are to be suitably reinforced.

7.1.3 Access openings

Streamlined rudders, including those filled with pitch, cork or foam, are to be fitted with plug-holes and the necessary devices to allow their mounting and dismounting.

Access openings to the pintles are to be provided. If necessary, the rudder blade plating is to be strengthened in way of these openings.

The corners of openings intended for the passage of the rudder horn heel and for the dismantling of pintle or stock nuts are to be rounded off with a radius as large as practicable.

Where the access to the rudder stock nut is closed with a welded plate, a full penetration weld is to be provided.

7.1.4 Connection of the rudder blade to the trailing edge for rudder blade area greater than 6 m²

Where the rudder blade area is greater than 6 m², the connection of the rudder blade plating to the trailing edge is to be made by means of a forged or cast steel fashion piece, a flat or a round bar.

7.2 Strength checks

7.2.1 Bending stresses

For the generic horizontal section of the rudder blade it is to be checked that the bending stress σ, in N/mm², induced by the loads defined in [3.1], is in compliance with the following formula:

$$\sigma \le \sigma_{ALL}$$

where:

σ_{ALL} : allowable bending stress, in N/mm², specified in Tab 8.

Table 8 : Allowable stresses for rudder blade scantlings

Type of rudder blade	Allowable bending stress σ_{ALL} in N/mm²	Allowable shear stress τ_{ALL} in N/mm²	Allowable equivalent stress $\sigma_{E,ALL}$ in N/mm²
Without cut-outs	110/k	50/k	120/k
With cut-outs (see Fig 2)	75/k	50/k	100/k

7.2.2 Shear stresses

For the generic horizontal section of the rudder blade it is to be checked that the shear stress τ, in N/mm², induced by the loads defined in [3.1], is in compliance with the following formula:

$$\tau \le \tau_{ALL}$$

where:

τ_{ALL} : allowable shear stress, in N/mm², specified in Tab 8.

7.2.3 Combined bending and shear stresses

For the generic horizontal section of the rudder blade it is to be checked that the equivalent stress σ_E is in compliance with the following formula:

$$\sigma_E \le \sigma_{E,ALL}$$

where:

σ_E : equivalent stress induced by the loads defined in [3.1], to be obtained, in N/mm², from the following formula:

$$\sigma_E = \sqrt{\sigma^2 + 3\tau^2}$$

Where unusual rudder blade geometries make it practically impossible to adopt ample corner radiuses or generous tapering between the various structural elements, the equivalent stress σ_E is to be obtained by means of direct calculations aiming at assessing the rudder blade areas where the maximum stresses, induced by the loads defined in [3.1], occur,

σ : bending stress, in N/mm^2,

τ : shear stress, in N/mm^2,

$\sigma_{E,ALL}$: allowable equivalent stress, in N/mm^2, specified in Tab 8.

7.3 Rudder blade plating

7.3.1 Plate thickness

The thickness of each rudder blade plate panel is to be not less than the value obtained, in mm, from the following formula:

$$t_F = \left(5{,}5 s\beta\sqrt{T + \frac{C_R 10^{-4}}{A}} + 2{,}5\right)\sqrt{k}$$

where:

β : coefficient equal to:

$$\beta = \sqrt{1{,}1 - 0{,}5\left(\frac{s}{b_L}\right)^2}$$

to be taken not greater than 1,0 if $b_L/s > 2{,}5$

s : length, in m, of the shorter side of the plate panel,

b_L : length, in m, of the longer side of the plate panel.

7.3.2 Thickness of the top and bottom plates of the rudder blade

The thickness of the top and bottom plates of the rudder blade is to be not less than the thickness t_F defined in [7.3.1], without being less than 1,2 times the thickness obtained from [7.3.1] for the attached side plating.

Where the rudder is connected to the rudder stock with a coupling flange, the thickness of the top plate which is welded in extension of the rudder flange is to be not less than 1,1 times the thickness calculated above.

7.3.3 Web spacing

The spacing between horizontal web plates is to be not greater than 1,20 m.

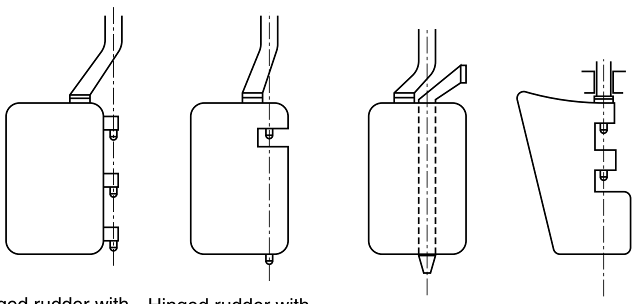
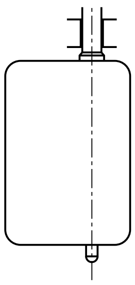
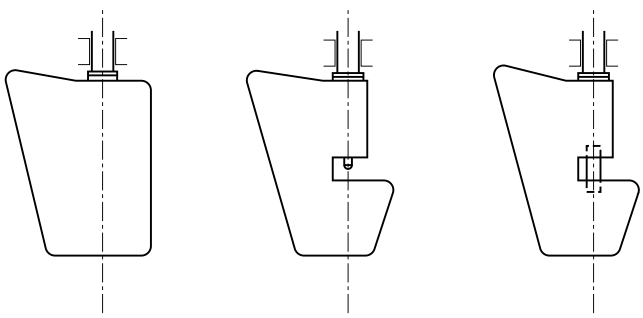
Vertical webs are to have spacing not greater than twice that of horizontal webs.

7.3.4 Web thickness

Web thickness is to be at least 70% of that required for rudder plating and in no case is it to be less than 8 mm, except for the upper and lower horizontal webs, for which the requirements in [7.3.2] apply.

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 9. In rudders having area less than 6 m^2, one vertical web only may be accepted provided its thickness is at least twice that of normal webs.

Table 9 : 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
Hinged rudders, Simplex type rudders and semi-spade with three bearings rudders  Hinged rudder with three bearings; Hinged rudder with two bearings; Simplex - type; 3 bearings semi-spade rudders with rudder horn	t_F	1,3 t_F	t_F	1,2 t_F
Rudder without intermediate pintles 	1,2 t_F	1,6 t_F	1,2 t_F	1,4 t_F
Spade and one bearing rudders  Spade rudder; Simple pintle; Inserted pintle	1,4 t_F	2,0 t_F	1,3 t_F	1,6 t_F

Note 1:
t_F : defined in [7.3.1].

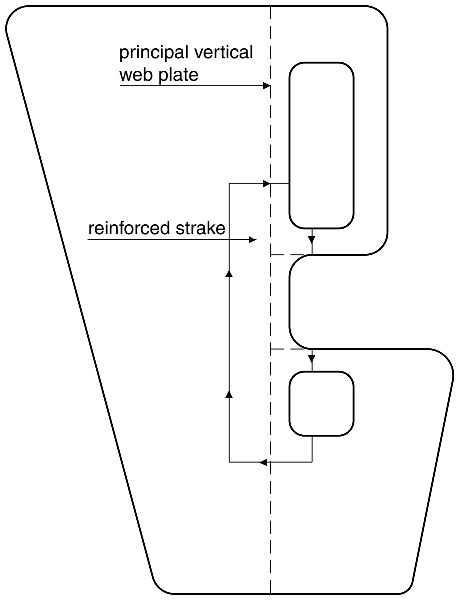
7.3.5 Thickness of side plating and vertical web plates welded to solid part or to rudder flange

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 9.

7.3.6 Reinforced strake of semi-spade rudders

A reinforced strake is to be provided in the lower pintle zone of semi-spade rudders. Its thickness is to be not less than 1,6 t_F, where t_F is defined in [7.3.1]. This strake is to be extended forward of the main vertical web plate (see Fig 6).

Figure 6 : Reinforced strake extension for semi-spade rudders



7.3.7 Main vertical webs of semi-spade rudders

The thickness of the main vertical web plate in the area between the rudder blade upper part and the pintle housing of semi-spade rudders is to be not less than 2,6 t_F, where t_F is defined in [7.3.1].

Under the pintle housing the thickness of this web is to be not less than the value obtained from Tab 9.

Where two main vertical webs are fitted, the thicknesses of these webs are to be not less than the values obtained from Tab 9 depending on whether the web is fitted in a rudder blade area without opening or if the web is along the recess cut in the rudder for the passage of the rudder horn heel.

7.3.8 Welding

The welded connections of blade plating to vertical and horizontal webs are to be in compliance with the applicable requirements of Part D of the Rules.

Where the welds of the rudder blade are accessible only from outside of the rudder, slots on a flat bar welded to the webs are to be provided to support the weld root, to be cut on one side of the rudder only.

7.3.9 Rudder nose plate thickness

Rudder nose plates are to have a thickness not less than 1,25 t_F, where t_F is defined in [7.3.1].

In general this thickness need not exceed 22 mm, unless otherwise required in special cases to be considered individually by the Society.

7.4 Connections of rudder blade structure with solid parts in forged or cast steel

7.4.1 General

Solid parts in forged or cast steel which ensure the housing of the rudder stock or of the pintle are in general to be connected to the rudder structure by means of two horizontal web plates and two vertical web plates.

7.4.2 Minimum section modulus of the connection with the rudder stock housing

The section modulus of the cross-section of the structure of the rudder blade which is connected with the solid part where the rudder stock is housed, which is made by vertical web plates and rudder plating, is to be not less than that obtained, in cm³, from the following formula:

$$w_S = d_1^3 \left(\frac{H_E - H_X}{H_E}\right)^2 \frac{k}{k_1} 10^{-4}$$

where:

d_1 : rudder stock diameter, in mm, defined in [5.1.1],

H_E : vertical distance, in m, between the lower edge of the rudder blade and the upper edge of the solid part,

H_X : vertical distance, in m, between the considered cross-section and the upper edge of the solid part,

k, k_1 : material factors, defined in [1.4], for the rudder blade plating and the rudder stock, respectively.

7.4.3 Calculation of the actual section modulus of the connection with the rudder stock housing

The actual section modulus of the cross-section of the structure of the rudder blade which is connected with the solid part where the rudder stock is housed is to be calculated with respect to the symmetrical axis of the rudder.

The breadth of the rudder plating to be considered for the calculation of this actual section modulus is to be not greater than that obtained, in m, from the following formula:

$$b = s_V + 2\frac{H_X}{m}$$

where:

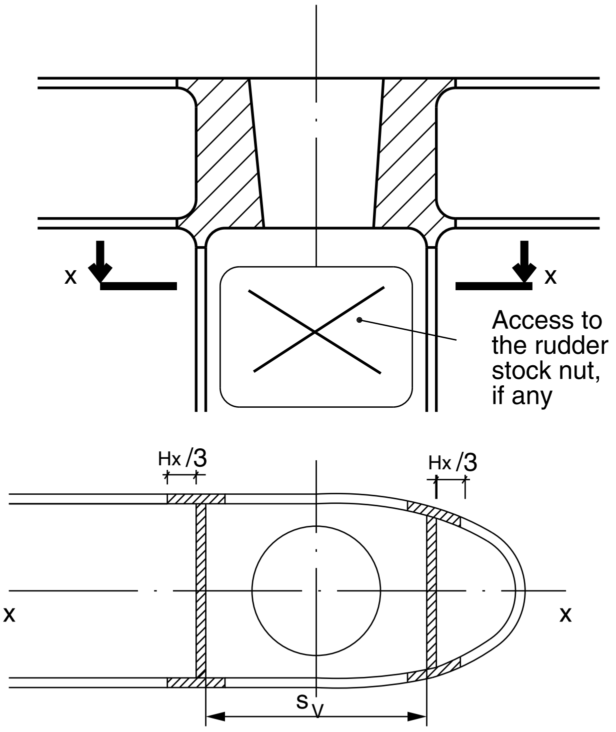
s_V : spacing, in m, between the two vertical webs (see Fig 7),

H_X : distance defined in [7.4.2],

m : coefficient to be taken, in general, equal to 3.

Where openings for access to the rudder stock nut are not closed by a full penetration welded plate according to [7.1.3], they are to be deducted (see Fig 7).

Figure 7 : Cross-section of the connection between rudder blade structure and rudder stock housing



Section x-x

7.4.4 Thickness of horizontal web plates

In the vicinity of the solid parts, the thickness of the horizontal web plates, as well as that of the rudder blade plating between these webs, is to be not less than the greater of the values obtained, in mm, from the following formulae:

$t_H = 1{,}2\ t_F$

$$t_H = 0{,}045 \frac{d_S^2}{s_H}$$

where:

- t_F : defined in [7.3.1],
- d_S : diameter, in mm, to be taken equal to:
  - d_1 for the solid part connected to the rudder stock,
  - d_A for the solid part connected to the pintle,
- d_1 : rudder stock diameter, in mm, defined in [5.1.1],
- d_A : pintle diameter, in mm, defined in [6.4.1],
- s_H : spacing, in mm, between the two horizontal web plates.

Different thickness may be accepted when justified on the basis of direct calculations submitted to the Society for approval.

7.4.5 Thickness of side plating and vertical web plates welded to the solid part

The thickness of the vertical web plates welded to the solid part where the rudder stock is housed as well as the thickness of the rudder side plating under this solid part is to be not less than the values obtained, in mm, from Tab 9.

7.4.6 Solid part protrusions

The solid parts are to be provided with protrusions. Vertical and horizontal web plates of the rudder are to be butt welded to these protrusions.

These protrusions are not required when the web plate thickness is less than:

- 10 mm for web plates welded to the solid part on which the lower pintle of a semi-spade rudder is housed and for vertical web plates welded to the solid part of the rudder stock coupling of spade rudders,
- 20 mm for the other web plates.

7.5 Connection of the rudder blade with the rudder stock by means of horizontal flanges

7.5.1 Minimum section modulus of the connection

The section modulus of the cross-section of the structure of the rudder blade which is directly connected with the flange, which is made by vertical web plates and rudder blade plating, is to be not less than the value obtained, in cm^3, from the following formula:

$w_S = 1{,}3\ d_1^3\ 10^{-4}$

where d_1 is the greater of the rudder stock diameters d_T and d_{TF}, in mm, to be calculated in compliance with the requirements in [4.2.1] and [4.2.2], respectively, taken k_1 equal to 1.

7.5.2 Actual section modulus of the connection

The section modulus of the cross-section of the structure of the rudder blade which is directly connected with the flange is to be calculated with respect to the symmetrical axis of the rudder.

For the calculation of this actual section modulus, the length of the rudder cross-section equal to the length of the rudder flange is to be considered.

Where the rudder plating is provided with an opening under the rudder flange, the actual section modulus of the rudder blade is to be calculated in compliance with [7.4.3].

7.5.3 Welding of the rudder blade structure to the rudder blade flange

The welds between the rudder blade structure and the rudder blade flange are to be full penetrated (or of equivalent strength) and are to be 100% inspected by means of non-destructive tests.

Where the full penetration welds of the rudder blade are accessible only from outside of the rudder, a backing flat bar is to be provided to support the weld root.

The external fillet welds between the rudder blade plating and the rudder flange are to be of concave shape and their throat thickness is to be at least equal to 0,5 times the rudder blade thickness.

Moreover, the rudder flange is to be checked before welding by non-destructive inspection for lamination and inclusion detection in order to reduce the risk of lamellar tearing.

7.5.4 Thickness of side plating and vertical web plates welded to the rudder flange

The thickness of the vertical web plates directly welded to the rudder flange as well as the plating thickness of the rudder blade upper strake in the area of the connection with the rudder flange is to be not less than the values obtained, in mm, from Tab 9.

7.6 Single plate rudders

7.6.1 Mainpiece diameter

The mainpiece diameter is to be obtained from the formulae in [4.2].

In any case, the mainpiece diameter is to be not less than the stock diameter.

For spade rudders the lower third may taper down to 0,75 times the stock diameter.

7.6.2 Blade thickness

The blade thickness is to be not less than the value obtained, in mm, from the following formula:

$$t_B = (1{,}5 s V_{AV} + 2{,}5)\sqrt{k}$$

where:

s : spacing of stiffening arms, in m, to be taken not greater than 1 m (see Fig 8).

7.6.3 Arms

The thickness of the arms is to be not less than the blade thickness.

The section modulus of the generic section is to be not less than the value obtained, in cm^3, from the following formula:

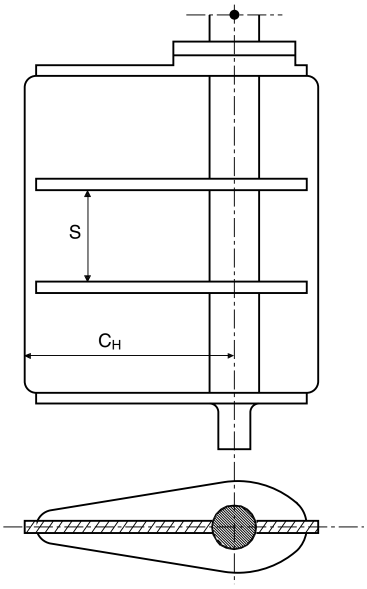
$$Z_A = 0{,}5 s C_H^2 V_{AV}^2 k$$

where:

C_H : horizontal distance, in m, from the aft edge of the rudder to the centreline of the rudder stock (see Fig 8),

s : defined in [7.6.2].

Figure 8 : Single plate rudder



8 Rudder horn and solepiece scantlings

8.1 General

8.1.1 The weight of the rudder is normally supported by a carrier bearing inside the rudder trunk.

In the case of unbalanced rudders having more than one pintle, the weight of the rudder may be supported by a suitable disc fitted in the solepiece gudgeon.

Robust and effective structural rudder stops are to be fitted, except where adequate positive stopping arrangements are provided in the steering gear, in compliance with the applicable requirements of Pt C, Ch 1, Sec 9.

8.2 Rudder horn

8.2.1 General

When the connection between the rudder horn and the hull structure is designed as a curved transition into the hull plating, special consideration is to be paid to the effectiveness of the rudder horn plate in bending and to the stresses in the transverse web plates.

8.2.2 Loads

The following loads acting on the generic section of the rudder horn are to be considered:

- bending moment,
- shear force,
- torque.

The requirements in [8.2.3], [8.2.4] and [8.2.5] apply for calculating the above loads in the case of 2 bearing semi-spade rudders.

In the case of 3 bearing semi-spade rudders, these loads are to be calculated on the basis of the support forces at the lower and upper pintles, obtained according to [6.1].

8.2.3 Bending moment

For 2 bearing semi-spade rudders, the bending moment acting on the generic section of the rudder horn is to be obtained, in N.m, from the following formula:

$$M_H = F_{A2}\, z$$

where:

F_{A2} : support force, in N, to be determined through a direct calculation to be performed in accordance with the static schemes and the load conditions specified in App 1. As an alternative, it may to be obtained from the following formula:

$$F_{A2} = C_R \frac{b}{\ell_{20} + \ell_{30}}$$

b, ℓ_{20}, ℓ_{30}: distances, in m, defined in Fig 9,

z : distance, in m, defined in Fig 10, in any case to be taken less than the distance d, in m, defined in the same figure.

Figure 9 : Geometrical parameters for the calculation of the bending moment in rudder horn

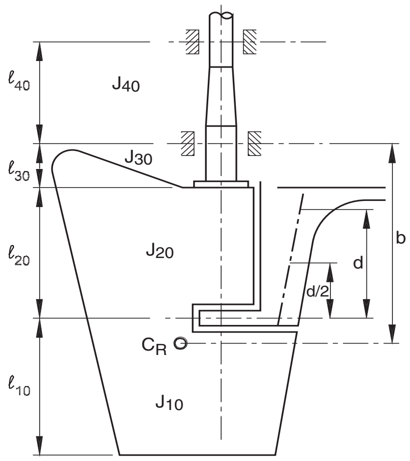
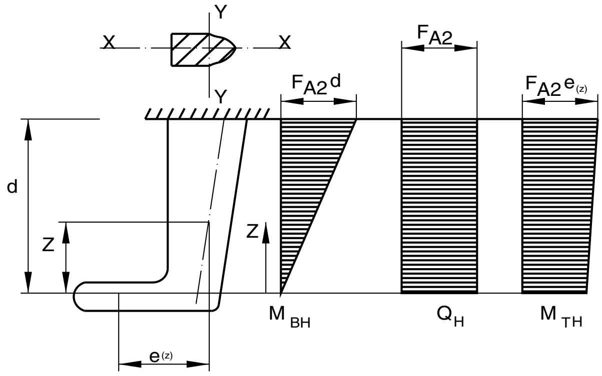


Figure 10 : Rudder horn geometry



8.2.4 Shear force

The shear force Q_H acting on the generic section of the rudder horn is to be obtained, in N, from the following formula:

$Q_H = F_{A2}$

where:

F_{A2} : force, in N, defined in [8.2.3].

8.2.5 Torque

The torque acting on the generic section of the rudder horn is to be obtained, in N.m, from the following formula:

$M_T = F_{A2}\, e$

where:

F_{A2} : force, in N, defined in [8.2.3],

e : distance, in m, defined in Fig 10.

8.2.6 Shear stress check

For the generic section of the rudder horn it is to be checked that:

$\tau_S + \tau_T \le \tau_{ALL}$

where:

τ_S : shear stress to be obtained, in N/mm², from the following formula:

$$\tau_S = \frac{F_{A2}}{A_H}$$

F_{A2} : force, in N, defined in [8.2.3],

A_H : shear sectional area of the rudder horn in Y direction, in mm²,

τ_T : torsional stress to be obtained for hollow rudder horn, in N/mm², from the following formula:

$$\tau_T = \frac{M_T 10^3}{2 A_T t_H}$$

For solid rudder horn, τ_T is to be considered by the Society on a case-by-case basis,

M_T : torque, in N.m, defined in [8.2.5],

A_T : area of the horizontal section enclosed by the rudder horn, in mm²,

t_H : plate thickness of rudder horn, in mm,

τ_{ALL} : allowable torsional shear stress, in N/mm²:

$\tau_{ALL} = 48/k_1$

8.2.7 Combined stress strength check

For the generic section of the rudder horn within the length d, defined in Fig 10, it is to be checked that:

$\sigma_E \le \sigma_{E,ALL}$

$\sigma_B \le \sigma_{B,ALL}$

where:

σ_E : equivalent stress to be obtained, in N/mm², from the following formula:

$$\sigma_E = \sqrt{\sigma_B^2 + 3(\tau_S^2 + \tau_T^2)}$$

Where unusual rudder horn geometries make it practically impossible to adopt ample corner radiuses or generous tapering between the various structural elements, the equivalent stress σ_E is to be obtained by means of direct calculations aiming at assessing the rudder horn areas where the maximum stresses, induced by the loads defined in [3.1], occur,

σ_B : bending stress to be obtained, in N/mm², from the following formula:

$$\sigma_B = \frac{M_H}{W_X}$$

M_H : bending moment at the section considered, in N.m, defined in [8.2.3],

W_X : section modulus, in cm³, around the horizontal axis X (see Fig 10),

τ_S , τ_T : shear and torsional stresses, in N/mm², defined in [8.2.6],

$\sigma_{E,ALL}$: allowable equivalent stress, in N/mm², equal to:

$\sigma_{E,ALL} = 120/k_1$ N/mm²

$\sigma_{B,ALL}$: allowable bending stress, in N/mm², equal to:

$\sigma_{B,ALL} = 67/k_1$ N/mm²

8.3 Solepieces

8.3.1 Bending moment

The bending moment acting on the generic section of the solepiece is to be obtained, in N.m, from the following formula:

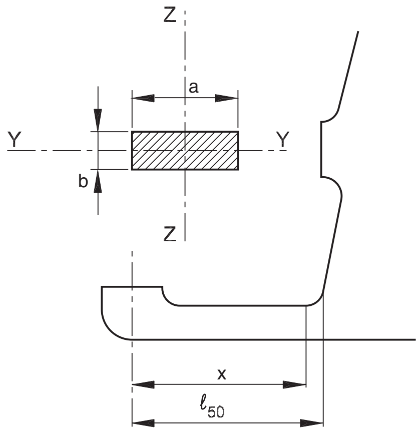
$M_S = F_{A2}\, x$

where:

F_{A2} : supporting force, in N, in the pintle bearing, to be determined through a direct calculation to be performed in accordance with the static schemes and the load conditions specified in App 1; where such a direct calculation is not carried out, this force may be taken equal to:

$$F_{A2} = \frac{C_R}{2}$$

Figure 11 : Solepiece geometry



x : distance, in m, defined in Fig 11.

8.3.2 Strength checks

For the generic section of the solepiece within the length ℓ_{50}, defined in Fig 11, it is to be checked that

$\sigma_E \leq \sigma_{E,ALL}$

$\sigma_B \leq \sigma_{B,ALL}$

$\tau \leq \tau_{ALL}$

where:

σ_E : equivalent stress to be obtained, in N/mm², from the following formula:

$$\sigma_E = \sqrt{\sigma_B^2 + 3\tau^2}$$

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:

$$\tau = \frac{F_{A2}}{A_S}$$

M_S : bending moment at the section considered, in N.m, defined in [8.3.1],

F_{A2} : force, in N, defined in [8.3.1],

W_Z : section modulus, in cm³, around the vertical axis Z (see Fig 11),

A_S : shear sectional area in Y direction, in mm²,

$\sigma_{E,ALL}$: allowable equivalent stress, in N/mm², equal to:

$\sigma_{E,ALL} = 115/k_1$ N/mm²

$\sigma_{B,ALL}$: allowable bending stress, in N/mm², equal to:

$\sigma_{B,ALL} = 80/k_1$ N/mm²

τ_{ALL} : allowable shear stress, in N/mm², equal to:

$\tau_{ALL} = 48/k_1$ N/mm²

8.3.3 Minimum section modulus around the horizontal axis

The section modulus around the horizontal axis Y (see Fig 11) is to be not less than the value obtained, in cm³, from the following formula:

$W_Y = 0,5\, W_Z$

where:

W_Z : section modulus, in cm³, around the vertical axis Z (see Fig 11).

9 Simplex rudder shaft

9.1 Scantlings

9.1.1 Diameter of the rudder shaft

The rudder shaft diameter is to be not less than the value obtained, in mm, from the following formula:

$$d = 17{,}9\left(\frac{\alpha A (V_{AV} + 2)^2}{\ell}\right)^{1/3}$$

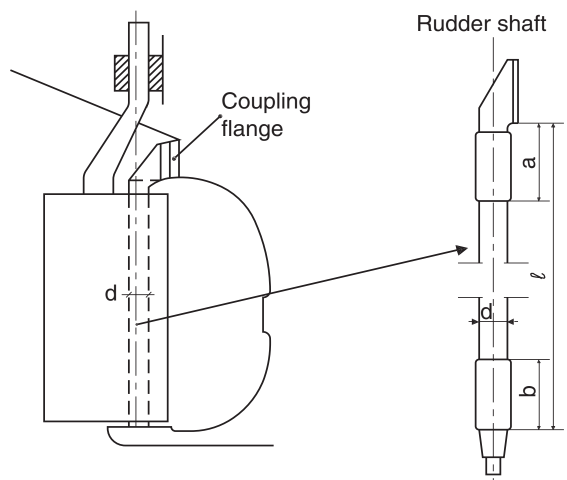
where:

α : coefficient equal to:

- $\alpha = b\,(\ell - b + a)$ if $a \leq b$
- $\alpha = a\,(\ell - a + b)$ if $a > b$

a, b, ℓ : geometrical parameters, in m, defined in Fig 12.

Figure 12 : Simplex rudder shaft geometry



9.1.2 Sectional area of rudder shaft

The overall sectional area of the rudder shaft is to be not less than the greater of the following values:

- 70% of the sectional area for the propeller post defined in Ch 9, Sec 2, [6.3],
- value of the sectional area of the pintle supporting half the rudder blade, whose diameter is to be calculated from the formula in [6.4.1].

If the latter value is the greater, it is to be applied only where the rudder bears on the rudder shaft; in such case, it is recommended that an overthickness or a bush is provided in way of the bearing areas.

9.1.3 Bearings

The bearing length of the rudder shaft is to be not less than 1,2 d, where d is the shaft diameter defined in [9.1.1].

The mean pressure acting on the bearings is not to exceed the relevant allowable values, defined in Tab 6.

9.2 Connections

9.2.1 Connection with the hull

The shaft is to be connected with the hull by means of a vertical coupling flange having thickness at least equal to d/4, where d is the shaft diameter, obtained from the formula in [9.1.1] (see Fig 12).

The coupling flange is to be secured by means of six fitted bolts. The shank diameter of the bolts is to be not less than the coupling flange thickness defined above.

The distance from the bolt centre lines to the coupling flange edge is to be not less than 1,17 times the bolt diameter defined above.

9.2.2 Connection with the solepiece

The rudder shaft is to be connected with the solepiece by means of a cone coupling, having a taper on the radius equal to about 1/10 and housing length not less than 1,1 d, where d is obtained from the formula in [9.1.1] (See Fig 12).

The mean pressure exerted by the rudder shaft on the bearing is to be not greater than the relevant allowable bearing pressure, defined in Tab 6 assuming a rudder with two pintles.

10 Steering nozzles

10.1 General

10.1.1 The requirements of this Article apply to scantling steering nozzles for which the power transmitted to the propeller, P, is less than the value P0 obtained, in kW, from the following formula:

$$P_0 = \frac{16900}{d_M}$$

where:

d_M : inner diameter of the nozzle, in m.

Nozzles for which the power transmitted is greater than the value obtained from the above formula are considered on a case-by-case basis.

The following requirements may apply also to fixed nozzle scantlings.

10.1.2 Nozzles normally consist of a double skin cylindrical structure stiffened by ring webs and other longitudinal webs placed perpendicular to the nozzle.

At least two ring webs are to be fitted, one of which, of greater thickness, 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.

10.1.3 Care is to be taken in the manufacture of the nozzle to ensure the welded connection between plating and webs.

10.1.4 The internal part of the nozzle is to be adequately protected against corrosion.

10.2 Nozzle plating and internal diaphragms

10.2.1 The thickness of the inner plating of the nozzle is to be not less than the value obtained, in mm, from the following formulae:

$$t_F = (0{,}085\sqrt{Pd_M} + 9{,}65)\sqrt{k} \qquad \text{for} \quad P \le \frac{6100}{d_M}$$

$$t_F = (0{,}085\sqrt{Pd_M} + 11{,}65)\sqrt{k} \qquad \text{for} \quad P > \frac{6100}{d_M}$$

where:

P, d_M : defined in [10.1.1].

The thickness t_F is to be extended to a length, across the transverse section containing the propeller blade tips, equal to one third of the total nozzle length.

Outside this length, the thickness of the inner plating is to be not less than (t_F - 7) mm and, in any case, not less than 7 mm.

10.2.2 The thickness of the outer plating of the nozzle is to be not less than (t_F - 9) mm, where t_F is defined in [10.2.1] and, in any case, not less than 7 mm.

10.2.3 The thicknesses of ring webs and longitudinal webs are to be not less than (t_F - 7) mm, where t_F is defined in [10.2.1], and, in any case, not less than 7 mm.

However, the thickness of the ring web, in way of the headbox and pintle support structure, is to be not less than t_F.

The Society may consider reduced thicknesses where an approved stainless steel is used, in relation to its type.

10.3 Nozzle stock

10.3.1 The diameter of the nozzle stock is to be not less than the value obtained, in mm, from the following formula:

$d_{NTF} = 64{,}2\ (M_T\ k_1)^{1/3}$

where:

M_T : torque, to be taken as the greater of those obtained, in N.m, from the following formulae:

- $M_{TAV} = 0{,}3\ S_{AV}\ a$
- $M_{TAD} = S_{AD}\ b$

S_{AV} : force, in N, equal to:

$S_{AV} = 150\ V^2_{AV}\ A_N$

S_{AD} : force, in N, equal to:

$S_{AD} = 200\ V^2_{AD}\ A_N$

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:

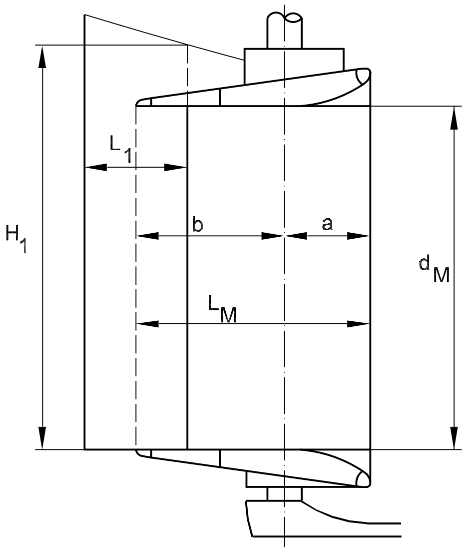
$A_{2N} = L_1\ H_1$

a, b, L_M, d_M, L_1, H_1 : geometrical parameters of the nozzle, in m, defined in Fig 13.

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 13 : Geometrical parameters of the nozzle



10.4 Pintles

10.4.1 The diameter of the pintles is to be not less than the value obtained, in mm, from the following formula:

$$d_A = \left(\frac{11 V_{AV}}{V_{AV}+3}\sqrt{S_{AV}} + 30\right)\sqrt{k_1}$$

where:

S_{AV} : defined in [10.3.1].

10.4.2 The net pintle length h_A, in mm, is to be not less than 1,2 d_A, where d_A is defined in [10.4.1].

Smaller values of h_A may be accepted provided that the pressure on the gudgeon bearing p_F is in compliance with the following formula:

$p_F \le p_{F,ALL}$

where:

p_F : mean bearing pressure acting on the gudgeon, to be obtained in N/mm², from the following formula:

$$p_F = 10^3\frac{0{,}6S'}{d'_A h'_A}$$

S' : the greater of the values S_{AV} and S_{AD}, in kN, defined in [10.3.1],

d'_A : actual pintle diameter, in mm,

h'_A : actual bearing length of pintle, in mm,

$p_{F,ALL}$: allowable bearing pressure, in N/mm², defined in Tab 6.

In any case, h_A is to be not less than d_A.

10.5 Nozzle coupling

10.5.1 Diameter of coupling bolts

The diameter of the coupling bolts is to be not less than the value obtained, in mm, from the following formula:

$$d_B = 0{,}23\, d_{NTF}\sqrt{\frac{k_{1B}}{k_{1A}}}$$

where:

d_{NTF} : diameter of the nozzle stock, in mm, defined in [10.3.1],

k_{1A} : material factor k_1 for the steel used for the stock,

k_{1B} : material factor k_1 for the steel used for the bolts.

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} x 0,10 d_{NT}) mm², where d_{NT} is defined in [10.3.1], and keyways in both the coupling flanges, and provided that at least two of the coupling bolts are fitted bolts.

The distance from the bolt axes to the external edge of the coupling flange is to be not less than 1,2 d_B.

10.5.2 Thickness of coupling flange

The thickness of the coupling flange is to be not less than the value obtained, in mm, from the following formula:

$$t_P = d_{NTF}\sqrt{\frac{k_{1F}}{k_{1B}}}$$

where:

d_{NTF} : diameter of the nozzle stock, in mm, defined in [10.3.1],

k_{1B}, : material factor k_1 for the steel used for the bolts,

k_{1F} : material factor k_1 for the steel used for the coupling flange.

10.5.3 Push up length of cone couplings with hydraulic arrangements for assembling and disassembling the coupling

It is to be checked that the push up length Δ_E of the nozzle stock tapered part into the boss is in compliance with the following formula:

$\Delta_0 \le \Delta_E \le \Delta_1$

where:

Δ_0 : the greater of:

- $6,2\frac{M_{TR}\eta\gamma}{cd_M t_S \mu_A \beta}$
- $16\frac{M_{TR}\eta\gamma}{ct_S^2\beta}\sqrt{\frac{d_{NTF}^6 - d_{NT}^6}{d_{NT}^6}}$

$$\Delta_1 = \frac{2\eta + 5}{1,8}\frac{\gamma d_0 R_{eH}}{10^6 c(1 + \rho_1)}$$

$$\rho_1 = \frac{80\sqrt{d_{NTF}^6 - d_{NT}^6}}{R_{eH} d_M t_S^2\left[1 - \left(\frac{d_0}{d_{NTF}}\right)^2\right]}$$

d_{NTF} : nozzle stock diameter, in mm, to be obtained from the formula in [10.3.1], considering k_1=1

d_{NT} : nozzle stock diameter, in mm, to be obtained from the formula in [10.3.1], considering k_1=1

η, c, β, d_M, d_E, μ_A, μ, γ:defined in Tab 5

t_S, d_U, d_0: defined in Fig 5

R_{eH} : defined in [1.4.3]

10.5.4 Locking device

A suitable locking device is to be provided to prevent the accidental loosening of nuts.

11 Azimuth propulsion system

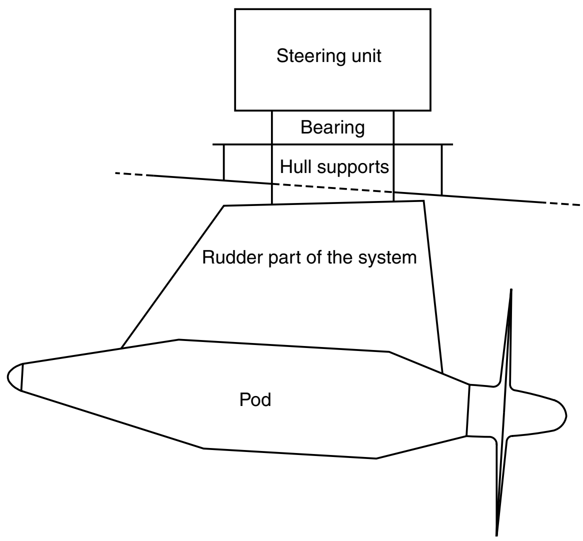
11.1 General

11.1.1 Arrangement

The azimuth propulsion system is constituted by the following sub-systems (see Fig 14):

- the steering unit,
- the bearing,
- the hull supports,
- the rudder part of the system,
- the pod, which contains the electric motor in the case of a podded propulsion system.

Figure 14 : Azimuth propulsion system



11.1.2 Application

The requirements of this Article apply to the scantlings of the hull supports, the rudder part and the pod.

The steering unit and the bearing are to comply with the requirements in Pt C, Ch 1, Sec 9 and Pt C, Ch 1, Sec 10, respectively.

11.1.3 Operating conditions

The maximum angle at which the azimuth propulsion system can be oriented on each side when the ship navigates at its maximum speed is to be specified by the Designer. Such maximum angle is generally to be less than 35° on each side.

In general, orientations greater than this maximum angle may be considered by the Society for azimuth propulsion systems during manoeuvres, provided that the orientation values together with the relevant speed values are submitted to the Society for approval.

11.2 Arrangement

11.2.1 Plans to be submitted

In addition to the plans showing the structural arrangement of the pod and the rudder part of the system, the plans showing the arrangement of the azimuth propulsion system supports are to be submitted to the Society for approval. The scantlings of the supports and the maximum loads which acts on the supports are to be specified in these drawings.

11.2.2 Locking device

The azimuth propulsion system is to be mechanically lockable in a fixed position, in order to avoid rotations of the system and propulsion in undesirable directions in the event of damage.

11.3 Design loads

11.3.1 The lateral pressure to be considered for scantling of plating and ordinary stiffeners of the azimuth propulsion system is to be determined for an orientation of the system equal to the maximum angle at which the azimuth propulsion system can be oriented on each side when the ship navigates at its maximum speed.

The total force which acts on the azimuth propulsion system is to be obtained by integrating the lateral pressure on the external surface of the system.

The calculations of lateral pressure and total force are to be submitted to the Society for information.

11.4 Plating

11.4.1 Plating of the rudder part of the azimuth propulsion system

The thickness of plating of the rudder part of the azimuth propulsion system is to be not less than that obtained, in mm, from the formulae in [7.3.1], in which the term C_R/A is to be replaced by the lateral pressure calculated according to [11.3].

11.4.2 Plating of the pod

The thickness of plating of the pod is to be not less than that obtained, in mm, from the formulae in Ch 7, Sec 1, where the lateral pressure is to be calculated according to [11.3].

11.4.3 Webs

The thickness of webs of the rudder part of the azimuth propulsion system is to be determined according to [7.3.4], where the lateral pressure is to be calculated according to [11.3].

11.5 Ordinary stiffeners

11.5.1 Ordinary stiffeners of the pod

The scantlings of ordinary stiffeners of the pod are to be not less than those obtained from the formulae in Ch 7, Sec 2, where the lateral pressure is to be calculated according to [11.3].

11.6 Primary supporting members

11.6.1 Analysis criteria

The scantlings of primary supporting members of the azimuth propulsion system are to be obtained through direct calculations, to be carried out according to the following requirements:

- the structural model is to include the pod, the rudder part of the azimuth propulsion system, the bearing and the hull supports,
- the boundary conditions are to represent the connections of the azimuth propulsion system to the hull structures,
- the loads to be applied are those defined in [11.6.2].

The direct calculation analyses (structural model, load and stress calculation, strength checks) carried out by the Designer are to be submitted to the Society for information.

11.6.2 Loads

The following loads are to be considered in the direct calculation of the primary supporting members of the azimuth propulsion system:

- gravity loads,
- buoyancy,
- maximum loads calculated for an orientation of the system equal to the maximum angle at which the azimuth propulsion system can be oriented on each side when the ship navigates at its maximum speed,
- maximum loads calculated for the possible orientations of the system greater than the maximum angle at the relevant speed (see [11.1.3]),
- maximum loads calculated for the crash stop of the ship obtained through inversion of the propeller rotation,
- maximum loads calculated for the crash stop of the ship obtained through a 180° rotation of the pod.

11.6.3 Strength check

It is to be checked that the Von Mises equivalent stress σ_E in primary supporting members, calculated, in N/mm², for the load cases defined in [11.6.2], is in compliance with the following formula:

$$\sigma_E \leq \sigma_{ALL}$$

where:

σ_{ALL} : allowable stress, in N/mm², to be taken equal to the lesser of the following values:

- 0,275 R_m
- 0,55 R_{eH}

R_m : tensile strength, in N/mm², of the material, defined in Ch 4, Sec 1, [2],

R_{eH} : minimum yield stress, in N/mm², of the material, defined in Ch 4, Sec 1, [2].

11.7 Hull supports of the azimuth propulsion system

11.7.1 Analysis criteria

The scantlings of hull supports of the azimuth propulsion system are to be obtained through direct calculations, to be carried out in accordance with the requirements in [11.6.1].

11.7.2 Loads

The loads to be considered in the direct calculation of the hull supports of the azimuth propulsion system are those specified in [11.6.2].

11.7.3 Strength check

It is to be checked that the Von Mises equivalent stress σ_E in hull supports, in N/mm², calculated for the load cases defined in [11.6.2], is in compliance with the following formula:

$$\sigma_E \leq \sigma_{ALL}$$

where:

σ_{ALL} : allowable stress, in N/mm², equal to:

$$\sigma_{ALL} = 65/k$$

k : material factor, defined in Ch 4, Sec 1, [2.3].

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

1 General

1.1 Introduction

1.1.1 The requirements of this Section apply to the arrangement of bulwarks and guard rails provided at boundaries of the freeboard deck, superstructure decks and tops of the first tier of deckhouses located on the freeboard deck.

1.2 General

1.2.1 Efficient bulwarks or guard rails are to be fitted at the boundaries of all exposed parts of the freeboard deck and superstructure decks directly attached to the freeboard deck, as well as the first tier of deckhouses fitted on the freeboard deck and the superstructure ends.

1.2.2 The height of the bulwarks or guard rails is to be at least 1 m from the deck. However, where their height would interfere with the normal operation of the ship, a lesser height may be accepted, if adequate protection is provided.

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

1.2.4 In type A and B-100 ships, open rails on the weather parts of the freeboard deck for at least half the length of the exposed parts are to be fitted.

Alternatively, freeing ports complying with Ch 9, Sec 9, [5] are to be fitted.

1.2.5 In ships with bulwarks and trunks of breadth not less than 0,6 B, which are included in the calculation of freeboard, open rails on the weather parts of the freeboard deck in way of the trunk for at least half the length of the exposed parts are to be fitted.

Alternatively, freeing ports complying with Ch 9, Sec 9, [4.3.1] are to be fitted.

1.2.6 In ships having superstructures which are open at either or both ends, adequate provision for freeing the space within such superstructures is to be provided.

1.2.7 The freeing port area in the lower part of the bulwarks is to be in compliance with the applicable requirements of Ch 9, Sec 9, [5].

2 Bulwarks

2.1 General

2.1.1 As a rule, plate bulwarks are to be stiffened at the upper edge by a suitable bar and supported either by stays or plate brackets spaced not more than 2,0 m apart.

Bulwarks are to be aligned with the beams located below or are to be connected to them by means of local transverse stiffeners.

As an alternative, the lower end of the stay may be supported by a longitudinal stiffener.

2.1.2 In type A, B-60 and B-100 ships, the spacing forward of 0,07 L from the fore end of brackets and stays is to be not greater than 1,2 m.

2.1.3 Where bulwarks are cut completely, the scantlings of stays or brackets are to be increased with respect to those given in [2.2].

2.1.4 As a rule, bulwarks are not to be connected either to the upper edge of the sheerstrake plate or to the stringer plate.

Failing this, the detail of the connection will be examined by the Society on a case-by-case basis.

2.2 Scantlings

2.2.1 The thickness of bulwarks on the freeboard deck not exceeding 1100 mm in height is to be not less than:

- 5,5 mm for $L \le 30$ m,
- 6,0 mm for $30 < L \le 120$ m,
- 6,5 mm for $120 < L \le 150$ m,
- 7,0 mm for $L > 150$ m.

Where the height of the bulwark is equal to or greater than 1800 mm, its thickness is to be equal to that calculated for the side of a superstructure situated in the same location as the bulwark.

For bulwarks between 1100 mm and 1800 mm in height, their thickness is to be calculated by linear interpolation.

2.2.2 Bulwark plating and stays are to be adequately strengthened in way of eyeplates used for shrouds or other tackles in use for cargo gear operation, as well as in way of hawserholes or fairleads provided for mooring or towing.

2.2.3 At the ends of partial superstructures and for the distance over which their side plating is tapered into the bulwark, the latter is to have the same thickness as the side plating; where openings are cut in the bulwark at these positions, adequate compensation is to be provided either by increasing the thickness of the plating or by other suitable means.

2.2.4 The section modulus of stays in way of the lower part of the bulwark is to be not less than the value obtained, in cm^3, from the following formula:

$$Z = 40\, s\, (1 + 0{,}01\, L)\, h_B^2$$

where:

L : length of ship, in m, to be assumed not greater than 100 m,

s : spacing of stays, in m,

h_B : height of bulwark, in m, measured between its upper edge and the deck.

The actual section of the connection between stays and deck structures is to be taken into account when calculating the above section modulus.

To this end, the bulb or face plate of the stay may be taken into account only where welded to the deck; in this case the beam located below is to be connected by double continuous welding.

For stays with strengthening members not connected to the deck, the calculation of the required minimum section modulus is considered by the Society on a case-by-case basis.

At the ends of the ship, where the bulwark is connected to the sheerstrake, an attached plating having width not exceeding 600 mm may also be included in the calculation of the actual section modulus of stays.

2.2.5 Openings in bulwarks are to be arranged so that the protection of the crew is to be at least equivalent to that provided by the horizontal courses in [3.1.2].

For this purpose, vertical rails or bars spaced approximately 230 mm apart may be accepted in lieu of rails or bars arranged horizontally.

2.2.6 In the case of ships intended for the carriage of timber deck cargoes, the specific provisions of the freeboard regulations are to be complied with.

3 Guard rails

3.1

3.1.1 Where guard rails are provided, the upper edge of sheerstrake is to be kept as low as possible.

3.1.2 The opening below the lowest course is to be not more than 230 mm. The other courses are to be not more than 380 mm apart.

3.1.3 In the case of ships with rounded gunwales or sheerstrake, the stanchions are to be placed on the flat part of the deck.

3.1.4 Fixed, removable or hinged stanchions are to be fitted about 1,5 m apart. At least every third stanchion is to be supported by a bracket or stay.

Removable or hinged stanchions are to be capable of being locked in the upright position.

3.1.5 Wire ropes may only be accepted in lieu of guard rails in special circumstances and then only in limited lengths. Wires are to be made taut by means of turnbuckles.

3.1.6 Chains may only be accepted in short lengths in lieu of guard rails if they are fitted between two fixed stanchions and/or bulwarks.

SECTION 3 PROPELLER SHAFT BRACKETS

1 Propeller shaft brackets

1.1 General

1.1.1 Propeller shafting is either enclosed in bossing or independent of the main hull and supported by shaft brackets.

1.2 Double arm propeller shaft brackets

1.2.1 General

This type of propeller shaft bracket consists of two arms arranged at right angles and converging in the propeller shaft bossing.

Single arm propeller shaft brackets are generally to be avoided.

Exceptions to this will be considered by the Society on a case-by-case basis.

1.2.2 Scantlings of elliptical arm

Cast or forged propeller shaft brackets having arms of elliptical section are to have a minor axis d_1 and a major axis d_2, in mm, not less than those obtained from the following formulae:

$$d_1 = 0,4 d_P$$

$$d_2 = 0,01 \ell_B \left(\frac{d_P}{d_1}\right)^3$$

where:

ℓ_B : length of the longer arm, in mm, measured from the section at the root of the palm to that at the root of the boss,

d_P : propeller shaft diameter, in mm, measured inside the liner, if any.

1.2.3 Minimum inertia of arm section

In the case of arms of other shapes, the inertia of the cross-section about its major axis is to be not less than the value obtained, in cm⁴, from the following formula:

$$J = 0,5 \ell_B d_P^3 10^{-7}$$

where:

ℓ_B, d_P : defined in [1.2.2].

1.2.4 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.

The thickness of the propeller shaft bossing is to be not less than 0,33 d_P.

1.2.5 Bracket arm attachments

In way of bracket arms attachments, the thickness of deep floors or girders is to be suitably increased. Moreover, the shell plating is to be increased in thickness and suitably stiffened.

1.3 Bossed propeller shaft brackets

1.3.1 General

Bossed propeller shaft brackets consist of a U-shaped cast steel arm connected to the hull by means of a substantial palm and ending in a boss for propeller shaft support.

1.3.2 Minimum modulus of arm section

The section modulus at the root of the arm calculated about the horizontal neutral axis of the root section is to be not less than the value obtained, in cm^3, from the following formula:

$$Z = 75 \ell_B d_P^2 10^{-7}$$

where:

ℓ_B, d_P : defined in [1.2.2].

1.3.3 Scantling of the boss

The length of the boss, in mm, is to be greater than 2,3 d_P, where d_P is defined in [1.2.2]. In any case, it is to be less than 3 d_P.

The thickness of the boss, in mm, is to be not less than 0,33 d_P.

The aft end of the bossing is to be adequately supported.

1.3.4 Scantling of the end supports

The scantlings of end supports are to be specially considered. Supports are to be adequately designed to transmit the loads to the main structure.

End supports are to be connected to at least two deep floors of increased thickness or connected to each other within the ship.

1.3.5 Stiffening of the boss plating

Stiffening of the boss plating is to be specially considered. At the aft end, transverse diaphragms are to be fitted at every frame and connected to floors of increased scantlings.

At the fore end, web frames spaced not more than four frames apart are to be fitted.

SECTION 4 EQUIPMENT

Symbols

EN : Equipment Number defined in [2.1],

σ_{ALL} : allowable stress, in N/mm², used for the yielding check in [4.9.7], [4.10.7], [4.11.2] and [4.11.3], to be taken as the lesser of:

- $\sigma_{ALL} = 0,67\ R_{eH}$
- $\sigma_{ALL} = 0,40\ R_m$

R_{eH} : minimum yield stress, in N/mm², of the material, defined in Ch 4, Sec 1, [2]

R_m : tensile strength, in N/mm², of the material, defined in Ch 4, Sec 1, [2].

1 General

1.1 General

1.1.1 The requirements in [2] to [4] apply to temporary mooring of a ship within or near harbour, or in a sheltered area, when the ship is awaiting a berth, the tide, etc.

Therefore, the equipment complying with the requirements in [2] to [4] is not intended for holding a ship off fully exposed coasts in rough weather or for stopping a ship which is moving or drifting.

1.1.2 The equipment complying with the requirements in [2] to [4] is intended for holding a ship in good holding ground, where the conditions are such as to avoid dragging of the anchor. In poor holding ground the holding power of the anchors is to be significantly reduced.

1.1.3 It is assumed that under normal circumstances a ship will use one anchor only.

2 Equipment number

2.1 Equipment number

2.1.1 General

All ships are to be provided with equipment in anchors and chain cables (or ropes according to [3.3.5]), to be obtained from Tab 1, based on their Equipment Number EN.

In general, stockless anchors are to be adopted.

For ships with EN greater than 16000, the determination of the equipment will be considered by the Society on a case by case basis.

For ships of special design or ships engaged in special services or on special voyages, the Society may consider equipment other than that in Tab 1.

2.1.2 Equipment Number for ships with perpendicular superstructure front bulkhead

The Equipment Number EN is to be obtained from the following formula:

$$EN = \Delta^{2/3} + 2\ h\ B + 0,1\ A$$

where:

Δ : moulded displacement of the ship, in t, to the summer load waterline,

h : effective height, in m, from the summer load waterline to the top of the uppermost house, to be obtained in accordance with the following formula:

$$h = a + \Sigma h_n$$

When calculating h, sheer and trim are to be disregarded,

a : freeboard amidships from the summer load waterline to the upper deck, in m,

h_n : height, in m, at the centreline of tier "n" of superstructures or deckhouses having a breadth greater than B/4. Where a house having a breadth greater than B/4 is above a house with a breadth of B/4 or less, the upper house is to be included and the lower ignored,

A : area, in m², in profile view, of the parts of the hull, superstructures and houses above the summer load waterline which are within the length L_E and also have a breadth greater than B/4,

L_E : equipment length, in m, equal to L without being taken neither less than 96% nor greater than 97% of the total length of the summer load waterline.

Fixed screens or bulwarks 1,5 m or more in height are to be regarded as parts of houses when determining h and A. In particular, the hatched area shown in Fig 2 is to be included.

The height of hatch coamings and that of any deck cargo, such as containers, may be disregarded when determining h and A.

Table 1 : Equipment

Equipment number EN A < EN ≤ B		Stockless anchors		Stud link chain cables for anchors			
		N (1)	Mass per anchor, in kg	Total length, in m	Diameter, in mm		
A	B				Q1	Q2	Q3
50	70	2	180	220,0	14,0	12,5	
70	90	2	240	220,0	16,0	14,0	
90	110	2	300	247,5	17,5	16,0	
110	130	2	360	247,5	19,0	17,5	
130	150	2	420	275,0	20,5	17,5	
150	175	2	480	275,0	22,0	19,0	
175	205	2	570	302,5	24,0	20,5	
205	240	3	660	302,5	26,0	22,0	20,5
240	280	3	780	330,0	28,0	24,0	22,0
280	320	3	900	357,5	30,0	26,0	24,0
320	360	3	1020	357,5	32,0	28,0	24,0
360	400	3	1140	385,0	34,0	30,0	26,0
400	450	3	1290	385,0	36,0	32,0	28,0
450	500	3	1440	412,5	38,0	34,0	30,0
500	550	3	1590	412,5	40,0	34,0	30,0
550	600	3	1740	440,0	42,0	36,0	32,0
600	660	3	1920	440,0	44,0	38,0	34,0
660	720	3	2100	440,0	46,0	40,0	36,0
720	780	3	2280	467,5	48,0	42,0	36,0
780	840	3	2460	467,5	50,0	44,0	38,0
840	910	3	2640	467,5	52,0	46,0	40,0
910	980	3	2850	495,0	54,0	48,0	42,0
980	1060	3	3060	495,0	56,0	50,0	44,0
1060	1140	3	3300	495,0	58,0	50,0	46,0
1140	1220	3	3540	522,5	60,0	52,0	46,0
1220	1300	3	3780	522,5	62,0	54,0	48,0
1300	1390	3	4050	522,5	64,0	56,0	50,0
1390	1480	3	4320	550,0	66,0	58,0	50,0
1480	1570	3	4590	550,0	68,0	60,0	52,0
1570	1670	3	4890	550,0	70,0	62,0	54,0
1670	1790	3	5250	577,5	73,0	64,0	56,0
1790	1930	3	5610	577,5	76,0	66,0	58,0
1930	2080	3	6000	577,5	78,0	68,0	60,0
2080	2230	3	6450	605,0	81,0	70,0	62,0
2230	2380	3	6900	605,0	84,0	73,0	64,0
2380	2530	3	7350	605,0	87,0	76,0	66,0
2530	2700	3	7800	632,5	90,0	78,0	68,0
2700	2870	3	8300	632,5	92,0	81,0	70,0
2870	3040	3	8700	632,5	95,0	84,0	73,0
3040	3210	3	9300	660,0	97,0	84,0	76,0
3210	3400	3	9900	660,0	100,0	87,0	78,0
3400	3600	3	10500	660,0	102,0	90,0	78,0
3600	3800	3	11100	687,5	105,0	92,0	81,0
3800	4000	3	11700	687,5	107,0	95,0	84,0
4000	4200	3	12300	687,5	111,0	97,0	87,0
4200	4400	3	12900	715,0	114,0	100,0	87,0
4400	4600	3	13500	715,0	117,0	102,0	90,0

(1) See [3.2.4].

Equipment number EN A < EN ≤ B		Stockless anchors		Stud link chain cables for anchors			
		N (1)	Mass per anchor, in kg	Total length, in m	Diameter, in mm		
A	B				Q1	Q2	Q3
4600	4800	3	14100	715,0	120,0	105,0	92,0
4800	5000	3	14700	742,5	122,0	107,0	95,0
5000	5200	3	15400	742,5	124,0	111,0	97,0
5200	5500	3	16100	742,5	127,0	111,0	97,0
5500	5800	3	16900	742,5	130,0	114,0	100,0
5800	6100	3	17800	742,5	132,0	117,0	102,0
6100	6500	3	18800	742,5		120,0	107,0
6500	6900	3	20000	770,0		124,0	111,0
6900	7400	3	21500	770,0		127,0	114,0
7400	7900	3	23000	770,0		132,0	117,0
7900	8400	3	24500	770,0		137,0	122,0
8400	8900	3	26000	770,0		142,0	127,0
8900	9400	3	27500	770,0		147,0	132,0
9400	10000	3	29000	770,0		152,0	132,0
10000	10700	3	31000	770,0			137,0
10700	11500	3	33000	770,0			142,0
11500	12400	3	35500	770,0			147,0
12400	13400	3	38500	770,0			152,0
13400	14600	3	42000	770,0			157,0
14600	16000	3	46000	770,0			162,0

(1) See [3.2.4].

2.1.3 Equipment Number for ships with inclined superstructure front bulkhead

For ships having superstructures with the front bulkhead with an angle of inclination aft, the Equipment Number EN is to be obtained from the following formula:

$EN = \Delta^{2/3} + 2 (a\ B + \Sigma b_N\ h_N \sin\theta_N) + 0{,}1\ A$

where:

Δ, a, h_N, A: as defined in [2.1.2],

θ_N : angle of inclination aft of each front bulkhead, shown in Fig 3,

b_N : greatest breadth, in m, of each tier n of superstructures or deckhouses having a breadth greater than B/4.

Fixed screens or bulwarks 1,5 m or more in height are to be regarded as parts of houses when determining h and A. In particular, the hatched area shown in Fig 3 is to be included.

3 Equipment

3.1 Shipboard fittings and supporting hull structures

3.1.1 Application

The requirements of [3.1] apply to ships of 500 gross tonnage and upwards; in particular they apply to bollards, bitts, fairleads, stand rollers, chocks used for the normal mooring of the ship and similar components used for the normal towing of the ship. For emergency towing arrangements, the requirements in [4] are to be applied.

The supporting hull structures are constituted by that part of the ship's structure on/in which the shipboard fitting is placed and which is directly submitted to the forces exerted on the shipboard fitting. The supporting hull structures of capstans, winches, etc used for normal towing and mooring operations are also covered by [3.1].

Other components such as capstans, winches, etc are not covered by this item. Any weld or bolt or equivalent device connecting the shipboard fitting to the supporting structure is part of the shipboard fitting and subject to the industry standard applicable to this shipboard fitting.

3.1.2 Net scantlings

The net minimum scantlings of the supporting hull structure are to comply with the requirements in [3.1.8] and [3.1.14]. The net thicknesses, t_{net}, are the member thicknesses necessary to obtain the above required minimum net scantlings. The required gross thicknesses are obtained by adding the total corrosion additions, t_c, given in [3.1.3], to t_{net}.

3.1.3 Corrosion Addition

The total corrosion addition, t_c, in mm, for both sides of the hull supporting structure is to be in accordance with Ch 4, Sec 2 and, in any case, it is to be not less than 2,0 mm.

3.1.4 Towing shipboard fittings selection

The selection of towing shipboard fittings is to be made by the shipyard in accordance with an industry standard (e.g. ISO 3913 Shipbuilding Welded Steel Bollards) accepted by the Society. When the shipboard fitting is not selected from an accepted industry standard, the design load considered for assessing its strength and its attachment to the ship is to be in accordance with [3.1.13].

3.1.5 Towing shipboard fittings location

Shipboard fittings for towing are to be located on longitudinal ordinary stiffeners, beams and/or girders which are part of the deck construction so as to facilitate efficient distribution of the towing loads. Other equivalent arrangements (e.g. Panama chocks) may be accepted provided the strength is confirmed adequate for the intended service.

3.1.6 Arrangement of supporting hull structures for towing fittings

The arrangement of the reinforced members (carling) beneath towing shipboard fittings is to be such as to withstand any variation of direction (laterally and vertically) of the towing forces defined in accordance with [3.1.7], acting through the arrangement of connection to the shipboard fittings.

3.1.7 Towing load model

Unless a greater safe working load (SWL) of shipboard fittings is specified by the applicant, the minimum design load to be used is the following value of (a) or (b), whichever is applicable:

a) for normal towing operations (e.g. harbour/manoeuvring), 1,25 times the intended maximum towing load (e.g. static bollard pull) as indicated on the towing and mooring arrangement plan.

b) for other towing service (e.g. escort), the nominal breaking strength of the towline according to Table 3 for the ship's corresponding EN is to be applied.

This force is to be considered as acting on the shipboard fittings at the attachment point of the towing line or mooring line or at a change in its direction, as applicable.

The design load is to be applied through the towline according to the arrangement shown on the towing and mooring arrangement plan.

When a specific SWL is applied for a shipboard fitting at the request of the applicant, by which the design load will be greater than the above minimum values, the strength of the fitting is to be designed using this specific design load.

The method of application of the design load to the fittings and supporting hull structures is to be taken into account such that the total load need not be more than twice the design load, i.e. no more than one turn of one line (see Fig 1).

3.1.8 Allowable stresses for towing fittings

When assessing the strength of supporting hull structures for towing fittings, the following allowable stresses are to be considered in association with a stress calculation that does not take into account any stress concentration factors:

- normal stress: the minimum yield stress of the supporting hull structure material
- shear stress: 0,6 times the minimum yield stress of the supporting hull structure material.

Normal stress is the sum of bending stress and axial stress with the corresponding shearing stress acting perpendicular to the normal stress.

3.1.9 Safe Working Load (SWL)

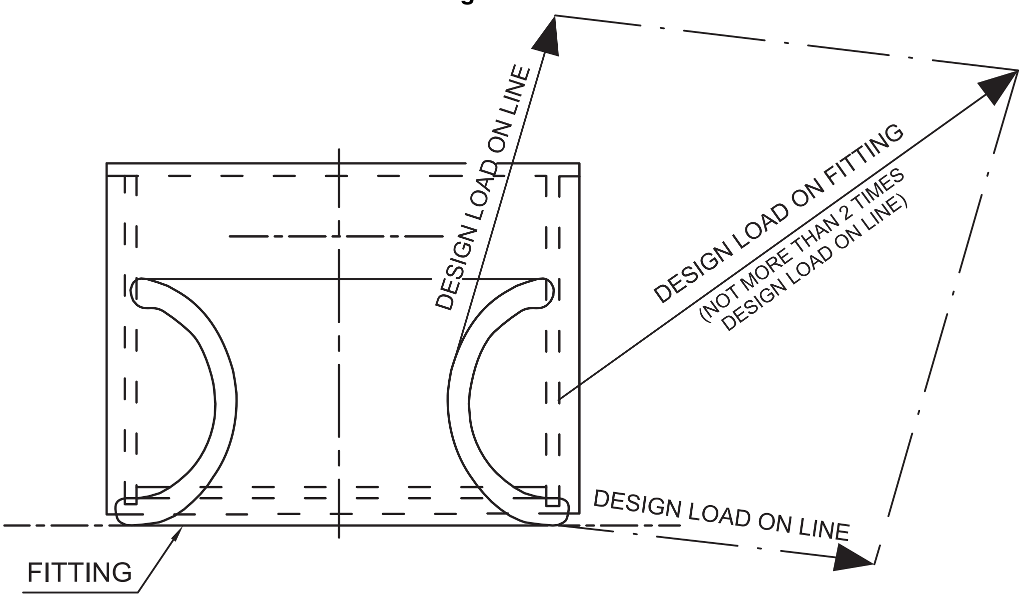
The SWL used for normal towing operations (e.g. harbour/manoeuvring) is not to exceed 80% of the design load as per [3.1.7] a) and the SWL used for other towing operations (e.g. escort) is not to exceed the design load as per [3.1.7] b). For fittings used for both normal and other towing operations, the greater of the design loads of [3.1.7] a) and [3.1.7] b) is to be used.

The SWL of each shipboard fitting is to be marked (by weld bead or equivalent) on the deck fittings used for towing.

The above requirements on SWL apply on a single post basis (no more than one turn of one cable).

The towing and mooring arrangement plan mentioned in [3.1.16] is to define the method of use of towing lines.

Figure 1



3.1.10 Mooring shipboard fittings selection

The selection of mooring shipboard fittings is to be made by the shipyard in accordance with an industry standard (e.g. ISO 3913 Shipbuilding Welded Steel Bollards) accepted by the Society. When the shipboard fitting is not selected from an accepted industry standard, the design load considered for assessing its strength and its attachment to the ship is to be in accordance with [3.1.13].

3.1.11 Mooring shipboard fittings location

Shipboard fittings for mooring are to be located on longitudinals, beams and/or girders which are part of the deck construction so as to facilitate efficient distribution of the mooring load. Other arrangements may be accepted (for Panama chocks, etc) provided the strength is confirmed adequate for the service.

3.1.12 Arrangement of supporting hull structures for mooring fittings

The arrangement of the reinforced members (carling) beneath mooring shipboard fittings is to be such as to withstand any variation of direction (laterally and vertically) of the mooring forces defined in accordance with [3.1.13], acting through the arrangement of connection to the shipboard fittings.

3.1.13 Mooring load model

a) Unless a greater safe working load (SWL) of shipboard fittings is specified by the applicant, the design load applied to shipboard fittings and supporting hull structures is to be 1,25 times the breaking strength of the mooring line according to Tab 3 for the ship's corresponding EN (see Note 1).

Note 1: Side projected area including maximum stacks of deck cargoes is to be taken into account for assessment of lateral wind forces, arrangements of tug boats and selection of mooring lines.

b) The design load applied to supporting hull structures for winches, etc is to be 1,25 times the intended maximum brake holding load and, for capstans, 1,25 times the maximum hauling-in force.

c) This force is to be considered as acting on the shipboard fittings at the attachment point of the mooring line or at a change in its direction, as applicable.

d) The design load is to be applied through the mooring line according to the arrangement shown on the towing and mooring arrangement plan.

e) The method of application of the design load to the fittings and supporting hull structures is to be taken into account such that the total load need not be more than twice the design load specified above, i.e. no more than one turn of one line.

f) When a specific SWL is applied for a shipboard fitting at the request of the applicant, by which the design load will be greater than the above minimum values, the strength of the fitting is to be designed using this specific design load.

3.1.14 Allowable stresses for mooring fittings

When assessing the strength of supporting hull structures for mooring fittings, the following allowable stresses are to be considered in association with a stress calculation that does not take into account any stress concentration factors:

- normal stress: the minimum yield stress of the supporting hull structure material
- shear stress: 0,6 times the minimum yield stress of the supporting hull structure material.

Normal stress is the sum of bending stress and axial stress with the corresponding shearing stress acting perpendicular to the normal stress.

3.1.15 Safe Working Load (SWL)

The SWL is not to exceed 80% of the design load as per [3.1.13] a).

The SWL of each shipboard fitting is to be marked (by weld bead or equivalent) on the deck fittings used for mooring.

The above requirements on SWL apply on a single post basis (no more than one turn of one cable).

The towing and mooring arrangement plan mentioned in [3.1.16] is to define the method of use of mooring lines.

3.1.16 Towing and mooring arrangement plan

The SWL for the intended use for each shipboard fitting is to be noted in the towing and mooring arrangement plan available on board for the guidance of the Master.

Information provided on the plan is to include in respect of each shipboard fitting:

- location on the ship;
- fitting type;
- SWL;
- purpose (mooring/harbour towing/escort towing); and
- manner of applying towing or mooring line load including limiting fleet angles.

Where the arrangements and details of deck fittings and their supporting hull structures are designed based on the mooring arrangements as permitted in [3.5.4], the following information is to be clearly indicated on the plan:

- the arrangement of mooring lines showing the number of lines (N), together with
- the breaking strength of each mooring line (BS).

This information is to be incorporated into the pilot card in order to provide the pilot with proper information on harbour/escorting operations.

3.2 Anchors

3.2.1 General

The anchoring arrangement is to be such as to prevent the cable from being damaged and fouled. Adequate arrangements are to be provided to secure the anchor under all operational conditions.

The scantlings of anchors are to be in compliance with the following requirements.

Anchors are to be manufactured according to approved plans or recognised standards and are to be tested as indicated in Pt D, Ch 4, Sec 1, [1].

3.2.2 Ordinary anchors

The required mass for each anchor is to be obtained from Tab 1.

The individual mass of a main anchor may differ by ±7% from the mass required for each anchor, provided that the total mass of anchors is not less than the total mass required in Tab 1.

The mass of the head of an ordinary stockless anchor, including pins and accessories, is to be not less than 60% of the total mass of the anchor.

Where a stock anchor is provided, the mass of the anchor, excluding the stock, is to be not less than 80% of the mass required in Tab 1 for a stockless anchor. The mass of the stock is to be not less than 25% of the mass of the anchor without the stock but including the connecting shackle.

3.2.3 High and super high holding power anchors

High holding power (HHP) and super high holding power (SHHP) anchors, i.e. anchors for which a holding power higher than that of ordinary anchors has been proved according to Pt D, Ch 4, Sec 1, [1], do not require prior adjustement or special placement on the sea bottom.

Where HHP or SHHP anchors are used as bower anchors, the mass of each anchor is to be not less than 75% or 50%, respectively, of that required for ordinary stockless anchors in Tab 1.

The mass of SHHP anchors is to be, in general, less than or equal to 1500 kg.

3.2.4 Third anchor

Where three anchors are provided, two are to be connected to their own chain cables and positioned on board always ready for use.

The third anchor is intended as a spare and is not required for the purpose of classification.

3.2.5 Test for high holding power anchors approval

For approval and/or acceptance as a HHP anchor, comparative tests are to be performed on various types of sea bottom. Such tests are to show that the holding power of the HHP anchor is at least twice the holding power of an ordinary stockless anchor of the same mass.

For approval and/or acceptance as a HHP anchor of a whole range of mass, such tests are to be carried out on anchors whose sizes are, as far as possible, representative of the full range of masses proposed. In this case, at least two anchors of different sizes are to be tested. The mass of the maximum size to be approved is to be not greater than 10 times the maximum size tested. The mass of the smallest is to be not less than 0,1 times the minimum size tested.

Figure 2 : Ships with perpendicular front bulkhead
Effective area of bulwarks or fixed screen to be included in the Equipment Number

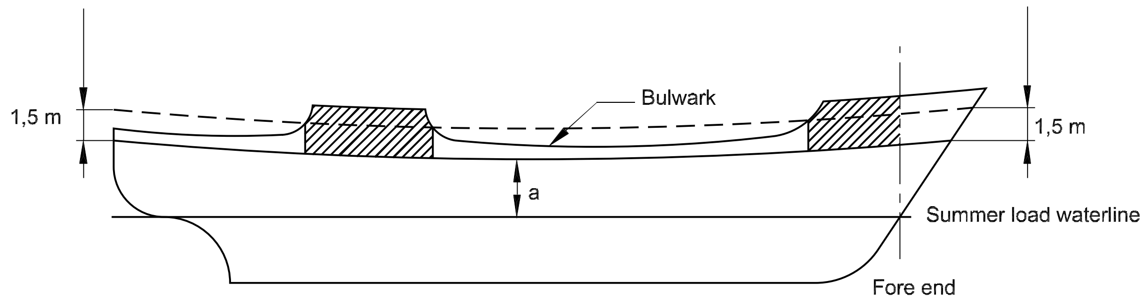
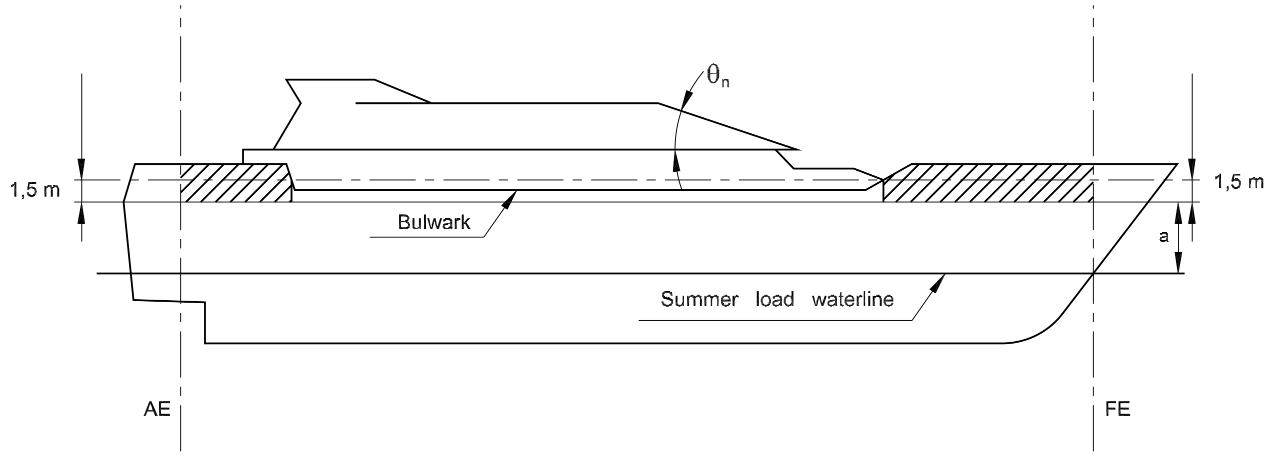


Figure 3 : Ships with inclined front bulkhead
Effective area of bulwarks or fixed screen to be included in the Equipment Number



3.2.6 Test for super high holding power anchors approval

For approval and/or acceptance as a SHHP anchor, comparative tests are to be performed at least on three types of sea bottom: soft mud or silt, sand or gravel and hard clay or similar compounded material. Such tests are to show that the holding power of the SHHP anchor is to be at least four times the holding power of an ordinary stockless anchor of the same mass or at least twice the holding power of a previously approved HHP anchor of the same mass.

The holding power test load is to be less than or equal to the proof load of the anchor, specified in Pt D, Ch 4, Sec 1, [1.6].

For approval and/or acceptance as a SHHP anchor of a whole range of mass, such tests are to be carried out on anchors whose sizes are, as far as possible, representative of the full range of masses proposed. In this case, at least three anchors of different sizes are to be tested. relevant to the bottom, middle and top of the mass range.

3.2.7 Specification for test on high holding power and super high holding power anchors

Tests are generally to be carried out from a tug. Shore based tests may be accepted by the Society on a case-by- case basis.

Alternatively, sea trials by comparison with a previous approved anchor of the same type (HHP or SHHP) of the one to be tested may be accepted by the Society on a case-by-case basis.

For each series of sizes, the two anchors selected for testing (ordinary stockless and HHP anchors for testing HHP anchors, ordinary stockless and SHHP anchors or, when ordinary stockless anchors are not available, HHP and SHHP anchors for testing SHHP anchors) are to have approximately the same mass.

The length of chain cable connected to each anchor, having a diameter appropriate to its mass, is to be such that the pull on the shank remains practically horizontal. For this purpose a value of the ratio between the length of the chain cable paid out and the water depth equal to 10 is considered normal. A lower value of this ratio may be accepted by the Society on a case-by-case basis.

Three tests are to be carried out for each anchor and type of sea bottom.

The pull is to be measured by dynamometer; measurements based on the RPM/bollard pull curve of tug may, however, be accepted instead of dynamometer readings.

Note is to be taken where possible of the stability of the anchor and its ease of breaking out.

3.3 Chain cables for anchors

3.3.1 Material

The chain cables are classified as grade Q1, Q2 or Q3 depending on the type of steel used and its manufacture.

The characteristics of the steel used and the method of manufacture of chain cables are to be approved by the Society for each manufacturer. The material from which chain cables are manufactured and the completed chain cables themselves are to be tested in accordance with the applicable requirements of Pt D, Ch 4, Sec 1.

Chain cables made of grade Q1 may not be used with high holding power and super high holding power anchors.

3.3.2 Scantlings of stud link chain cables

The mass and geometry of stud link chain cables, including the links, are to be in compliance with the requirements in Pt D, Ch 4, Sec 1.

The diameter of stud link chain cables is to be not less than the value in Tab 1.

3.3.3 Studless link chain cables

For ships with EN less than 90, studless short link chain cables may be accepted by the Society as an alternative to stud link chain cables, provided that the equivalence in strength is based on proof load, defined in Pt D, Ch 4, Sec 1, [3], and that the steel grade of the studless chain is equivalent to the steel grade of the stud chains it replaces, as defined in [3.3.1].

3.3.4 Chain cable arrangement

Chain cables are to be made by lengths of 27,5 m each, joined together by Dee or lugless shackles.

The total length of chain cable, required in Tab 1, is to be divided in approximately equal parts between the two anchors ready for use.

Where different arrangements are provided, they are considered by the Society on a case-by-case basis.

Where the ship may anchor in areas with current speed greater than 2,5 m/s, the Society may require a length of heavier chain cable to be fitted between the anchor and the rest of the chain in order to enhance anchor bedding.

3.3.5 Wire ropes

As an alternative to the stud link or short link chain cables mentioned, wire ropes may be used in the following cases:

- wire ropes for both the anchors, for ship length less than 30 m,
- wire rope for one of the two anchors, for ship length between 30 m and 40 m,
- wire ropes for both the anchors, for ships with restricted navigation notations and having special anchoring design and operational characteristics, to be considered on a case-by-case basis taking into account the operational and safety aspects; in any case, the weight of the anchors is to be 1,25 times the value required according to Tab 1.

The wire ropes above are to have a total length equal to 1,5 times the corresponding required length of stud link chain cables, obtained from Tab 1, and a minimum breaking load equal to that given for the corresponding stud link chain cable (see [3.3.2]).

Unless incompatible with the anchor operation, to be evaluated on a case-by-case basis, a short length of chain cable is to be fitted between the wire rope and the anchor, having a length equal to 12,5m or the distance from the anchor in the stowed position to the winch, whichever is the lesser.

3.4 Attachment pieces

3.4.1 General

Where the lengths of chain cable are joined to each other by means of shackles of the ordinary Dee type, the anchor may be attached directly to the end link of the first length of chain cable by a Dee type end shackle.

A detachable open link in two parts riveted together may be used in lieu of the ordinary Dee type end shackle; in such case the open end link with increased diameter, defined in [3.4.2], is to be omitted.

Where the various lengths of chain cable are joined by means of lugless shackles and therefore no special end and increased diameter links are provided, the anchor may be attached to the first length of chain cable by a special pear-shaped lugless end shackle or by fitting an attachment piece.

3.4.2 Scantlings

The diameters of the attachment pieces, in mm, are to be not less than the values indicated in Tab 2.

Attachment pieces may incorporate the following items between the increased diameter stud link and the open end link:

- swivel, having diameter = 1,2 d
- increased stud link, having diameter = 1,1 d

Where different compositions are provided, they will be considered by the Society on a case-by-case basis.

Table 2 : Diameters of attachment pieces

Attachment piece	Diameter, in mm
End shackle	1,4 d
Open end link	1,2 d
Increased stud link	1,1 d
Common stud link	d
Lugless shackle	d
Note 1: d : diameter, in mm, of the common link.	

3.4.3 Material

Attachment pieces, joining shackles and end shackles are to be of such material and design as to provide strength equivalent to that of the attached chain cable, and are to be tested in accordance with the applicable requirements of Pt D, Ch 4, Sec 1.

3.4.4 Spare attachment pieces

A spare pear-shaped lugless end shackle or a spare attachment piece is to be provided for use when the spare anchor is fitted in place.

3.5 Towlines and mooring lines

3.5.1 General

The towlines having the characteristics defined in Tab 3 are intended as those belonging to the ship to be towed by a tug or another ship.

3.5.2 Materials

Towlines and mooring lines may be of wire, natural or synthetic fibre or a mixture of wire and fibre.

The breaking loads defined in Tab 3 refer to steel wires or natural fibre ropes.

Steel wires and fibre ropes are to be tested in accordance with the applicable requirements in Pt D, Ch 4, Sec 1.

3.5.3 Steel wires

Steel wires are to be made of flexible galvanised steel and are to be of types defined in Tab 4.

Where the wire is wound on the winch drum, steel wires to be used with mooring winches may be constructed with an independent metal core instead of a fibre core. In general such wires are to have not less than 186 threads in addition to the metallic core.

3.5.4 Number of mooring lines

When the breaking load of each mooring line is greater than 490kN, either a greater number of mooring lines than those required in Tab 3 having lower strength or a lower number of mooring lines than those required in Tab 3 having greater strength may be used, provided the total breaking load of all lines aboard the ship is greater than the value defined in Tab 3.

In any case, the number of lines is to be not less than 6 and the breaking load of each line is to be greater than 490kN.

See also [3.1.16].

3.5.5 Length of mooring lines

The length of individual mooring lines may be reduced by up to 7% of the length defined in Tab 3, provided that the total length of mooring lines is greater than that obtained by adding the lengths of the individual lines defined in Tab 3.

3.5.6 Equivalence between the breaking loads of synthetic and natural fibre ropes

Generally, fibre ropes are to be made of polyamide or other equivalent synthetic fibres.

The equivalence between the breaking loads of synthetic fibre ropes B_{LS} and of natural fibre ropes B_{LN} is to be obtained, in kN, from the following formula:

$$B_{LS} = 7{,}4\ \delta\ B_{LN}^{8/9}$$

where:

δ : elongation to breaking of the synthetic fibre rope, to be assumed not less than 30%.

3.5.7 Length of mooring lines for supply vessels

For ships with the service notation **supply vessel**, the length of mooring lines may be reduced. The reduced length ℓ is to be not less than that obtained, in m, from the following formula:

$$\ell = L + 20$$

Table 3 : Towlines and mooring lines

Equipment number EN A< EN ≤ B		Towline **(1)**		Mooring lines		
A	B	Minimum length, in m	Breaking load, in kN	N **(2)**	Length of each line, in m	Breaking load, in kN
50	70	180	98,1	3	80	34
70	90	180	98,1	3	100	37
90	110	180	98,1	3	110	39
110	130	180	98,1	3	110	44
130	150	180	98,1	3	120	49
150	175	180	98,1	3	120	54
175	205	180	112	3	120	59
205	240	180	129	4	120	64
240	280	180	150	4	120	69
280	320	180	174	4	140	74
320	360	180	207	4	140	78
360	400	180	224	4	140	88
400	450	180	250	4	140	98
450	500	180	277	4	140	108
500	550	190	306	4	160	123
550	600	190	338	4	160	132
600	660	190	371	4	160	147
660	720	190	406	4	160	157
720	780	190	441	4	170	172
780	840	190	480	4	170	186
840	910	190	518	4	170	201
910	980	190	550	4	170	216
980	1060	200	603	4	180	230
1060	1140	200	647	4	180	250
1140	1220	200	692	4	180	270
1220	1300	200	739	4	180	284
1300	1390	200	786	4	180	309
1390	1480	200	836	4	180	324
1480	1570	220	889	5	190	324

(1) The towline is not compulsory. It is recommended for ships having length not greater than 180 m.
(2) See [3.5.7].

Equipment number EN A< EN ≤ B		Towline (1)		Mooring lines		
A	B	Minimum length, in m	Breaking load, in kN	N (2)	Length of each line, in m	Breaking load, in kN
1570	1670	220	942	5	190	333
1670	1790	220	1024	5	190	353
1790	1930	220	1109	5	190	378
1930	2080	220	1168	5	190	402
2080	2230	240	1259	5	200	422
2230	2380	240	1356	5	200	451
2380	2530	240	1453	5	200	481
2530	2700	260	1471	6	200	481
2700	2870	260	1471	6	200	490
2870	3040	260	1471	6	200	500
3040	3210	280	1471	6	200	520
3210	3400	280	1471	6	200	554
3400	3600	280	1471	6	200	588
3600	3800	300	1471	6	200	612
3800	4000	300	1471	6	200	647
4000	4200	300	1471	7	200	647
4200	4400	300	1471	7	200	657
4400	4600	300	1471	7	200	667
4600	4800	300	1471	7	200	677
4800	5000	300	1471	7	200	686
5000	5200	300	1471	8	200	686
5200	5500	300	1471	8	200	696
5500	5800	300	1471	8	200	706
5800	6100	300	1471	9	200	706
6100	6500			9	200	716
6500	6900			9	200	726
6900	7400			10	200	726
7400	7900			11	200	726
7900	8400			11	200	735
8400	8900			12	200	735
8900	9400			13	200	735
9400	10000			14	200	735
10000	10700			15	200	735
10700	11500			16	200	735
11500	12400			17	200	735
12400	13400			18	200	735
13400	14600			19	200	735
14600	16000			21	200	735

(1) The towline is not compulsory. It is recommended for ships having length not greater than 180 m.
(2) See [3.5.7].

Table 4 : Steel wire composition

Breaking load B_L ,in kN	Steel wire components		
	Number of threads	Ultimate tensile strength of threads, in N/mm²	Composition of wire
$B_L < 216$	72	1420 ÷ 1570	6 strands with 7-fibre core
$216 < B_L < 490$	144	1570 ÷ 1770	6 strands with 7-fibre core
$B_L > 490$	216 or 222	1770 ÷ 1960	6 strands with 1-fibre core

3.6 Hawse pipes

3.6.1 Hawse pipes are to be built according to sound marine practice.

Their position and slope are to be so arranged as to create an easy lead for the chain cables and efficient housing for the anchors, where the latter are of the retractable type, avoiding damage to the hull during these operations.

For this purpose chafing lips of suitable form with ample lay-up and radius adequate to the size of the chain cable are to be provided at the shell and deck. The shell plating in way of the hawse pipes is to be reinforced as necessary.

Table 5 : Additional mooring lines

A/EN	Number of additional mooring lines
0,9 < A/EN ≤ 1,1	1
1,1 < A/EN ≤ 1,2	2
1,2 < A/EN	3
Note 1: A and EN are defined in [2.1.2].	

3.6.2 In order to obtain an easy lead of the chain cables, the hawse pipes may be provided with rollers. These rollers are to have a nominal diameter not less than 10 times the size of the chain cable where they are provided with full imprints, and not less than 12 times its size where provided with partial imprints only.

3.6.3 All mooring units and accessories, such as timbler, riding and trip stoppers are to be securely fastened to the Surveyor's satisfaction.

3.7 Windlass

3.7.1 General

The windlass, which is generally single, is to be power driven and suitable for the size of chain cable and the mass of the anchors.

In mechanically propelled ships of less than 200 t gross tonnage, a hand-operated windlass may be fitted. In such case it is to be so designed as to be capable of weighing the anchors in a reasonably short time.

The windlass is to be fitted in a suitable position in order to ensure an easy lead of the chain cables to and through the hawse pipes. The deck in way of the windlass is to be suitably reinforced.

3.7.2 Assumptions for the calculation of the continuous duty pull

The calculation of the continuous duty pull P_C that the windlass unit prime mover is to be able to supply is based on the following assumptions:

- ordinary stockless anchors,
- wind force equal to 6 on Beaufort Scale,
- water current velocity 3 knots,
- anchorage depth 100 m,
- P_C includes the influences of buoyancy and hawse pipe efficiency; the latter is assumed equal to 70%,
- the anchor masses assumed are those defined in Pt D, Ch 4, Sec 1, excluding tolerances,
- only one anchor is assumed to be raised at a time.

Owing to the buoyancy, the chain masses assumed are smaller than those defined in Pt D, Ch 4, Sec 1, and are obtained, per unit length of the chain cable, in kg/m, from the following formula:

$m_L = 0,0218\ d^2$

where d is the chain cable diameter, in mm.

3.7.3 Calculation of the continuous duty pull

According to the assumptions in [3.7.2], the windlass unit prime mover is to be able to supply for a least 30 minutes a continuous duty pull P_C to be obtained, in kN, from Tab 6.

Table 6 : Continuous duty pull

Material of chain cables	Continuous duty pull, in kN
Mild steel	$P_C = 0,0375\ d^2$
High tensile strength steel	$P_C = 0,0425\ d^2$
Very high tensile strength steel	$P_C = 0,0475\ d^2$
Note 1: d : chain cable diameter, in mm.	

3.7.4 Temporary overload capacity

The windlass unit prime mover is to provide the necessary temporary overload capacity for breaking out the anchor.

The temporary overload capacity, or short term pull, is to be not less than 1,5 times the continuous duty pull P_C and it is to be provided for at least two minutes.

The speed in this overload period may be lower than the nominal speed specified in [3.7.5].

3.7.5 Nominal hoisting speed

The nominal speed of the chain cable when hoisting the anchor and cable, to be assumed as an average speed, is to be not less than 0,15 m/s.

The speed is to be measured over two shots of chain cable during the entire trip; the trial is to commence with 3 shots (82,5 m) of chain fully submerged.

3.7.6 Windlass brake

A windlass brake is to be provided having sufficient capacity to stop the anchor and chain cable when paying out the latter with safety, in the event of failure of the power supply to the prime mover. Windlasses not actuated by steam are also to be provided with a non-return device.

A windlass with brakes applied and the cable lifter declutched is to be able to withstand a pull of 45% of the breaking load of the chain without any permanent deformation of the stressed parts or brake slip.

3.7.7 Chain stoppers

Where a chain stopper is fitted, it is to be able to withstand a pull of 80% of the breaking load of the chain.

Where a chain stopper is not fitted, the windlass is to be able to withstand a pull of 80% of the breaking load of the chain without any permanent deformation of the stressed part or brake slip.

3.7.8 Green sea loads

For ships of length 80 m or more, where the height of the exposed deck in way of the item is less than 0,1L or 22 m above the summer load waterline, whichever is the lesser, the securing devices of windlasses located within the forward quarter length of the ship are to resist green sea forces.

The green sea pressure and associated areas are to be taken equal to (see Fig 4):

- 200 kN/m² normal to the shaft axis and away from the forward perpendicular, over the projected area in this direction,
- 150 kN/m² parallel to the shaft axis and acting both inboard and outboard separately, over the multiple of f times the projected area in this direction,

where:

f	:	1+ B/H, but not greater than 2,5
B	:	width of windlass measured parallel to the shaft axis,
H	:	overall height of windlass.

Where mooring winches are integral with the anchor windlass, they are to be considered as part of the windlass.

3.7.9 Forces in the securing devices of windlasses due to green sea loads

Forces in the bolts, chocks and stoppers securing the windlass to the deck are to be calculated by considering the green sea loads specified in [3.7.8].

The windlass is supported by N bolt groups, each containing one or more bolts (see also Fig 5).

The axial force R_i in bolt group (or bolt) i, positive in tension, is to be obtained, in kN, from the following formulae:

$R_{xi} = P_x h_{xi} A_i / I_x$

$R_{yi} = P_y h_{yi} A_i / I_y$

and $R_i = R_{xi} + R_{yi} - R_{si}$

where:

P_x	:	force, in kN, acting normal to the shaft axis
P_y	:	force, in kN, acting parallel to the shaft axis, either inboard or outboard, whichever gives the greater force in bolt group i
H	:	shaft height, in cm, above the windlass mounting
x_i , y_i	:	x and y co-ordinates, in cm, of bolt group i from the centroid of all N bolt groups, positive in the direction opposite to that of the applied force
A_i	:	cross-sectional area, in cm², of all bolts in group i
I_x	:	$\Sigma A_i x_i^2$ for N bolt groups
I_y	:	$\Sigma A_i y_i^2$ for N bolt groups
R_{si}	:	static reaction, in kN, at bolt group i, due to weight of windlass.

Shear forces F_{xi} , F_{yi} applied to the bolt group i, and the resultant combined force F_i are to be obtained, in kN, from the following formulae:

$F_{xi} = (P_x - \alpha g M) / N$

$F_{yi} = (P_y - \alpha g M) / N$

and

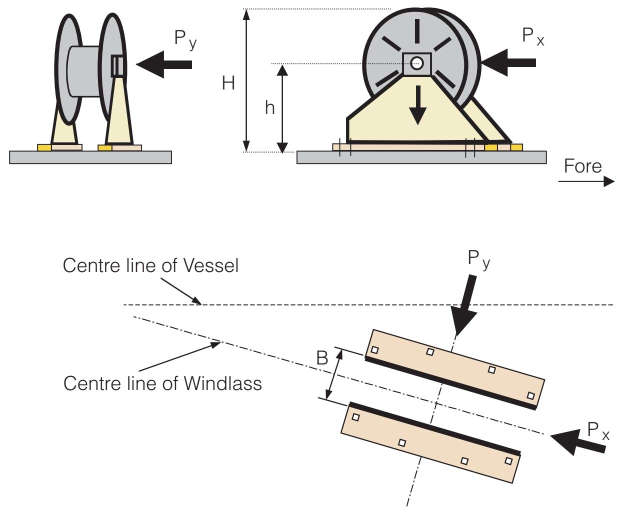
$F_i = (F_{xi}^2 + F_{yi}^2)^{0,5}$

where:

α	:	coefficient of friction, to be taken equal to 0,5
M	:	mass, in t, of windlass
g	:	gravity acceleration, in m/s², to be taken equal to 9,81 m/s²
N	:	number of bolt groups.

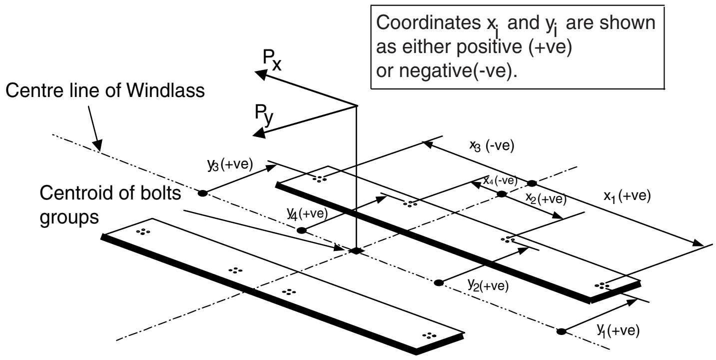
Axial tensile and compressive forces and lateral forces calculated according to these requirements are also to be considered in the design of the supporting structure.

Figure 4 : Direction of Forces and Weight



Note: Py to be examined from both inboard and outboard directions separately - see [3.7.8]. The sign convention for yi is reversed when Py is from the opposite direction as shown.

Figure 5 : Sign Convention



3.7.10 Strength criteria for windlass subject to anchor and chain loads

The stresses on the parts of the windlass, its frame and stopper are to be less than the yield stress of the material used.

For the calculation of the above stresses, special attention is to be paid to:

- stress concentrations in keyways and other stress raisers,
- dynamic effects due to sudden starting or stopping of the prime mover or anchor chain,
- calculation methods and approximation.

3.7.11 Strength criteria for securing devices of windlass

Tensile axial stresses in the individual bolts in each bolt group i are to be calculated according to the requirements specified in [3.7.9]. The horizontal forces F_{xi} and F_{yi}, to be calculated according to the requirements specified in [3.7.9], are normally to be reacted by shear chocks.

Where "fitted" bolts are designed to support these shear forces in one or both directions, the equivalent Von Mises stress σ, in N/mm², in the individual bolt is to comply with following formula:

$\sigma \leq 0,5\ \sigma_{BPL}$

where σ_{BPL} is the stress in the bolt considered as being loaded by the proof load.

Where pourable resins are incorporated in the holding down arrangements, due account is to be taken in the calculations.

3.7.12 Connection with deck

The windlass, its frame and the stoppers are to be efficiently bedded to the deck.

3.8 Chain stoppers

3.8.1 A chain stopper is generally to be fitted between the windlass and the hawse pipe in order to relieve the windlass of the pull of the chain cable when the ship is at anchor. A chain stopper is to be capable of withstanding a pull of 80% of the breaking load of the chain cable. The deck at the chain stopper is to be suitably reinforced.

For the same purpose, a piece of chain cable may be used with a rigging screw capable of supporting the weight of the anchor when housed in the hawse pipe or a chain tensioner. Such arrangements are not to be considered as chain stoppers.

3.8.2 Where the windlass is at a distance from the hawse pipes and no chain stoppers are fitted, suitable arrangements are to be provided to lead the chain cables to the windlass.

3.9 Chain locker

3.9.1 The capacity of the chain locker is to be adequate to stow all chain cable equipment and provide an easy direct lead to the windlass.

3.9.2 Where two chains are used, the chain lockers are to be divided into two compartments, each capable of housing the full length of one line.

3.9.3 The inboard ends of chain cables are to be secured to suitably reinforced attachments in the structure by means of end shackles, whether or not associated with attachment pieces.

Generally, such attachments are to be able to withstand a force not less than 15% of the breaking load of the chain cable.

In an emergency, the attachments are to be easily released from outside the chain locker.

3.9.4 Where the chain locker is arranged aft of the collision bulkhead, its boundary bulkheads are to be watertight and a drainage system is to be provided.

3.10 Fairleads and bollards

3.10.1 Fairleads and bollards of suitable size and design are to be fitted for towing, mooring and warping operations.

4 Emergency towing arrangements

4.1 Definitions

4.1.1 Deadweight

Deadweight is the difference, in t, between the displacement of a ship in water of a specific gravity of 1,025 t/m³ at the load waterline corresponding to the assigned summer freeboard and the lightweight of the ship.

4.2 General and application

4.2.1 This Article applies to ships which are to comply with Regulation 3-4 of Chapter II-1 of SOLAS Convention. It concerns the equipment arrangements for towing ships out of danger in emergencies such as complete mechanical breakdowns, loss of power or loss of steering capability.

4.2.2 An emergency towing arrangement is to be fitted at both ends on board of ships of 20000 t deadweight and above with one of the following service notations:

- **oil tanker ESP**,
- **FLS tanker**.

4.3 Documentation

4.3.1 Documentation for approval

In addition to the documents in Ch 1, Sec 3, the following documentation is to be submitted to the Society for approval:

- general layout of the bow and stern towing arrangements and associated equipment,
- operation manual for the bow and stern towing arrangements,
- construction drawings of the bow and stern strongpoints (towing brackets or chain cable stoppers) and fairleads (towing chocks), together with material specifications and relevant calculations,
- drawings of the local ship structures supporting the loads applied by strongpoints, fairleads and roller pedestals.

4.3.2 Documentation for information

The following documentation is to be submitted to the Society for information (see Ch 1, Sec 3):

- specifications of chafing gears, towing pennants, pick-up gears and roller fairleads,
- height, in m, of the lightest seagoing ballast freeboard measured at stern towing fairlead,
- deadweight, in t, of the ship at summer load line.

4.4 General

4.4.1 Scope

The emergency towing arrangements are to be so designed as to facilitate salvage and emergency towing operations on the concerned ship, primarily to reduce the risk of pollution.

4.4.2 Main characteristics

The emergency towing arrangements are, at all times, to be capable of rapid deployment in the absence of main power on the ship to be towed and easy connection to the towing ship. At least one of the emergency towing arrangements is to be pre-rigged for rapid deployment.

To demonstrate such rapid and easy deployment, the emergency towing arrangements are to comply with the requirements in [4.12].

To this end, the emergency towing arrangements are to comply with the requirements in [4.6] to [4.11].

Emergency towing arrangements at both ends are to be of adequate strength taking into account the size and deadweight of the ship and the expected forces during bad weather conditions.

4.4.3 Typical layout

Fig 6 shows an emergency towing arrangement which may be used as reference.

4.4.4 List of major components

The major components of the towing arrangements, their position on board and the requirements of this Article which they are to comply with are defined in Tab 7.

4.4.5 Inspection and maintenance

All the emergency towing arrangement components are to be inspected by ship personnel at regular intervals and maintained in good working order.

Figure 6 : Typical emergency towing arrangement

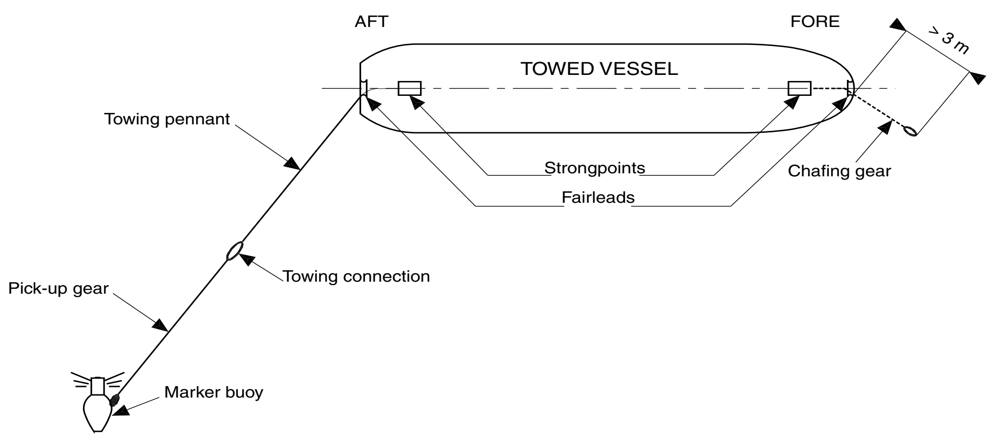


Table 7 : Major components of the emergency towing arrangement

Towing component	Non-pre-rigged	Pre-rigged	Reference of applicable requirements
Towing pennant	Optional	Required	[4.7]
Fairlead	Required	Required	[4.9]
Strongpoint (inboard end fastening of the towing gear)	Required	Required	[4.10]
Pick-up gear	Optional	Required	No requirements
Pedestal roller fairlead	Required	Depending on design	No requirements
Chafing gear	Required	Depending on design	[4.8]

4.5 Emergency towing arrangement approval

4.5.1 General

Emergency towing arrangements of ships are to comply with the following requirements:

- they are to comply with the requirements of this item,
- they are to be type approved according to the requirements in [4.13],
- Certificates of inspection of materials and equipment are to be provided according to [4.13.2],
- fitting on board of the emergency towing arrangements is to be witnessed by a Surveyor of the Society and a relevant Certificate is to be issued,
- demonstration of the rapid deployment according to the criteria in [4.12] is to be effected for each ship and this is to be reported in the above Certificate.

4.5.2 Alternative to testing the rapid deployment for each ship

At the request of the Owner, the testing of the rapid deployment for each ship according to [4.5.1] may be waived provided that:

- the design of emergency towing arrangements of the considered ship is identical to the type approved arrangements and this is confirmed by the on board inspection required in [4.5.1],
- the strongpoints (chain stoppers, towing brackets or equivalent fittings) are type approved (prototype tested).

In this case, an exemption certificate is to be issued.

In general, such dispensation may be granted to subsequent ships of a series of identical new buildings fitted with identical arrangements.

pennants MBS_{PC} is to be not less than that obtained, in kN,

4.6 Safe working load (SWL) of towing pennants, chafing gears, fairleads and strongpoints

4.6.1 Safe working load

The safe working load (defined as one half of the ultimate strength) of towing pennants, chafing gear, fairleads and strongpoints is to be not less than that obtained, in kN, from Tab 8.

The strength of towing pennants, chafing gear, fairleads and strongpoints is to be sufficient for all pulling angles of the towline, i.e. up to 90° from the ship's centreline to port and starboard and 30° vertical downwards.

The safe working load of other components is to be sufficient to withstand the load to which such components may be subjected during the towing operation.

Table 8 : Safe working load

Ship deadweight DWT, in t	Safe working load,in kN
$20000 \leq DWT < 50000$	1000
$DWT \geq 50000$	2000

4.7 Towing pennant

4.7.1 Material

The towing pennant may be made of steel wire rope or synthetic fibre rope, which is to comply with the applicable requirements in Pt D, Ch 4, Sec 1.

4.7.2 Length of towing pennant

The length ℓ_P of the towing pennant is to be not less than that obtained, in m, from the following formula:

$$\ell_P = 2H + 50$$

where:

H : lightest seagoing ballast freeboard measured, in m, at the fairlead.

4.7.3 Minimum breaking strength of towing pennants when separate chafing gear is used

Where a separate chafing gear is used, the minimum breaking strength MBS_p of towing pennants, including their terminations, is to be not less than that obtained from the following formula:

$$MBS_P = 2\ \mu\ SWL$$

where:

μ : coefficient that accounts for the possible loss in strength at eye terminations, to be taken not less than 1,1

SWL : safe working load of the towing pennants, defined in [4.6.1].

4.7.4 Minimum breaking strength of towing pennants when no separate chafing gear is used

Where no separate chafing gear is used (i.e. where the towing pennant may chafe against the fairlead during towing operation), the minimum breaking strength of the towing from the following formula:

$MBS_{PC} = \varphi \, MBS_P$

where:

MBS_P : minimum breaking strength, in kN, defined in [4.7.3],

φ : coefficient to be taken equal to:

$$\varphi = \frac{2\sqrt{\rho}}{2\sqrt{\rho} - 1}$$

φ may be taken equal to 1,0 if tests carried out under a test load equal to twice the safe working load defined in [4.6.1] demonstrate that the strength of the towing pennants is satisfactory,

ρ : bending ratio (ratio between the minimum bearing surface diameter of the fairlead and the towing pennant diameter), to be taken not less than 7.

4.7.5 Towing pennant termination

For towing connection, the towing pennant is to have a hard eye-formed termination allowing connection to a standard shackle.

Socketed or ferrule-secured eye terminations of the towing pennant are to be type tested in order to demonstrate that their minimum breaking strength is not less than twice the safe working load defined in [4.6.1].

4.8 Chafing gear

4.8.1 General

Different solutions for the design of chafing gear may be used.

If a chafing chain is to be used, it is to have the characteristics defined in the following requirements.

4.8.2 Type

Chafing chains are to be stud link chains.

Chafing chains are to be designed, manufactured, tested and certified in accordance with the requirements in Pt D, Ch 4, Sec 1.

Chafing chains are to be manufactured by works approved by the Society in accordance with the requirements in Pt D, Ch 4, Sec 1.

4.8.3 Material

The materials used for the manufacture of the chafing chain and associated accessories are to comply with the requirements in Pt D, Ch 4, Sec 1.

The common link is to be of grade Q2 or Q3.

4.8.4 Chafing chain length

The chafing chain is to be long enough to ensure that the towing pennant, or the towline, remains outside the fairlead during the towing operation. A chain extending from the strongpoint to a point at least 3m beyond the fairlead complies with this requirement.

4.8.5 Minimum breaking strength

The minimum breaking strength of the stud link chafing chain and the associated links is to be not less than twice the safe working load defined in [4.6.1].

4.8.6 Diameter of the common links

The nominal diameter of the common links for chafing chains is to be not less than the values indicated in Tab 9.

Table 9 : Nominal diameter of common links for chafing chains

Safe working load, in kN; refer to [4.6.1]	Nominal diameter, in mm	
	Grade Q2	Grade Q3
1000	62	52
2000	90	76

4.8.7 Chafing chain ends

One end of the chafing chain is to be suitable for connection to the strongpoint. Where a chain stopper is used, the inboard end of the chafing chain is to be efficiently secured in order to prevent any inadvertent loss of the chafing chain when operating the stopping device. Where the chafing chain is connected to a towing bracket, the corresponding chain end may be constructed as shown in Fig 7, but the inner dimension of the pear link may be taken as 5,30d (instead of 5,75d).

The other end of the chafing chain is to be fitted with a standard pear-shaped open link allowing connection to a standard bow shackle. A typical arrangement of this chain end is shown in Fig 7. Arrangements different than that shown in Fig 7 are considered by the Society on a case-by-case basis.

4.8.8 Storing

The chafing chain is to be stored and stowed in such a way that it can be rapidly connected to the strongpoint.

4.9 Fairleads

4.9.1 General

Fairleads are normally to be of a closed type (such as Panama chocks).

Fairleads are to have an opening large enough to pass the largest portion of the chafing gear, towing pennant or towline. The corners of the opening are to be suitably rounded.

Where the fairleads are designed to pass chafing chains, the openings are to be not less than 600mm in width and 450mm in height.

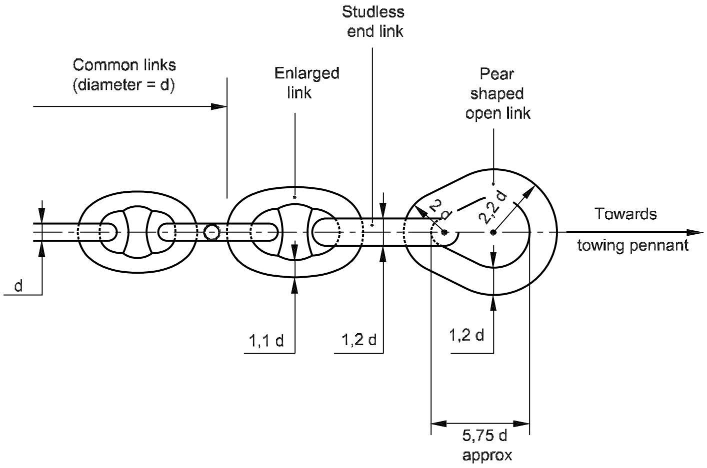
4.9.2 Material

Fairleads are to be made of fabricated steel plates or other ductile materials such as weldable forged or cast steel complying with the applicable requirements of Part D, Chapter 2.

4.9.3 Operating condition

The bow and stern fairleads are to give adequate support for the towing pennant during towing operation, which means bending 90° to port and and starboard side and 30° vertical downwards.

Figure 7 : Typical outboard chafing chain end



4.9.4 Positioning

The bow and stern fairleads are to be located so as to facilitate towing from either side of the bow or stern and minimise the stress on the towing system.

The bow and stern fairleads are to be located as close as possible to the deck and, in any case, in such a position that the chafing chain is approximately parallel to the deck when it is under strain between the strongpoint and the fairlead.

Furthermore, the bow and stern fairleads are normally to be located on the ship's centreline. Where it is practically impossible to fit the towing fairleads exactly on the ship's centreline, it may be acceptable to have them slightly shifted from the centreline.

4.9.5 Bending ratio

The bending ratio (ratio between the towing pennant bearing surface diameter and the towing pennant diameter) is to be not less than 7.

4.9.6 Fairlead lips

The lips of the fairlead are to be suitably faired in order to prevent the chafing chain from fouling on the lower lip when deployed or during towing.

4.9.7 Yielding check

The equivalent Von Mises stress σ_E, in N/mm^2, induced in the fairlead by a load equal to the safe working load defined in [4.6.1], is to comply with the following formula:

$\sigma_E \leq \sigma_{ALL}$

Areas subjected to stress concentrations are considered by the Society on a case-by-case basis.

Where the fairleads are analysed through fine mesh finite element models, the allowable stress may be taken as 1,1 σ_{ALL}.

4.9.8 Alternative to the yielding check

The above yielding check may be waived provided that fairleads are tested with a test load equal to twice the safe working load defined in [4.6.1] and this test is witnessed by a Surveyor of the Society. In this case, the Designer is responsible for ensuring that the fairlead scantlings are sufficient to withstand such a test load.

Unless otherwise agreed by the Society, components subjected to this test load are considered as prototype items and are to be discarded.

4.10 Strongpoint

4.10.1 General

The strongpoint is to be type approved according to [4.13] and is to be clearly marked with its SWL.

The strongpoint (inboard end fastening of the towing gear) is to be a chain cable stopper or a towing bracket or other fitting of equivalent strength and ease of connection. The strongpoint can be designed integral with the fairlead.

4.10.2 Materials

The strongpoint is to be made of fabricated steel or other ductile materials such as forged or cast steel complying with the applicable requirements of Part D, Chapter 2.

Use of spheroidal graphite cast iron (SG iron) may be accepted for the main framing of the strongpoint provided that:

- the part concerned is not intended to be a component part of a welded assembly,
- the SG iron is of ferritic structure with an elongation not less than 12%,
- the yield stress at 0,2% is measured and certified,
- the internal structure of the component is inspected by suitable non-destructive means.

The material used for the stopping device (pawl or hinged bar) of chain stoppers and for the connecting pin of towing brackets is to have mechanical properties not less than those of grade Q3 chain cables, defined in Pt D, Ch 4, Sec 1.

4.10.3 Typical strongpoint arrangement

Typical arrangements of chain stoppers and towing brackets are shown in Fig 8, which may be used as reference.

Chain stoppers may be of the hinged bar type or pawl (tongue) type or of other equivalent design.

4.10.4 Position and operating condition

The operating conditions and the positions of the strongpoints are to comply with those defined in [4.9.3] and [4.9.4], respectively, for the fairleads.

4.10.5 Stopping device

The stopping device (chain engaging pawl or bar) is to be arranged, when in closed position, to prevent the chain stopper from working in the open position, in order to avoid chain cable release and allow it to pay out.

Stopping devices are to be easy and safe to operate and, in the open position, are to be properly secured.

4.10.6 Connecting pin of the towing bracket

The scantlings of the connecting pin of the towing bracket are to be not less than those of a pin of a grade Q3 end shackle, as shown in Fig 8, provided that clearance between the two side lugs of the bracket does not exceed 2,0d, where d is the chain diameter specified in [4.8.6] (see also Fig 7).

4.10.7 Yielding check

The equivalent Von Mises stress σ_E , in N/mm², induced in the strongpoint by a load equal to the safe working load defined in [4.6.1], is to comply with the following formula:

$\sigma_E \leq \sigma_{ALL}$

Areas subjected to stress concentrations are considered by the Society on a case-by-case basis.

Where the strongpoints are analysed through fine mesh finite element models, the allowable stress may be taken as 1,1 σ_{ALL}.

4.10.8 Alternative to the yielding check

The above yielding check may be waived provided that strongpoints are tested with a test load equal to twice the safe working load defined in [4.6.1] and this test is witnessed by a Surveyor. In this case, the Designer is responsible for ensuring that the fairlead scantlings are sufficient to withstand such a test load.

Unless otherwise agreed by the Society, components subjected to this test load are considered as prototype items and are to be discarded.

4.10.9 Bolted connection

Where a chain stopper or a towing bracket is bolted to a seating welded to the deck, the bolts are to be relieved from shear force by means of efficient thrust chocks capable of withstanding a horizontal force equal to 1,3 times the safe working load defined in [4.6.1] within the allowable stress defined in [4.10.7].

The steel quality of bolts is to be not less than grade 8.8 as defined by ISO standard No. 898/1.

Bolts are to be pre-stressed in compliance with appropriate standards and their tightening is to be suitably checked.

4.11 Hull structures in way of fairleads or strongpoints

4.11.1 Materials and welding

The materials used for the reinforcement of the hull structure in way of the fairleads or the strongpoints are to comply with the applicable requirements of Part D.

Main welds of the strongpoints with the hull structure are to be 100% inspected by adequate non-destructive tests.

4.11.2 Yielding check of bulwark and stays

The equivalent Von Mises stress σ_E , in N/mm², induced in the bulwark plating and stays in way of the fairleads by a load equal to the safe working load defined in [4.6.1], for the operating condition of the fairleads defined in [4.9.3], is to comply with the following formula:

$\sigma_E \leq \sigma_{ALL}$

4.11.3 Yielding check of deck structures

The equivalent Von Mises stress σ_E , in N/mm², induced in the deck structures in way of chain stoppers or towing brackets, including deck seatings and deck connections, by a horizontal load equal to 1,3 times the safe working load defined in [4.6.1], is to comply with the following formula:

$\sigma_E \leq \sigma_{ALL}$

4.11.4 Minimum gross thickness of deck plating

The gross thickness of the deck is to be not less than:

- 12 mm for a safe working load, defined in [4.6.1], equal to 1000 kN,
- 15 mm for a safe working load, defined in [4.6.1], equal to 2000 kN.

4.12 Rapid deployment of towing arrangement

4.12.1 General

To facilitate approval of towing arrangements and to ensure rapid deployment, emergency towing arrangements are to comply with the requirements of this item.

4.12.2 Marking

All components, including control devices, of the emergency towing arrangements are to be clearly marked to facilitate safe and effective use even in darkness and poor visibility.

4.12.3 Pre-rigged

The pre-rigged emergency towing arrangement is to be capable of being deployed in a controlled manner in harbour conditions in not more than 15 minutes.

The pick-up gear for the pre-rigged towing pennant is to be designed at least for manual operation by one person taking into account the absence of power and the potential for adverse environmental conditions that may prevail during such emergency towing operations.

The pick-up gear is to be protected against the weather and other adverse conditions that may prevail.

4.12.4 Non pre-rigged

The non pre-rigged emergency towing arrangement is to be capable of being deployed in harbour conditions in not more than 1 hour.

The non pre-rigged emergency towing arrangement is to be designed at least with a means of securing a towline to the chafing gear using a suitably positioned pedestal roller to facilitate connection of the towing pennant.

Pre-rigged emergency towing arrangements at both ends of the ship may be accepted.

4.13 Type approval

4.13.1 Type approval procedure

Emergency towing arrangements are to be type approved according to the following procedure:

- the arrangement design is to comply with the requirements of this Section,
- each component of the towing arrangement is to be tested and its manufacturing is to be witnessed and certified by a Surveyor according to [4.13.2],
- prototype tests are to be carried out in compliance with [4.13.3].

4.13.2 Inspection and certification

The materials and equipment are to be inspected and certified as specified in Tab 10.

4.13.3 Prototype tests

Prototype tests are to be witnessed by a Surveyor and are to include the following:

- demonstration of the rapid deployment according to the criteria in [4.12],
- load test of the strongpoints (chain stoppers, towing brackets or equivalent fittings) under a proof load equal to 1,3 times the safe working load defined in [4.6.1].

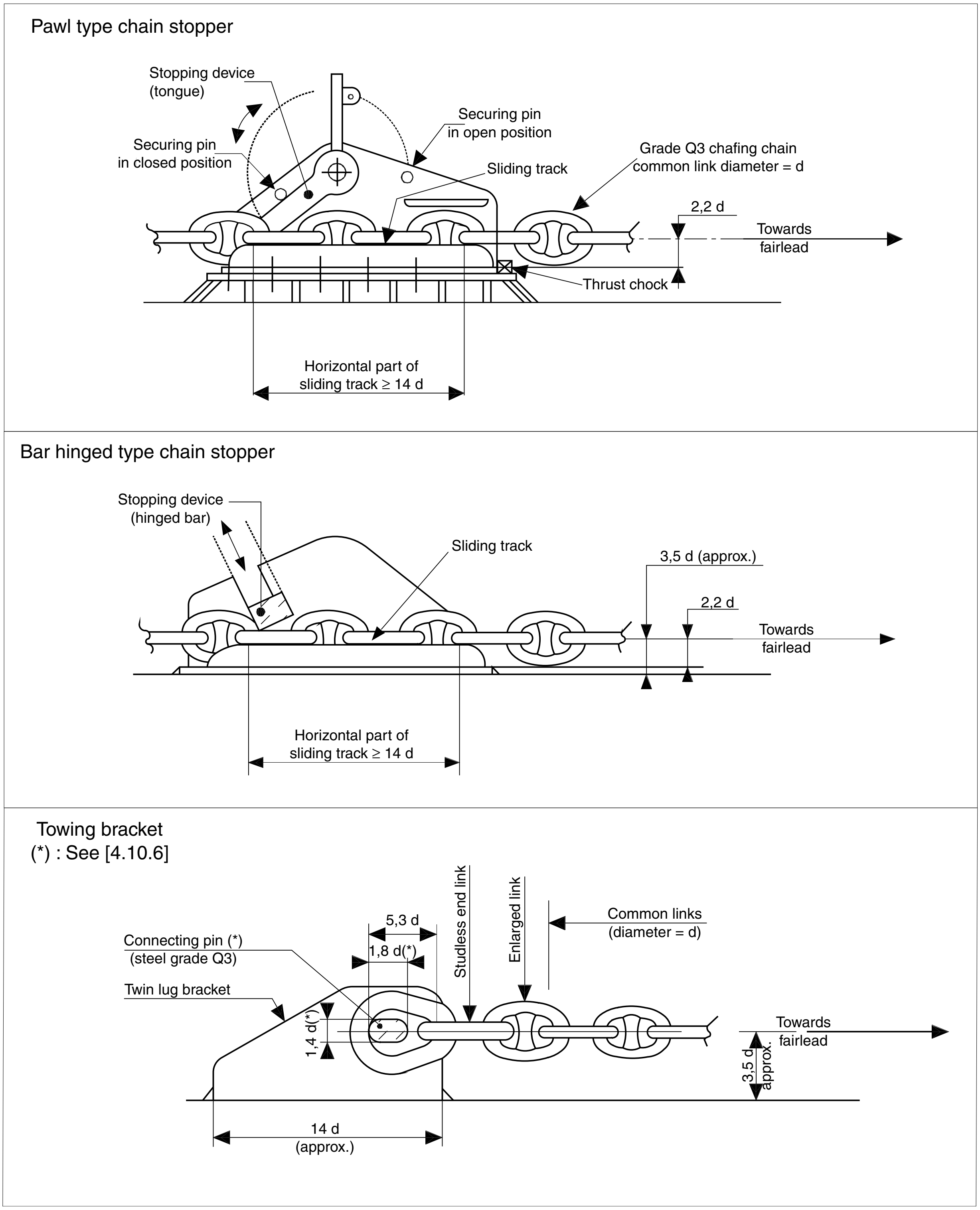
A comprehensive test report duly endorsed by the Surveyor is to be submitted to the Society for review.

Table 10 : Material and equipment certification status

Component	Material		Equipment	
	Certificate	Reference of applicable requirements	Certificate	Reference of applicable requirements
Towing pennant	Not applicable	[4.7.1]	COI **(1)**	[4.7]
Chafing chain and associated accessories	COI **(2)**	[4.8.3]	COI **(1)**	[4.8]
Fairleads	CW	[4.9.2]	COI	[4.9]
Strongpoint: • main framing • stopping device	 COI **(2)** COI **(2)**	 [4.10.2] [4.10.2]	COI **(3)**	[4.10]
Pick-up gear: • rope • buoy • line-throwing appliance	 Not applicable Not applicable Not applicable	 - - -	 CW Not required **(4)** Not required **(4)**	[4.11] [4.11.1] and [4.11.2] [4.11.3] [4.11.4]
Pedestal roller fairlead	CW	-	Not required **(4)**	[4.12]

(1) according to Pt D, Ch 4, Sec 1.
(2) according to Part D, Chapter 1.
(3) to be type approved.
(4) may be type approved.
Note 1:
COI : certificate of inspection,
CW : works' certificate 3.1.B according to EN 10204.

Figure 8 : Typical strongpoint arrangement



APPENDIX 1 CRITERIA FOR DIRECT CALCULATION OF RUDDER LOADS

Symbols

ℓ_{10}, ℓ_{20}, ℓ_{30}, ℓ_{40} : lengths, in m, of the individual girders of the rudder system (see Fig 1, Fig 2 and Fig 3)

ℓ_{50} : llength, in m, of the solepiece (see Fig 2 and Fig 4)

J_{10}, J_{20}, J_{30}, J_{40} : moments of inertia about the x axis, in cm^4, of the individual girders of the rudder system having lengths ℓ_{10}, ℓ_{20}, ℓ_{30}, ℓ_{40} (see Fig 1, Fig 2 and Fig 3). For rudders supported by a solepiece only, J_{20} indicates the moment of inertia of the pintle in the sole piece

J_{50} : moment of inertia about the z axis, in cm^4, of the solepiece (see Fig 2 and Fig 4)

C_R : rudder force, in N, acting on the rudder blade, defined in Sec 1, [2.1.1]

C_{R1}, C_{R2} : rudder forces, in N, defined in Sec 1, [2.2.3].

1 Criteria for direct calculation of the loads acting on the rudder structure

1.1 General

1.1.1 Application

The requirements of this Appendix apply to the following types of rudders:

- spade rudders (see Fig 1),
- 2 bearing rudders with solepiece (see Fig 2),
- 2 bearing semi-spade rudders with rudder horn (see Fig 3).

The requirements of this Appendix provide the criteria for calculating the following loads:

- bending moment M_B in the rudder stock,
- support forces F_A,
- bending moment M_R and shear force Q_R in the rudder body.

1.1.2 Load calculation

The loads in [1.1.1] are to be calculated through direct calculations based on the model specified in Fig 1, Fig 2 and Fig 3, depending on the type of rudder.

They are to be used for the stress analysis required in:

- Sec 1, [4], for the rudder stock,
- Sec 1, [6], for the rudder pintles and the pintle bearings,
- Sec 1, [7] for the rudder blade,
- Sec 1, [8] for the rudder horn and the solepiece.

1.1.3 Specific case of spade rudders

For spade rudders, the results of direct calculations carried out in accordance with [1.1.2] may be expressed in an analytical form. The loads in [1.1.1] may therefore 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 1,

- support forces, in N:

$$F_{A3} = \frac{M_B}{\ell_{30}}$$

$$F_{A1} = C_R + F_{A3}$$

- maximum shear force in the rudder body, in N:

$Q_R = C_R$

1.2 Data for the direct calculation

1.2.1 Forces per unit length

The following forces per unit length are to be calculated, in N/m, according to [1.3]:

- p_R for spade rudders and rudders with solepiece (see Fig 1 and Fig 2, respectively),
- p_{R10} and p_{R20} for semi-spade rudders with rudder horn (see Fig 3).

1.2.2 Spring constant

The following support spring constants are to be calculated, in N/m, according to [1.4]:

- Z_C for rudders with solepiece (see Fig 2),
- Z_P for semi-spade rudders with rudder horn (see Fig 3).

1.3 Force per unit length on the rudder body

1.3.1 Spade rudders and 2 bearing rudders with solepiece

The force per unit length p_R (see Fig 1 and Fig 2) acting on the rudder body is to be obtained, in N/m, from the following formula:

$$p_R = \frac{C_R}{\ell_{10}}$$

1.3.2 2 bearing semi-spade rudders with rudder horn

The forces per unit length p_{R10} and p_{R20} (see Fig 3) acting on the rudder body are to be obtained, in N/m, from the following formulae:

$$p_{R10} = \frac{C_{R2}}{\ell_{10}}$$

$$p_{R20} = \frac{C_{R1}}{\ell_{20}}$$

1.4 Support spring constant

1.4.1 Sole piece

The spring constant Z_C for the support in the solepiece (see Fig 2) is to be obtained, in N/m, from the following formula:

$$Z_C = \frac{6180 J_{50}}{\ell_{50}^3}$$

1.4.2 Rudder horn

The spring constant Z_P for the support in the rudder horn (see Fig 3) is to be obtained, in N/m, from the following formula:

$$Z_P = \frac{1}{f_B + f_T}$$

where:

f_B : unit displacement of rudder horn due to a unit force of 1 N acting in the centroid of the rudder horn, to be obtained, in m/N, from the following formula:

$$f_B = 1{,}3 \frac{d^3}{6180 J_N}$$

d : height, in m, of the rudder horn, defined in Fig 3,

J_N : moment of inertia of rudder horn about the x axis, in cm^4 (see Fig 5),

f_T : unit displacement due to torsion to be obtained, in m/N, from the following formula:

$$f_T = 10^{-8} \frac{de^2}{3140 F_T^2} \sum_i \frac{u_i}{t_i}$$

d, e : lengths, in m, defined in Fig 3

F_T : mean sectional area of rudder horn, in m^2,

u_i : length, in mm, of the individual plates forming the mean horn sectional area,

t_i : thickness of the individual plates mentioned above, in mm.

Figure 1 : Spade rudders

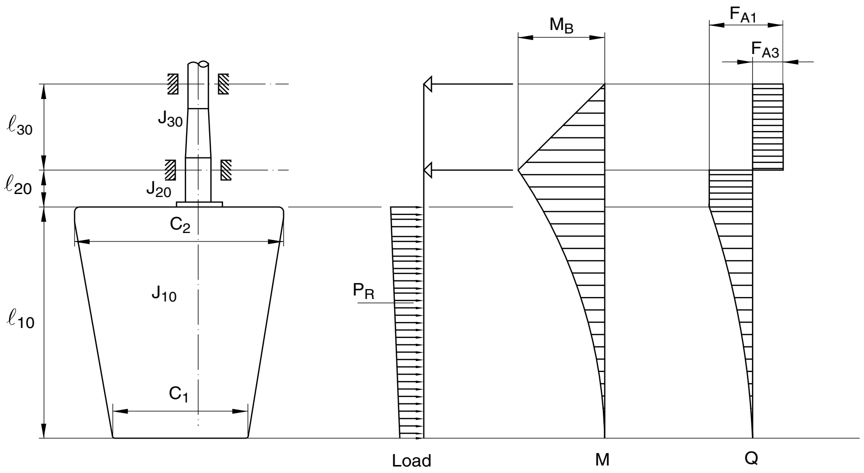


Figure 2 : Two bearing rudders with solepiece

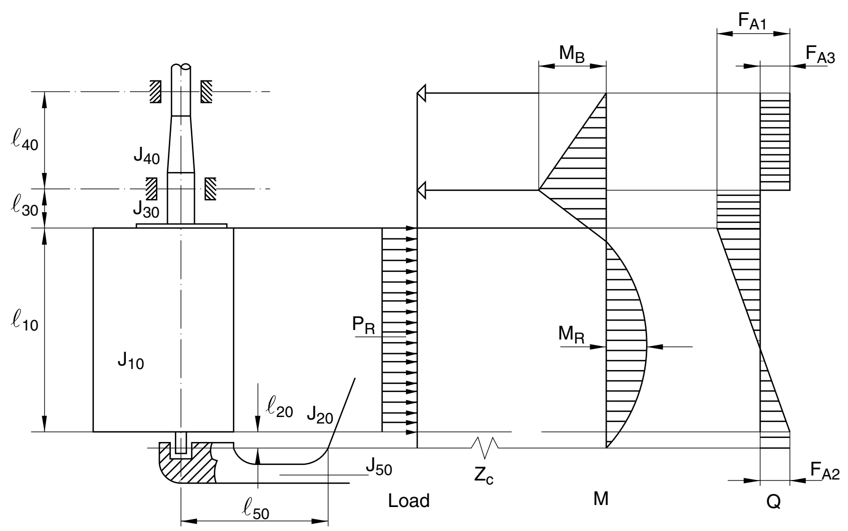


Figure 3 : Two bearing semi-spade rudders with rudder horn

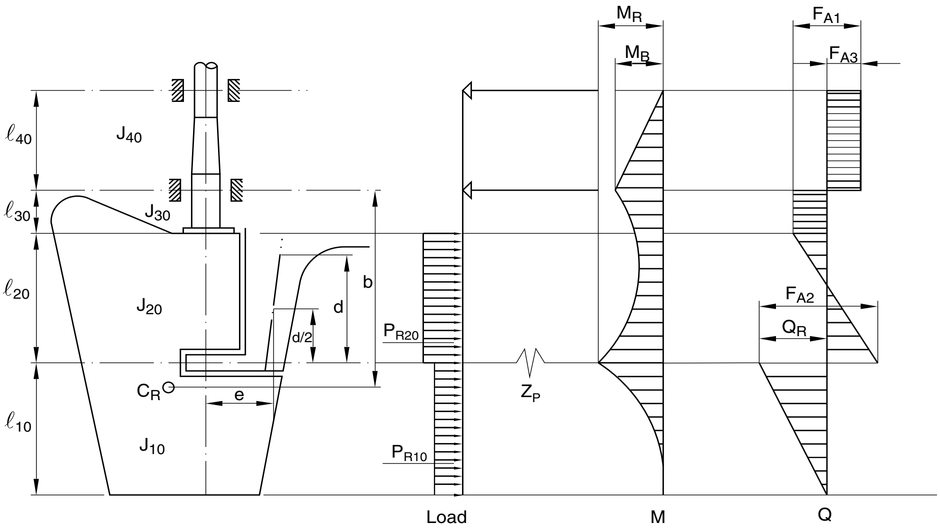


Figure 4 : Solepiece geometry

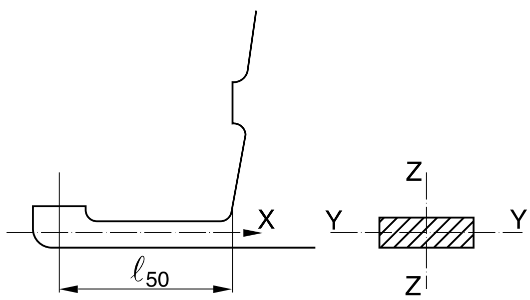
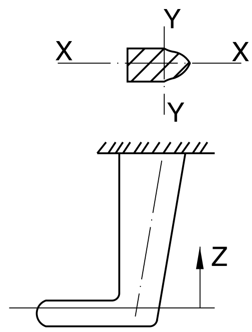


Figure 5 : Rudder horn geometry



Part B
Hull and Stability

Chapter 11
CORROSION PROTECTION AND LOADING INFORMATION

SECTION 1 PROTECTION OF HULL METALLIC STRUCTURES

1 Protection by coating

1.1 General

1.1.1 It is the responsibility of the shipbuilder and the Owner to choose the coating and have it applied in accordance with the manufacturer's requirements.

1.2 Structures to be protected

1.2.1 All salt water ballast spaces with boundaries formed by the hull envelope are to have a corrosion protective coating, epoxy or equivalent, applied in accordance with the manufacturer's requirements.

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

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

2 Cathodic protection

2.1 General

2.1.1 Internal structures in spaces intended to carry liquids may be provided with cathodic protection.

Cathodic protection may be fitted in addition to the required corrosion protective coating, if any.

2.1.2 Details concerning the type of anodes used and their location and attachment to the structure are to be submitted to the Society for approval.

2.2 Anodes

2.2.1

Magnesium or magnesium alloy anodes are not permitted in oil cargo tanks and tanks adjacent to cargo tanks.

2.2.2

Aluminium anodes are only permitted in cargo tanks and tanks adjacent to cargo tanks in locations where the potential energy does not exceed 28 kg m. The height of the anode is to be measured from the bottom of the tank to the centre of the anode, and its weight is to be taken as the weight of the anode as fitted, including the fitting devices and inserts.

However, where aluminium anodes are located on horizontal surfaces such as bulkhead girders and stringers not less than 1 m wide and fitted with an upstanding flange or face flat projecting not less than 75 mm above the horizontal surface, the height of the anode may be measured from this surface.

Aluminium anodes are not to be located under tank hatches or Butterworth openings, unless protected by the adjacent structure.

2.2.3 There is no restriction on the positioning of zinc anodes.

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

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

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

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

2.3 Impressed current systems

2.3.1 Impressed current systems are not permitted in oil cargo tanks.

3 Protection against galvanic corrosion

3.1 General

3.1.1 Non-stainless steel is to be electrically insulated from stainless steel or from aluminium alloys.

3.1.2 Where stainless steel or aluminium alloys are fitted in the same tank as non-stainless steel, a protective coating is to cover both materials.

4 Protection of bottom by ceiling

4.1 General

4.1.1 In double bottom ships, ceiling is to be laid over the inner bottom and lateral bilges, if any.

Ceiling on the inner bottom is not required where the thickness of the inner bottom is increased in accordance with Ch 7, Sec 1, [2.3.1].

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 faclilitate 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 protective composition is applied beforehand.

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

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

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

4.3 Scantlings

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

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

5 Protection of decks by wood sheathing

5.1 General

5.1.1 Where decks are intended to carry specific loads, such as caterpillar trucks and unusual vehicles, the Society may require such decks wood sheathed.

5.2 Arrangement

5.2.1 Wood sheathing is to be fixed to the plating by welded studs or bolts of at least 12 mm in diameter, every second frame.

5.2.2 Before fitting the wood sheathing, deck plates are to be provided with protective coating declared to be suitable by the Shipyard.
Caulking is Shipyard's responsibility.

5.3 Scantlings

5.3.1 The thickness of wood sheathing of decks is to be not less than:

- 65 mm if made of pine
- 50 mm if made of hardwood, such as teak.

The width of planks is not to exceed twice their thickness.

6 Protection of cargo sides by battens

6.1 General

6.1.1 The requirements in [6.2] apply to sides in cargo spaces of ships with the service notation **general cargo ship** or **livestock carrier**.

6.2 Arrangement

6.2.1 In the case of transversally framed sides, longitudinal battens formed by spaced planks are to be fitted to the frames by means of clips.

6.2.2 Where sides are longitudinally framed, battens are to be fitted vertically.

6.2.3 Battens are to extend from the bottom of the cargo space to at least the underside of the beam knees.

6.2.4 Cargo battens are to be not less than 50 mm in thickness and 150 mm in width. The space between battens is not to exceed 300 mm.

SECTION 2 LOADING MANUAL AND LOADING INSTRUMENTS

1 Definitions

1.1 Perpendiculars

1.1.1 Forward perpendicular

The forward perpendicular is the perpendicular to the waterline at the forward side of the stem on the summer load waterline

1.1.2 After perpendicular

The after perpendicular is the perpendicular to the waterline at the after side of the rudder post on the summer load waterline. For ships without rudder post, the after perpendicular is the perpendicular to the waterline at the centre of the rudder stock on the summer load waterline.

1.1.3 Midship perpendicular

The midship perpendicular is the perpendicular to the waterline at half the distance between forward and after perpendiculars.

2 Loading manual and loading instrument requirement criteria

2.1 Ship categories

2.1.1 Category I ships

- Ships with large deck openings where combined stresses due to vertical and horizontal hull girder bending and torsional and lateral loads need to be considered
- Ships liable to carry non-homogeneous loadings, where the cargo and/or ballast may be unevenly distributed; exception is made for ships less than 120 metres in length, when their design takes into account uneven distribution of cargo or ballast: such ships belong to Category II

2.1.2 Category II ships

- Ships whose arrangement provides small possibilities for variation in the distribution of cargo and ballast
- Ships on a regular and fixed trading pattern where the loading manual gives sufficient guidance
- the exception given under Category I.

2.2 Requirement criteria

2.2.1 All ships

An approved loading manual is to be supplied for all ships, except those of Category II less than 90 m in length in which the deadweight does not exceed 30% of the displacement at the summer loadline draught.

For ships with length less than 65 m, the Society may waive the above-mentioned request for an approved loading manual at its discretion taking into account the ship's service and arrangement.

In addition, an approved loading instrument is to be supplied for all ships of Category I equal to or greater than 100 m in length.

The loading instrument is ship specific onboard equipment and the results of the calculations are only applicable to the ship for which it has been approved.

An approved loading instrument may not replace an approved loading manual.

3 Loading manual

3.1 Definitions

3.1.1 All ships

A loading manual is a document which describes:

- the loading conditions on which the design of the ship has been based, including permissible limits of still water bending moment and shear force
- the results of the calculations of still water bending moments, shear forces and, where applicable, limitations due to torsional and lateral loads
- the allowable local loading for the structure (hatch covers, decks, double bottom, etc.).

3.2 Conditions of approval

3.2.1 All ships

The approved loading manual is to be based on the final data of the ship. The manual is to include the design (cargo and ballast) loading conditions, subdivided into departure and arrival conditions as appropriate, upon which the approval of the hull scantlings is based, defined in Ch 5, Sec 2, [2.1.2].

In the case of modifications resulting in changes to the main data of the ship, a new approved loading manual is to be issued.

3.2.2 Language

The loading manual is to be prepared in a language understood by the users. If this is not English, a translation into English is to be included.

4 Loading instrument

4.1 Definitions

4.1.1 All ships

A loading instrument is an instrument which is either analog or digital and by means of which it can be easily and quickly ascertained that, at specified read-out points, the still water bending moments, shear forces and still water torsional moments and lateral loads, where applicable, in any load or ballast condition, do not exceed the specified permissible values.

An operational manual is always to be provided for the loading instrument.

Single point loading instruments are not acceptable.

4.2 Conditions of approval

4.2.1 All ships

The loading instrument is subject to approval, which is to include:

- verification of type approval, if any
- verification that the final data of the ship have been used
- acceptance of number and position of all read-out points
- acceptance of relevant limits for read-out points
- checking of proper installation and operation of the instrument on board, under agreed test conditions, and that a copy of the operation manual is available.

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

4.2.3 The operation manual and the instrument output are to be prepared in a language understood by the users. If this is not English, a translation into English is to be included.

4.2.4 The operation of the loading instrument is to be verified upon installation under the agreed test conditiony. It is to be checked that the agreed test conditions and the operation manual for the instrument are available on board.

4.2.5 When the loading instrument also performs stability calculations, it is to be approved for stability purposes in accordance with the procedures indicated in [4.5], [4.6], [4.7] and [4.7], as applicable.

4.3 Approval procedure

4.3.1 General

The loading instrument approval process includes the following procedures for each ship:

- data verification which results in endorsed test conditions
- approval of computer hardware, where necessary, as specified in Pt C, Ch 3, Sec 6, [2.5.1]
- installation testing which results in an Installation Test Report.

4.3.2 Data verification approval - Endorsed test conditions

The Society is to verify the results and actual ship data used by the calculation program for the particular ship on which the program will be installed.

Upon application for data verification, the Society is to advise the applicant of a minimum of four loading conditions, taken from the ship's approved loading manual, which are to be used as the test conditions. Within the range of these test conditions, each compartment is to be loaded at least once. The test conditions normally cover the range of load draughts from the deepest envisaged loaded condition to the light ballast condition. In addition, the lightship test condition is to be submitted.

When the loading instrument also performs stability calculations, the test conditions are to be taken from the ship's approved trim and stability booklet.

The data indicated in [4.3.3] and contained in the loading program are to be consistent with the data specified in the approved loading manual. Particular attention is drawn to the final lightship weight and centres of gravity derived from the inclining experiment or lightweight check.

The approval of the computer application software is based on the acceptance of the results of the test conditions according to [4.4], [4.6], [4.7], and [4.7], as applicable.

When the requested information has been submitted and the results of the test conditions are considered satisfactory, the Society endorses the test conditions, a copy of which is to be available on board.

4.3.3 Data to be submitted

The following data, submitted by the applicant, are to be consistent with the as-built ship:

- identification of the calculation program including the version number
- main dimensions, hydrostatic particulars and, if applicable, ship profile
- position of the forward and after perpendiculars and, if appropriate, the calculation method to derive the forward and after draughts at the actual position of the ship's draught marks
- ship lightweight and lightweight distribution along the ship's length
- lines plans and/or offset tables
- compartment definitions, including frame spacing and centre of volumes, together with capacity tables (sounding/ullage tables), if appropriate
- deadweight definitions for each loading condition.

4.3.4 Installation testing

During the installation test, one of the ship's senior officers is to operate the loading instrument and calculate the test conditions. This operation is to be witnessed by a Surveyor of the Society. The results obtained from the loading instrument are to be identical to those stated in the endorsed test conditions. If the numerical output from the loading instrument is different from the endorsed test conditions, no approval will be confirmed.

An installation test is also to be carried out on the second nominated computer, when applicable as indicated in Pt C, Ch 3, Sec 6, [2.5.1], which would be used in the event of failure of the first computer. Where the installation test is carried out on a type approved computer, a second nominated computer and test are not required.

Subject to the satisfactory completion of installation tests, the Society's Surveyor endorses the test conditions, adding details of the place and the date of the installation test survey, as well as the Society stamp and the Surveyor's signature.

4.3.5 Operational manual

A uniquely identified ship specific operational manual is to be submitted to the Society for documentation.

The operational manual is to be written in a concise and unambiguous manner. The use of illustrations and flow-charts is recommended.

The operational manual is to contain:

- a general description of the program denoting identification of the program and its stated version number
- details of the hardware specification needed to run the loading program
- a description of error messages and warnings likely to be encountered, and unambiguous instructions for subsequent actions to be taken by the user in each case
- where applicable, the shear force correction factors
- where applicable, the local permissible limits for single and two adjacent hold loadings as a function of the appropriate draught and the maximum weight for each hold
- where applicable, the Society's restrictions (maximum allowable load on double bottom, maximum specific gravity allowed in liquid cargo tanks, maximum filling level or percentage in liquid cargo tanks)
- example of a calculation procedure supported by illustrations and sample computer output
- example computer output of each screen display, complete with explanatory text.

4.3.6 Calculation program specifications

The software is to be written so as to ensure that the user cannot alter the critical ship data files containing the following information:

- lightship weight and lightship weight distribution and associated centres of gravity
- the Society's structural limitations or restrictions
- geometric hull form data
- hydrostatic data and cross curves, where applicable
- compartment definitions, including frame spacing and centre of volumes, together with capacity tables (sounding/ullage tables), if appropriate.

Any changes in the software are to be made by the manufacturer or his appointed representative and the Society is to be informed immediately of such changes. Failure to advise of any modifications to the calculation program may invalidate the approval issued. In cases where the approval is considered invalid by the Society, the modified calculation program is to be re-assessed in accordance with the approval procedure.

4.3.7 Functional specification

The calculation program is to be user-friendly and designed such that it limits possible input errors by the user.

The forward, midship and after draughts, at the respective perpendiculars, are to be calculated and presented to the user on screen and hardcopy output in a clear and unambiguous manner.

It is recommended that the forward, midship and after draughts, at the actual position of the ship's draught marks are calculated and presented to the user on screen and hard copy output in a clear and unambiguous manner.

The displacement is to be calculated for the specified loading condition and corresponding draught readings and presented to the user on screen and hardcopy output.

The loading instrument is to be capable of producing print-outs of the results in both numerical and graphical forms. The numerical values are to be given in both forms, as absolute values and as the percentage of the permissible values. This print-out is to include a description of the corresponding loading condition.

All screen and hardcopy output data is to be presented in a clear and unambiguous manner with an identification of the calculation program (the version number is to be stated).

4.4 Hull girder forces and moments

4.4.1 General

The loading program is to be capable of calculating the following hull girder forces and moments in accordance with Ch 5, Sec 2, [2]:

- Still Water Shear Force (SWSF) including the shear force correction, where applicable
- Still Water Bending Moment (SWBM)
- Still Water Torsion Moment (SWTM), where applicable
- For ships with relatively large deck openings, additional considerations such as torsional loads are to be considered.

The data which are to be provided to or accepted by the Society are specified in Tab 1.

Read-out points are usually to be selected at the position of the transverse bulkheads or other obvious boundaries. Additional read-out points may be required between bulkheads of long holds or tanks, or between container stacks.

Where the still water torsion moments are required to be calculated, one test condition is to demonstrate such a calculation.

The calculated forces and moments are to be displayed in both graphical and tabular formats, including the percentage of permissible values. The screen and hardcopy output is to display the calculated forces or moments, and the corresponding permissible limits, at each specified read-out point. Alternative limits may be considered by the Society on a case by case basis.

Table 1 : Data to be provided to/or accepted by the Society

Calculation	Data to be provided to or accepted by the Society
Still Water Shear Force (SWSF)	• The read-out points (frame locations) for the SWSF calculations. These points are normally selected at the position of the transverse bulkhead or other obvious boundaries. Additional read-out points may be specified between the bulkheads of long holds or tanks or between container stacks. • Shear force correction factors and method of application. • The permissible seagoing and harbour SWSF limits at the read-out points. Where appropriate, additional sets of permissible SWSF values may be specified.
Still Water Bending Moment (SWBM)	• The read-out points (frame locations) for the SWBM calculations. These points are normally selected at the position of the transverse bulkhead, mid-hold or other obvious boundaries. • The permissible seagoing and harbour SWBM limits at the read-out points. Where appropriate, additional sets of permissible SWBM values may be specified.
Still Water Torsion Moment (SWTM), where applicable	• The read-out points (frame locations) for the SWTM calculations, where applicable. • The permissible limits at the read-out points.

4.4.2 Acceptable tolerances

The accuracy of the calculation program is to be within the acceptable tolerance band, specified in Tab 2, of the results at each read-out point obtained by the Society, using an independent program or the approved loading manual with identical input.

Table 2 : Tolerance band for the comparison of computational accuracy

Computation	Tolerance (percentage of the permissible values)
Still Water Shear Force	± 5%
Still Water Bending Moment	± 5%
Still Water Torsion Moment, where applicable	± 5%

4.4.3 Permissible limits and restrictions

The user is to be able to view the following Society structural limitations in a clear and unambiguous manner:

- all permissible still water shear forces and still water bending moments
- where applicable, the permissible still water torsion moments
- where applicable, all local loading limits both for one hold and for adjacent hold loadings
- cargo hold weight
- ballast tank/hold capacities
- filling restrictions.

It is to be readily apparent to the user when any of the structural limits has been exceeded.

4.5 Stability

4.5.1 Premise

The use of shipboard computers for stability calculations is not a requirement of class.

However, stability software installed on board is to cover all stability requirements applicable to the ship. These provisions, which require only software approval, apply to shipboard computers which are provided with software capable of performing stability calculations for the ship.

Active and passive systems are defined in [4.5.3]. These requirements cover passive systems and the off-line operation mode of active systems only.

4.5.2 General

The scope of stability calculation software is to be in accordance with the stability information as approved by the Society and is to at least include all information and perform all calculations or checks as necessary to ensure compliance with the applicable stability requirements.

Approved stability software is not a substitute for the approved stability information, and is used as a supplement to the approved stability information to facilitate stability calculations.

The input/output information should be easily comparable with approved stability information so as to avoid confusion and possible misinterpretation by the operator relative to the approved stability information.

An operation manual is to be provided for the shipboard computer stability software.

The language in which the stability information is displayed and printed out and in which the operation manual is written should be the same as that used for the ship's approved stability information. The Society may require a translation into a language considered appropriate.

The shipboard computer software for stability calculations is ship specific and the results of the calculations are only applicable to the ship for which it has been approved.

In the case of modifications implying changes in the main data or internal arrangement of the ship, the specific approval of any original stability calculation software is no longer valid. The software is to be modified accordingly and re-approved.

4.5.3 Calculation systems

A passive system requires manual data entry, an active system replaces the manual entry with sensors reading and entering the contents of tanks, etc., and a third system, an integrated system, controls or initiates actions based on the sensor supplied inputs and is not within the scope of these requirements.

4.5.4 Types of stability software

Three types of calculations performed by stability software are acceptable depending upon a vessel's stability requirements:

- Type 1: software calculating intact stability only (for vessels not required to meet a damage stability criterion)
- Type 2: software calculating intact stability and checking damage stability on the basis of a limit curve (e.g. for vessels applicable to SOLAS Part B-1 damage stability calculations, etc.) or previously approved loading conditions and
- Type 3: software calculating intact stability and damage stability by direct application of pre-programmed damage cases for each loading condition (for some tankers etc.)

4.5.5 Functional requirements

The calculation program is to present relevant parameters of each loading condition in order to assist the Master in his judgement on whether the ship is loaded within the approval limits. The following parameters are to be presented for a given loading condition:

- deadweight data;
- lightship data;
- trim;
- draft at the draft marks and perpendiculars;
- summary of loading condition displacement, VCG, LCG and, if applicable, TCG;
- downflooding angle and corresponding downflooding opening;
- compliance with stability criteria: listing of all calculated stability criteria, the limit values, the values obtained and the conclusions (criteria fulfilled or not fulfilled).

If direct damage stability calculations are performed, the relevant damage cases according to the applicable Rules are to be pre-defined for automatic check of a given loading condition.

A clear warning is to be given on screen and in hard copy printout if any of the loading limitations are not complied with.

The data are to be presented on screen and in hard copy printout in a clear unambiguous manner.

The date and time of a saved calculation are to be part of the screen display and hard copy printout.

Each hard copy printout is to contain identification of the calculation program, including version number.

Units of measurement are to be clearly identified and used consistently within a loading calculation.

4.5.6 Acceptable tolerances

Depending on the type and scope of programs, the acceptable tolerances are to be determined differently, according to a) or b) below, as appropriate. Deviation from these tolerances are not acceptable unless the Society considers that there is a satisfactory explanation for the difference and that there will be no adverse effect on the safety of the ship.

Examples of pre-programmed input data include the following:

- Hydrostatic data: Displacement, LCB, LCF, VCB, KMt and MCT versus draught.
- Stability data: KN or MS values at appropriate heel/ trim angles versus displacement, stability limits.
- Compartment data: Volume, LCG, VCG, TCG and FSM/ Grain heeling moments vs level of the compartment's contents.

Examples of output data include the following:

- Hydrostatic data: Displacement, LCB, LCF, VCB, KMt and MCT versus draught as well as actual draughts, trim.
- Stability data: FSC (free surface correction), GZ-values, KG, GM, KG/GM limits, allowable grain heeling moments, derived stability criteria, e.g. areas under the GZ curve, weather criteria.
- Compartment data: Calculated Volume, LCG, VCG, TCG and FSM/ Grain heeling moments vs level of the compartment's contents.

The computational accuracy of the calculation program results is to be within the acceptable tolerances specified in a) or b) below as appropriate, in comparison with the results obtained by the Society using an independent program or the approved stability information with identical input.

a) Programs which use only pre-programmed data from the approved stability information as the basis for stability calculations are to have zero tolerances for the printouts of input data.

   Output data tolerances are to be close to zero; however, small differences associated with calculation rounding or abridged input data are acceptable.

   Additionally, differences associated with the use of hydrostatic and stability data for trims that differ from those in the approved stability information are acceptable subject to review by the Society.

b) Programs which use hull form models as their basis for stability calculations are to have tolerances for the printouts of basic calculated data established against either data from the approved stability information or data obtained using the approval Society's model. Acceptable tolerances are to be in accordance with Tab 3.

Table 3 : Applicable tolerances

Hull Form Dependent	
Displacement	2%
Longitudinal centre of bouyancy, from AP	1% / 50 cm max
Vertical centre of bouyancy	1% / 5 cm max
Transverse centre of bouyancy	0,5% of B / 5 cm max
Longitudinal centre of flotation, from AP	1% / 50 cm max
Moment to trim 1 cm	2%
Transverse metacentric height	1% / 5 cm max
Longitudinal metacentric height	1% / 50 cm max
Cross curves of stability	5 cm
Compartment dependent	
Volume or deadweight	2%
Longitudinal centre of gravity, from AP	1% / 50 cm max
Vertical centre of gravity	1% / 5 cm max
Transverse centre of gravity	0,5% of B / 5 cm max
Free surface moment	2%
Shifting moment	5%
Level of contents	2%
Trim and stability	
Draughts (forward, aft, mean)	1% / 5 cm max
GMt	1% / 5 cm max
GZ values	5% / 5 cm max
FS correction	2%
Downflooding angle	2°
Equilibrium angles	1°
Distance to unprotected openings or margin line from WL, if applicable	±5 % / 5 cm max
Areas under righting arm curve	5 % or 0,0012 mrad
Note 1: Deviation in % = {(base value-applicant's value)/base value} *100, where the "base value" may be from the approved stability information or the Society's computer model.	

4.5.7 Approval Procedure

The shipboard software used for stability calculations is subject to approval, which is to include:

- verification of type approval, if any;
- verification that the data used is consistent with the current condition of the ship (see item c));
- verification and approval of the test conditions;
- verification that the software is appropriate for the type of ship and stability calculations required.

The satisfactory operation of the software with the shipboard computer(s) for stability calculations is to be verified by testing upon installation in compliance with [4.5.9]. A copy of the approved test conditions and the operation manual for the computer/ software are to be available on board.

a) The Society verifies the accuracy of the computational results and actual ship data used by the calculation program for the particular ship on which the program will be installed.

b) Upon application to the Society for data verification, the Society and the applicant are to agree on a minimum of four loading conditions, taken from the ship's approved stability information, which are to be used as the test conditions. For ships carrying liquids in bulk, at least one of the conditions is to include partially filled tanks. For ships carrying grain in bulk, one of the grain loading conditions is to include a partially filled grain compartment. Within the test conditions each compartment is to be loaded at least once. The test conditions normally are to cover the range of load draughts from the deepest envisaged loaded condition to the light ballast condition and are to include at least one departure and one arrival condition.

c) The Society is to verify that the following data, submitted by the applicant, are consistent with arrangements and the most recently approved lightship characteristics of the ship according to current plans and documentation on file with the Society, subject to possible further verification on board:
   - identification of the calculation program including version number;
   - main dimensions, hydrostatic particulars and, if applicable, the ship profile;
   - the position of the forward and after perpendiculars, and if appropriate, the calculation method to derive the forward and after draughts at the actual position of the ship's draught marks;
   - ship lightweight and centre of gravity derived from the most recently approved inclining experiment or lightweight check;
   - lines plan, offset tables or other suitable presentation of hull form data if necessary for the Society to model the ship;
   - compartment definitions, including frame spacing, and centres of volume, together with capacity tables (sounding/ullage tables), free surface corrections, if appropriate;
   - cargo and consumables distribution for each loading condition.

Verification by the Society does not absolve the applicant and Owner from responsibility for ensuring that the information programmed into the shipboard computer software is consistent with the current condition of the ship.

4.5.8 Operation manual

A simple and straightforward operation manual is to be provided, containing descriptions and instructions, as appropriate, for at least the following:

- installation
- function keys
- menu displays
- input and output data
- required minimum hardware to operate the software
- use of the test loading conditions
- computer-guided dialogue steps
- list of warnings.

4.5.9 Installation testing

To ensure correct working of the computer after the final or updated software has been installed, it is the responsibility of the ship's Master to have test calculations carried out according to a) or b) in the presence of a Surveyor of the Society.

a) In compliance with [4.3.4], test conditions are to be selected and the test calculation performed by entering all deadweight data for each selected test condition into the program as if it were a proposed loading.

b) From the approved test conditions at least one load case (other than lightship) is to be calculated.

   The following steps are to be performed:
   - retrieve the test load case and start a calculation run; compare the stability results with those in the documentation;
   - change several items of deadweight (tank weights and the cargo weight) sufficiently to change the draught or displacement by at least 10%. The results are to be reviewed to ensure that they differ in a logical way from those of the approved test condition;
   - revise the above modified load condition to restore the initial test condition and compare the results. The relevant input and output data of the approved test condition are to be replicated.

In general, the test conditions are permanently stored in the computer.

The results are to be verified as identical to those in the approved copy of the test conditions.

If the numerical output from the loading instrument is different from the endorsed test conditions, no approval will be confirmed.

An installation test is also to be carried out on the second nominated computer, when applicable as indicated in Pt C, Ch 3, Sec 6, [2.5.1], which would be used in the event of failure of the first computer. Where the installation test is carried out on a type approved computer, a second nominated computer and test are not required.

Subject to the satisfactory completion of installation tests, the Society's Surveyor endorses the test conditions, adding details of the place and date of the installation test survey, as well as the Society stamp and the Surveyor's signature.

Actual loading condition results are not suitable for checking the correct working of the computer.

4.5.10 Additional requirements

Protection against unintentional or unauthorised modification of programs and data is to be provided.

The program is to monitor operation and activate an alarm when the program is incorrectly or abnormally used.

The program and any data stored in the system are to be protected from corruption by loss of power.

Error messages with regard to limitations such as filling a compartment beyond capacity, or exceeding the assigned load line, etc. are to be included.

4.6 Intact stability

4.6.1 Application

The loading instrument approval for stability purposes is required when a loading instrument to be installed on board a ship performs stability calculations, as stated in [4.2.5].

4.6.2 Data verification approval - Endorsed test conditions

The requirements in [4.3.2] apply. In addition, at least one of the four loading conditions required is to show the compartments, intended for liquid loads in which the free surface effect is considerable, filled in order to have the maximum free surface moment.

The additional data necessary for the approval of the loading instrument for stability purposes are specified in [4.6.3].

In order to obtain the approval of the loading instrument, all the intact stability requirements (and relevant criteria) applicable to the ship, reported in Ch 3, Sec 2 as well as in Part E, are to be available in the computer output; the lack of any one of them is sufficient to prevent the endorsement of the test conditions.

4.6.3 Additional data to be submitted

In addition to the data required in [4.3.3], the following are to be submitted:

- cross curves of stability calculated on a free trimming basis, for the ranges of displacement and trim anticipated in normal operating conditions, with indication of the volumes which have been considered in the computation of these curves,
- capacity tables indicating, for each compartment or space, the values of the co-ordinates X_G, Y_G and Z_G of the centre of gravity, as well as the inertia, corresponding to an adequate number of filling percentages
- list of all the openings (location, tightness, means of closure), pipes or other sources which may lead to progressive flooding
- deadweight definitions for each loading condition in which, for any load taken into account, the following information is to be specified:
  - weight and centre of gravity co-ordinates
  - percentage of filling (if liquid load)
  - free surface moment (if liquid load)
- information on loading restrictions (maximum filling level or percentage in liquid cargo tanks, maximum KG or minimum GM curve or table which can be used to determine compliance with the applicable intact and damage stability criteria), when applicable
- all the intact stability criteria applicable to the ship concerned.

4.7 Damage stability

4.7.1 Application

The loading instrument approval for stability purposes is required when a loading instrument to be installed on board a ship performs damage stability calculations, as stated in [4.2.5].

In such case, the loading instrument is also to perform intact stability calculations, and therefore the approval is to be based on the requirements specified in [4.6].

Additional requirements relevant to damage stability are given in [4.7.2] and [4.7.3].

4.7.2 Data verification approval - Endorsed test conditions

The requirements specified in [4.6.2] apply.

The additional data necessary for the approval of the loading instrument for stability purposes are specified in [4.7.3].

The approval of damage stability calculations performed by a loading instrument is limited to those relevant to deterministic damage stability rules specified in Part E applicable to ships with the service notation **oil tanker ESP**. In order to obtain the approval of the loading instrument, all the damage stability requirements (and relevant criteria) applicable to the ship are to be available in the computer output. The lack of any one of them is sufficient to prevent the endorsement of the test conditions.

4.7.3 Additional data to be submitted

In addition to the data required in [4.6.3], the following are to be submitted:

- list of all the damage cases which are to be considered in accordance with the relevant deterministic damage stability rules. Each damage case is to clearly indicate all the compartments or spaces taken into account, as well as the permeability associated with each compartment or space.

  This information is to be taken from the approved damage stability documentation, and the source details are to be clearly indicated; in the case of unavailability of such documentation, the above-mentioned information may be requested from the Society.
- all the damage stability criteria applicable to the ship concerned.

Part B
Hull and Stability

Chapter 12
CONSTRUCTION AND TESTING

SECTION 1 WELDING AND WELD CONNECTIONS

1 General

1.1 Application

1.1.1 The requirements of this Section apply for the preparation, execution and inspection of welded connections in hull structures.

The general requirements relevant to fabrication by welding and qualification of welding procedures are given in Part D, Chapter 5. As guidance see also the indications given in the "Guide for Welding".

The requirements relevant to the non-destructive examination of welded connections are given in the Rules for carrying out non-destructive examination of welding.

1.1.2 Weld connections are to be executed according to the approved plans. Any detail not specifically represented in the plans is, in any event, to comply with the applicable requirements.

1.1.3 It is understood that welding of the various types of steel is to be carried out by means of welding procedures approved for the purpose, even though an explicit indication to this effect may not appear on the approved plans.

1.1.4 The quality standard adopted by the shipyard is to be submitted to the Society and applies to all constructions unless otherwise specified on a case-by-case basis.

1.2 Base material

1.2.1 The requirements of this Section apply for the welding of hull structural steels or aluminium alloys of the types considered in Part D or other types accepted as equivalent by the Society.

1.2.2 The service temperature is intended to be the ambient temperature, unless otherwise stated.

1.3 Welding consumables and procedures

1.3.1 Approval of welding consumables and procedures

Welding consumables and welding procedures adopted are to be approved by the Society.

The requirements for the approval of welding consumables are given in Pt D, Ch 5, Sec 2.

The requirements for the approval of welding procedures for the individual users are given in Pt D, Ch 5, Sec 4 and Pt D, Ch 5, Sec 5.

1.3.2 Consumables

For welding of hull structural steels, the minimum consumable grades to be adopted are specified in Tab 1 depending on the steel grade.

For welding of other materials, the consumables indicated in the welding procedures to be approved are considered by the Society on a case by case basis.

Table 1 : Consumable grades

Steel grade	Consumable minimum grade	
	Butt welding, partial and full T penetration welding	Fillet welding
A	1	1
B - D	2	
E	3	
AH32 - AH36 DH32 - DH36	2Y	2Y
EH32 - EH36	3Y	
FH32 - FH36	4Y	
AH40	2Y40	2Y40
DH40 - EH40	3Y40	
FH40	4Y40	

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.

1.3.3 Electrodes for manual welding

Basic covered electrodes are to be used for the welding of structural members made in higher strength steels and, irrespective of the steel type, for the welding of special and primary structural members, as defined in Ch 4, Sec 1, Tab 3 and Ch 4, Sec 1, Tab 7, as applicable.

Non-basic covered electrodes are generally allowed for manual fillet welding of structural members of moderate thickness (gross thickness less than 25 mm) made in normal strength steels.

1.4 Personnel and equipment

1.4.1 Welders

Manual and semi-automatic welding is to be performed by welders certified by the Society in accordance with recognised standards (see Pt D, Ch 5, Sec 1, [2.2.3] and Pt D, Ch 5, Sec 1, [2.2.5]); the welders are to be employed within the limits of their respective approval.

1.4.2 Automatic welding operators

Personnel manning automatic welding machines and equipment are to be competent and sufficiently trained.

1.4.3 Organisation

The internal organisation of the shipyard is to be such as to ensure compliance in full with the requirements in [1.4.1] and [1.4.2] and to provide for assistance and inspection of welding personnel, as necessary, by means of a suitable number of competent supervisors.

1.4.4 NDT operators

Non-destructive tests are to be carried out by operators qualified according to the requirements of Pt D, Ch 1, Sec 1, [3.6.4].

The qualifications are to be appropriate to the specific applications.

1.4.5 Technical equipment and facilities

The welding equipment is to be appropriate to the adopted welding procedures, of adequate output power and such as to provide for stability of the arc in the different welding positions.

In particular, the welding equipment for special welding procedures is to be provided with adequate and duly calibrated measuring instruments, enabling easy and accurate reading, and adequate devices for easy regulation and regular feed.

Manual electrodes, wires and fluxes are to be stocked in suitable locations so as to ensuring their preservation in good condition.

1.5 Documentation to be submitted

1.5.1 The structural plans to be submitted for approval, according to Ch 1, Sec 3, are to contain the necessary data relevant to the fabrication by welding of the structures and items represented. Any detail not clearly represented in the plans is, in any event, to comply with the applicable Rule requirements.

For important structures, the main sequences of prefabrication, assembly and welding and non-destructive examination planned are also to be represented in the plans.

1.5.2 A plan showing the location of the various steel types is to be submitted at least for outer shell, deck and bulkhead structures.

1.6 Design

1.6.1 General

For the various structural details typical of welded construction in shipbuilding and not dealt with in this Section, the rules of good practice, recognised standards and past experience are to apply as agreed by the Society.

1.6.2 Plate orientation

The plates of the shell and strength deck are generally to be arranged with their length in the fore-aft direction. Possible exceptions to the above will be considered by the Society on a case by case basis; tests as deemed necessary (for example, transverse impact tests) may be required by the Society.

1.6.3 Overall arrangement

Particular consideration is to be given to the overall arrangement and structural details of highly stressed parts of the hull.

Special attention is to be given to the above details in the plan approval stage; accurate plans relevant to the special details specified in Sec 2 are to be submitted.

1.6.4 Prefabrication sequences

Prefabrication sequences are to be arranged so as to facilitate positioning and assembling as far as possible.

The amount of welding to be performed on board is to be limited to a minimum and restricted to easily accessible connections.

1.6.5 Distance between welds

Welds located too close to one another are to be avoided. The minimum distance between two adjacent welds is considered on a case by case basis, taking into account the level of stresses acting on the connected elements.

In general, the distance between two adjacent butts in the same strake of shell or deck plating is to be greater than two frame spaces.

2 Type of connections and preparation

2.1 General

2.1.1 The type of connection and the edge preparation are to be appropriate to the welding procedure adopted, the structural elements to be connected and the stresses to which they are subjected.

2.2 Butt welding

2.2.1 General

In general, butt connections of plating are to be full penetration, welded on both sides except where special procedures or specific techniques, considered equivalent by the Society, are adopted.

Connections different from the above may be accepted by the Society on a case by case basis; in such cases, the relevant detail and workmanship specifications are to be approved.

2.2.2 Welding of plates with different thicknesses

In the case of welding of plates with a difference in gross thickness equal to or greater than:

- 3 mm, if the thinner plate has a gross thickness equal to or less than 10 mm
- 4 mm, if the thinner plate has a gross thickness greater than 10 mm,

a taper having a length of not less than 4 times the difference in gross thickness is to be adopted for connections of plating perpendicular to the direction of main stresses. For connections of plating parallel to the direction of main stresses, the taper length may be reduced to 3 times the difference in gross thickness.

When the difference in thickness is less than the above values, it may be accommodated in the weld transition between plates.

2.2.3 Edge preparation, root gap

Typical edge preparations and gaps are indicated in the "Guide for welding".

The acceptable root gap is to be in accordance with the adopted welding procedure and relevant bevel preparation.

2.2.4 Butt welding on permanent backing

Butt welding on permanent backing, i.e. butt welding assembly of two plates backed by the flange or the face plate of a stiffener, may be accepted where back welding is not feasible or in specific cases deemed acceptable by the Society.

The type of bevel and the gap between the members to be assembled are to be such as to ensure a proper penetration of the weld on its backing and an adequate connection to the stiffener as required.

2.2.5 Section, bulbs and flat bars

When lengths of longitudinals of the shell plating and strength deck within 0,6 L amidships, or elements in general subject to high stresses, are to be connected together by butt joints, these are to be full penetration. Other solutions may be adopted if deemed acceptable by the Society on a case by case basis.

The work is to be done in accordance with an approved procedure; in particular, this requirement applies to work done on board or in conditions of difficult access to the welded connection. Special measures may be required by the Society.

2.3 Fillet welding

2.3.1 General

In general, ordinary fillet welding (without bevel) may be adopted for T connections of the various simple and composite structural elements, where they are subjected to low stresses (in general not exceeding 30 N/mm^2) and adequate precautions are taken to prevent the possibility of local laminations of the element against which the T web is welded.

Where this is not the case, partial or full T penetration welding according to [2.4] is to be adopted.

2.3.2 Fillet welding types

Fillet welding may be of the following types:

- continuous fillet welding, where the weld is constituted by a continuous fillet on each side of the abutting plate (see [2.3.3])
- intermittent fillet welding, which may be subdivided (see [2.3.4]) into:
  - chain welding
  - scallop welding
  - staggered welding.

2.3.3 Continuous fillet welding

Continuous fillet welding is to be adopted:

- for watertight connections
- for connections of brackets, lugs and scallops
- at the ends of connections for a length of at least 75mm
- where intermittent welding is not allowed, according to [2.3.4].

Continuous fillet welding may also be adopted in lieu of intermittent welding wherever deemed suitable, and it is recommended where the spacing p, calculated according to [2.3.4], is low.

2.3.4 Intermittent welding

The spacing p and the length d, in mm, of an intermittent weld, shown in:

- Fig 1, for chain welding
- Fig 2, for scallop welding
- Fig 3, for staggered welding

are to be such that:

$$\frac{p}{d} \le \varphi$$

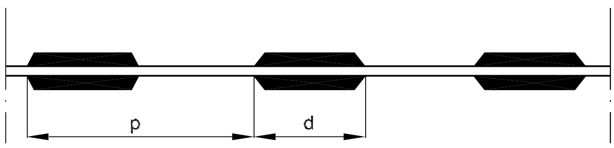
where the coefficient φ is defined in Tab 2 and Tab 3 for the different types of intermittent welding, depending on the type and location of the connection.

In general, staggered welding is not allowed for connections subjected to high alternate stresses.

In addition, the following limitations are to be complied with:

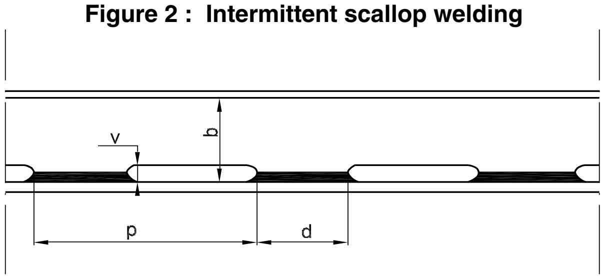
- chain welding (see Fig 1):
  $d \ge 75$ mm
  $p - d \le 200$ mm

Figure 1 : Intermittent chain welding



- scallop welding (see Fig 2):
  $d \ge 75$ mm
  $p - d \le 150$ mm
  $v \le 0{,}25b$, without being greater than 75 mm

Figure 2 : Intermittent scallop welding

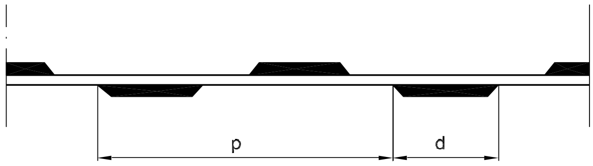


- staggered welding (see Fig 3):
  $d \ge 75$ mm

p-2d ≤ 300 mm

p ≤ 2d for connections subjected to high alternate stresses.

Figure 3 : Intermittent staggered welding



2.3.5 Throat thickness of fillet weld T connections

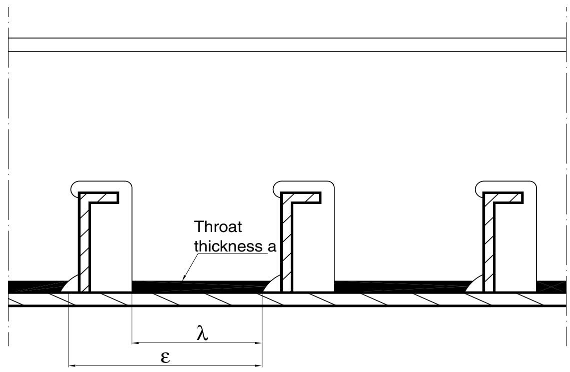
The throat thickness of fillet weld T connections is to be obtained, in mm, from the following formula:

$$t_T = w_F t \frac{p}{d}$$

where:

- w_F : Welding factor, defined in Tab 2 for the various hull structural connections; for connections of primary supporting members belonging to single skin structures and not mentioned in Tab 2, w_F is defined in Tab 3; for some connections of specific ship types, the values of w_F specified in Part E for these ship types are to be used in lieu of the corresponding values in Tab 2 or Tab 3
- 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].

Figure 4 : Continuous fillet welding between cut-outs



For continuous fillet welds, p/d is to be taken equal to 1.

In no case may the throat thickness be less than:

- 3,0 mm, where the gross thickness of the thinner plate is less than 6 mm
- 3,5 mm, otherwise.

The throat thickness may be required by the Society to be increased, depending on the results of structural analyses.

For some connections of special structural details, as defined in Sec 2, the throat thickness is specified in the relevant sheets of App 1.

The leg length of fillet weld T connections is to be not less than 1,4 times the required throat thickness.

2.3.6 Weld dimensions in a specific case

Where intermittent fillet welding is adopted with:

- length d = 75 mm
- throat thickness t_T specified in Tab 4 depending on the thickness t defined in [2.3.5]

the weld spacing may be taken equal to the value p_1 defined in Tab 2. The values of p_1 in Tab 2 may be used when $8 \le t \le 16$ mm.

For thicknesses t less than 8 mm, the values of p_1 may be increased, with respect to those in Tab 2, by:

- 10 mm for chain or scallop welding
- 20 mm for staggered welding

without exceeding the limits in [2.3.4].

For thicknesses t greater than 16 mm, the values of p_1 are to be reduced, with respect to those in Tab 2, by:

- 10 mm for chain or scallop welding
- 20 mm for staggered welding.

Figure 5 : Intermittent scallop fillet welding between cut-outs

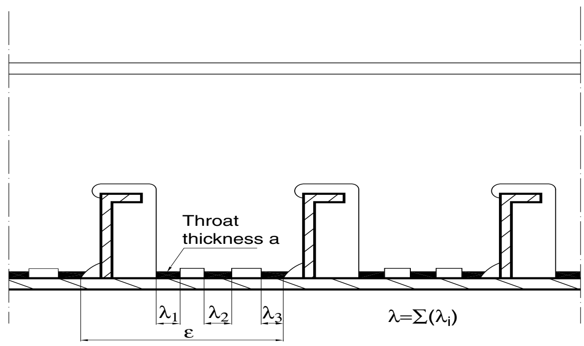


Table 2 : Welding factors w_F and coefficient φ for the various hull structural connections

Hull area	Connection			w_F **(1)**	φ **(2) (3)**			p_1, in mm (see [2.3.6]) **(3)**
	of	to			CH	SC	ST	
General, unless otherwise specified in the table	watertight plates	boundaries		0,35				
	webs of ordinary stiffeners	plating		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 of	Connection to		w_F **(1)**	φ **(2)** **(3)** CH	SC	ST	p_1, in mm (see [2.3.6]) **(3)**
Bottom and double bottom	longitudinal ordinary stiffeners	bottom and inner bottom plating		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 in double side skin ships	side and inner side plating		0,35				
Deck	strength deck	side plating		Partial penetration welding				
	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				
		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				

Hull area	Connection of	Connection to		w_F **(1)**	φ **(2) (3)** CH	SC	ST	p_1, in mm (see [2.3.6]) **(3)**
Structures located forward of 0,75 L from the AE **(6)**	bottom longitudinal ordinary stiffeners	bottom plating		0,20	2,2			CH 160
	floors and girders	bottom and inner bottom plating		0,25	1,8			CH 130
	side frames in panting area	side plating		0,20	2,2			CH 160
	webs of side girders in single side skin structures	side plating and face plate	A< 65 cm² **(7)**	0,25	1,8	1,8		CH/SC 130
			A ≥ 65 cm² **(7)**	See Tab 3				
After peak **(6)**	internal structures	each other		0,20				
	side ordinary stiffeners	side plating		0,20				
	floors	bottom and inner bottom plating		0,20				
Machinery space **(6)**	centre girder	keel and inner bottom plating	in way of main engine foundations	0,45				
			in way of seating of auxiliary machinery and boilers	0,35				
			elsewhere	0,25	1,8	1,8		CH/SC 130
	side girders	bottom and inner bottom plating	in way of main engine foundations	0,45				
			in way of seating of auxiliary machinery and boilers	0,35				
			elsewhere	0,20	2,2	2,2		CH/SC 160
	floors (except in way of main engine foundations)	bottom and inner bottom plating	in way of seating of auxiliary machinery and boilers	0,35				
			elsewhere	0,20	2,2	2,2		CH/SC 160
	floors in way of main engine foundations	bottom plating		0,35				
		foundation plates		0,45				
	floors	centre girder	single bottom	0,45				
			double bottom	0,25	1,8	1,8		CH/SC 130
Superstructures 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	Full penetration welding				
Ventilators	coamings	deck		0,35				

Hull area	Connection of	Connection to		w_F **(1)**	φ **(2) (3)** CH	φ SC	φ ST	p_1, in mm (see [2.3.6]) **(3)**
Rudders	webs in general	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				
		solid parts or rudder stock		According to Ch 10, Sec 1, [7.4] or Ch 10, Sec 1, [7.5]				
	horizontal and vertical webs directly connected to solid parts	each other		0,45				
		plating		0,35				

(1) In connections for which $w_F \geq 0,35$, continuous fillet welding is to be adopted.
(2) For coefficient φ, see [2.3.4]. In connections for which no φ value is specified for a certain type of intermittent welding, such type is not permitted and continuous welding is to be adopted.
(3) CH = chain welding, SC = scallop welding, ST = staggered welding.
(4) Ends of ordinary stiffeners means the area extended 75 mm from the span ends. 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 cm^2.

2.3.7 Throat thickness of welds between cut-outs

The throat thickness of the welds between the cut-outs in primary supporting member webs for the passage of ordinary stiffeners is to be not less than the value obtained, in mm, from the following formula:

$$t_{TC} = t_T \frac{\varepsilon}{\lambda}$$

where:

t_T : Throat thickness defined in [2.3.5]

ε, λ : Dimensions, in mm, to be taken as shown in:
- Fig 4, for continuous welding
- Fig 5, for intermittent scallop welding.

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. Further requirements are specified in Sec 2.

Where primary supporting member web stiffeners are welded to ordinary stiffener face plates, in certain cases the Society may require the above throat thickness to be obtained, in mm, from the following formula:

$$t_T = \frac{4(p_S + p_W)s\ell\left(1 - \frac{s}{2\ell}\right)}{u + v\left(\frac{c + 0,2d}{b + 0,2d}\right)}$$

where:

p_S, p_W : Still water and wave pressure, respectively, in kN/m^2, acting on the ordinary stiffener, defined in Ch 7, Sec 2, [3.3.2]

b,c,d,u,v: Main dimensions, in mm, of the cut-out shown in Fig 6.

Table 3 : Welding factors w_F and coefficient φ for connections of primary supporting members

Primary supporting member	Connection of	Connection to		w_F **(1)**	φ **(2) (3)** CH	SC	ST	p_1, in mm (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 $w_F \geq 0,35$, continuous fillet welding is to be adopted.
(2) For coefficient φ, see [2.3.4]. In connections for which no φ value is specified for a certain type of intermittent welding, such type is not permitted.
(3) CH = chain welding, SC = scallop welding, ST = staggered welding.
(4) For cantilever deck beams, continuous welding is to be adopted.
(5) For primary supporting members in tanks intended for the carriage of ballast or fresh water, continuous welding is to be adopted.

Note 1:
A is the face plate sectional area of the primary supporting member, in cm².

Note 2:
Ends of primary supporting members means the area extended 20% of the span from the span ends. Where end brackets are fitted, ends means the area extended in way of brackets and at least 100 mm beyond the bracket toes.

Figure 6 : End connection of ordinary stiffener Dimensions of the cut-out

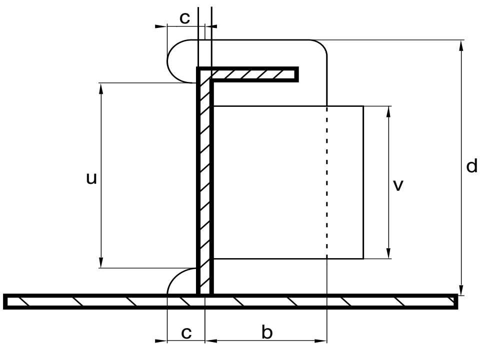


Table 4 : Required throat thickness

t, in mm	t_T, in mm	t, in mm	t_T, in mm
6	3,0	17	7,0
8	3,5	18	7,0
9	4,0	19	7,5
10	4,5	20	7,5
11	5,0	21	8,5
12	5,5	22	8,5
13	6,0	23	9,0
14	6,0	24	9,0
15	6,5	25	10,0
16	6,5	26	10,0

2.3.9 Throat thickness of deep penetration fillet welding

When fillet welding is carried out with automatic welding procedures, the throat thickness required in [2.3.5] may be reduced up to 15%, depending on the properties of the electrodes and consumables. However, this reduction may not be greater than 1,5 mm.

The same reduction applies also for semi-automatic procedures where the welding is carried out in the downhand position.

2.4 Partial and full T penetration welding

2.4.1 General

Partial or full T penetration welding is to be adopted for connections subjected to high stresses for which fillet welding is considered unacceptable by the Society.

Partial or full T penetration welding is required, in any event, where indicated for the connections specified in Part E depending on the ship type. Further requirements are specified in Sec 2.

Typical edge preparations are indicated in:

- for partial penetration welds: Fig 7 and Fig 8, in which f, in mm, is to be taken between 3 mm and t/3, and α between 45° and 60°
- for full penetration welds: Fig 9 and Fig 10, in which f, in mm, is to be taken between 0 and 3 mm, and α between 45° and 60°

  Back gouging is generally required for full penetration welds.

2.4.2 Lamellar tearing

Precautions are to be taken in order to avoid lamellar tears, which may be associated with:

- cold cracking when performing T connections between plates of considerable thickness or high restraint
- large fillet welding and full penetration welding on higher strength steels.

2.5 Lap-joint welding

2.5.1 General

Lap-joint welding may be adopted for:

- peripheral connection of doublers
- internal structural elements subjected to very low stresses.

Elsewhere, lap-joint welding may be allowed by the Society on a case by case basis, if deemed necessary under specific conditions.

Continuous welding is generally to be adopted.

2.5.2 Gap

The surfaces of lap-joints are to be in sufficiently close contact.

2.5.3 Dimensions

The dimensions of the lap-joint are to be specified and are considered on a case by case basis. Typical details are given in the "Guide for welding".

Figure 7 : Partial penetration weld

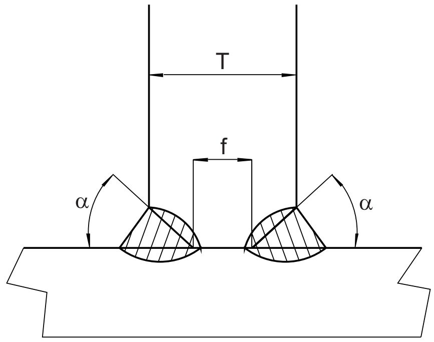


Figure 8 : Partial penetration weld

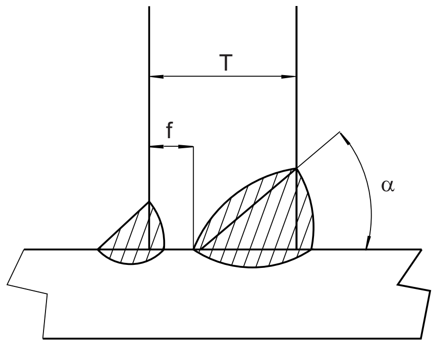


Figure 9 : Full penetration weld

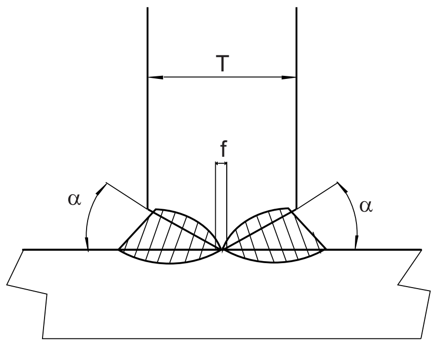
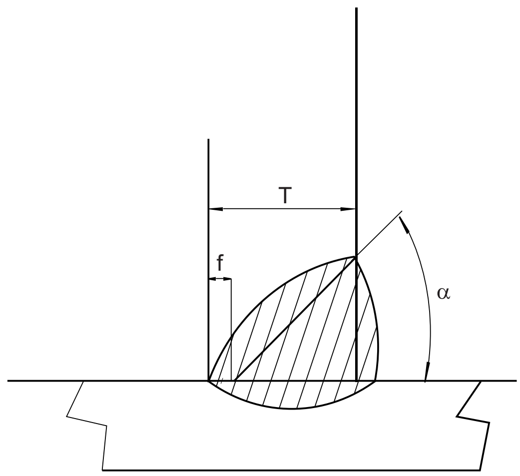


Figure 10 : Full penetration weld



2.6 Slot welding

2.6.1 General

Slot welding may be adopted in very specific cases subject to the special agreement of the Society, e.g. for doublers according to Ch 4, Sec 3, [2.1].

In general, slot welding of doublers on the outer shell and strength deck is not permitted within 0,6L amidships. Beyond this zone, slot welding may be accepted by the Society on a case by case basis.

Slot welding is, in general, permitted only where stresses act in a predominant direction. Slot welds are, as far as possible, to be aligned in this direction.

2.6.2 Dimensions

Slot welds are to be of appropriate shape (in general oval) and dimensions, depending on the plate thickness, and may not be completely filled by the weld.

Typical dimensions of the slot weld and the throat thickness of the fillet weld are given in the "Guide for welding".

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 the "Guide for welding".

3 Specific weld connections

3.1 Corner joint welding

3.1.1 Corner joint welding, as adopted in some cases at the corners of tanks, performed with ordinary fillet welds, is permitted provided the welds are continuous and of the required size for the whole length on both sides of the joint.

3.1.2 Alternative solutions to corner joint welding may be considered by the Society on a case by case basis.

3.2 Bilge keel connection

3.2.1 The intermediate flat, through which the bilge keel is connected to the shell according to Ch 4, Sec 4, [6], is to be welded as a shell doubler by continuous fillet welds.

The butt welds of the doubler and bilge keel are to be full penetration and shifted from the shell butts.

The butt welds of the bilge plating and those of the doublers are to be flush in way of crossing, respectively, with the doubler and with the bilge keel.

3.3 Connection between propeller post and propeller shaft bossing

3.3.1 Fabricated propeller posts are to be welded with full penetration welding to the propeller shaft bossing.

3.4 Bar stem connections

3.4.1 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.

4 Workmanship

4.1 Forming of plates

4.1.1 Hot or cold forming is to be performed according to the requirements of recognised standards or those accepted by the Society on a case by case basis depending on the material grade and rate of deformation.

Recommendations for cold and hot forming are given in the "Guide for welding".

4.2 Welding procedures and consumables

4.2.1 The various welding procedures and consumables are to be used within the limits of their approval and in accordance with the conditions of use specified in the respective approval documents.

4.3 Welding operations

4.3.1 Weather protection

Adequate protection from the weather is to be provided to parts being welded; in any event, such parts are to be dry.

In welding procedures using bare, cored or coated wires with gas shielding, the welding is to be carried out in weather protected conditions, so as to ensure that the gas outflow from the nozzle is not disturbed by winds and draughts.

4.3.2 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.

Recommendations for edge preparation are given in the "Guide for welding".

4.3.3 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 Pt D, Ch 5, Sec 3.

4.3.4 Assembling and gap

The setting appliances and system to be used for positioning are to ensure adequate tightening adjustment and an appropriate gap of the parts to be welded, while allowing maximum freedom for shrinkage to prevent cracks or other defects due to excessive restraint.

The gap between the edges is to comply with the required tolerances or, when not specified, it is to be in accordance with normal good practice.

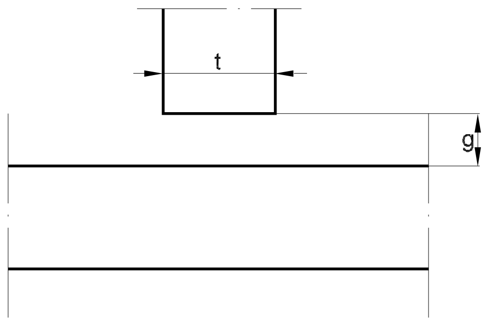
4.3.5 Gap in fillet weld T connections

In fillet weld T connections, a gap g, as shown in Fig 11, not greater than 2 mm may be accepted without increasing the throat thickness calculated according to [2.3.5] to [2.3.9], as applicable.

In the case of a gap greater than 2 mm, the above throat thickness is to be increased accordingly as specified in Sec 2 for some special connections of various ship types. Recommendations are also given in the "Guide for welding".

In any event, the gap g may not exceed 3 mm.

Figure 11 : Gap in fillet weld T connections



4.3.6 Plate misalignment in butt connections

The misalignment m, measured as shown in Fig 12, between plates with the same gross thickness t is to be less than 0,15t, without being greater than 4 mm, where t is the gross thickness of the thinner abutting plate.

4.3.7 Misalignment in cruciform connections

The misalignment m in cruciform connections, measured on the median lines as shown in Fig 13, is to be less than:

- t/2, in general, where t is the gross thickness of the thinner abutting plate
- the values specified in Sec 2 for some special connections of various ship types.

The Society may require lower misalignment to be adopted for cruciform connections subjected to high stresses.

Figure 12 : Plate misalignment in butt connections

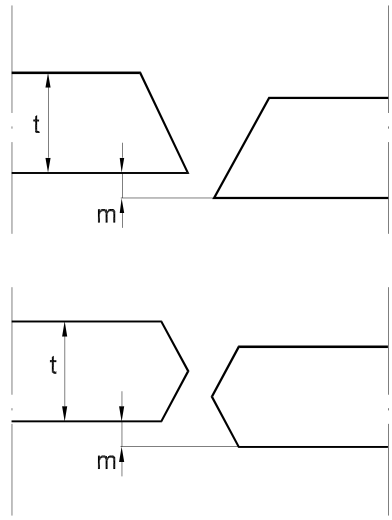
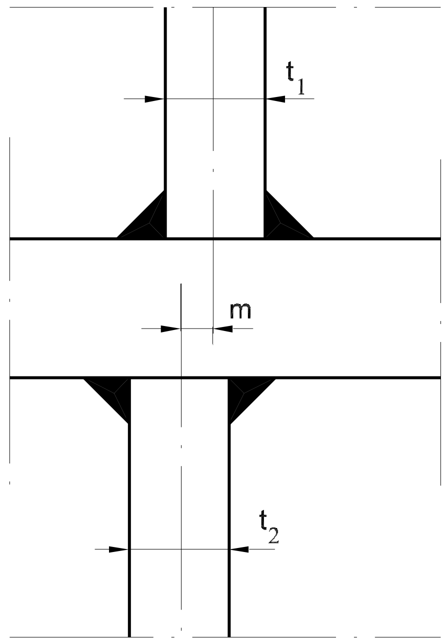


Figure 13 : Misalignment in cruciform connections



4.3.8 Assembling of aluminium alloy parts

When welding aluminium alloy parts, particular care is to be taken so as to:

- reduce as far as possible restraint from welding shrinkage, by adopting assembling and tack welding procedures suitable for this purpose
- keep possible deformations within the allowable limits.

4.3.9 Preheating and interpass temperatures

Suitable preheating, to be maintained during welding, and slow cooling may be required by the Society on a case by case basis.

4.3.10 Welding sequences

Welding sequences and direction of welding are to be determined so as to minimise deformations and prevent defects in the welded connection.

All main connections are generally to be completed before the ship is afloat.

Departures from the above provision may be accepted by the Society on a case by case basis, taking into account any detailed information on the size and position of welds and the stresses of the zones concerned, both during ship launching and with the ship afloat.

4.3.11 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.

4.3.12 Stress relieving

It is recommended and in some cases it may be required that special structures subject to high stresses, having complex shapes and involving welding of elements of considerable thickness (such as rudder spades and stern frames), are prefabricated in parts of adequate size and stress-relieved in the furnace, before final assembly, at a temperature within the range 550°C ÷ 620°C, as appropriate for the type of steel.

4.4 Crossing of structural elements

4.4.1 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 When the gap exceeds the required values, welding by building up or repairs are to be authorised by the Society's Surveyor.

Recommendations for repairing gap and weld deformations not complying with the required standards are given in the "Guide for welding".

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, considering these modifications as repairs of the in-service ship's hull.

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 suitable to check compliance with the applicable requirements, approved plans and standards.

6.1.2 The manufacturer is to make available to the Surveyor a list of the manual welders and welding operators and their respective qualifications.

The manufacturer'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 manufacturer is responsible for ensuring that the operating conditions, welding procedures and work schedule are in accordance with the applicable requirements, approved plans and recognised good welding practice.

6.2 Visual and non-destructive examinations

6.2.1 After completion of the welding operation and workshop inspection, the structure is to be presented to the Surveyor for visual examination at a suitable stage of fabrication.

As far as possible, the results on non-destructive examinations are to be submitted.

6.2.2 Non-destructive examinations are to be carried out with appropriate methods and techniques suitable for the individual applications, to be agreed with the Surveyor on a case by case basis.

6.2.3 Radiographic examinations are to be carried out on the welded connections of the hull in accordance with the Society's requirements, the approved plans and the Surveyor's instructions.

6.2.4 The Society may allow radiographic examinations to be partially replaced by ultrasonic examinations.

6.2.5 When the visual or non-destructive examinations reveal the presence of unacceptable defects, the relevant connection is to be repaired to sound metal for 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 at least as effective as that adopted the first time and 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.

6.2.6 Ultrasonic and magnetic particle examinations may also be required by the Surveyor in specific cases to verify the quality of the base material.

SECTION 2 SPECIAL STRUCTURAL DETAILS

Symbols

T_B : Ship's draft in light ballast condition, see Ch 5, Sec 1, [2.4.3].

1 General

1.1 Application

1.1.1 Special structural details are those characterised by complex geometry, possibly associated with high or alternate stresses.

In addition, the hull areas in which they are located are such that the ship operation and overall safety could be impaired by an unsatisfactory structural performance of the detail.

1.1.2 For special structural details, specific requirements are to be fulfilled during:

- design
- construction
- selection of materials
- welding
- survey.

The purpose of these requirements is specified in [1.2] to [1.6].

1.1.3 Special structural details are those listed in [2] together with the specific requirements which are to be fulfilled.

Other structural details may be considered by the Society as special details, when deemed necessary on the basis of the criteria in [1.1.1]. The criteria to be fulfilled in such cases are defined by the Society on a case by case basis.

1.1.4 As regards matters not explicitly specified in [2], the Rule requirements are to be complied with in any event; in particular:

- Chapter 4 for design principles and structural arrangements
- Chapter 7 or Chapter 8, as applicable, for structural scantling
- Chapter 12 for construction and welding requirements
- the applicable requirements in Part E and Part F.

1.2 Design requirements

1.2.1 General requirements

Design requirements specify:

- the local geometry, dimensions and scantlings of the structural elements which constitute the detail
- any local strengthening
- the cases where a fatigue check is to be carried out according to Ch 7, Sec 4.

1.2.2 Fatigue check requirements

Where a fatigue check is to be carried out, the design requirements specify see Ch 7, Sec 4, [3]:

- the locations (hot spots) where the stresses are to be calculated and the fatigue check performed
- the direction in which the normal stresses are to be calculated
- the stress concentration factors K_h and $K\ell$ to be used for calculating the hot spot stress range.

1.3 Constructional requirements

1.3.1 Constructional requirements specify the allowable misalignment and tolerances, depending on the detail arrangement and any local strengthening.

1.4 Material requirements

1.4.1 Material requirements specify the material quality to be used for specific elements which constitute the detail, depending on their manufacturing procedure, the type of stresses they are subjected to, and the importance of the detail with respect to the ship operation and overall safety.

In addition, these requirements specify where material inspections are to be carried out.

1.5 Welding requirements

1.5.1 Welding requirements specify where partial or full T penetration welding (see Sec 1, [2.4]) or any particular welding type or sequence is to be adopted. In addition, these requirements specify when welding procedures are to be approved.

For some fillet welding connections the minimum required throat thickness is also specified.

Since weld shape and undercuts are influencing factors on fatigue behaviour, fillet welds are to be elongated in the direction of the highest stresses and care is to be taken to avoid undercuts, in particular at the hot spots.

1.6 Survey requirements

1.6.1 Survey requirements specify where non-destructive examinations of welds are to be carried out and, where this is the case, which type is to be adopted.

2 List and characteristics of special structural details

2.1 General

2.1.1 This Article lists and describes, depending on the ship type, the special structural details and specifies the specific requirements which are to be fulfilled according to [1.2] to [1.6]. This is obtained through:

- a description of the hull areas where the details are located
- the detail description
- the requirements for the fatigue check
- a reference to a sheet in the Appendixes where a picture of the detail is shown together with the specific requirements which are to be fulfilled.

2.2 All types of ships with longitudinally framed sides

2.2.1 The special structural details relevant to all types of longitudinally framed ships are listed and described in Tab 1.

2.3 Oil tankers

2.3.1 The special structural details relevant to ships with the service notation **oil tanker ESP** are listed and described in Tab 2 for various hull areas.

When the structural arrangement in a certain area is such that the details considered in Tab 2 are not possible, specific requirements are defined by the Society on a case by case basis, depending on the arrangement adopted.

Table 1 : Ships with longitudinally framed sides - Special structural details

Area reference number	Area description	Detail description	Fatigue check	Reference sheet in App 1
1	Part of side extended: • longitudinally, between the after peak bulkhead and the collision bulkhead • vertically, between 0,7T_B and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with transverse primary supporting members	No	Sheets 1.1 to 1.6
		Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members	For L≥150m	Sheets 1.7 to 1.13

Table 2 : Oil tankers - Special structural details

Area reference number	Area description	Detail description	Fatigue check	Reference sheet in App 1
1	Part of side extended: • longitudinally, between the after peak bulkhead and the collision bulkhead • vertically, between 0,7T_B and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with transverse primary supporting members	No	Sheets 1.1 to 1.6
		Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members	For L≥150m	Sheets 1.7 to 1.13
2	Part of inner side and longitudinal bulkheads in the cargo area extended vertically above half tank height, where the tank breadth exceeds 0,55B	Connection of inner side or bulkhead longitudinal ordinary stiffeners with transverse primary supporting members	No	Sheets 2.1 to 2.6
		Connection of inner side or bulkhead longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members	For L≥150m	Sheets 2.7 to 2.13
3	Double bottom in way of transverse bulkheads	Connection of bottom and inner bottom longitudinal ordinary stiffeners with floors	For L≥150m	Sheets 3.1 to 3.3
		Connection of inner bottom with transverse bulkheads or lower stools	For L≥150m	Sheet 3.4
4	Double bottom in way of hopper tanks	Connection of inner bottom with hopper tank sloping plates	For L≥150m	Sheets 4.1 to 4.4
5	Lower part of transverse bulkheads with lower stools	Connection of lower stools with plane bulkheads	For L≥150m	Sheets 5.1 to 5.7
		Connection of lower stools with corrugated bulkheads	For L≥150m (No for 5.11, 5.15)	Sheets 5.8 to 5.15
6	Lower part of inner side	Connection of hopper tank sloping plates with inner side	For L≥150m	Sheets 6.1 to 6.7

SECTION 3 TESTING

1 Pressure tests

1.1 Application

1.1.1 The following requirements determine the testing conditions for:

- gravity tanks, excluding independent tanks of less than $5m^3$ in capacity
- watertight or weathertight structures.

The purpose of these tests is to check the tightness and/or the strength of structural elements.

1.1.2 Tests are to be carried out in the presence of the Surveyor at a stage sufficiently close to completion so that any subsequent work would not impair the strength and tightness of the structure.

In particular, tests are to be carried out after air vents and sounding pipes are fitted.

1.1.3 The Society may accept that structural testing of a sister ship is limited to a single tank for each type of structural arrangement.

However, if the Surveyor detects anomalies, he may require the number of tests is increased or that the same number of tests is provided as for the first ship in a series.

1.2 Definitions

1.2.1 Shop primer

Shop primer is a thin coating applied after surface preparation and prior to fabrication as a protection against corrosion during fabrication.

1.2.2 Protective coating

Protective coating is a final coating protecting the structure from corrosion.

1.2.3 Structural testing

Structural testing is a hydrostatic test carried out to demonstrate the tightness of the tanks and the structural adequacy of the design. Where practical limitations prevail and hydrostatic testing is not feasible (for example when it is difficult, in practice, to apply the required head at the top of the tank), hydropneumatic testing may be carried out instead.

Structural testing is to be carried out according to [2.2].

1.2.4 Hydropneumatic testing

Hydropneumatic testing is a combination of hydrostatic and air testing, consisting in filling the tank to the top with water and applying an additional air pressure.

Hydropneumatic testing is to be carried out according to [2.3].

1.2.5 Leak testing

Leak testing is an air or other medium test carried out to demonstrate the tightness of the structure.

Leak testing is to be carried out according to [2.4].

1.2.6 Hose testing

Hose testing is carried out to demonstrate the tightness of structural items not subjected to hydrostatic or leak testing and of other components which contribute to the watertight or weathertight integrity of the hull.

Hose testing is to be carried out according to [2.5].

1.2.7 Margin line

The margin line is a line drawn at least 76 mm below the upper surface of the bulkhead deck at side.

1.2.8 Sister ship

A sister ship is a ship having the same main dimensions, general arrangement, capacity plan and structural design as those of the first ship in a series.

2 Watertight compartments

2.1 General

2.1.1 The requirements in [2.1] to [2.6] intend generally to verify the adequacy of the structural design of the tanks, based on the loading conditions which prevailed when determining the tank structure scantlings.

2.1.2 General requirements for testing of watertight compartments are given in Tab 1, in which the types of testing referred to are defined in [1.2].

Table 1 : Watertight compartments - General testing requirements

Compartment or structure to be tested	Type of testing	Structural test pressure	Remarks
Double bottom tanks	Structural testing **(1)**	The greater of the following: • head of water up to the top of overflow • head of water up to the margin line	Tank boundaries tested from at least one side
Double side tanks	Structural testing **(1)**	The greater of the following: • head of water up to the top of overflow • 2,4 m head of water above highest point of tank **(5)**	Tank boundaries tested from at least one side
Tank bulkheads, deep tanks	Structural testing **(1)**	The greater of the following **(2)**: • head of water up to the top of overflow • 2,4 m head of water above highest point of tank **(5)** • setting pressure of the safety relief valves, where relevant	Tank boundaries tested from at least one side
Fuel oil bunkers	Structural testing		
Ballast holds in **bulk carriers**	Structural testing **(1)**	The greater of the following: • head of water up to the top of overflow • 0,9 m head of water above top of hatch	
Fore and after peaks used as tank	Structural testing	The greater of the following: • head of water up to the top of overflow • 2,4 m head of water above highest point of tank **(5)**	Test of the after peak carried out after the sterntube has been fitted
Fore peak not used as tank	Structural testing	The greater of the following: • maximum head of water to be sustained in the event of damage • head of water up to the margin line	
After peak not used as tank	Leak testing		
Cofferdams	Structural testing **(3)**	The greater of the following: • head of water up to the top of overflow • 2,4 m head of water above highest point of tank **(5)**	
Watertight bulkheads	Hose testing **(4)**		
Watertight doors below freeboard or bulkhead deck **(6) (7)**	Structural testing	Head of water up to the bulkhead deck	Test to be carried out before the ship is put into service, either before or after the door is fitted on board (see [2.7])
Double plate rudders	Leak testing		
Shaft tunnel clear of deep tanks	Hose testing		
Shell doors	Hose testing		
Weathertight hatch covers and closing appliances	Hose testing		
Chain locker (if aft of collision bulkhead)	Structural testing	Head of water up to the top	
Independent tanks	Structural testing	Head of water up to the top of overflow, but not less than 0,90 m	

Compartment or structure to be tested	Type of testing	Structural test pressure	Remarks
Ballast ducts	Structural testing	Ballast pump maximum pressure	

(1) Hydropneumatic or leak testing may be accepted under the conditions specified in [2.3] and [2.4], respectively, provided that at least one tank of each type is structurally tested, to be selected in connection with the approval of the design. in general, structural testing need not be repeated for subsequent ships of a series of identical new buildings. This relaxation does not apply to cargo space boundaries in ships with the service notation **oil tanker ESP** and to tanks for segregated cargoes or pollutants. If the structural test reveals weakness or severe faults not detected by the leak test, all tanks are to be structurally tested.
(2) Where applicable, the highest point of the tank is to be measured to deck and excluding hatches. In holds for liquid cargo or ballast with large hatch covers, the highest point of tanks is to be taken at the top of the hatch.
(3) Hydropneumatic or leak testing may be accepted under the conditions specified in [2.3] and [2.4], respectively, when, at the Society's discretion, it is considered significant also in relation to the construction techniques and the welding procedures adopted.
(4) When a hose test cannot be performed without damaging possible outfitting (machinery, cables, switchboards, insulation, etc...) already installed, it may be replaced, at the Society's discretion, by a careful visual inspection of all the crossings and welded joints. Where necessary, a dye penetrant test or ultrasonic leak test may be required.
(5) For ships of less than 40 m in length, 2,4 m may be replaced by 0,3H with $0,9 \leq 0,3\ H \leq 2,4$, where H is the height of compartment, in m.
(6) Watertight doors are those defined in Pt F, Ch 10, Sec 9, [2.1.4].
(7) The means of closure are to be subjected to a hose test after fitting on board.

2.2 Structural testing

2.2.1 Structural testing may be carried out before or after launching.

2.2.2 Structural testing may be carried out after application of the shop primer.

2.2.3 Structural testing may be carried out after the protective coating has been applied, provided that one of the following two conditions is satisfied:

- all the welds are completed and carefully inspected visually to the satisfaction of the Surveyor prior to the application of the protective coating
- leak testing is carried out prior to the application of the protective coating.

In the absence of leak testing, protective coating is to be applied after the structural testing of:

- all erection welds, both manual and automatic
- all manual fillet weld connections on tank boundaries and manual penetration welds.

2.3 Hydropneumatic testing

2.3.1 When a hydropneumatic testing is performed, the conditions are to simulate, as far as practicable, the actual loading of the tank.

The value of the additional air pressure is at the discretion of the Society, but is to be at least as defined in [2.4.2] for leak testing.

The same safety precautions as for leak testing (see [2.4.2]) are to be adopted.

2.4 Leak testing

2.4.1 An efficient indicating liquid, such as a soapy water solution, is to be applied to the welds.

2.4.2 Where leak testing is carried out, in accordance with Tab 1, an air pressure of $0,15.10^5$ Pa is to be applied during the test.

Prior to inspection, it is recommended that the air pressure in the tank should be raised to $0,2.10^5$ Pa and kept at this level for approximately 1 hour to reach a stabilised state, with a minimum number of personnel in the vicinity of the tank, and then lowered to the test pressure.

The test may be conducted after the pressure has reached a stabilised state at $0,2.10^5$ Pa, without lowering the pressure, provided the Society is satisfied of the safety of the personnel involved in the test.

2.4.3 A U-tube filled with water up to a height corresponding to the test pressure is to be fitted to avoid overpressure of the compartment tested and verify the test pressure.

The U-tube is to have a cross-section larger than that of the pipe supplying air.

In addition, the test pressure is also to be verified by means of one master pressure gauge.

Alternative means which are considered to be equivalently reliable may be accepted at the discretion of the Surveyor.

2.4.4 Leak testing is to be carried out, prior to the application of a protective coating, on all fillet weld connections on tank boundaries, and penetration and erection welds on tank boundaries excepting welds made by automatic processes.

Selected locations of automatic erection welds and pre-erection manual or automatic welds may be required to be similarly tested to the satisfaction of the Surveyor, taking account of the quality control procedures operating in the shipyard.

For other welds, leak testing may be carried out after the protective coating has been applied, provided that such welds have been carefully inspected visually to the satisfaction of the Surveyor.

2.4.5 Any other recognised method may be accepted to the satisfaction of the Surveyor.

2.5 Hose testing

2.5.1 When hose testing is required to verify the tightness of the structures, as defined in Tab 1, the minimum pressure in the hose, at least equal to $2,0.10^5$ Pa, is to be applied at a maximum distance of 1,5 m.

The nozzle diameter is to be not less than 12 mm.

2.6 Other testing methods

2.6.1 Other testing methods may be accepted, at the discretion of the Society, based upon equivalency considerations.

2.7 Acceptance criteria for watertight doors

2.7.1 The following acceptable leakage criteria apply:

Doors with gaskets: No leakage

Doors with metallic sealing: Maximum leakage 1 l/min

Limited leakage may be accepted for pressure tests on large doors located in cargo spaces employing gasket seals or guillotine doors located in conveyor tunnels, in accordance with the following:

Leakage rate (l/min) = $(P + 4,572)\ h^3 / 6568$

where:

P = perimeter of door opening, in m

h = test head of water, in m

However, in the case of doors where the water head taken for the determination of the scantling does not exceed 6,1 m, the leakage rate may be taken equal to 0,375 l/min if this value is greater than that calculated by the above-mentioned formula.

2.7.2 For large doors intended for use in watertight subdivision boundaries of cargo spaces, structural analysis may be accepted in lieu of pressure testing on a case-by-case basis. Where such doors use gasket seals, a prototype pressure test is to be carried out to confirm that the compression of the gasket material is capable of accommodating any deflection, revealed by the structural analysis.

3 Miscellaneous

3.1 Watertight decks, trunks, etc.

3.1.1 After completion, a hose or flooding test is to be applied to watertight decks and a hose test to watertight trunks, tunnels and ventilators.

3.2 Doors in bulkheads above the bulkhead deck

3.2.1 Doors are to be designed and constructed as weathertight doors and, after installation, subjected to a hose test from each side for weathertightness.

3.3 Semi-watertight doors

3.3.1 Semi-watertight doors are those defined in Pt F, Ch 10, Sec 9, [2.1.4].

These means of closure are to be subjected to a structural test at the manufacturer's works. The head of water is to be up to the highest waterline after damage at the equilibrium of the intermediate stages of flooding. The duration of the test is to be at least 30 min.

A leakage quantity of approximately 100 l/hour is considered as being acceptable for a 1,35 m^2 opening.

The means of closure are to be subjected to a hose test after fitting on board.

3.4 Steering nozzles

3.4.1 Upon completion of manufacture, the nozzle is to be subjected to a leak test.

4 Working tests

4.1 Working test of windlass

4.1.1 The working test of the windlass is to be carried out on board in the presence of a Surveyor.

4.1.2 The test is to demonstrate that the windlass complies with the requirements of Ch 10, Sec 4, [3.7] and, in particular, that it works adequately and has sufficient power to simultaneously weigh the two bower anchors (excluding the housing of the anchors in the hawse pipe) when both are suspended to 55 m of chain cable, in not more than 6 min.

4.1.3 Where two windlasses operating separately on each chain cable are adopted, the weighing test is to be carried out for both, weighing an anchor suspended to 82,5 m of chain cable and verifying that the time required for the weighing (excluding the housing in the hawse pipe) does not exceed 9 min.

APPENDIX 1 REFERENCE SHEETS FOR SPECIAL STRUCTURAL DETAILS

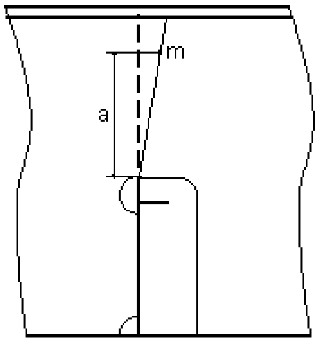
1 Contents

1.1 General

1.1.1 This appendix includes the reference sheets for special structural details, as referred to in Sec 2.

ALL LONGITUDINALLY FRAMED SIDE SHIPS

AREA 1: Side between $0,7T_B$ and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with transverse primary supporting members - No collar plate	Sheet 1.1



t_W = web thickness of transverse primary supporting member

SCANTLINGS:	FATIGUE:
Net sectional area of the web stiffener according to Ch 4, Sec 3, 4.7.	Fatigue check not required.
CONSTRUCTION:	**NDE:**
• Web stiffener not compulsory. When fitted, its misalignment m with the web of the side longitudinal $\leq$ a / 50. • Cut-outs in the web free of sharps notches. • Gap between web and side longitudinal to be not greater than 4 mm.	Visual examination 100%.

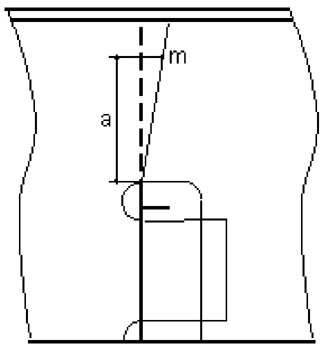
WELDING AND MATERIALS:

Welding requirements:

- continuous fillet welding along the connection of web with side longitudinal,
- throat thickness according to Ch 12, Sec 1, [2.3.7], in case of gap g greater than 2 mm increase the throat thickness by 0,7(g-2) mm,
- weld around the cuts in the web at the connection with the longitudinal and the side shell,
- avoid burned notches on web.

ALL LONGITUDINALLY FRAMED SIDE SHIPS

AREA 1: Side between $0,7T_B$ and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with transverse primary supporting members - One collar plate	Sheet 1.2



t_W = web thickness of transverse primary supporting member

t_{CP} = collar plate thickness

SCANTLINGS:	FATIGUE:
Net sectional area of the web stiffener according to Ch 4, Sec 3, 4.7.	Fatigue check not required.

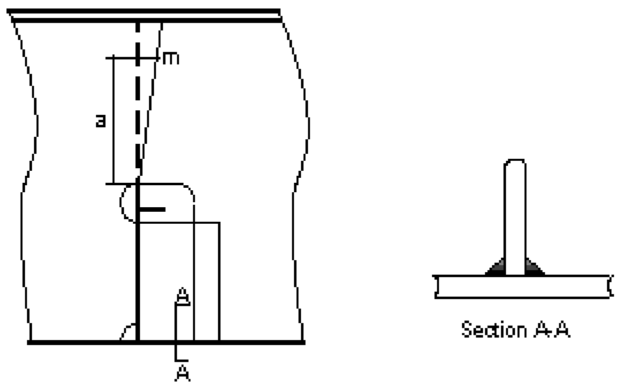
CONSTRUCTION:	NDE:
• Web stiffener not compulsory. When fitted, its misalignment m with the web of the side longitudinal $\leq$ a / 50. • Misalignment between web and collar plate $\leq t_{CP}$. • Cut-outs in the web free of sharps notches. • Gap between web and side longitudinal and between collar plate and side longitudinal to be not greater than 4 mm.	Visual examination 100%.

WELDING AND MATERIALS:

- Welding requirements:
  - continuous fillet welding along the connection of web and collar plate with side longitudinal and at the lap joint between web and collar plate,
  - throat thickness according to Ch 12, Sec 1, [2.3.7], in case of gap g greater than 2 mm increase the throat thickness by 0,7(g-2) mm,
  - weld around the cuts in the web at the connection with the longitudinal and the side shell,
  - avoid burned notches on web.
- Fillet welding of overlapped joint to be done all around.

ALL LONGITUDINALLY FRAMED SIDE SHIPS

AREA 1: Side between $0,7T_B$ and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with transverse primary supporting members - One large collar plate	Sheet 1.3



t_W = web thickness of transverse primary supporting member

t_{CP} = collar plate thickness

SCANTLINGS:	FATIGUE:
Net sectional area of the web stiffener according to Ch 4, Sec 3, [4.7].	Fatigue check not required.

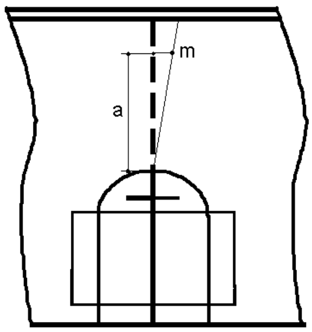
CONSTRUCTION:	NDE:
• Web stiffener not compulsory. When fitted, its misalignment m with the web of the side longitudinal $\leq$ a / 50. • Misalignment between web and collar plate $\leq t_{CP}$. • Cut-outs in the web free of sharps notches. • Gap between web and side longitudinal and between collar plate and side longitudinal to be not greater than 4 mm.	Visual examination 100%.

WELDING AND MATERIALS:

- Welding requirements:
  - continuous fillet welding along the connection of web and collar plate with side longitudinal and at the lap joint between web and collar plate,
  - throat thickness according to Ch 12, Sec 1, [2.3.7], in case of gap g greater than 2 mm increase the throat thickness by 0,7(g-2) mm,
  - T joint connection of collar plate with side shell: see section A-A,
  - weld around the cuts in the web at the connection with the longitudinal and the side shell,
  - avoid burned notches on web.
- Fillet welding of overlapped joint to be done all around.

ALL LONGITUDINALLY FRAMED SIDE SHIPS

AREA 1: Side between 0,7T_B and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with transverse primary supporting members - Two collar plates	Sheet 1.4



t_W = web thickness of transverse primary supporting member

t_{CP} = collar plate thickness

SCANTLINGS:	FATIGUE:
Net sectional area of the web stiffener according to Ch 4, Sec 3, [4.7].	Fatigue check not required.

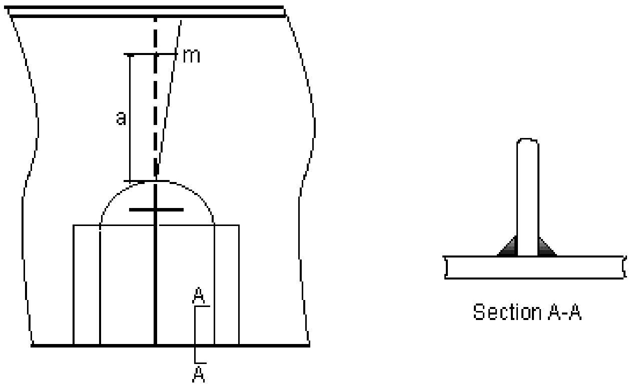
CONSTRUCTION:	NDE:
• Web stiffener not compulsory. When fitted, its misalignment m with the web of the side longitudinal $\leq$ a / 50. • Misalignment between collar plates across the side longitudinal $\leq t_{CP}$ / 2. • Cut-outs in the web free of sharps notches. • Gap between collar plates and side longitudinal to be not greater than 4 mm.	Visual examination 100%.

WELDING AND MATERIALS:

- Welding requirements:
  - continuous fillet welding along the connection of collar plates with side longitudinal and at the lap joint between web and collar plates,
  - throat thickness according to Ch 12, Sec 1, [2.3.7], in case of gap g greater than 2 mm increase the throat thickness by 0,7(g-2) mm,
  - avoid burned notches on web.
- Fillet welding of overlapped joint to be done all around.

ALL LONGITUDINALLY FRAMED SIDE SHIPS

AREA 1: Side between 0,7T_B and 1,15T from the baseline	**Connection of side longitudinal ordinary stiffeners with transverse primary supporting members - Two large collar plates**	**Sheet 1.5**



t_W = web thickness of transverse primary supporting member

t_{CP} = collar plate thickness

SCANTLINGS:	FATIGUE:
Net sectional area of the web stiffener according to Ch 4, Sec 3, [4.7].	Fatigue check not required.

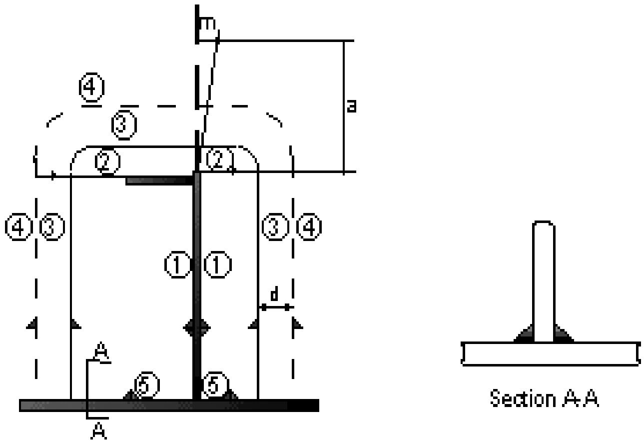
CONSTRUCTION:	NDE:
• Web stiffener not compulsory. When fitted, its misalignment m with the web of the side longitudinal $\leq$ a / 50. • Misalignment between collar plates across the side longitudinal $\leq t_{CP}$ / 2. • Cut-outs in the web free of sharps notches. • Gap between collar plates and side longitudinal to be not greater than 4 mm.	Visual examination 100%.

WELDING AND MATERIALS:

- Welding requirements:
  - continuous fillet welding along the connection of collar plates with side longitudinal and at the lap joint between web and collar plates,
  - throat thickness according to Ch 12, Sec 1, [2.3.7], in case of gap g greater than 2 mm increase the throat thickness by 0,7(g-2) mm,
  - T joint connection of collar plates with side shell: see section A-A,
  - avoid burned notches on web.
- Fillet welding of overlapped joint to be done all around.

ALL LONGITUDINALLY FRAMED SIDE SHIPS

AREA 1: Side between $0{,}7T_B$ and 1,15T from the baseline	**Watertight connection of side longitudinal ordinary stiffeners with watertight side diaphragms or transverse bulkheads – Example of connection with lugs**	**Sheet 1.6**



t_W = transverse bulkhead web thickness

t_L = lug thickness

SCANTLINGS:	**FATIGUE:**
• d = 30 ÷ 60 mm. • $t_L \geq t_W$.	Fatigue check not required.
CONSTRUCTION:	**NDE:**
• Web stiffener not compulsory. When fitted, its misalignment m with the web of the side longitudinal ≤ a / 50. • Misalignment between lugs across the side longitudinal ≤ t_L / 2. • Misalignment at the butts within lug parts ≤ t_L / 5. • Gap between bulkhead plating and lugs to be not greater than 4 mm.	• Visual examination 100%. • Magnetic particle or dye penetrant examination: when deemed necessary depending on the quality of the lap joint weld.

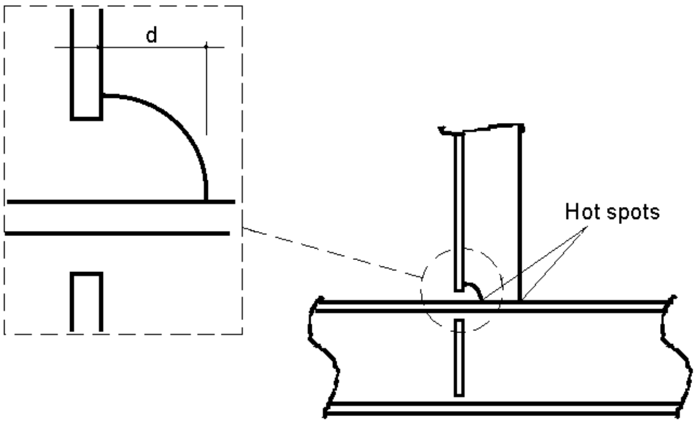
WELDING AND MATERIALS:

Welding requirements:

- continuous fillet welding along the connection of lugs with the side longitudinal and at the lap joints between web and lugs,
- throat thickness according to Ch 12, Sec 1, [2.3.7], in case of gap g greater than 2 mm increase the throat thickness by 0,7(g-2) mm,
- T joint connection of collar plates with side shell: see section A-A,
- welding sequence: ① to ⑤ (see sketch).

ALL LONGITUDINALLY FRAMED SIDE SHIPS

AREA 1: Side between $0,7T_B$ and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - No bracket	Sheet 1.7



t = minimum thickness between those of:
- web of side longitudinal,
- stiffener of transverse primary supporting member.

SCANTLINGS:	FATIGUE:
d to be as small as possible, maximum 35 mm recommended.	Fatigue check to be carried out for L ≥ 150 m: K_h = 1,3 K_ℓ = 1,65

CONSTRUCTION:	NDE:
Misalignment (measured between the outer edges) between longitudinal and web stiffener to be in general equal to or less than 0,7 t. For bulbs, a misalignment equal to 0,8 t may generally be accepted.	Visual examination 100%.

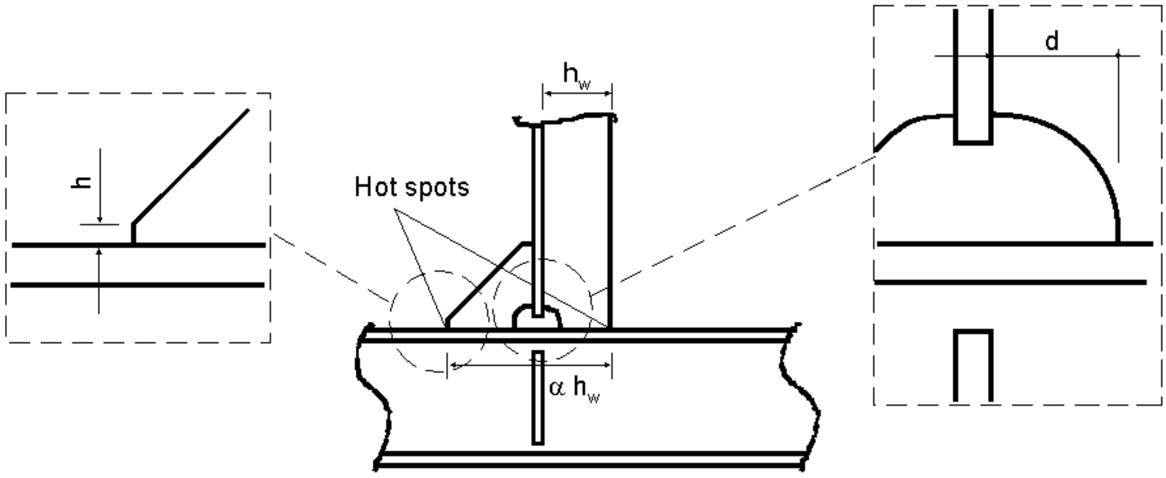
WELDING AND MATERIALS:

Welding requirements:

- continuous fillet welding,
- throat thickness = 0,45 t_W , where t_W is the web stiffener thickness,
- weld around the stiffener's toes,
- fair shape of fillet at toes in longitudinal direction.

ALL LONGITUDINALLY FRAMED SIDE SHIPS

AREA 1: Side between 0,7T_B and 1,15T from the baseline	**Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - One bracket**	**Sheet 1.8**



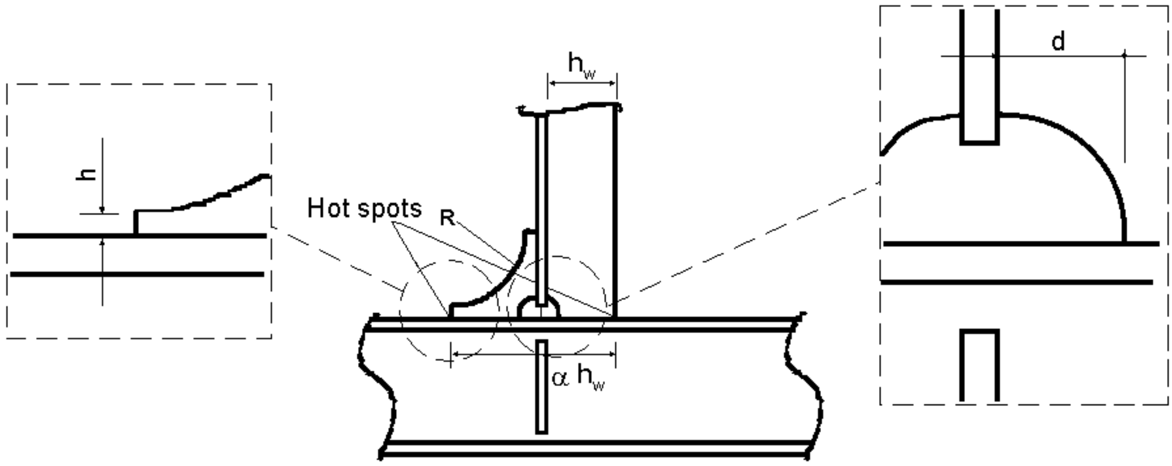
t = minimum thickness among those of the connected elements

SCANTLINGS:	**FATIGUE:**
• $\alpha \geq 2$. • Bracket to be symmetric. • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the bracket to be not less than that of web stiffener.	Fatigue check to be carried out for L ≥ 150 m: – for $2 \leq \alpha < 2,5$ $K_h = 1,2$ $K_\ell = 1,4$ – for $\alpha \geq 2,5$ $K_h = 1,15$ $K_\ell = 1,4$
CONSTRUCTION:	**NDE:**
Misalignment (measured between the outer edges) between longitudinal, web stiffener and bracket to be in general equal to or less than 0,7 t. For bulbs, a misalignment equal to 0,8 t may generally be accepted.	Visual examination 100%.

WELDING AND MATERIALS:
Welding requirements: - continuous fillet welding, - throat thickness = 0,45 t_W , where t_W is the web stiffener thickness, - weld around the stiffener's toes, - fair shape of fillet at toes in longitudinal direction.

ALL LONGITUDINALLY FRAMED SIDE SHIPS

AREA 1: Side between $0,7T_B$ and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - One radiused bracket	Sheet 1.9



t = minimum thickness among those of the connected elements

SCANTLINGS:	FATIGUE:
• $\alpha \geq 2$. • Bracket to be symmetric. • $R \geq 1,5\ (\alpha - 1)\ h_W$ • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the bracket to be not less than that of web stiffener.	Fatigue check to be carried out for L ≥ 150 m: - for $2 \leq \alpha < 2,5$ $K_h = 1,15$ $K_\ell = 1,35$ - for $\alpha \geq 2,5$ $K_h = 1,1$ $K_\ell = 1,35$

CONSTRUCTION:	NDE:
Misalignment (measured between the outer edges) between longitudinal, web stiffener and bracket to be in general equal to or less than 0,7 t. For bulbs, a misalignment equal to 0,8 t may generally be accepted.	Visual examination 100%.

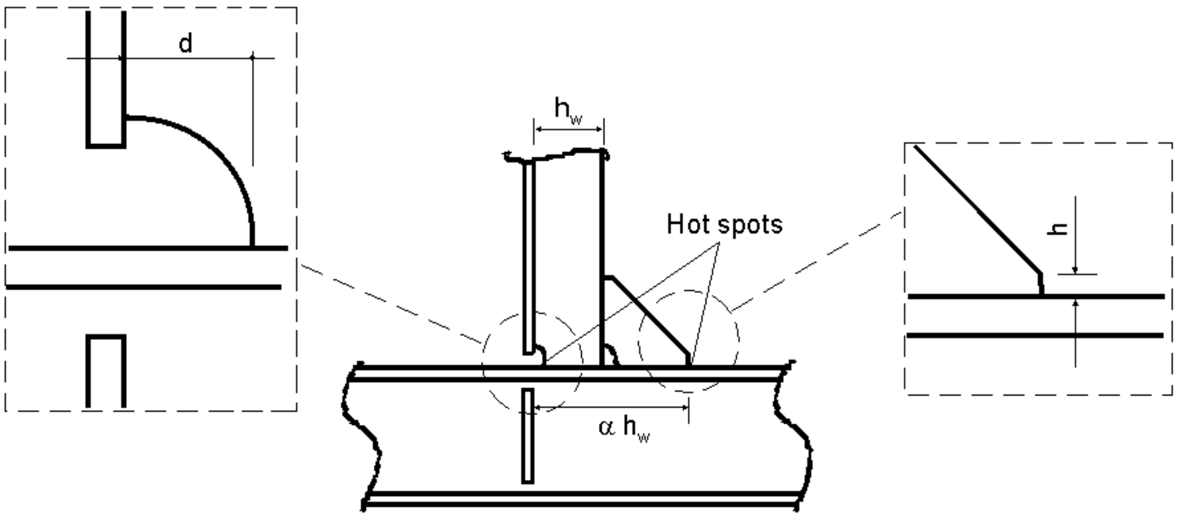
WELDING AND MATERIALS:

Welding requirements:

- continuous fillet welding,
- throat thickness = 0,45 t_W , where t_W is the web stiffener thickness,
- weld around the stiffener's toes,
- fair shape of fillet at toes in longitudinal direction.

ALL LONGITUDINALLY FRAMED SIDE SHIPS

AREA 1: Side between $0,7T_B$ and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - One bracket	Sheet 1.10



t = minimum thickness among those of the connected elements

SCANTLINGS:	FATIGUE:
• $\alpha \geq 2$. • Bracket to be symmetric. • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the bracket to be not less than that of web stiffener.	Fatigue check to be carried out for L ≥ 150 m: - for $2 \leq \alpha < 2,5$ $K_h = 1,3$ $K_\ell = 1,55$ - for $\alpha \geq 2,5$ $K_h = 1,25$ $K_\ell = 1,5$
CONSTRUCTION:	**NDE:**
Misalignment (measured between the outer edges) between longitudinal, web stiffener and bracket to be in general equal to or less than 0,7 t. For bulbs, a misalignment equal to 0,8 t may generally be accepted.	Visual examination 100%.

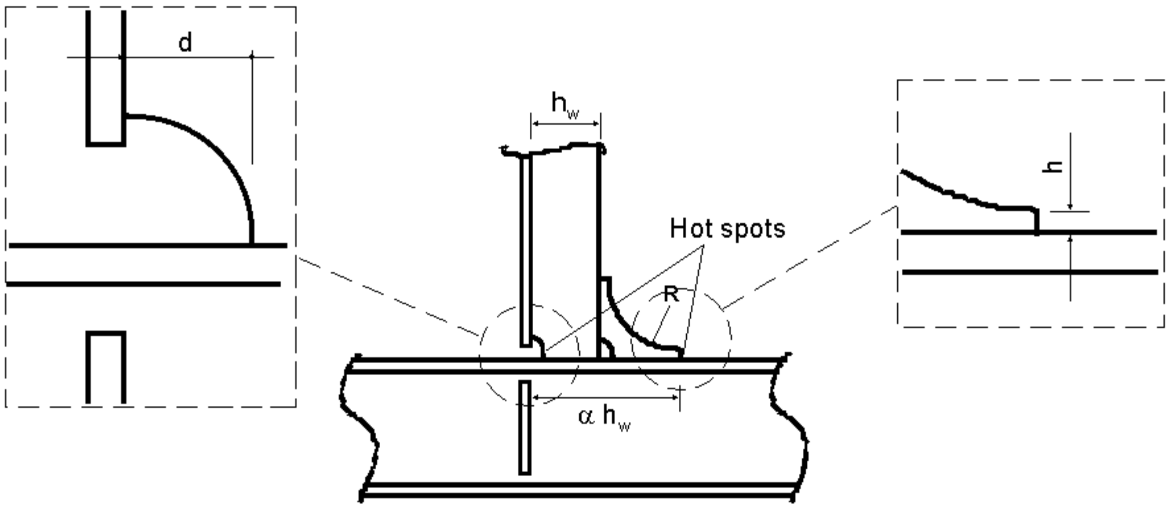
WELDING AND MATERIALS:

Welding requirements:

- continuous fillet welding,
- throat thickness = 0,45 t_W , where t_W is the web stiffener thickness,
- weld around the stiffener's toes,
- fair shape of fillet at toes in longitudinal direction.

ALL LONGITUDINALLY FRAMED SIDE SHIPS

AREA 1: Side between $0,7T_B$ and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - One radiused bracket	Sheet 1.11



t = minimum thickness among those of the connected elements

SCANTLINGS:	FATIGUE:
• $\alpha \geq 2$ • Bracket to be symmetric. • $R \geq 1,5\ (\alpha - 1)\ h_W$ • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the bracket to be not less than that of web stiffener.	Fatigue check to be carried out for L ≥ 150 m: - for $2 \leq \alpha < 2,5$: $K_h = 1,25$, $K_\ell = 1,5$ - for $\alpha \geq 2,5$: $K_h = 1,2$, $K_\ell = 1,45$

CONSTRUCTION:	NDE:
Misalignment (measured between the outer edges) between longitudinal, web stiffener and bracket to be in general equal to or less than 0,7 t. For bulbs, a misalignment equal to 0,8 t may generally be accepted.	Visual examination 100%.

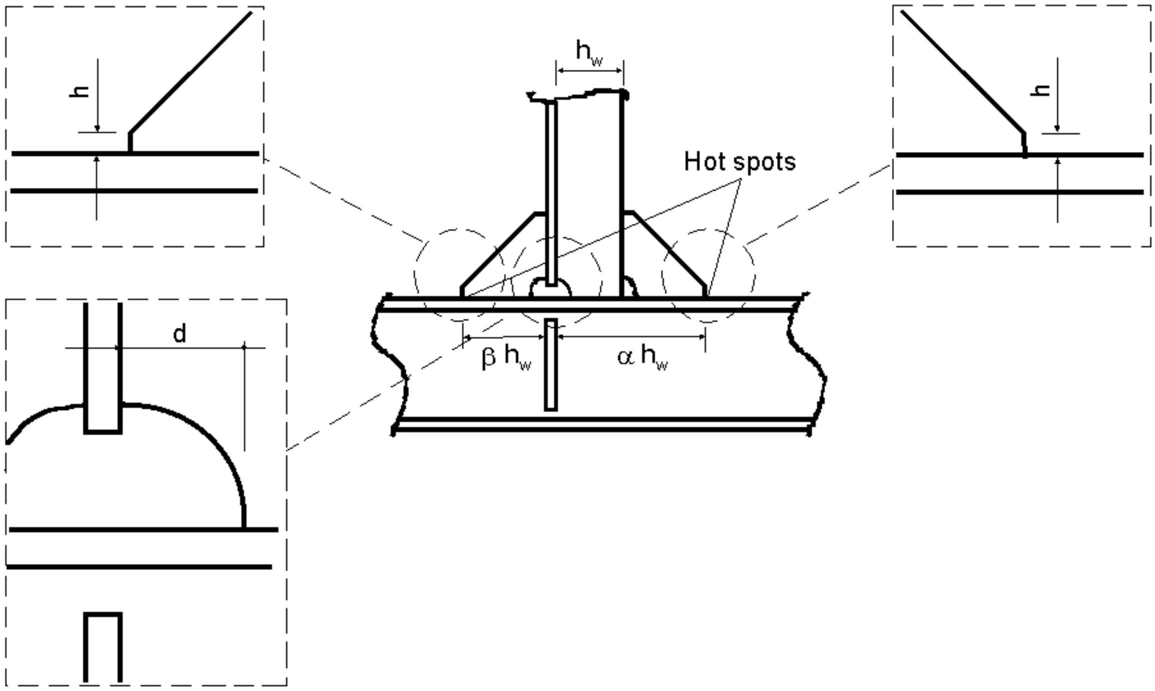
WELDING AND MATERIALS:

Welding requirements:

- continuous fillet welding,
- throat thickness = $0,45\ t_W$, where t_W is the web stiffener thickness,
- weld around the stiffener's toes,
- fair shape of fillet at toes in longitudinal direction.

ALL LONGITUDINALLY FRAMED SIDE SHIPS

AREA 1: Side between $0,7T_B$ and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - Two brackets	Sheet 1.12



t = minimum thickness among those of the connected elements

SCANTLINGS:	FATIGUE:
• $\alpha \geq 2$. • $\beta \geq 1$. • Brackets to be symmetric. • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the brackets to be not less than that of web stiffener.	Fatigue check to be carried out for L ≥ 150 m: - for $2 \leq \alpha < 2,5$ and $1 \leq \beta < 1,5$: $K_h = K_\ell = 1,15$ - for $\alpha \geq 2,5$ and $\beta \geq 1,5$: $K_h = K_\ell = 1,1$

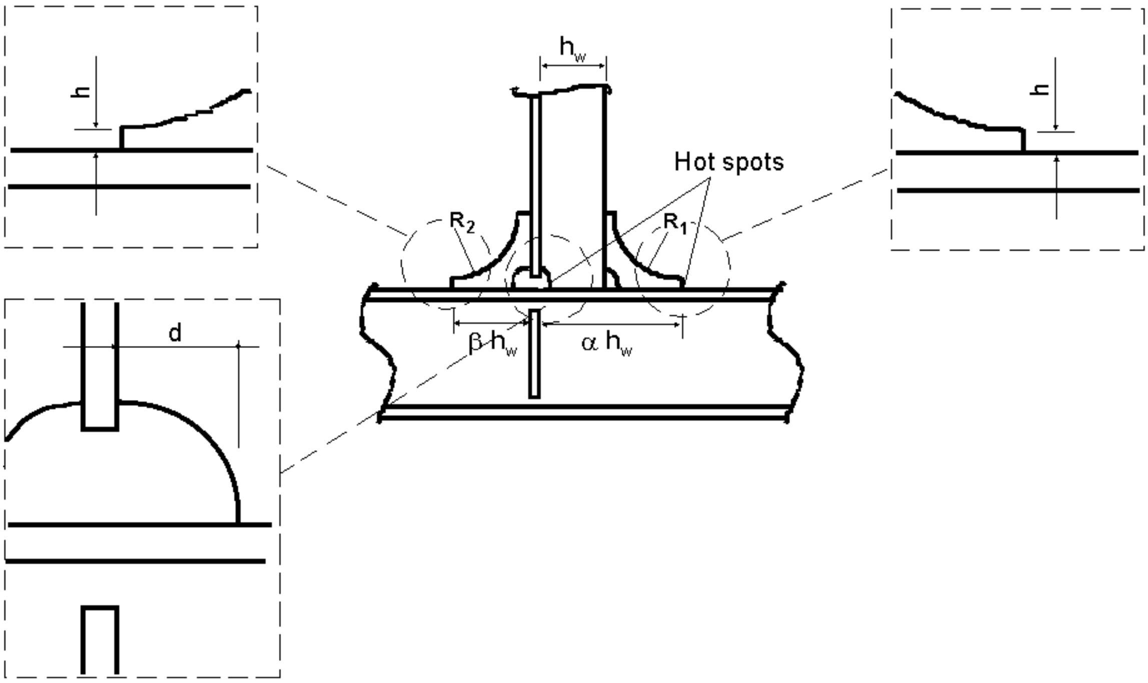
CONSTRUCTION:	NDE:
Misalignment (measured between the outer edges) between longitudinal, web stiffener and bracket to be in general equal to or less than 0,7 t. For bulbs, a misalignment equal to 0,8 t may generally be accepted.	Visual examination 100%.

WELDING AND MATERIALS:

- Welding requirements:
  - continuous fillet welding,
  - throat thickness = 0,45 t_W , where t_W is the web stiffener thickness,
  - weld around the stiffener's toes,
  - fair shape of fillet at toes in longitudinal direction.
- Material requirements:
  - material of brackets to be the same of longitudinals.

ALL LONGITUDINALLY FRAMED SIDE SHIPS

AREA 1: Side between $0,7T_B$ and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - Two radiused brackets	Sheet 1.13



t = minimum thickness among those of the connected elements

SCANTLINGS:	FATIGUE:
• $\alpha \geq 2$. • $\beta \geq 1$. • Brackets to be symmetric. • $R_1 \geq 1,5\ (\alpha - 1)\ h_W$ • $R_2 \geq 1,5\ \beta\ h_W$ • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the brackets to be not less than that of web stiffener.	Fatigue check to be carried out for L ≥ 150 m: - for $2 \leq \alpha < 2,5$ and $1 \leq \beta < 1,5$: $K_h = K_\ell = 1,1$ - for $\alpha \geq 2,5$ and $\beta \geq 1,5$: $K_h = K_\ell = 1,05$

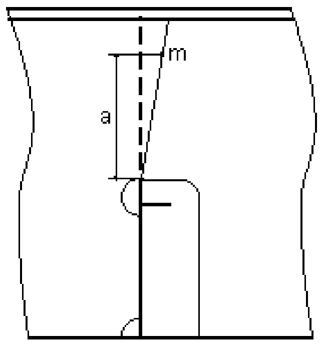
CONSTRUCTION:	NDE:
Misalignment (measured between the outer edges) between longitudinal, web stiffener and bracket to be in general equal to or less than 0,7 t. For bulbs, a misalignment equal to 0,8 t may generally be accepted.	Visual examination 100%.

WELDING AND MATERIALS:

- Welding requirements:
  - continuous fillet welding,
  - throat thickness = $0,45\ t_W$, where t_W is the web stiffener thickness,
  - weld around the stiffener's toes,
  - fair shape of fillet at toes in longitudinal direction.
- Material requirements:
  - material of brackets to be the same of longitudinals.

OIL TANKERS

AREA 2: Inner side and longitudinal bulkheads above 0,5H	**Connection of inner side or bulkhead longitudinal ordinary stiffeners with transverse primary supporting members - No collar plate**	**Sheet 2.1**



t_W = web thickness of transverse primary supporting member

SCANTLINGS:	**FATIGUE:**
Net sectional area of the web stiffener according to Ch 4, Sec 3, 4.7.	Fatigue check not required.

CONSTRUCTION:	**NDE:**
• Web stiffener not compulsory. When fitted, its misalignment m with the web of the longitudinal $\leq$ a / 50. • Cut-outs in the web free of sharps notches. • Gap between web and longitudinal to be not greater than 4 mm.	Visual examination 100%.

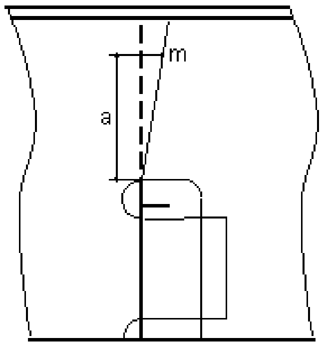
WELDING AND MATERIALS:

Welding requirements:

- continuous fillet welding along the connection of web with longitudinal,
- throat thickness according to Ch 12, Sec 1, 2.3.7, in case of gap g greater than 2 mm increase the throat thickness by 0,7(g-2) mm,
- weld around the cuts in the web at the connection with the longitudinal and the plating,
- avoid burned notches on web.

OIL TANKERS

AREA 2: Inner side and longitudinal bulkheads above 0,5H	Connection of inner side or bulkhead longitudinal ordinary stiffeners with transverse primary supporting members - One collar plate	Sheet 2.2



t_W = web thickness of transverse primary supporting member

t_{CP} = collar plate thickness

SCANTLINGS:	FATIGUE:
Net sectional area of the web stiffener according to Ch 4, Sec 3, 4.7.	Fatigue check not required.

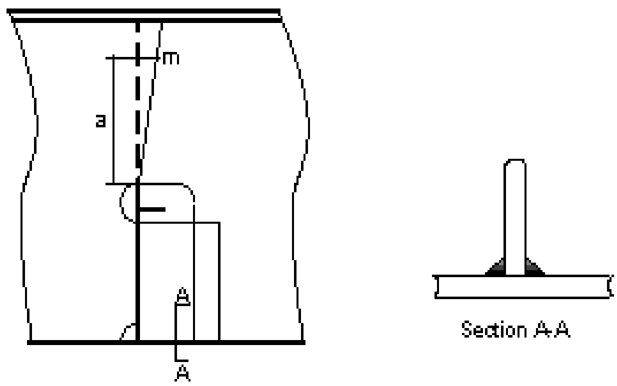
CONSTRUCTION:	NDE:
• Web stiffener not compulsory. When fitted, its misalignment m with the web of the longitudinal $\leq$ a / 50. • Misalignment between web and collar plate $\leq t_{CP}$. • Cut-outs in the web free of sharps notches. • Gap between web and longitudinal and between collar plate and longitudinal to be not greater than 4 mm.	Visual examination 100%.

WELDING AND MATERIALS:

- Welding requirements:
  - continuous fillet welding along the connection of web and collar plate with longitudinal and at the lap joint between web and collar plate,
  - throat thickness according to Ch 12, Sec 1, [2.3.7], in case of gap g greater than 2 mm increase the throat thickness by 0,7(g-2) mm,
  - weld around the cuts in the web at the connection with the longitudinal and the plating,
  - avoid burned notches on web.
- Fillet welding of overlapped joint to be done all around.

OIL TANKERS

AREA 2: Inner side and longitudinal bulkheads above 0,5H	Connection of inner side or bulkhead longitudinal ordinary stiffeners with transverse primary supporting members - One large collar plate	Sheet 2.3



t_W = web thickness of transverse primary supporting member

t_{CP} = collar plate thickness

SCANTLINGS:	FATIGUE:
Net sectional area of the web stiffener according to Ch 4, Sec 3, [4.7].	Fatigue check not required.

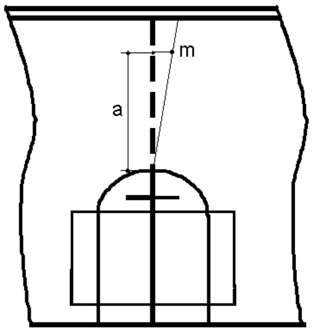
CONSTRUCTION:	NDE:
• Web stiffener not compulsory. When fitted, its misalignment m with the web of the longitudinal $\leq$ a / 50. • Misalignment between web and collar plate $\leq t_{CP}$. • Cut-outs in the web free of sharps notches. • Gap between web and longitudinal and between collar plate and longitudinal to be not greater than 4 mm.	Visual examination 100%.

WELDING AND MATERIALS:

- Welding requirements:
  - continuous fillet welding along the connection of web and collar plate with longitudinal and at the lap joint between web and collar plate,
  - throat thickness according to Ch 12, Sec 1, [2.3.7], in case of gap g greater than 2 mm increase the throat thickness by 0,7(g-2) mm,
  - T joint connection of collar plate with the plating: see section A-A,
  - weld around the cuts in the web at the connection with the longitudinal and the plating,
  - avoid burned notches on web.
- Fillet welding of overlapped joint to be done all around.

OIL TANKERS

AREA 2: Inner side and longitudinal bulkheads above 0,5H	Connection of inner side or bulkhead longitudinal ordinary stiffeners with transverse primary supporting members - Two collar plates	Sheet 2.4



t_W = web thickness of transverse primary supporting member

t_{CP} = collar plate thickness

SCANTLINGS:	FATIGUE:
Net sectional area of the web stiffener according to Ch 4, Sec 3, [4.7].	Fatigue check not required.

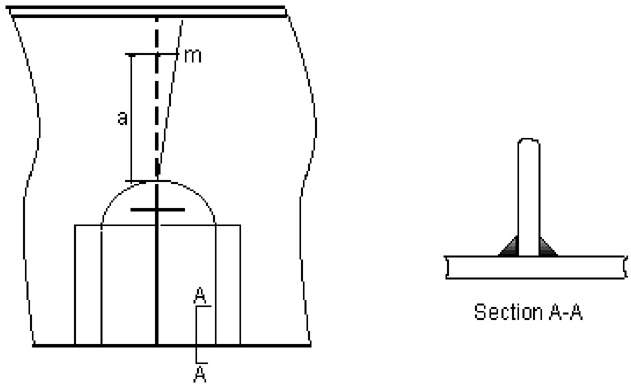
CONSTRUCTION:	NDE:
• Web stiffener not compulsory. When fitted, its misalignment m with the web of the longitudinal $\leq$ a / 50. • Misalignment between collar plates across the longitudinal $\leq t_{CP}$ / 2. • Cut-outs in the web free of sharps notches. • Gap between collar plates and longitudinal to be not greater than 4 mm.	Visual examination 100%.

WELDING AND MATERIALS:

- Welding requirements:
  - continuous fillet welding along the connection of collar plates with longitudinal and at the lap joint between web and collar plates,
  - throat thickness according to Ch 12, Sec 1, [2.3.7], in case of gap g greater than 2 mm increase the throat thickness by 0,7(g-2) mm,
  - avoid burned notches on web.
- Fillet welding of overlapped joint to be done all around.

OIL TANKERS

AREA 2: Inner side and longitudinal bulkheads above 0,5H	Connection of inner side or bulkhead longitudinal ordinary stiffeners with transverse primary supporting members - Two large collar plates	Sheet 2.5



t_W = web thickness of transverse primary supporting member

t_{CP} = collar plate thickness

SCANTLINGS:	FATIGUE:
Net sectional area of the web stiffener according to Ch 4, Sec 3, [4.7].	Fatigue check not required.

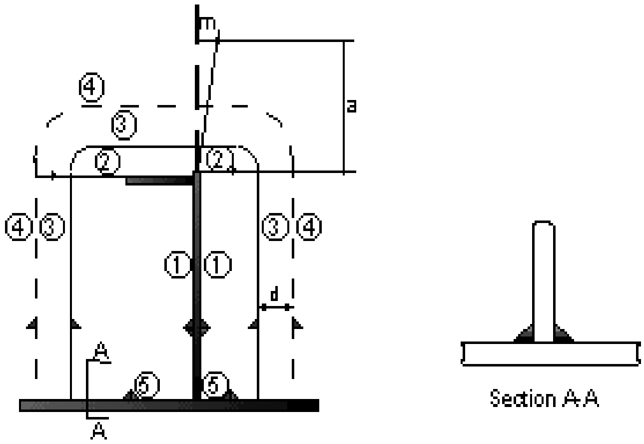
CONSTRUCTION:	NDE:
• Web stiffener not compulsory. When fitted, its misalignment m with the web of the longitudinal $\leq$ a / 50. • Misalignment between collar plates across the longitudinal $\leq t_{CP}$ / 2. • Cut-outs in the web free of sharps notches. • Gap between collar plates and longitudinal to be not greater than 4 mm.	Visual examination 100%.

WELDING AND MATERIALS:

- Welding requirements:
  - continuous fillet welding along the connection of collar plates with longitudinal and at the lap joint between web and collar plates,
  - throat thickness according to Ch 12, Sec 1, [2.3.7], in case of gap g greater than 2 mm increase the throat thickness by 0,7(g-2) mm,
  - T joint connection of collar plates with the plating: see section A-A,
  - avoid burned notches on web.
- Fillet welding of overlapped joint to be done all around.

OIL TANKERS

AREA 2: Inner side and longitudinal bulkheads above 0,5H	**Watertight connection of inner side or bulkhead longitudinal ordinary stiffeners with watertight side diaphragms or transverse bulkheads – Example of connection with lugs**	**Sheet 2.6**



t_W = transverse bulkhead web thickness

t_L = lug thickness

SCANTLINGS:	**FATIGUE:**
• d = 30 ÷ 60 mm. • $t_L \geq t_W$.	Fatigue check not required.
CONSTRUCTION:	**NDE:**
• Web stiffener not compulsory. When fitted, its misalignment m with the web of the longitudinal ≤ a / 50. • Misalignment between lugs across the longitudinal ≤ t_L / 2. • Misalignment at the butts within lug parts ≤ t_L / 5. • Gap between bulkhead plating and lugs to be not greater than 4 mm.	• Visual examination 100%. • Magnetic particle or dye penetrant examination: when deemed necessary depending on the quality of the lap joint weld.

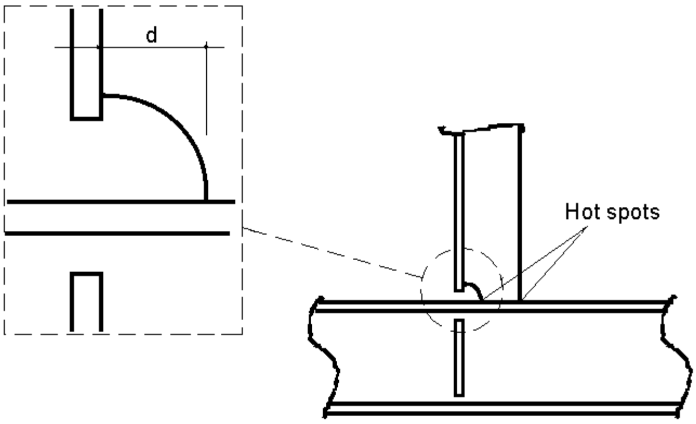
WELDING AND MATERIALS:

Welding requirements:

- continuous fillet welding along the connection of lugs with the longitudinal and at the lap joints between web and lugs,
- throat thickness according to Ch 12, Sec 1, [2.3.7], in case of gap g greater than 2 mm increase the throat thickness by 0,7(g-2) mm,
- T joint connection of collar plates with the plating: see section A-A,
- welding sequence: ① to ⑤ (see sketch).

OIL TANKERS

AREA 2: Inner side and longitudinal bulkheads above 0,5H	Connection of inner side or bulkhead longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - No bracket	Sheet 2.7



t = minimum thickness between those of:
- web of longitudinal,
- stiffener of transverse primary supporting member.

SCANTLINGS:	FATIGUE:
d to be as small as possible, maximum 35 mm recommended.	Fatigue check to be carried out for L ≥ 150 m: K_h = 1,3 K_ℓ = 1,65

CONSTRUCTION:	NDE:
Misalignment (measured between the outer edges) between longitudinal and web stiffener to be in general equal to or less than 0,7 t. For bulbs, a misalignment equal to 0,8 t may generally be accepted.	Visual examination 100%.

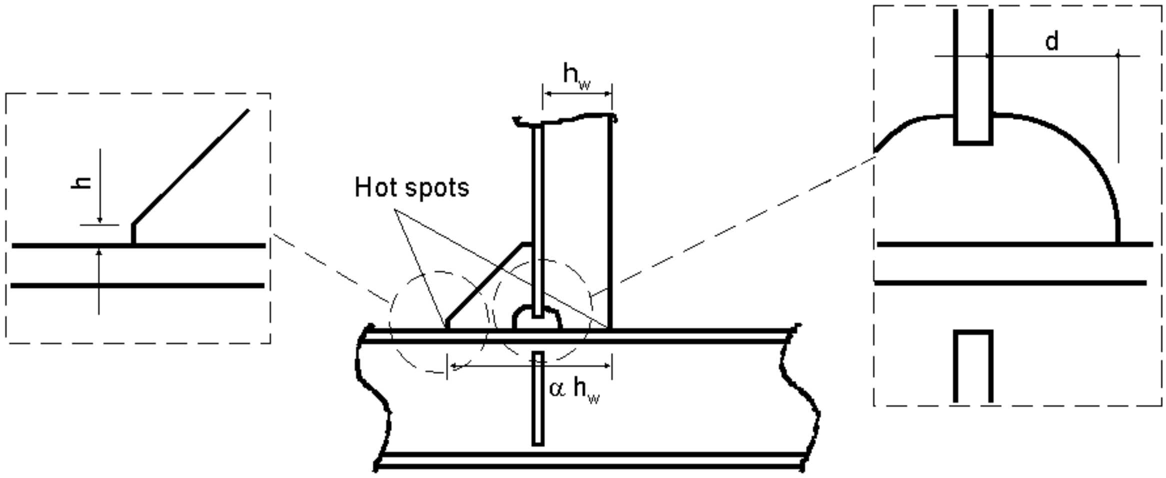
WELDING AND MATERIALS:

Welding requirements:

- continuous fillet welding,
- throat thickness = 0,45 t_W , where t_W is the web stiffener thickness,
- weld around the stiffener's toes,
- fair shape of fillet at toes in longitudinal direction.

OIL TANKERS

AREA 2: Inner side and longitudinal bulkheads above 0,5H	**Connection of inner side or bulkhead longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - One bracket**	**Sheet 2.8**



t = minimum thickness among those of the connected elements

SCANTLINGS:	**FATIGUE:**
• $\alpha \geq 2$. • Bracket to be symmetric. • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the bracket to be not less than that of web stiffener.	Fatigue check to be carried out for L ≥ 150 m: – for $2 \leq \alpha < 2,5$ $K_h = 1,2$ $K_\ell = 1,4$ – for $\alpha \geq 2,5$ $K_h = 1,15$ $K_\ell = 1,4$

CONSTRUCTION:	**NDE:**
Misalignment (measured between the outer edges) between longitudinal, web stiffener and bracket to be in general equal to or less than 0,7 t. For bulbs, a misalignment equal to 0,8 t may generally be accepted.	Visual examination 100%.

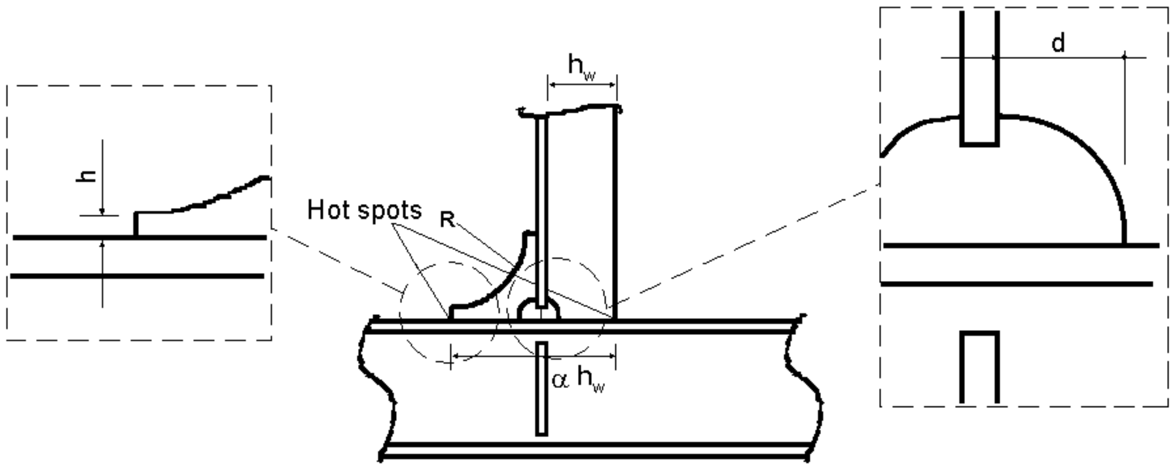
WELDING AND MATERIALS:

Welding requirements:

- continuous fillet welding,
- throat thickness = 0,45 t_W , where t_W is the web stiffener thickness,
- weld around the stiffener's toes,
- fair shape of fillet at toes in longitudinal direction.

OIL TANKERS

AREA 2: Inner side and longitudinal bulkheads above 0,5H	**Connection of inner side or bulkhead longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - One radiused bracket**	**Sheet 2.9**



t = minimum thickness among those of the connected elements

SCANTLINGS:	**FATIGUE:**
• $\alpha \geq 2$. • Bracket to be symmetric. • $R \geq 1,5\ (\alpha - 1)\ h_W$ • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the bracket to be not less than that of web stiffener.	Fatigue check to be carried out for L ≥ 150 m: - for $2 \leq \alpha < 2,5$ $K_h = 1,15$, $K_\ell = 1,35$ - for $\alpha \geq 2,5$ $K_h = 1,1$, $K_\ell = 1,35$
CONSTRUCTION:	**NDE:**
Misalignment (measured between the outer edges) between longitudinal, web stiffener and bracket to be in general equal to or less than 0,7 t. For bulbs, a misalignment equal to 0,8 t may generally be accepted.	Visual examination 100%.

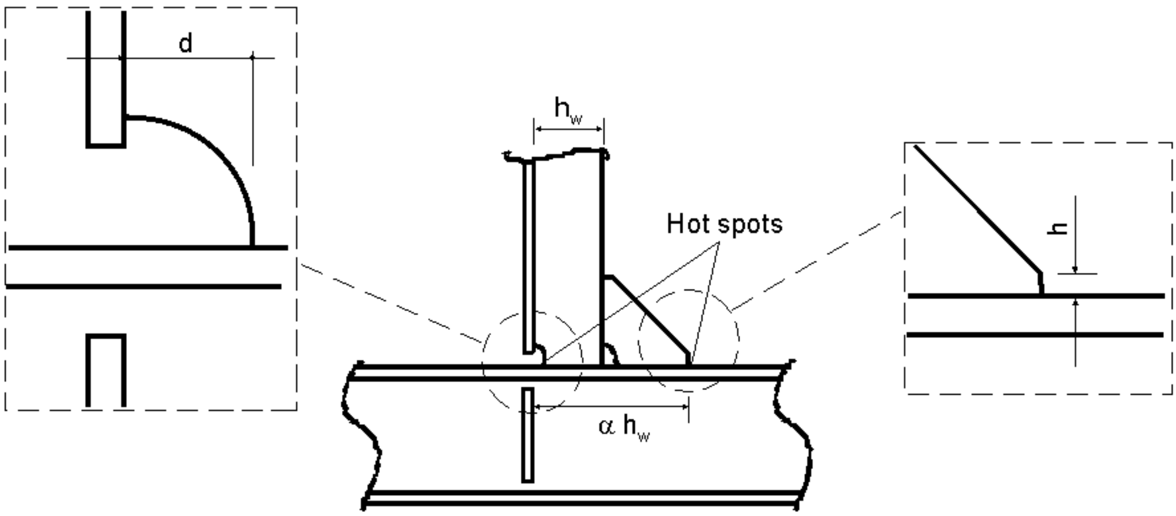
WELDING AND MATERIALS:

Welding requirements:

- continuous fillet welding,
- throat thickness = 0,45 t_W , where t_W is the web stiffener thickness,
- weld around the stiffener's toes,
- fair shape of fillet at toes in longitudinal direction.

OIL TANKERS

AREA 2: Inner side and longitudinal bulkheads above 0,5H	Connection of inner side or bulkhead longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - One bracket	Sheet 2.10



t = minimum thickness among those of the connected elements

SCANTLINGS:	FATIGUE:
• $\alpha \geq 2$. • Bracket to be symmetric. • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the bracket to be not less than that of web stiffener.	Fatigue check to be carried out for L ≥ 150 m: - for $2 \leq \alpha < 2,5$ $K_h = 1,3$ $K_\ell = 1,55$ - for $\alpha \geq 2,5$ $K_h = 1,25$ $K_\ell = 1,5$

CONSTRUCTION:	NDE:
Misalignment (measured between the outer edges) between longitudinal, web stiffener and bracket to be in general equal to or less than 0,7 t. For bulbs, a misalignment equal to 0,8 t may generally be accepted.	Visual examination 100%.

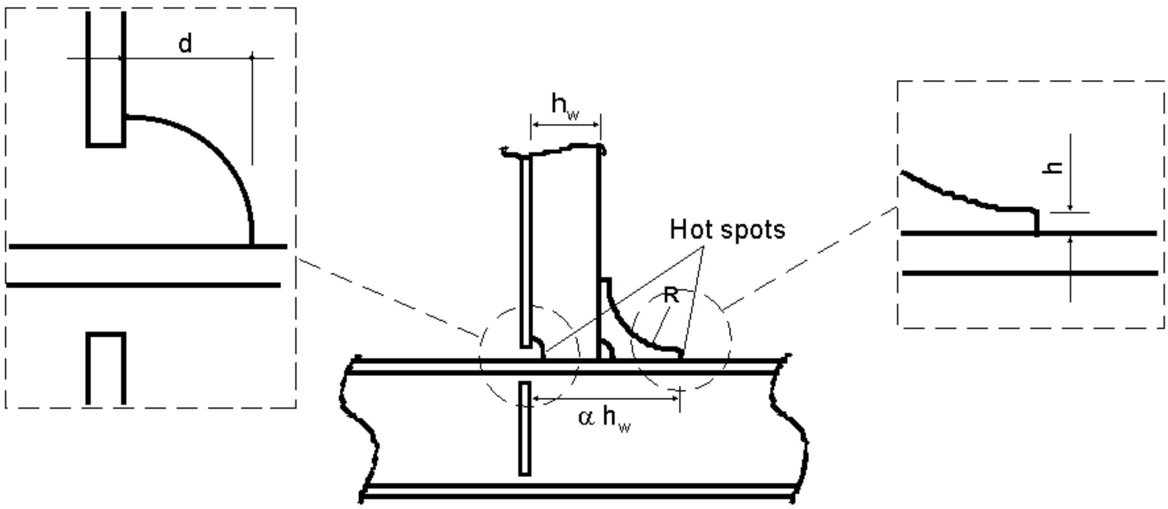
WELDING AND MATERIALS:

Welding requirements:

- continuous fillet welding,
- throat thickness = 0,45 t_W , where t_W is the web stiffener thickness,
- weld around the stiffener's toes,
- fair shape of fillet at toes in longitudinal direction.

OIL TANKERS

AREA 2: Inner side and longitudinal bulkheads above 0,5H	Connection of inner side or bulkhead longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - One radiused bracket	Sheet 2.11



t = minimum thickness among those of the connected elements

SCANTLINGS:	FATIGUE:
• $\alpha \geq 2$ • Bracket to be symmetric. • $R \geq 1,5\ (\alpha - 1)\ h_W$ • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the bracket to be not less than that of web stiffener.	Fatigue check to be carried out for L ≥ 150 m: - for $2 \leq \alpha < 2,5$: $K_h = 1,25$, $K_\ell = 1,5$ - for $\alpha \geq 2,5$: $K_h = 1,2$, $K_\ell = 1,45$

CONSTRUCTION:	NDE:
Misalignment (measured between the outer edges) between longitudinal, web stiffener and bracket to be in general equal to or less than 0,7 t. For bulbs, a misalignment equal to 0,8 t may generally be accepted.	Visual examination 100%.

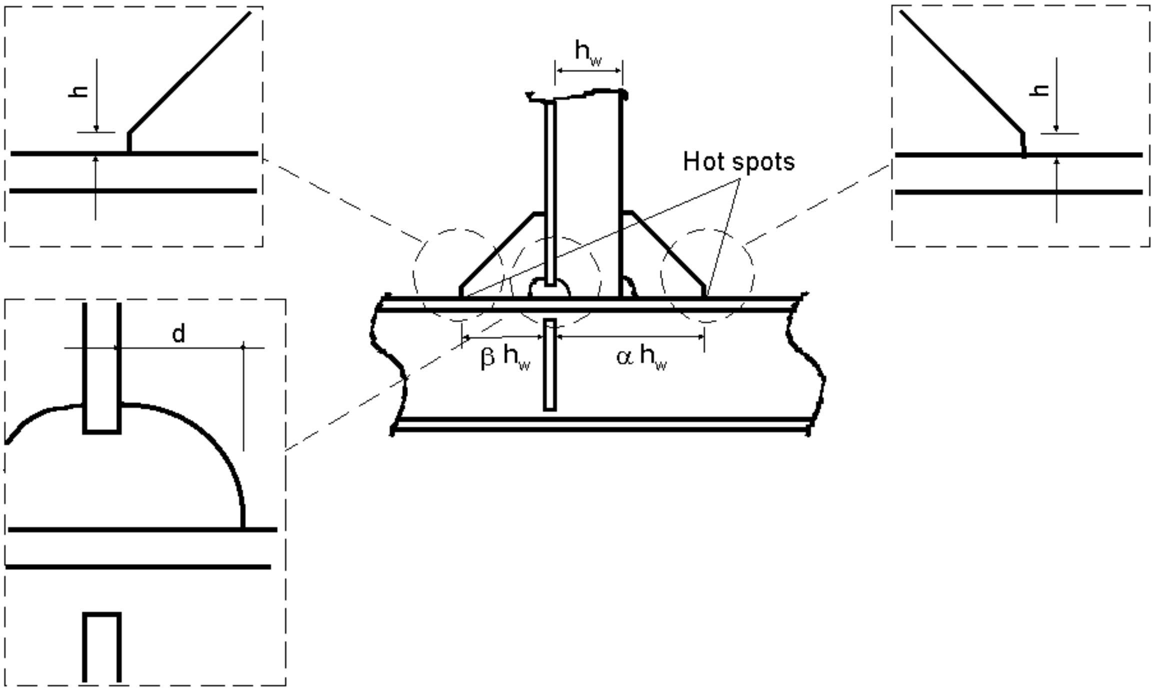
WELDING AND MATERIALS:

Welding requirements:

- continuous fillet welding,
- throat thickness = 0,45 t_W , where t_W is the web stiffener thickness,
- weld around the stiffener's toes,
- fair shape of fillet at toes in longitudinal direction.

OIL TANKERS

AREA 2: Inner side and longitudinal bulkheads above 0,5H	Connection of inner side or bulkhead longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - Two brackets	Sheet 2.12



t = minimum thickness among those of the connected elements

SCANTLINGS:	FATIGUE:
• $\alpha \geq 2$. • $\beta \geq 1$. • Brackets to be symmetric. • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the brackets to be not less than that of web stiffener.	Fatigue check to be carried out for $L \geq 150$ m: - for $2 \leq \alpha < 2,5$ and $1 \leq \beta < 1,5$: $K_h = K_\ell = 1,15$ - for $\alpha \geq 2,5$ and $\beta \geq 1,5$: $K_h = K_\ell = 1,1$

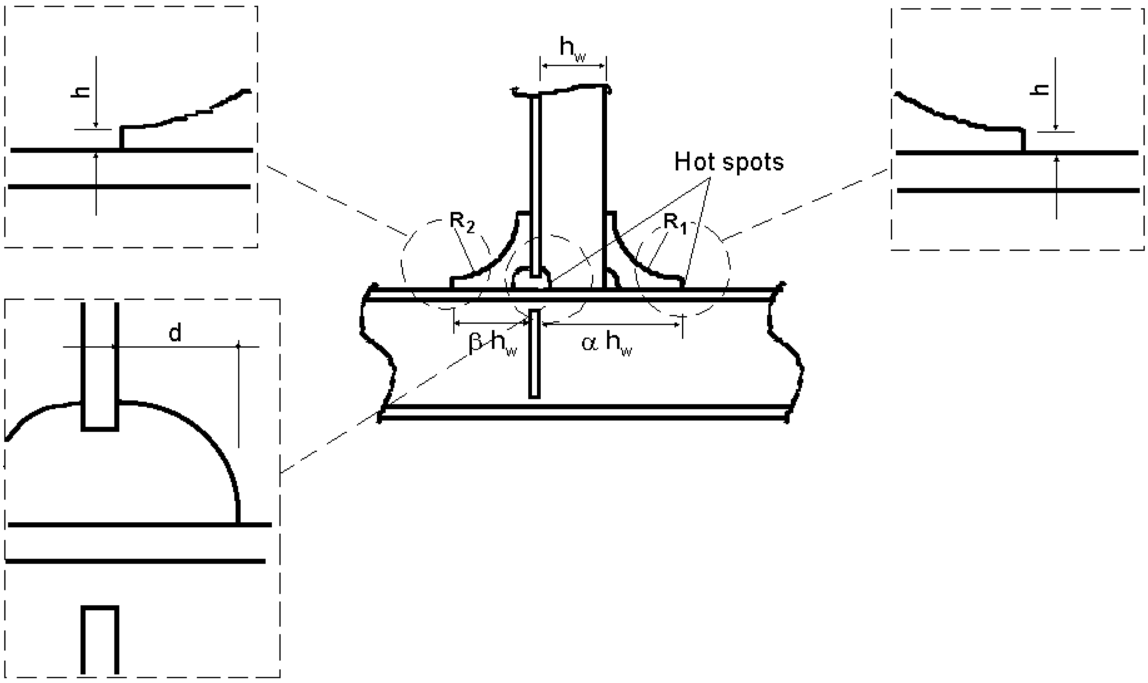
CONSTRUCTION:	NDE:
Misalignment (measured between the outer edges) between longitudinal, web stiffener and bracket to be in general equal to or less than 0,7 t. For bulbs, a misalignment equal to 0,8 t may generally be accepted.	Visual examination 100%.

WELDING AND MATERIALS:

- Welding requirements:
  - continuous fillet welding,
  - throat thickness = 0,45 t_W , where t_W is the web stiffener thickness,
  - weld around the stiffener's toes,
  - fair shape of fillet at toes in longitudinal direction.
- Material requirements:
  - material of brackets to be the same of longitudinals.

OIL TANKERS

AREA 2: Inner side and longitudinal bulkheads above 0,5H	Connection of inner side or bulkhead longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - Two radiused brackets	Sheet 2.13



t = minimum thickness among those of the connected elements

SCANTLINGS:

- $\alpha \geq 2$.
- $\beta \geq 1$.
- Brackets to be symmetric.
- $R_1 \geq 1,5 (\alpha - 1) h_W$
- $R_2 \geq 1,5 \beta h_W$
- h as necessary to allow the required fillet throat size, but ≤ 15 mm.
- d to be as small as possible, maximum 35 mm recommended.
- Thickness of the brackets to be not less than that of web stiffener.

FATIGUE:

Fatigue check to be carried out for L ≥ 150 m:

- for $2 \leq \alpha < 2,5$ and $1 \leq \beta < 1,5$:

  $K_h = K_\ell = 1,1$

- for $\alpha \geq 2,5$ and $\beta \geq 1,5$:

  $K_h = K_\ell = 1,05$

CONSTRUCTION:

Misalignment (measured between the outer edges) between longitudinal, web stiffener and bracket to be in general equal to or less than 0,7 t. For bulbs, a misalignment equal to 0,8 t may generally be accepted.

NDE:

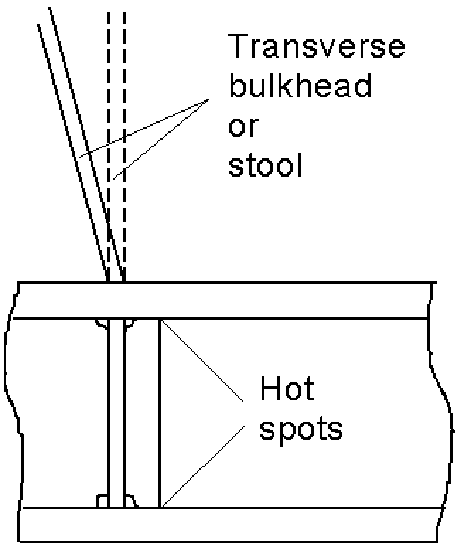
Visual examination 100%.

WELDING AND MATERIALS:

- Welding requirements:
  - continuous fillet welding,
  - throat thickness = 0,45 t_W , where t_W is the web stiffener thickness,
  - weld around the stiffener's toes,
  - fair shape of fillet at toes in longitudinal direction.
- Material requirements:
  - material of brackets to be the same of longitudinals.

OIL TANKERS

AREA 3: Double bottom in way of transverse bulkheads	**Connection of bottom and inner bottom longitudinal ordinary stiffeners with floors - No bracket**	**Sheet 3.1**



t = minimum thickness between those of:

- web of bottom or inner bottom longitudinal,
- floor stiffener.

SCANTLINGS:	**FATIGUE:**
	Fatigue check to be carried out for L ≥ 150 m: $K_h = 1,3$ $K_\ell = 1,65$

CONSTRUCTION:	**NDE:**
Misalignment (measured between the outer edges) between webs of bottom and inner bottom longitudinals with floor stiffener to be in general equal to or less than 0,7 t. For bulbs, a misalignment equal to 0,8 t may generally be accepted.	Visual examination 100%.

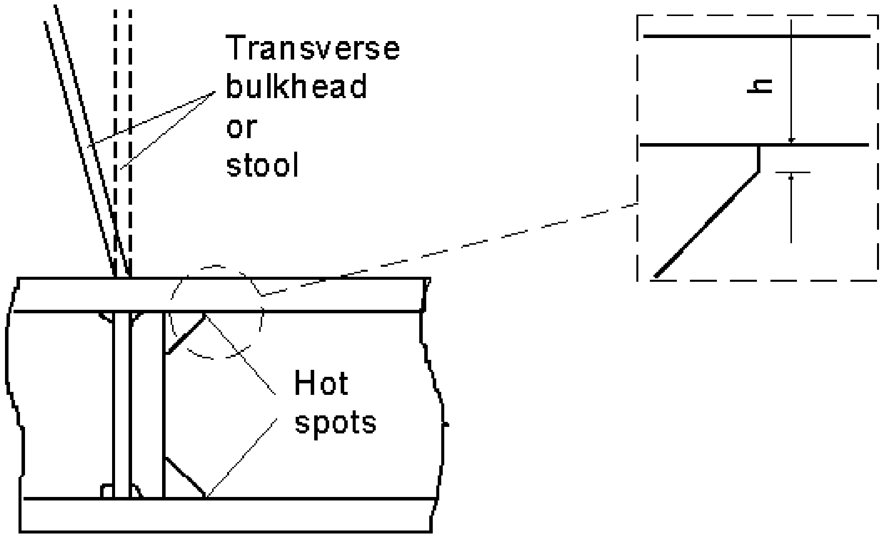
WELDING AND MATERIALS:

Welding requirements:

- floor stiffeners to be connected with continuous fillet welding to bottom and inner bottom longitudinals,
- throat thickness = 0,45 t_W , where t_W is the floor stiffener thickness,
- weld all around the stiffeners,
- fair shape of fillet at toes in longitudinal direction.

OIL TANKERS

AREA 3: Double bottom in way of transverse bulkheads	Connection of bottom and inner bottom longitudinal ordinary stiffeners with floors - Brackets	Sheet 3.2



t = minimum thickness among those of the connected elements

SCANTLINGS:	FATIGUE:
h as necessary to allow the required fillet throat size, but ≤ 15 mm.	Fatigue check to be carried out for L ≥ 150 m: $K_h = 1,3$ $K_\ell = 1,55$

CONSTRUCTION:	NDE:
Misalignment (measured between the outer edges) between webs of bottom and inner bottom longitudinals with floor stiffener to be in general equal to or less than 0,7 t. For bulbs, a misalignment equal to 0,8 t may generally be accepted.	Visual examination 100%.

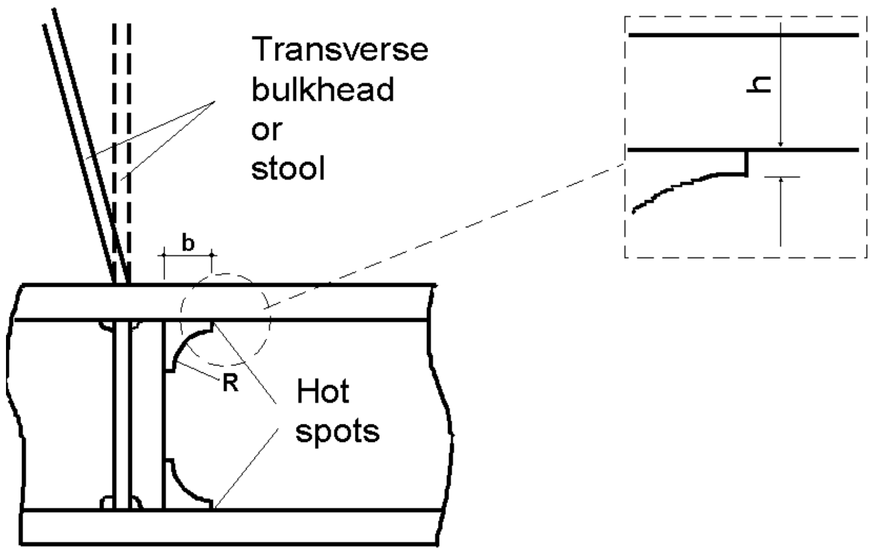
WELDING AND MATERIALS:

Welding requirements:

- floor stiffeners and brackets to be connected with continuous fillet welding to bottom and inner bottom longitudinals,
- throat thickness = 0,45 t_W , where t_W is the floor stiffener or bracket thickness, as applicable,
- partial penetration welding between stiffeners and brackets,
- weld all around the stiffeners and brackets,
- fair shape of fillet at toes in longitudinal direction.

OIL TANKERS

AREA 3: Double bottom in way of transverse bulkheads	Connection of bottom and inner bottom longitudinal ordinary stiffeners with floors - Radiused brackets	Sheet 3.3



t = minimum thickness among those of the connected elements

SCANTLINGS:	FATIGUE:
• Brackets to be symmetric. • R ≥ 1,5 b • h as necessary to allow the required fillet throat size, but ≤ 15 mm.	Fatigue check to be carried out for L ≥ 150 m: K_h = 1,25 K_ℓ = 1,5

CONSTRUCTION:	NDE:
Misalignment (measured between the outer edges) between webs of bottom and inner bottom longitudinals with floor stiffener to be in general equal to or less than 0,7 t. For bulbs, a misalignment equal to 0,8 t may generally be accepted.	Visual examination 100%.

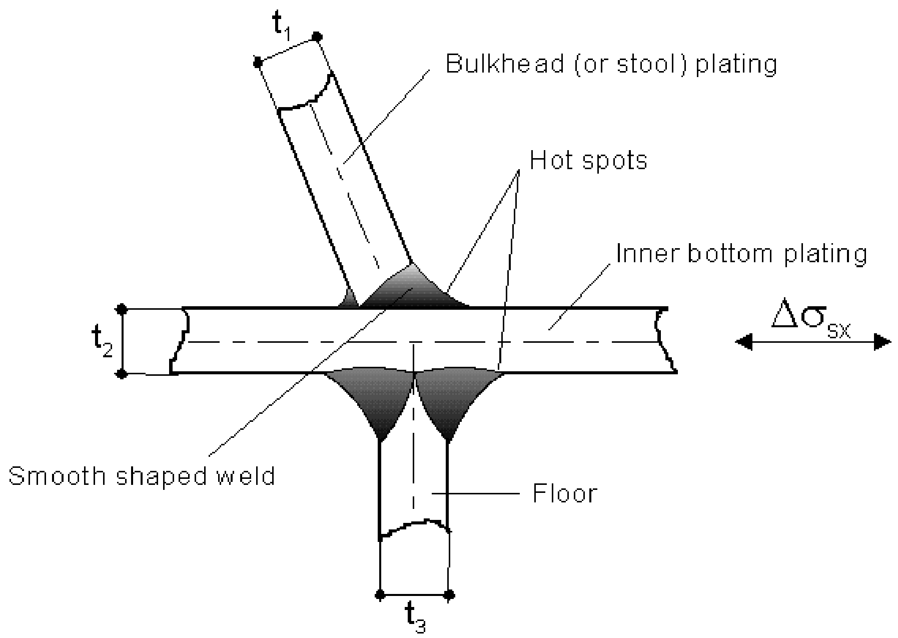
WELDING AND MATERIALS:

Welding requirements:

- floor stiffeners and brackets to be connected with continuous fillet welding to bottom and inner bottom longitudinals,
- throat thickness = 0,45 t_W , where t_W is the floor stiffener or bracket thickness, as applicable,
- partial penetration welding between stiffeners and brackets,
- weld all around the stiffeners and brackets,
- fair shape of fillet at toes in longitudinal direction.

OIL TANKERS

AREA 3: Double bottom in way of transverse bulkheads	Connection of inner bottom with transverse bulkheads or lower stools	Sheet 3.4



Hot spot stresses:

$\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{sx}$

$t = \min(t_1, t_2, t_3)$

SCANTLINGS:	FATIGUE:
	Fatigue check to be carried out for $L \geq 150$ m: $K_{SX} = 3{,}85$

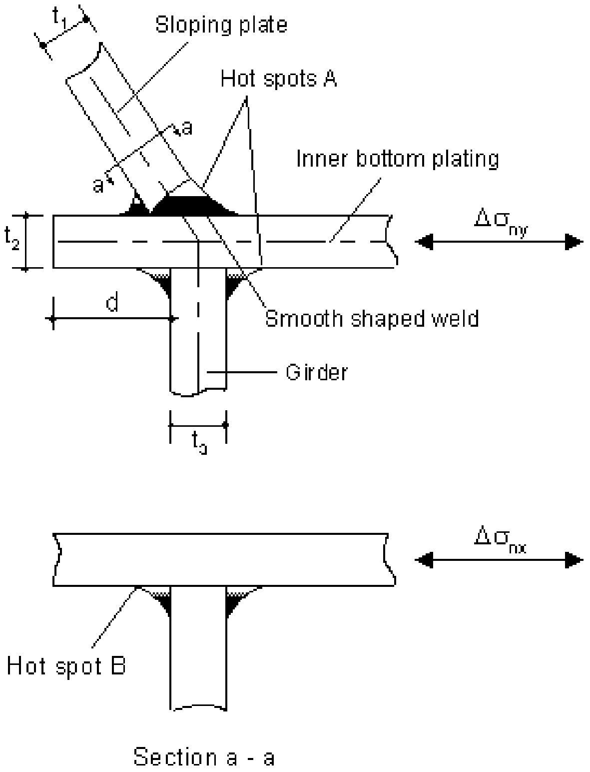
CONSTRUCTION:	NDE:
• Misalignment (median lines) between floor and bulkhead (or stool) plating $\leq t / 3$. • Cut-outs for connections of the inner bottom longitudinals to double bottom floors to be closed by collar plates welded to the inner bottom.	The following NDE are required: – VE 100%, – UE 35% of full penetration weld for absence of cracks, lack of penetration and lamellar tears.

WELDING AND MATERIALS:

- Welding requirements:
  - bulkhead (or stool) plating and supporting floors generally to be connected with full penetration welding to inner bottom plating (if not full penetration welding, the weld preparation is to be indicated on the approved drawings),
  - corrugated bulkheads (without stool) to be connected with full penetration welding to inner bottom plating,
  - in the case of corrugated bulkheads, stool side plating (if any) and supporting floors to be connected with full penetration or partial penetration welding to inner bottom plating,
  - special approval of the procedure on a sample representative of the actual conditions foreseen in production,
  - welding sequence against the risk of lamellar tearing,
  - weld finishing well faired to the inner bottom plating.
- Material requirements:
  - the strake of inner bottom plating in way of the connection is recommended to be of Z25/ZH25 quality. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding.

OIL TANKERS

AREA 4: Double bottom in way of hopper tanks	Connection of inner bottom with hopper tank sloping plates	Sheet 4.1



Hot spot stresses:

- At hot spot A:

  $\Delta\sigma_{SY} = K_{SY} \cdot \Delta\sigma_{nY}$

- At hot spot B:

  $\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX} + K_{SYX} \cdot \Delta\sigma_{nY}$

$t_A = \min(t_1, t_2, t_3)$,

t_B = minimum among:
- floor thickness,
- hopper transverse web thickness,
- t_3.

SCANTLINGS:	FATIGUE:
$d \geq 50$ mm.	Fatigue check to be carried out for $L \geq 150$ m: – K_{SY} = 3,85 where closed scallops 5,4 where open scallops – K_{SX} = 1,3 – K_{SYX} = 2,0

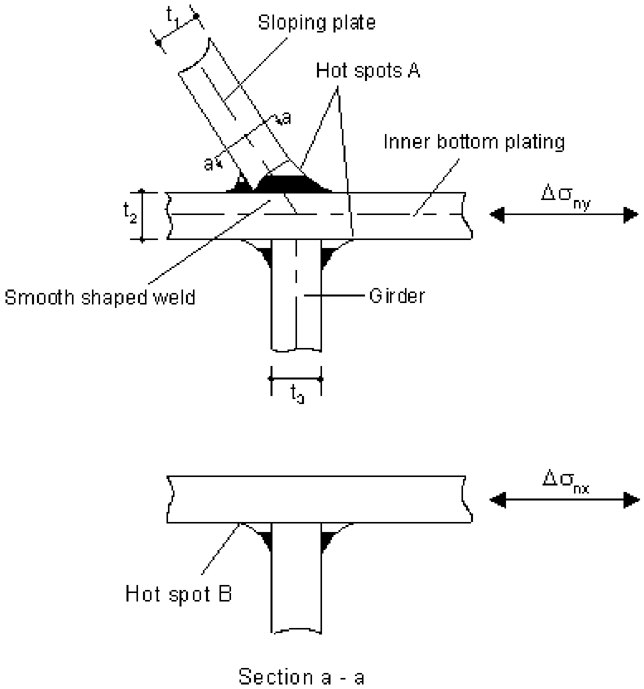
CONSTRUCTION:	NDE:
• Misalignment (median lines) between girder and sloping plate $\leq t_A / 3$. • Misalignment (median lines) between floor and hopper transverse web $\leq t_B / 3$.	The following NDE are required: – VE 100%, – UE 25% of full penetration weld for absence of cracks, lack of penetration and lamellar tears.

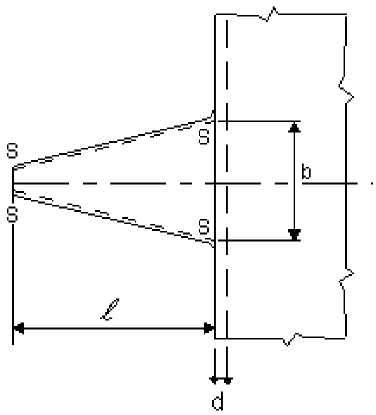
WELDING AND MATERIALS:

- Welding requirements:
  - sloping plate to be connected with partial penetration welding to inner bottom plating,
  - approval of the procedure on a sample representative of the actual conditions foreseen in production,
  - welding sequence against the risk of lamellar tearing,
  - weld finishing well faired to the inner bottom plating on tank side.
- Material requirements:
  - the strake of inner bottom plating in way of the connection is recommended to be of Z25/ZH25 quality. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding.

OIL TANKERS

AREA 4: Double bottom in way of hopper tanks	Connection of inner bottom with hopper tank sloping plates – Prolonging brackets	Sheet 4.2





Hot spot stresses:

- At hot spot A: $\Delta\sigma_{SY} = K_{SY} \cdot \Delta\sigma_{nY}$
- At hot spot B: $\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX} + K_{SYX} \cdot \Delta\sigma_{nY}$

t_A = min (t_1, t_2, t_3),

t_B = minimum among:
- floor thickness,
- hopper transverse web thickness,
- t_3.

SCANTLINGS:	FATIGUE:
• Inner bottom plating to be prolonged within the hopper tank structure by brackets as shown in the sketch. • d ≥ 50 mm. • Guidance values, to be confirmed by calculations carried out according to Ch 7, Sec 3: – thickness of the above brackets ≥ t_2, – b ≥ 0,4 times the floor spacing, – ℓ ≥ 1,5b.	Fatigue check to be carried out for L ≥ 150 m: – K_{SY} = 2,4 where closed scallops 3,4 where open scallops – K_{SX} = 1,3 – K_{SYX} = 1,5

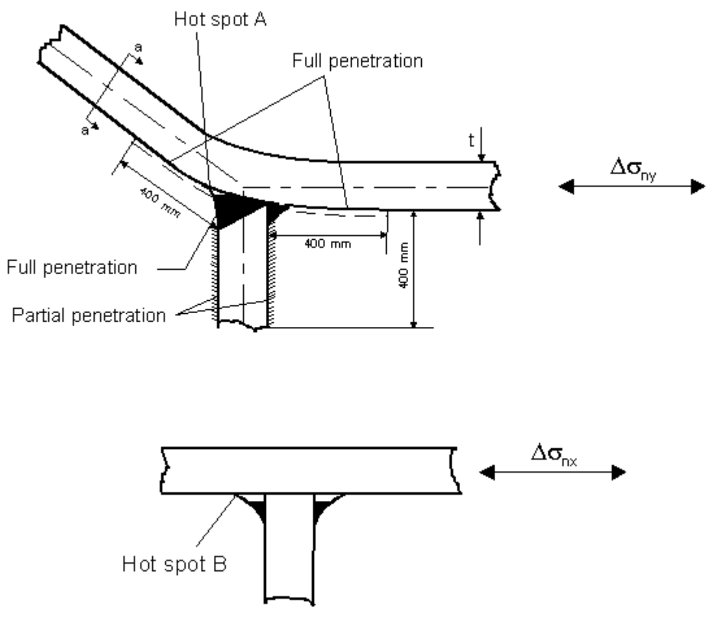
CONSTRUCTION:	NDE:
• Misalignment (median lines) between girder and sloping plate ≤ t_A / 3. • Misalignment (median lines) between floor and hopper transverse web ≤ t_B / 3.	The following NDE are required: – VE 100%, – UE 25% of full penetration weld for absence of cracks, lack of penetration and lamellar tears.

WELDING AND MATERIALS:

- Welding requirement:
  - sloping plate to be connected with partial penetration welding to inner bottom plating,
  - brackets to be connected with full penetration welding to inner bottom plating,
  - approval of the procedure on a sample representative of the actual conditions foreseen in production,
  - welding sequence against the risk of lamellar tearing,
  - weld finishing well faired to the inner bottom plating on tank side.
- Material requirement:
  - the strake of inner bottom plating in way of the connection is recommended to be of Z25/ZH25 quality. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding,
  - material properties of prolonging brackets to be not less than those of the inner bottom plating.

OIL TANKERS

AREA 4: Double bottom in way of hopper tanks	Connection of inner bottom with hopper tank sloping plates – Radiused construction	Sheet 4.3



Section a - a

Hot spot stresses:

- At hot spot A:

  $\Delta\sigma_{SY} = K_{SY} \cdot \Delta\sigma_{nY}$

- At hot spot B:

  $\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX} + K_{SYX} \cdot \Delta\sigma_{nY}$

t_A = minimum thickness between those of the girder and sloping plate,

t_B = minimum among:
- floor thickness,
- hopper transverse web thickness,
- girder thickness.

SCANTLINGS:

- Inner radius of the bent plate to be between 3,5 and 5 times the thickness of the bent plate and to be indicated in the approved plan.
- Transverse brackets extended to the closest longitudinals to be fitted on each side of the girder, at mid-span between floors.
- Thickness of these brackets, in mm $\geq 9 + 0{,}03\ L_1 \sqrt{k}$.

FATIGUE:

Fatigue check to be carried out for $L \geq 150$ m:
- $K_{SY} = 3{,}15$
- $K_{SX} = 1{,}3$
- $K_{SYX} = 2{,}05$

CONSTRUCTION:

- Misalignment (median lines) between girder and sloping plate $\leq t_A / 3$.
- Misalignment (median lines) between floor and hopper transverse web $\leq t_B / 3$.
- In floor or transverse webs, in way of the bent area, scallops to be avoided or closed by collar plates.

NDE:

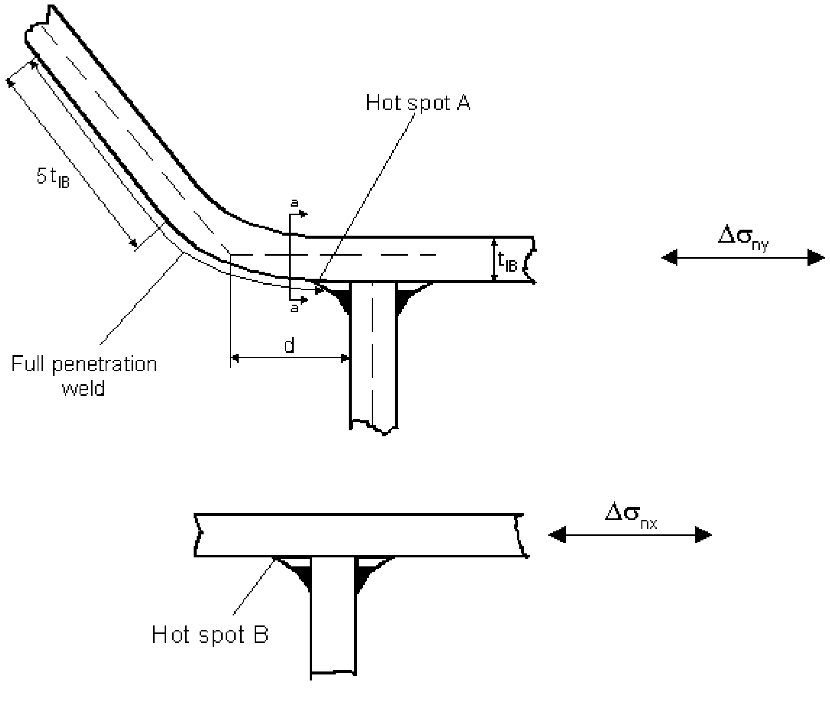
The following NDE are required:
- VE 100%,
- UE 25% of full penetration weld for absence of cracks, lack of penetration and lamellar tears.

WELDING AND MATERIALS:

- Welding requirements:
  - floors to be connected (see sketches):
    - with full penetration welding to the inner bottom for a length ≥ 400 mm,
    - with partial penetration welding to the girder for a length ≥ 400 mm,
    - with continuous fillet welding in the remaining areas,
  - approval of the procedure on a sample representative of the actual conditions foreseen in production,
  - welding sequence against the risk of lamellar tearing,
  - welding procedures of longitudinal girder to the bent plate to be submitted to the Society for review, with evidence given that there is no risk of ageing after welding,
  - weld finishing of butt welds well faired to the inner bottom plating on ballast tank,
  - fair shape of fillet at hot spots.
- Material requirements:
  - the radiused construction may be accepted provided that the folding procedure is submitted to the Society for review, with evidence given that the mechanical properties and, in particular, the impact properties are not deteriorated by the folding operation.

OIL TANKERS

AREA 4: Double bottom in way of hopper tanks	Connection of inner bottom with hopper tank sloping plates – Radiused construction	Sheet 4.4



Section a - a

Hot spot stresses:

- At hot spot A:

$\Delta\sigma_{SY} = K_{SY} \cdot \Delta\sigma_{nY}$

- At hot spot B:

$\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX} + K_{SYX} \cdot \Delta\sigma_{nY}$

t = minimum among:
- floor thickness,
- hopper transverse web thickness,
- girder thickness,

t_{IB} = inner bottom plating.

SCANTLINGS:	FATIGUE:
• Inner radius of the bent plate to be between 3,5 and 5 times the thickness of the bent plate and to be indicated in the approved plan. • d ≤ 40 mm. • Transverse brackets extended to the closest longitudinals to be fitted on each side of the girder, at mid-span between floors. • Thickness of these brackets, in mm ≥ $9 + 0{,}03\, L_1 \sqrt{k}$.	Fatigue check to be carried out for L ≥ 150m – K_{SY} = 3,85 – K_{SX} = 1,3 – K_{SYX} = 4,5

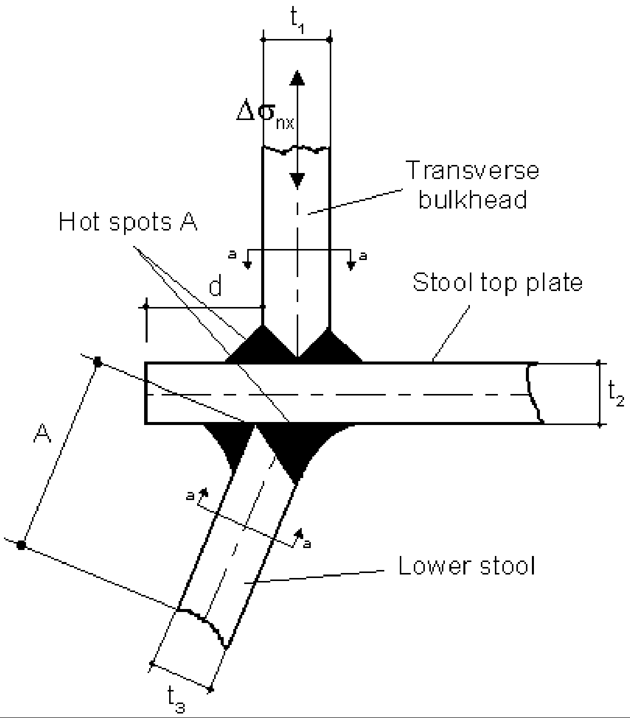
CONSTRUCTION:	NDE:
• Misalignment (median lines) between floor and hopper transverse web ≤ t / 3. • In floor or transverse webs, in way of the bent area, scallops to be avoided or closed by collar plates..	Visual examination 100%.

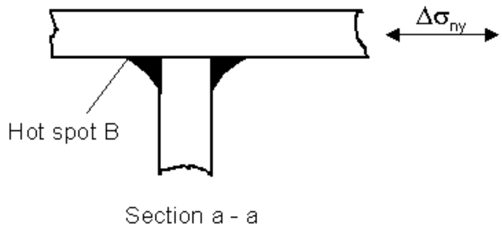
WELDING AND MATERIALS:

- Welding requirements:
  - floors to be connected with full penetration welding to the inner bottom plating for a length ≥ $5t_{IB}$,
  - where girder is welded within the bent area, welding procedures to be submitted to the Society for review.
- Material requirements:
  - where girder is welded within the bent area, folding procedure to be submitted to the Society for review, with evidence given that the mechanical properties and, in particular, the impact properties are not deteriorated by the folding operation.

OIL TANKERS

AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with plane bulkheads	Sheet 5.1





A = distance to be taken not less than the spacing of bulkhead vertical webs

Hot spot stresses:

- At hot spot A: $\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX}$
- At hot spot B: $\Delta\sigma_{SY} = K_{SY} \cdot \Delta\sigma_{nY} + K_{SXY} \cdot \Delta\sigma_{nX}$

t_A = min (t_1, t_2, t_3)

t_B = minimum among:

- thickness of member above stool top plate,
- thickness of member below stool top plate,
- t_2.

SCANTLINGS:

- $d \geq t_1$.
- $t_2 \geq t_1$.
- $t_3 \geq t_1$ in portion A.
- Thickness of members above and below stool top plate to be not less than that of bulkhead vertical webs.

FATIGUE:

Fatigue check to be carried out for $L \geq 150$ m:

- $K_{SX} = 3,85$
- $K_{SY} = 1,3$
- $K_{SXY} = 2,0$

CONSTRUCTION:

- Misalignment (median lines) between bulkhead plating and stool side plating $\leq t_A / 3$.
- Misalignment (median lines) between members above and below stool top plate $\leq t_B / 3$.

NDE:

The following NDE are required:

- VE 100%,
- UE 35% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

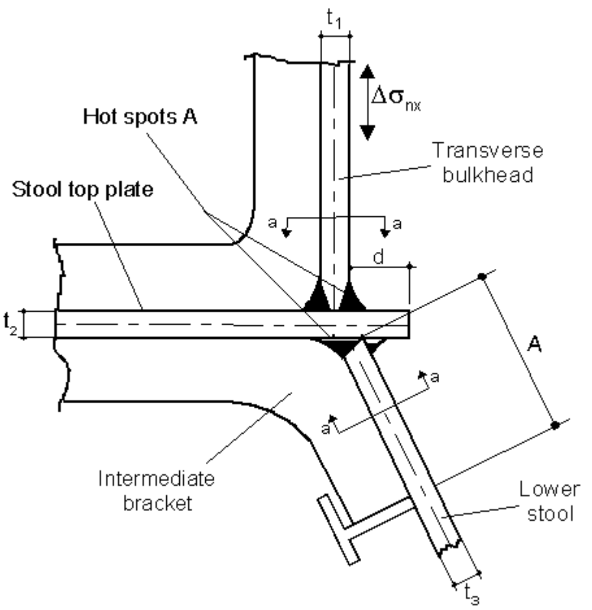
WELDING AND MATERIALS:

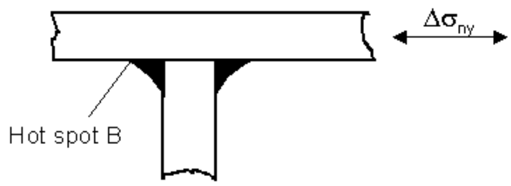
- Welding requirements:
  - bulkhead and stool side plating generally to be connected with full penetration welding to stool top plate (if not full penetration welding, the weld preparation is to be indicated on the approved drawings),
  - approval of the procedure on a sample representative of the actual conditions foreseen in production,
  - welding sequence against the risk of lamellar tearing is recommended in case Z material is not adopted for the stool top plate,
  - weld finishing well faired to the stool top plate.
- Material requirements:
  - the stool top plate is recommended to be Z25/ZH25 quality. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding,
  - material properties of:
    - the stool top plate,
    - the portion A of the stool side plating,

    to be not less than those of the transverse bulkhead plating.

OIL TANKERS

AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with plane bulkheads in way of intermediate brackets	Sheet 5.2





Section a - a

A = distance to be taken not less than the spacing of bulkhead vertical webs

Hot spot stresses:

- At hot spot A: $\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX}$
- At hot spot B: $\Delta\sigma_{SY} = K_{SY} \cdot \Delta\sigma_{nY} + K_{SXY} \cdot \Delta\sigma_{nX}$

$t_A = \min(t_1, t_2, t_3)$

t_B = minimum among:

- thickness of member above stool top plate,
- thickness of intermediate bracket,
- t_2.

SCANTLINGS:

- $d \geq t_1$.
- $t_2 \geq t_1$.
- $t_3 \geq t_1$ in portion A.
- Thickness of intermediate brackets and members above stool top plate to be not less than that of bulkhead vertical webs.

FATIGUE:

Fatigue check to be carried out for $L \geq 150$ m:

- $K_{SX} = 3{,}55$
- $K_{SY} = 1{,}3$
- $K_{SXY} = 1{,}75$

CONSTRUCTION:

- Misalignment (median lines) between bulkhead plating and stool side plating $\leq t_A / 3$.
- Misalignment (median lines) between intermediate bracket and member above stool top plate $\leq t_B/3$.
- Intermediate brackets to be fitted in place and welded after the welding of the joint between the stool side plating and the stool top plate.

NDE:

The following NDE are required:

- VE 100%,
- UE 35% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

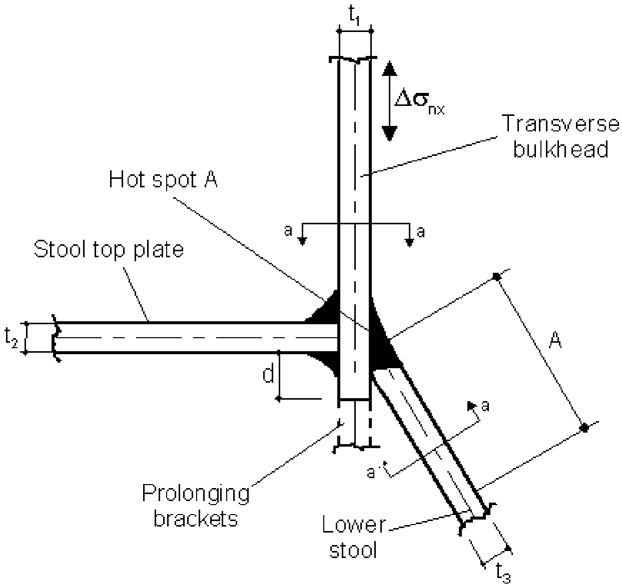
WELDING AND MATERIALS:

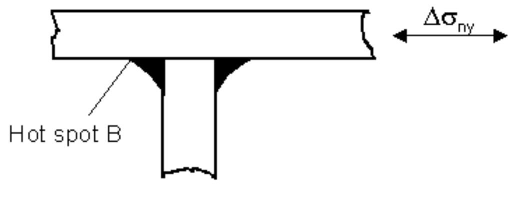
- Welding requirements:
  - bulkhead and stool side plating generally to be connected with full penetration welding to stool top plate (if not full penetration welding, the weld preparation is to be indicated on the approved drawings),
  - brackets to be connected with continuous fillet welding to plating and stiffeners,
  - approval of the procedure on a sample representative of the actual conditions foreseen in production,
  - welding sequence against the risk of lamellar tearing is recommended in case Z material is not adopted for the stool top plate,
  - weld finishing well faired to the stool top plate.
- Material requirements:
  - the stool top plate is recommended to be Z25/ZH25 quality. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding,
  - material properties of:
    - the stool top plate,
    - the portion A of the stool side plating,

    to be not less than those of the transverse bulkhead plating.

OIL TANKERS

AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with plane bulkheads – Prolonging brackets	Sheet 5.3





A = distance to be taken not less than the spacing of bulkhead vertical webs

Hot spot stresses:

- At hot spot A: $\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX}$
- At hot spot B: $\Delta\sigma_{SY} = K_{SY} \cdot \Delta\sigma_{nY} + K_{SXY} \cdot \Delta\sigma_{nX}$

$t_A = \min(t_1, t_2, t_3)$

t_B = minimum among:
- thickness of member above stool top plate,
- thickness of member below stool top plate,
- t_2.

SCANTLINGS:

- $d \geq 50$ mm.
- $t_2 \geq t_1$.
- $t_3 \geq t_1$ in portion A.
- Thickness of prolonging brackets $\geq t_1$.
- Thickness of members above and below stool top plate to be not less than that of bulkhead vertical webs.

FATIGUE:

Fatigue check to be carried out for $L \geq 150$ m:
- $K_{SX} = 2,4$
- $K_{SY} = 1,3$
- $K_{SXY} = 1,5$

CONSTRUCTION:

- Misalignment (median lines) between stool top plate and stool side plating $\leq t_A / 3$.
- Misalignment (median lines) between members above and below stool top plate $\leq t_B / 3$.

NDE:

The following NDE are required:
- VE 100%,
- UE 35% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

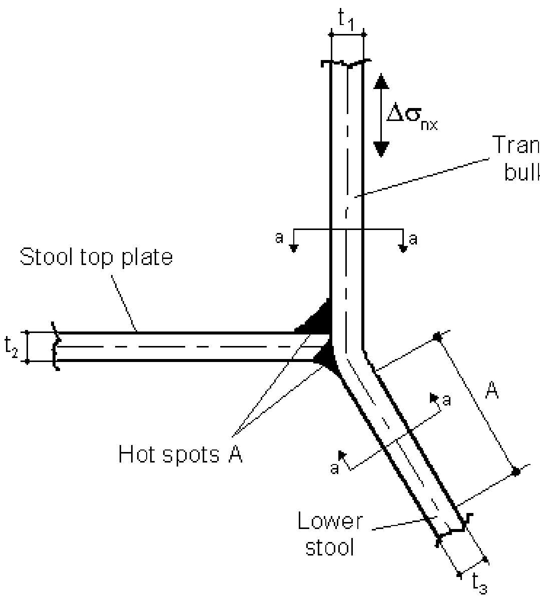
WELDING AND MATERIALS:

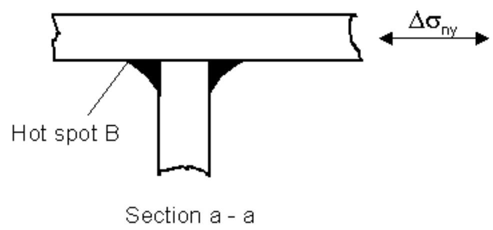
- Welding requirements:
  - stool side plating to be connected with full penetration welding to the bulkhead plating. Root gap to be checked along the production steps as appropriate,
  - brackets to be connected with full penetration welding to transverse bulkhead plating,
  - full penetration weld of stool side plating to bulkhead plating to be welded first,
  - welding sequence against lamellar tearing in the bulkhead plating is recommended.
- Material requirements:
  - the lower strake of transverse bulkhead plating is recommended to be Z25/ZH25 quality. If a steel of such a quality is not adopted, 100% UE of the strake in way of the weld is required prior to and after welding,
  - material properties of:
    - the stool top plate,
    - the portion A of the stool side plating,

    to be not less than those of the transverse bulkhead plating,
  - material properties of prolonging brackets to be not less than those of the bulkhead plating.

OIL TANKERS

AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with plane bulkheads – Radiused construction	Sheet 5.4





A = distance to be taken not less than the spacing of bulkhead vertical webs

Hot spot stresses:

- At hot spot A: $\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX}$
- At hot spot B: $\Delta\sigma_{SY} = K_{SY} \cdot \Delta\sigma_{nY} + K_{SXY} \cdot \Delta\sigma_{nX}$

$t_A = \min (t_1, t_2, t_3)$

t_B = minimum among:

- thickness of member above stool top plate,
- thickness of member below stool top plate,
- t_2.

SCANTLINGS:

- Inner radius of the bent plate to be between 3,5 and 5 times the thickness of the bent plate and to be indicated in the approved plan.
- $t_2 \geq t_1$.
- $t_3 \geq t_1$ in portion A.
- Thickness of members above and below stool top plate to be not less than that of bulkhead vertical webs.

FATIGUE:

Fatigue check to be carried out for L ≥ 150 m:

- $K_{SX} = 3,3$
- $K_{SY} = 1,3$
- $K_{SXY} = 2,25$

CONSTRUCTION:

- Misalignment (median lines) between stool top plate and stool side plating ≤ t_A / 3.
- Misalignment (median lines) between members above and below stool top plate ≤ t_B / 3.
- If not full penetration welding of stool top plate to bulkhead, the weld preparation is to be indicated on the approved drawings.
- Butt welds between transverse bulkhead and stool side plating at a distance greater than 500 mm from the stool top plate.

NDE:

The following NDE are required:

- VE 100%,
- UE 35% of full penetration welds, if any, for absence of cracks, lack of penetration and lamellar tears.

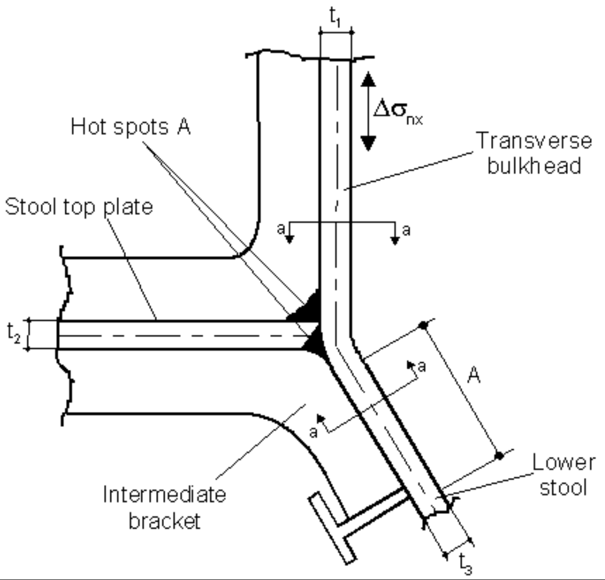
WELDING AND MATERIALS:

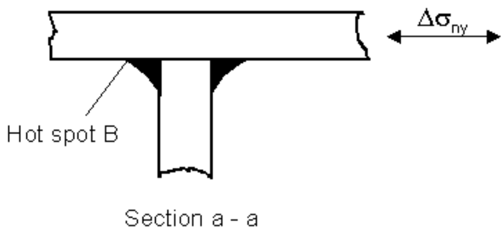
- Welding requirements:
  - welding sequence against the risk of lamellar tearing in the bulkhead plate is recommended,
  - weld finishing well faired to the bulkhead plating and stool side plating.
- Material requirements:
  - the radiused construction may be accepted provided that the folding procedure is submitted to the Society for review, with evidence given that the mechanical properties and, in particular, the impact properties are not deteriorated by the folding operation.
  - material properties of:
    - the stool top plate,
    - the portion A of the stool side plating,

    to be not less than those of the transverse bulkhead plating.

OIL TANKERS

AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with plane bulkheads in way of intermediate brackets – Radiused construction	Sheet 5.5





A = distance to be taken not less than the spacing of bulkhead vertical webs

Hot spot stresses:

- At hot spot A: $\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX}$
- At hot spot B: $\Delta\sigma_{SY} = K_{SY} \cdot \Delta\sigma_{nY} + K_{SXY} \cdot \Delta\sigma_{nX}$

$t_A = \min (t_1, t_2, t_3)$

t_B = minimum among:

- thickness of member above stool top plate,
- thickness of intermediate bracket,
- t_2.

SCANTLINGS:

- Inner radius of the bent plate to be between 3,5 and 5 times the thickness of the bent plate and to be indicated in the approved plan.
- $t_2 \geq t_1$.
- $t_3 \geq t_1$ in portion A.
- Thickness of intermediate brackets and members above stool top plate to be not less than that of bulkhead vertical webs.

FATIGUE:

Fatigue check to be carried out for $L \geq 150$ m:

- $K_{SX} = 3,15$
- $K_{SY} = 1,3$
- $K_{SXY} = 2,05$

CONSTRUCTION:

- Misalignment (median lines) between stool top plate and stool side plating $\leq t_A / 3$.
- Misalignment (median lines) between intermediate bracket and member below stool top plate $\leq t_B/3$.
- If not full penetration welding of stool top plate to bulkhead, the weld preparation is to be indicated on the approved drawings.
- Intermediate brackets to be fitted in place and welded after the welding of the joint between the stool top plate and the bulkhead plating.
- Butt welds between transverse bulkhead and stool side plating at a distance greater than 500 mm from the stool top plate.

NDE:

The following NDE are required:

- VE 100%,
- UE 35% of full penetration welds, if any, for absence of cracks, lack of penetration and lamellar tears.

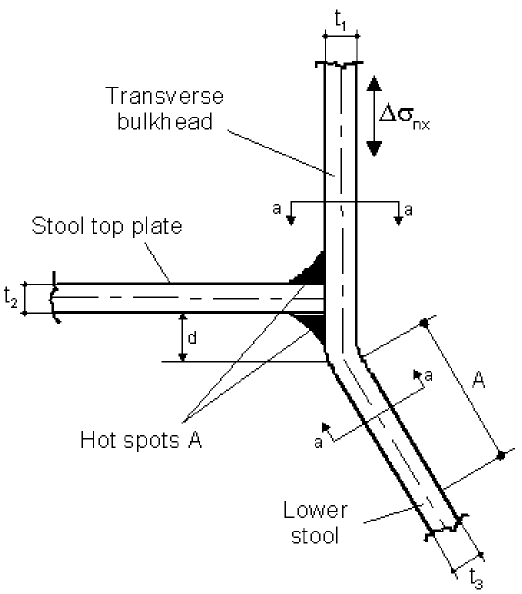
WELDING AND MATERIALS:

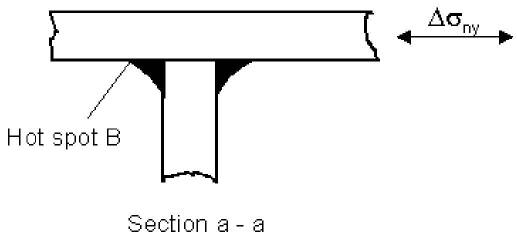
- Welding requirements:
  - brackets to be connected with continuous fillet welding to plating and stiffeners,
  - welding sequence against the risk of lamellar tearing in the bulkhead plate is recommended,
  - weld finishing well faired to the bulkhead plating and stool side plating.
- Material requirements:
  - the radiused construction may be accepted provided that the folding procedure is submitted to the Society for review, with evidence given that the mechanical properties and, in particular, the impact properties are not deteriorated by the folding operation.
  - material properties of:
    - the stool top plate,
    - the portion A of the stool side plating,

    to be not less than those of the transverse bulkhead plating.

OIL TANKERS

AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with plane bulkheads – Radiused construction	Sheet 5.6





A = distance to be taken not less than the spacing of bulkhead vertical webs

Hot spot stresses:

- At hot spot A: $\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX}$
- At hot spot B: $\Delta\sigma_{SY} = K_{SY} \cdot \Delta\sigma_{nY} + K_{SXY} \cdot \Delta\sigma_{nX}$

t = minimum among:

- thickness of member above stool top plate,
- thickness of member below stool top plate,
- t_2.

SCANTLINGS:

- Inner radius of the bent plate to be between 3,5 and 5 times the thickness of the bent plate and to be indicated in the approved plan.
- $d \leq 40$ mm.
- $t_2 \geq t_1$.
- $t_3 \geq t_1$ in portion A.
- Thickness of members above and below stool top plate to be not less than that of bulkhead vertical webs.

FATIGUE:

Fatigue check to be carried out for L ≥ 150 m:

- $K_{SX} = 4,5$
- $K_{SY} = 1,3$
- $K_{SXY} = 5,6$

CONSTRUCTION:

- Misalignment (median lines) between members above and below stool top plate ≤ t / 3.
- If not full penetration welding of stool top plate to bulkhead, the weld preparation is to be indicated on the approved drawings.
- Butt welds between transverse bulkhead and stool side plating at a distance greater than 500 mm from the stool top plate.

NDE:

The following NDE are required:

- VE 100%,
- UE 35% of full penetration welds, if any, for absence of cracks, lack of penetration and lamellar tears.

WELDING AND MATERIALS:

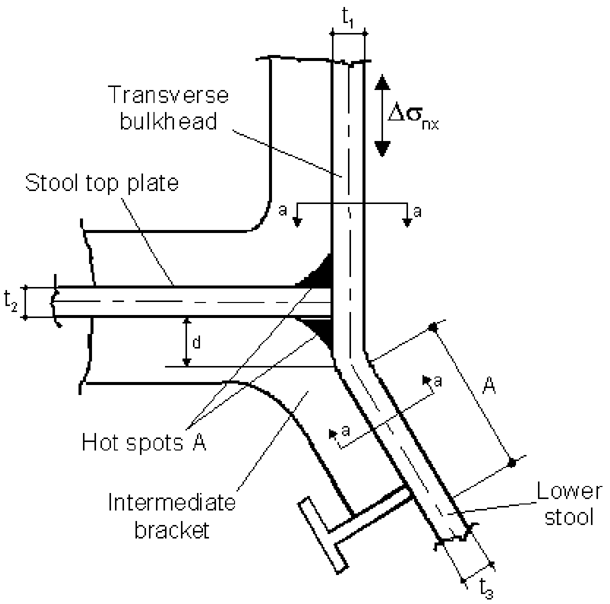
Material requirements:

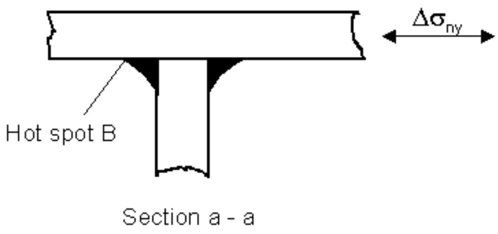
- where stool top plate is welded within the bent area, folding procedure to be submitted to the Society for review, with evidence given that the mechanical properties and, in particular, the impact properties are not deteriorated by the folding operation,
- material properties of:
  - the stool top plate,
  - the portion A of the stool side plating,

  to be not less than those of the transverse bulkhead plating.

OIL TANKERS

AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with plane bulkheads in way of intermediate brackets - Radiused construction	Sheet 5.7





A = distance to be taken not less than the spacing of bulkhead vertical webs

Hot spot stresses:

- At hot spot A: $\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX}$
- At hot spot B: $\Delta\sigma_{SY} = K_{SY} \cdot \Delta\sigma_{nY} + K_{SXY} \cdot \Delta\sigma_{nX}$

t = minimum among:

- thickness of member above stool top plate,
- thickness of intermediate bracket,
- t_2.

SCANTLINGS:

- Inner radius of the bent plate to be between 3,5 and 5 times the thickness of the bent plate and to be indicated in the approved plan.
- $d \le 40$ mm.
- $t_2 \ge t_1$.
- $t_3 \ge t_1$ in portion A.
- Thickness of intermediate brackets and members above stool top plate to be not less than that of bulkhead vertical webs.

FATIGUE:

Fatigue check to be carried out for $L \ge 150$ m:

- $K_{SX} = 3,85$
- $K_{SY} = 1,3$
- $K_{SXY} = 4,5$

CONSTRUCTION:

- Misalignment (median lines) between intermediate bracket and member above stool top plate $\le t/3$.
- If not full penetration welding of stool top plate to bulkhead, the weld preparation is to be indicated on the approved drawings.
- Intermediate brackets to be fitted in place and welded after the welding of the joint between the stool top plate and the bulkhead plating.
- Butt welds between transverse bulkhead and stool side plating at a distance greater than 500 mm from the stool top plate.

NDE:

The following NDE are required:

- VE 100%,
- UE 35% of full penetration welds, if any, for absence of cracks, lack of penetration and lamellar tears.

WELDING AND MATERIALS:

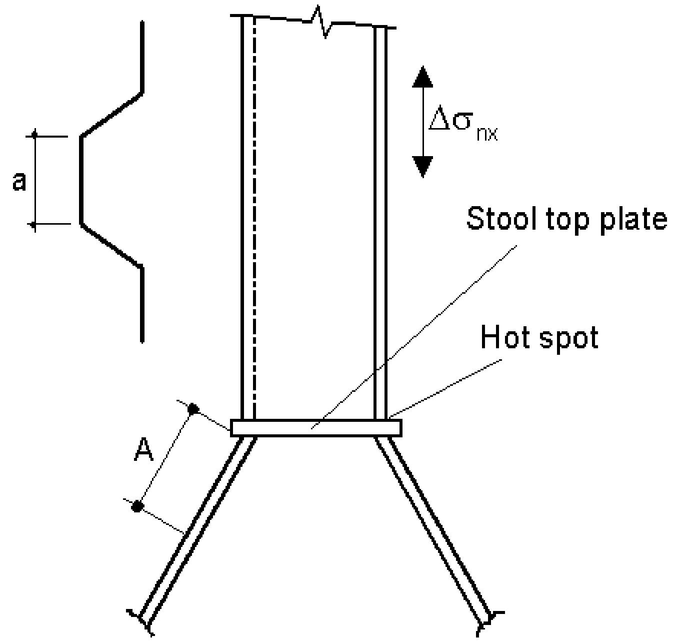
Material requirements:

- where stool top plate is welded within the bent area, folding procedure to be submitted to the Society for review, with evidence given that the mechanical properties and, in particular, the impact properties are not deteriorated by the folding operation,
- material properties of:
  - the stool top plate,
  - the portion A of the stool side plating,

  to be not less than those of the transverse bulkhead plating.

OIL TANKERS

AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with corrugated bulkheads	Sheet 5.8



$A \geq a$.

Hot spot stress:

$\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX}$

t_F = corrugation flange thickness,
t_T = stool top plate thickness,
t_S = stool side plating thickness,

$t = \min(t_F, t_T, t_S)$.

SCANTLINGS:	FATIGUE:
• $t_T \geq t_F$. • $t_S \geq t_F$ in portion A.	Fatigue check to be carried out for $L \geq 150$ m: – $K_{SX} = 2{,}35$

CONSTRUCTION:	NDE:
• Misalignment (median lines) between corrugation flanges and stool side plating $\leq t / 3$. • Distance from the edge of the stool top plate to the surface of the corrugation flanges $\geq t_F$. • Corrugation radius according to Ch 4, Sec 7, [3.1.3]	The following NDE are required: • VE 100%, • UE 35% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

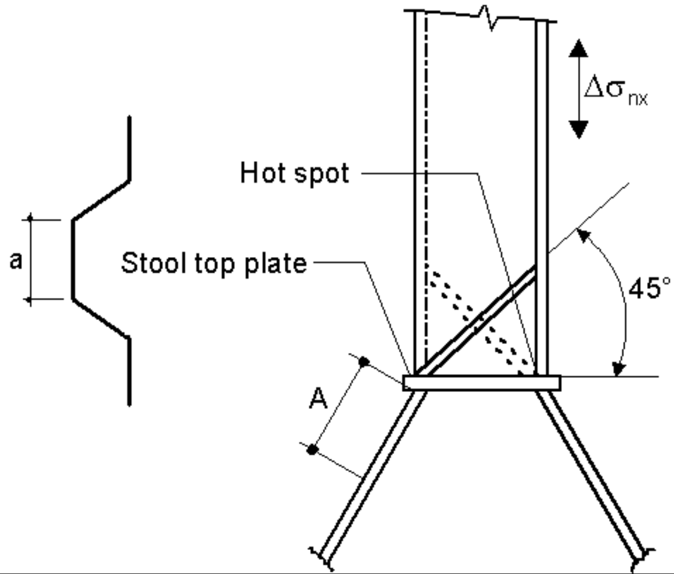
WELDING AND MATERIALS:

- Welding requirements:
  - corrugations to be connected with full penetration welding to stool top plate; root gap to be checked along the production,
  - stool side plating to be connected with full penetration or partial penetration welding to stool top plate,
  - welding sequence against the risk of lamellar tearing
  - start and stop welding away from the locations of corrugation bents,
  - weld finishing well faired to the stool top plate, corrugation flanges and stool side plating.
- Material requirements:
  - the stool top plate is recommended to be of Z25/ZH25 quality. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding,
  - material properties of:
    - the stool top plate,
    - the portion A of the stool side plating,

    to be not less than those of the corrugation flanges.

OIL TANKERS

AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with corrugated bulkheads – Shedder plates 45°	Sheet 5.9



$A \geq a$.

Hot spot stress:

$\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX}$

t_F = corrugation flange thickness,
t_T = stool top plate thickness,
t_S = stool side plating thickness,
t_{SH} = shedder plate thickness,

$t_A = \min(t_F, t_T, t_S)$,

$t_B = \min(t_{SH}, t_T, t_S)$.

SCANTLINGS:	FATIGUE:
• $t_T \geq t_F$. • $t_S \geq t_F$ in portion A. • $t_{SH} \geq 0,75\ t_F$	Fatigue check to be carried out for $L \geq 150$ m: – $K_{SX} = 1,35$

CONSTRUCTION:	NDE:
• Misalignment (median lines) between corrugation flanges and stool side plating $\leq t_A / 3$. • Misalignment (median lines) between lower edge of shedder plates and stool side plating $\leq t_B / 3$. • Knuckled shedder plates are to be avoided. • Distance from the edge of the stool top plate to the surface of the corrugation flanges $\geq t_F$. • Corrugation radius according to Ch 4, Sec 7, [3.1.3]. • In ships with service notations oil tankers, closed spaces to be filled with suitable compound compatible with the products carried.	The following NDE are required: • VE 100%, • UE 35% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

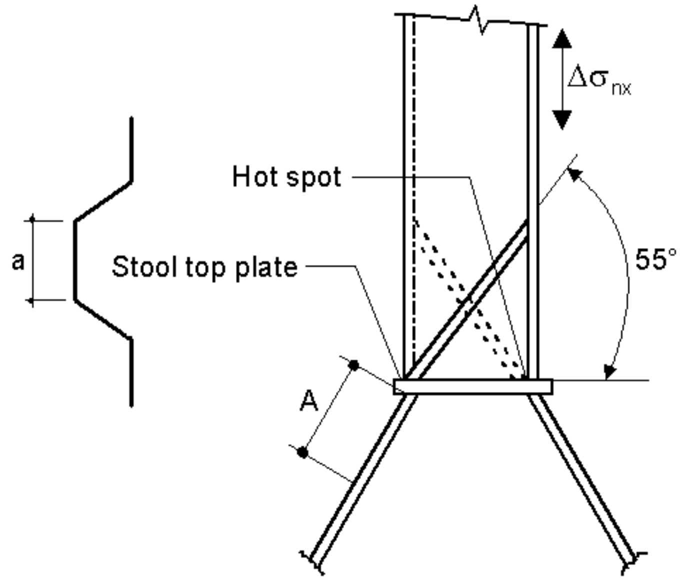
WELDING AND MATERIALS:

- Welding requirements:
  - corrugations to be connected with full penetration welding to stool top plate; root gap to be checked along the production,
  - stool side plating to be connected with full penetration or partial penetration welding to stool top plate,
  - shedder plates to be connected with one side penetration, or equivalent, to corrugations and stool top plate,
  - welding sequence against the risk of lamellar tearing
  - start and stop welding away from the locations of corrugation bents,
  - weld finishing well faired to the stool top plate, corrugation flanges and stool side plating.
- Material requirements:
  - the stool top plate is recommended to be of Z25/ZH25 quality. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding,
  - material properties of:
    - the shedder plates,
    - the stool top plate,
    - the portion A of the stool side plating,

    to be not less than those of the corrugation flanges.

OIL TANKERS

AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with corrugated bulkheads – Shedder plates 55°	Sheet 5.10



$A \geq a$.

Hot spot stress:

$\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX}$

t_F = corrugation flange thickness,
t_T = stool top plate thickness,
t_S = stool side plating thickness,
t_{SH} = shedder plate thickness,

$t_A = \min(t_F, t_T, t_S)$,

$t_B = \min(t_{SH}, t_T, t_S)$.

SCANTLINGS:

- $t_T \geq t_F$.
- $t_S \geq t_F$ in portion A.
- $t_{SH} \geq 0{,}75\ t_F$

FATIGUE:

Fatigue check to be carried out for $L \geq 150$ m:
– $K_{SX} = 1{,}25$

CONSTRUCTION:

- Misalignment (median lines) between corrugation flanges and stool side plating $\leq t_A / 3$.
- Misalignment (median lines) between lower edge of shedder plates and stool side plating $\leq t_B / 3$.
- Knuckled shedder plates are to be avoided.
- Distance from the edge of the stool top plate to the surface of the corrugation flanges $\geq t_F$.
- Corrugation radius according to Ch 4, Sec 7, [3.1.3].
- In ships with service notations oil tankers, closed spaces to be filled with suitable compound compatible with the products carried.

NDE:

The following NDE are required:

- VE 100%,
- UE 35% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

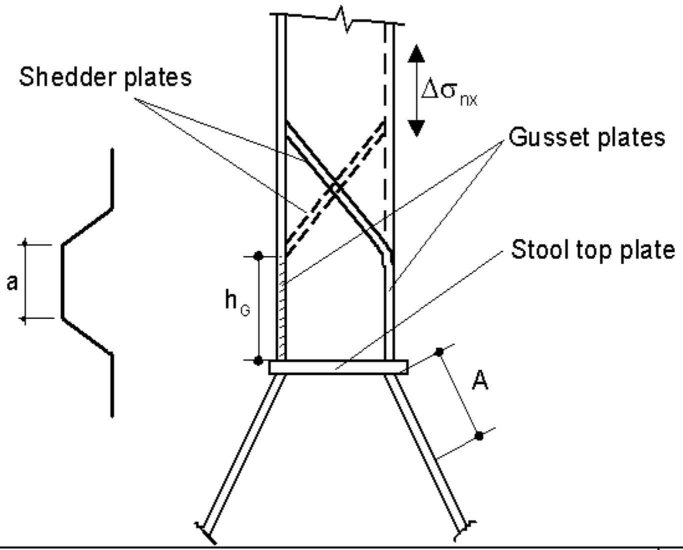
WELDING AND MATERIALS:

- Welding requirements:
  - corrugations to be connected with full penetration welding to stool top plate; root gap to be checked along the production,
  - stool side plating to be connected with full penetration or partial penetration welding to stool top plate,
  - shedder plates to be connected with one side penetration, or equivalent, to corrugations and stool top plate,
  - welding sequence against the risk of lamellar tearing
  - start and stop welding away from the locations of corrugation bents,
  - weld finishing well faired to the stool top plate, corrugation flanges and stool side plating.
- Material requirements:
  - the stool top plate is recommended to be of Z25/ZH25 quality. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding,
  - material properties of:
    - the shedder plates,
    - the stool top plate,
    - the portion A of the stool side plating,

    to be not less than those of the corrugation flanges.

OIL TANKERS

AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with corrugated bulkheads - Gusset and shedder plates	Sheet 5.11



$A \geq a$.

Hot spot stress:

$\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX}$

t_F = corrugation flange thickness,
t_T = stool top plate thickness,
t_S = stool side plating thickness,
t_G = gusset plate thickness,
t_{SH} = shedder plate thickness,

$t_A = \min(t_F, t_T, t_S)$,

$t_B = \min(t_G, t_T, t_S)$.

SCANTLINGS:

- $t_T \geq t_F$ $t_S \geq t_F$ in portion A
- $t_G \geq t_F$ $t_{SH} \geq 0,75\ t_F$ $h_G \geq a / 2$.

FATIGUE:

Fatigue check not required.

CONSTRUCTION:

- Misalignment (median lines) between corrugation flanges and stool side plating $\leq t_A / 3$.
- Misalignment (median lines) between lower edge of gusset plates and stool side plating $\leq t_B / 3$.
- Distance from the edge of the stool top plate to the surface of the corrugation flanges $\geq t_F$.
- Corrugation radius according to Ch 4, Sec 7, [3.1.3].
- In ships with service notations oil tankers, closed spaces to be filled with suitable compound compatible with the products carried.

NDE:

The following NDE are required:
- VE 100%,
- UE 35% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

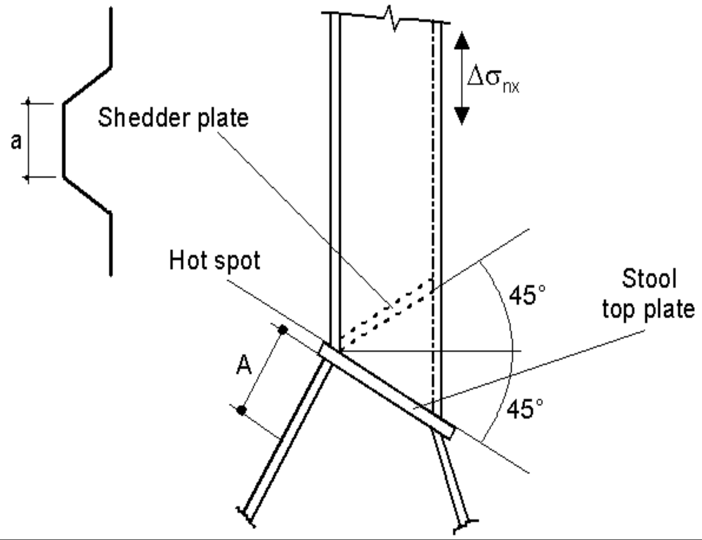
WELDING AND MATERIALS:

- Welding requirements:
  - corrugations to be connected with full penetration welding to stool top plate; root gap to be checked along the production,
  - stool side plating to be connected with full penetration or partial penetration welding to stool top plate,
  - gusset plates to be connected with full penetration welding to stool top plate and with one side penetration, or equivalent, to corrugations and shedder plates,
  - shedder plates to be connected with one side penetration, or equivalent, to corrugations and gusset plates,
  - welding sequence against the risk of lamellar tearing
  - start and stop welding away from the locations of corrugation bents,
  - weld finishing well faired to the stool top plate, corrugation flanges and stool side plating.
- Material requirements:
  - the stool top plate is recommended to be of Z25/ZH25 quality. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding,
  - material properties of:
    - the gusset plates,
    - the shedder plates,
    - the stool top plate,
    - the portion A of the stool side plating,

    to be not less than those of the corrugation flanges.

OIL TANKERS

AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with corrugated bulkheads - Sloping stool top plate	Sheet 5.12



$A \geq a$.

Hot spot stress:
$\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX}$

t_F = corrugation flange thickness,
t_T = stool top plate thickness,
t_S = stool side plating thickness,
t_{SH} = shedder plate thickness,

$t_A = \min (t_F, t_T, t_S)$,

$t_B = \min (t_{SH}, t_T, t_S)$.

SCANTLINGS:

- $t_T \geq t_F$.
- $t_S \geq t_F$ in portion A.
- $t_{SH} \geq 0,75\ t_F$

FATIGUE:

Fatigue check to be carried out for $L \geq 150$ m:
- $K_{SX} = 1,9$

CONSTRUCTION:

- Misalignment (median lines) between corrugation flanges and stool side plating $\leq t_A / 3$.
- Misalignment (median lines) between lower edge of shedder plates and stool side plating $\leq t_B / 3$.
- Knuckled shedder plates are to be avoided.
- Distance from the edge of the stool top plate to the surface of the corrugation flanges $\geq t_F$.
- Corrugation radius according to Ch 4, Sec 7, [3.1.3].
- In ships with service notations oil tankers, closed spaces to be filled with suitable compound compatible with the products carried.

NDE:

The following NDE are required:
- VE 100%,
- UE 35% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

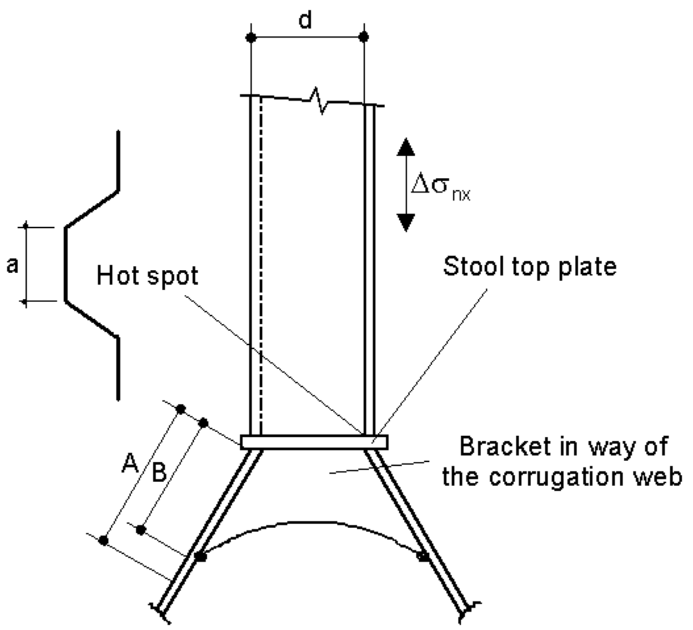
WELDING AND MATERIALS:

- Welding requirements:
  - corrugations to be connected with full penetration welding to stool top plate; root gap to be checked along the production,
  - stool side plating to be connected with full penetration or partial penetration welding to stool top plate,
  - shedder plates to be connected with one side penetration, or equivalent, to corrugations and stool top plate,
  - welding sequence against the risk of lamellar tearing
  - start and stop welding away from the locations of corrugation bents,
  - weld finishing well faired to the stool top plate, corrugation flanges and stool side plating.
- Material requirements:
  - the stool top plate is recommended to be of Z25/ZH25 quality. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding,
  - material properties of:
    - the shedder plates,
    - the stool top plate,
    - the portion A of the stool side plating,

    to be not less than those of the corrugation flanges.

OIL TANKERS

AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with corrugated bulkheads - Brackets below stool top plate	Sheet 5.13



$A \geq a$,

B = bracket dimension.

Hot spot stress:

$\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX}$

t_F = corrugation flange thickness,
t_W = corrugation web thickness,
t_T = stool top plate thickness,
t_S = stool side plating thickness,
t_B = bracket thickness,

$t_A = \min(t_F, t_T, t_S)$,
$t_B = \min(t_W, t_T, t_B)$.

SCANTLINGS:

- $t_T \geq t_F$
- $t_S \geq t_F$ in portion A
- $t_B \geq t_W$
- $B \geq d$

FATIGUE:

Fatigue check to be carried out for $L \geq 150$ m:
- $K_{SX} = 1,95$

CONSTRUCTION:

- Misalignment (median lines) between corrugation flanges and stool side plating $\leq t_A / 3$.
- Misalignment (median lines) between corrugation webs and brackets below stool top plate $\leq t_B / 3$.
- Distance from the edge of the stool top plate to the surface of the corrugation flanges $\geq t_F$.
- Corrugation radius according to Ch 4, Sec 7, [3.1.3].

NDE:

The following NDE are required:
- VE 100%,
- UE 35% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

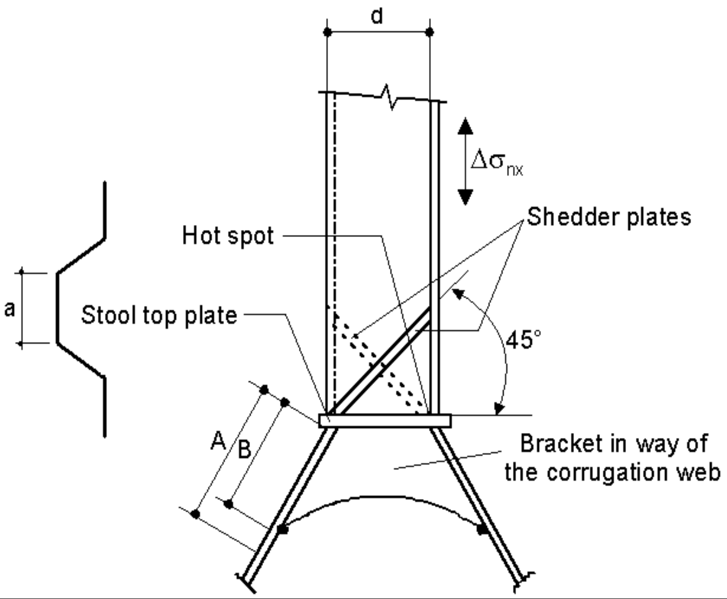
WELDING AND MATERIALS:

- Welding requirements:
  - corrugations to be connected with full penetration welding to stool top plate; root gap to be checked along the production,
  - stool side plating to be connected with full penetration or partial penetration welding to stool top plate,
  - welding sequence against the risk of lamellar tearing
  - start and stop welding away from the locations of corrugation bents,
  - weld finishing well faired to the stool top plate, corrugation flanges and stool side plating.
- Material requirements:
  - the stool top plate is recommended to be of Z25/ZH25 quality. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding,
  - material properties of:
    - the stool top plate,
    - the portion A of the stool side plating,

    to be not less than those of the corrugation flanges.

OIL TANKERS

AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with corrugated bulkheads - Shedder plates 45° and brackets below stool top plate	Sheet 5.14



$A \geq a$,

B = bracket dimension.

Hot spot stress:
$\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX}$

t_F = corrugation flange thickness,
t_W = corrugation web thickness,
t_T = stool top plate thickness,
t_S = stool side plating thickness,
t_{SH} = shedder plate thickness,
t_B = bracket thickness,

$t_A = \min(t_F, t_T, t_S)$,
$t_B = \min(t_{SH}, t_T, t_S)$
$t_C = \min(t_W, t_T, t_B)$.

SCANTLINGS:	FATIGUE:
• $t_T \geq t_F$ $t_S \geq t_F$ in portion A • $t_{SH} \geq 0{,}75\ t_F$ $t_B \geq t_W$ $B \geq d$	Fatigue check to be carried out for $L \geq 150$ m: – $K_{SX} = 1{,}25$

CONSTRUCTION:

- Misalignment (median lines) between corrugation flanges and stool side plating $\leq t_A / 3$.
- Misalignment (median lines) between lower edge of shedder plates and stool side plating $\leq t_B / 3$.
- Misalignment (median lines) between corrugation webs and brackets below stool top plate $\leq t_C / 3$.
- Knuckled shedder plates are to be avoided.
- Distance from the edge of the stool top plate to the surface of the corrugation flanges $\geq t_F$.
- Corrugation radius according to Ch 4, Sec 7, [3.1.3].
- In ships with service notations oil tankers, closed spaces to be filled with suitable compound compatible with the products carried.

NDE:

The following NDE are required:
- VE 100%,
- UE 35% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

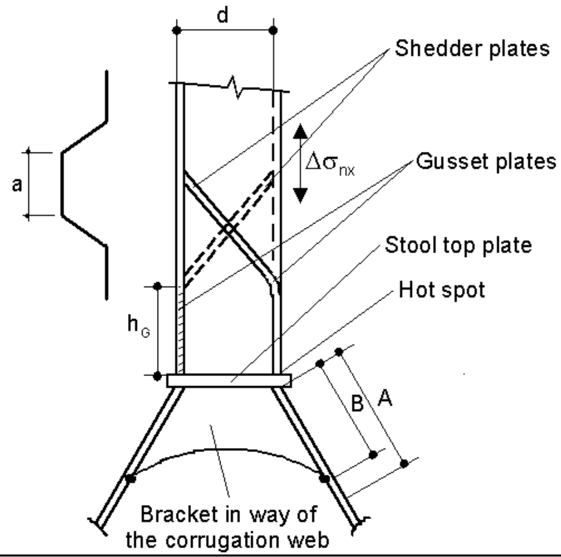
WELDING AND MATERIALS:

- Welding requirements:
  - corrugations to be connected with full penetration welding to stool top plate; root gap to be checked along the production,
  - stool side plating to be connected with full penetration or partial penetration welding to stool top plate,
  - shedder plates to be connected with one side penetration, or equivalent, to corrugations and stool top plate,
  - welding sequence against the risk of lamellar tearing
  - start and stop welding away from the locations of corrugation bents,
  - weld finishing well faired to the stool top plate, corrugation flanges and stool side plating.
- Material requirements:
  - the stool top plate is recommended to be of Z25/ZH25 quality. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding,
  - material properties of:
    - the shedder plates,
    - the stool top plate,
    - the portion A of the stool side plating,

    to be not less than those of the corrugation flanges.

OIL TANKERS

AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with corrugated bulkheads - Gusset and shedder plates and brackets below stool top plate	Sheet 5.15



$A \geq a$,
B = bracket dimension.

Hot spot stress:

$\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX}$

t_F = corrugation flange thickness,
t_W = corrugation web thickness,
t_T = stool top plate thickness,
t_S = stool side plating thickness,
t_G = gusset plate thickness,
t_{SH} = shedder plate thickness,
t_B = bracket thickness,

$t_A = \min (t_F, t_T, t_S)$,
$t_B = \min (t_G, t_T, t_S)$

$t_C = \min (t_W, t_T, t_B)$.

SCANTLINGS:	FATIGUE:
• $t_T \geq t_F$ $t_S \geq t_F$ in portion A $t_G \geq t_F$ $t_{SH} \geq 0,75\ t_F$ • $t_B \geq t_W$ $h_G \geq a / 2$ $B \geq d$	Fatigue check not required.

CONSTRUCTION:	NDE:
• Misalignment (median lines) between corrugation flanges and stool side plating $\leq t_A / 3$. • Misalignment (median lines) between lower edge of gusset plates and stool side plating $\leq t_B / 3$. • Misalignment (median lines) between corrugation webs and brackets below stool top plate $\leq t_C / 3$. • Distance from the edge of the stool top plate to the surface of the corrugation flanges $\geq t_F$. • Corrugation radius according to Ch 4, Sec 7, [3.1.3]. • In ships with service notations oil tankers, closed spaces to be filled with suitable compound compatible with the products carried.	The following NDE are required: • VE 100%, • UE 35% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

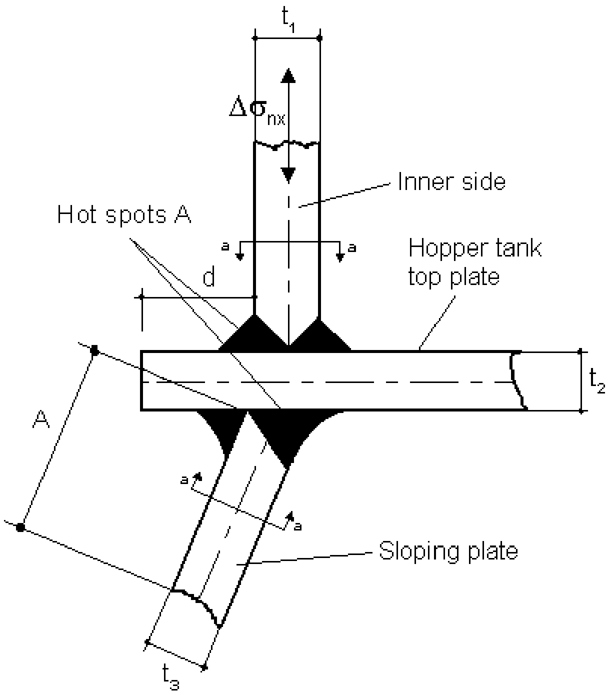
WELDING AND MATERIALS:

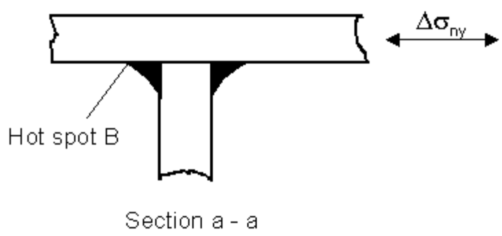
- Welding requirements:
  - corrugations to be connected with full penetration welding to stool top; root gap to be checked along the production,
  - stool side plating to be connected with full penetration or partial penetration welding to stool top plate,
  - gusset plates to be connected with full penetration welding to stool top and with one side penetration, or equivalent, to corrugations and shedder plates,
  - shedder plates to be connected with one side penetration, or equivalent, to corrugations and gusset plates,
  - welding sequence against the risk of lamellar tearing
  - start and stop welding away from the locations of corrugation bents,
  - weld finishing well faired to the stool top plate, corrugation flanges and stool side plating.
- Material requirements:
  - the stool top plate is recommended to be of Z25/ZH25 quality. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding,
  - material properties of:
    - the gusset plates,
    - the shedder plates,
    - the stool top plate,
    - the portion A of the stool side plating,

    to be not less than those of the corrugation flanges.

OIL TANKERS

AREA 6: Lower part of inner side	Connection of hopper tank sloping plates with inner side	Sheet 6.1





A = distance to be taken not less than the spacing of side transverses

Hot spot stresses:
- At hot spot A: $\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX}$
- At hot spot B: $\Delta\sigma_{SY} = K_{SY} \cdot \Delta\sigma_{nY} + K_{SXY} \cdot \Delta\sigma_{nX}$

$t_A = \min(t_1, t_2, t_3)$

t_B = minimum among:
- thickness of member above hopper tank top plate,
- thickness of member below hopper tank top plate,
- t_2.

SCANTLINGS:

- $d \geq t_1$.
- $t_2 \geq t_1$.
- $t_3 \geq t_1$ in portion A.
- Thickness of members above and below hopper tank top plate to be not less than that of side transverses.

FATIGUE:

Fatigue check to be carried out for L ≥ 150 m:
- $K_{SX} = 3,85$
- $K_{SY} = 1,3$
- $K_{SXY} = 2,0$

CONSTRUCTION:

- Misalignment (median lines) between inner side plating and hopper tank sloping plate ≤ t_A / 3.
- Misalignment (median lines) between members above and below hopper tank top plate ≤ t_B / 3.

NDE:

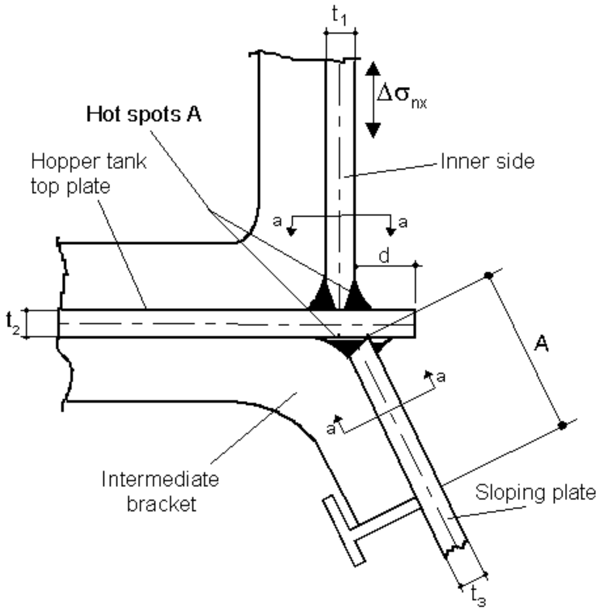
The following NDE are required:
- VE 100%,
- UE 25% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

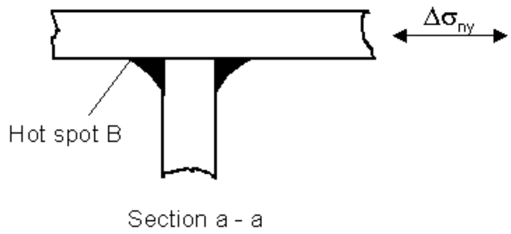
WELDING AND MATERIALS:

- Welding requirements:
  - inner side and hopper tank sloping plate generally to be connected with full penetration welding to hopper tank top plate (if not full penetration welding, the weld preparation is to be indicated on the approved drawings),
  - approval of the procedure on a sample representative of the actual conditions foreseen in production,
  - welding sequence against the risk of lamellar tearing is recommended in case Z material is not adopted for the hopper tank top plate,
  - weld finishing well faired to the hopper tank top plate.
- Material requirements:
  - the hopper tank top plate is recommended to be Z25/ZH25 quality. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding,
  - material properties of the portion A of the hopper tank sloping plate to be not less than those of the inner side plating.

OIL TANKERS

AREA 6: Lower part of inner side	Connection of hopper tank sloping plates with inner side in way of intermediate brackets	Sheet 6.2





A = distance to be taken not less than the spacing of side transverses

Hot spot stresses:

- At hot spot A: $\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX}$
- At hot spot B: $\Delta\sigma_{SY} = K_{SY} \cdot \Delta\sigma_{nY} + K_{SXY} \cdot \Delta\sigma_{nX}$

$t_A = \min (t_1, t_2, t_3)$

t_B = minimum among:

- thickness of member above hopper tank top plate,
- thickness of intermediate bracket,
- t_2.

SCANTLINGS:	FATIGUE:
• $d \geq t_1$. • $t_2 \geq t_1$. • $t_3 \geq t_1$ in portion A. • Thickness of intermediate brackets and members above hopper tank top plate to be not less than that of side transverses.	Fatigue check to be carried out for $L \geq 150$ m: – $K_{SX} = 3,55$ – $K_{SY} = 1,3$ – $K_{SXY} = 1,75$

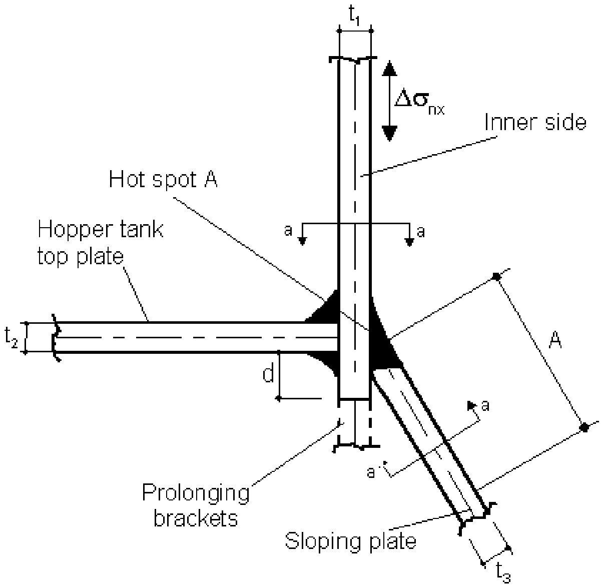
CONSTRUCTION:	NDE:
• Misalignment (median lines) between inner side plating and hopper tank sloping plate $\leq t_A / 3$. • Misalignment (median lines) between intermediate bracket and member above hopper tank top plate $\leq t_B/3$. • Intermediate brackets to be fitted in place and welded after the welding of the joint between the hopper tank sloping plate and the hopper tank top plate.	The following NDE are required: – VE 100%, – UE 25% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

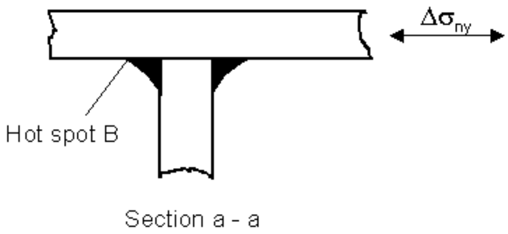
WELDING AND MATERIALS:

- Welding requirements:
  - inner side and hopper tank sloping plate generally to be connected with full penetration welding to hopper tank top plate (if not full penetration welding, the weld preparation is to be indicated on the approved drawings),
  - brackets to be connected with continuous fillet welding to plating and stiffeners,
  - approval of the procedure on a sample representative of the actual conditions foreseen in production,
  - welding sequence against the risk of lamellar tearing is recommended in case Z material is not adopted for the hopper tank top plate,
  - weld finishing well faired to the hopper tank top plate.
- Material requirements:
  - the hopper tank top plate is recommended to be Z25/ZH25 quality. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding,
    material properties of the portion A of the hopper tank sloping plate to be not less than those of the inner side plating.

OIL TANKERS

AREA 6: Lower part of inner side	Connection of hopper tank sloping plates with inner side – Prolonging brackets	Sheet 6.3





A = distance to be taken not less than the spacing of side transverses

Hot spot stresses:

- At hot spot A: $\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX}$
- At hot spot B: $\Delta\sigma_{SY} = K_{SY} \cdot \Delta\sigma_{nY} + K_{SXY} \cdot \Delta\sigma_{nX}$

$t_A = \min(t_1, t_2, t_3)$

t_B = minimum among:

- thickness of member above hopper tank top plate,
- thickness of member below hopper tank top plate,
- t_2.

SCANTLINGS:

- $d \geq 50$ mm.
- $t_2 \geq t_1$.
- $t_3 \geq t_1$ in portion A.
- Thickness of prolonging brackets $\geq t_1$.
- Thickness of members above and below hopper tank top plate to be not less than that of side transverses.

FATIGUE:

Fatigue check to be carried out for $L \geq 150$ m:

- $K_{SX} = 2,4$
- $K_{SY} = 1,3$
- $K_{SXY} = 1,5$

CONSTRUCTION:

- Misalignment (median lines) between hopper tank top plate and hopper tank sloping plate $\leq t_A / 3$.
- Misalignment (median lines) between members above and below hopper tank top plate $\leq t_B / 3$.

NDE:

The following NDE are required:

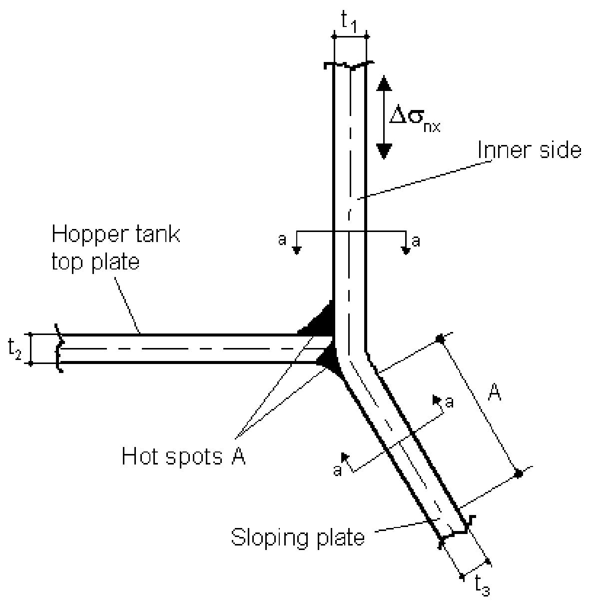
- VE 100%,
- UE 25% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

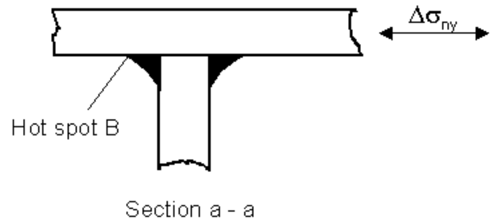
WELDING AND MATERIALS:

- Welding requirements:
  - Hopper tank sloping plate to be connected with full penetration welding to the inner side plating. Root gap to be checked along the production steps as appropriate,
  - Prolonging brackets to be connected with full penetration welding to inner side plating,
  - full penetration weld of hopper tank sloping plate to inner side plating to be welded first,
  - welding sequence against lamellar tearing in the inner side plating is recommended.
- Material requirements:
  - the lower strake of inner side plating is recommended to be Z25/ZH25 quality. If a steel of such a quality is not adopted, 100% UE of the strake in way of the weld is required prior to and after welding,
  - material properties of the portion A of the hopper tank sloping plate to be not less than those of the inner side plating,
  - material properties of prolonging brackets to be not less than those of the inner side plating.

OIL TANKERS

AREA 6: Lower part of inner side	Connection of hopper tank sloping plates with inner side – Radiused construction	Sheet 6.4





A = distance to be taken not less than the spacing of side transverses

Hot spot stresses:

- At hot spot A: $\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX}$
- At hot spot B: $\Delta\sigma_{SY} = K_{SY} \cdot \Delta\sigma_{nY} + K_{SXY} \cdot \Delta\sigma_{nX}$

$t_A = \min (t_1, t_2, t_3)$

t_B = minimum among:

- thickness of member above hopper tank top plate,
- thickness of member below hopper tank top plate,
- t_2.

SCANTLINGS:

- Inner radius of the bent plate to be between 3,5 and 5 times the thickness of the bent plate and to be indicated in the approved plan.
- $t_2 \geq t_1$.
- $t_3 \geq t_1$ in portion A.
- Thickness of members above and below hopper tank top plate to be not less than that of side transverses.

FATIGUE:

Fatigue check to be carried out for L ≥ 150 m:

- $K_{SX} = 3,3$
- $K_{SY} = 1,3$
- $K_{SXY} = 2,25$

CONSTRUCTION:

- Misalignment (median lines) between hopper tank top plate and hopper tank sloping plate $\leq t_A / 3$.
- Misalignment (median lines) between members above and below hopper tank top plate $\leq t_B / 3$.
- If not full penetration welding of hopper tank top plate to inner side, the weld preparation is to be indicated on the approved drawings.
- Butt welds between inner side and hopper tank sloping plate at a distance greater than 500 mm from the hopper tank top plate.

NDE:

The following NDE are required:

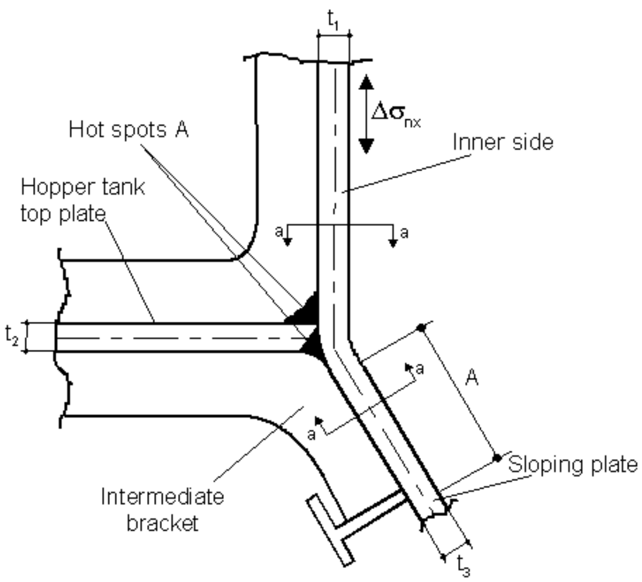
- VE 100%,
- UE 25% of full penetration welds, if any, for absence of cracks, lack of penetration and lamellar tears.

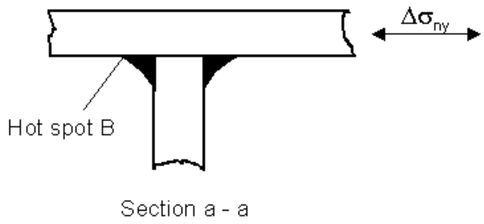
WELDING AND MATERIALS:

- Welding requirements:
  - Welding sequence against the risk of lamellar tearing in the inner side plate is recommended,
  - Weld finishing well faired to the inner side plating and hopper tank sloping plate.
- Material requirements:
  - the radiused construction may be accepted provided that the folding procedure is submitted to the Society for review, with evidence given that the mechanical properties and, in particular, the impact properties are not deteriorated by the folding operation.
  - material properties of the portion A of the hopper tank sloping plate to be not less than those of the inner side plating.

OIL TANKERS

AREA 6: Lower part of inner side	Connection of hopper tank sloping plates with inner side in way of intermediate brackets – Radiused construction	Sheet 6.5





A = distance to be taken not less than the spacing of side transverses

Hot spot stresses:

- At hot spot A: $\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX}$
- At hot spot B: $\Delta\sigma_{SY} = K_{SY} \cdot \Delta\sigma_{nY} + K_{SXY} \cdot \Delta\sigma_{nX}$

$t_A = \min (t_1, t_2, t_3)$

t_B = minimum among:

- thickness of member above hopper tank top plate,
- thickness of intermediate bracket,
- t_2.

SCANTLINGS:

- Inner radius of the bent plate to be between 3,5 and 5 times the thickness of the bent plate and to be indicated in the approved plan.
- $t_2 \geq t_1$.
- $t_3 \geq t_1$ in portion A.
- Thickness of intermediate brackets and members above hopper tank top plate to be not less than that of side transverses.

FATIGUE:

Fatigue check to be carried out for $L \geq 150$ m:

- $K_{SX} = 3{,}15$
- $K_{SY} = 1{,}3$
- $K_{SXY} = 2{,}05$

CONSTRUCTION:

- Misalignment (median lines) between hopper tank top plate and hopper tank sloping plate $\leq t_A / 3$.
- Misalignment (median lines) between intermediate bracket and member below hopper tank top plate $\leq t_B/3$.
- If not full penetration welding of hopper tank top plate to inner side, the weld preparation is to be indicated on the approved drawings.
- Intermediate brackets to be fitted in place and welded after the welding of the joint between the hopper tank top plate and the inner side plating.
- Butt welds between inner side and hopper tank sloping plate at a distance greater than 500 mm from the hopper tank top plate.

NDE:

The following NDE are required:

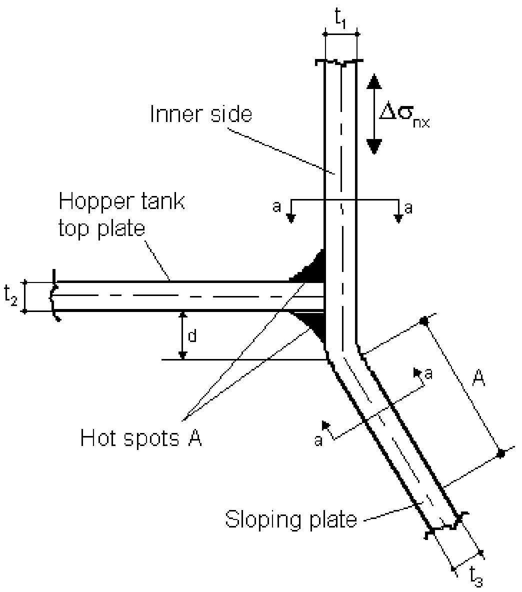
- VE 100%,
- UE 25% of full penetration welds, if any, for absence of cracks, lack of penetration and lamellar tears.

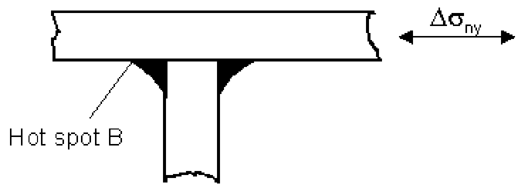
WELDING AND MATERIALS:

- Welding requirements:
  - brackets to be connected with continuous fillet welding to plating and stiffeners,
  - welding sequence against the risk of lamellar tearing in the inner side plate is recommended,
  - weld finishing well faired to the inner side plating and hopper tank sloping plate.
- Material requirements:
  - the radiused construction may be accepted provided that the folding procedure is submitted to the Society for review, with evidence given that the mechanical properties and, in particular, the impact properties are not deteriorated by the folding operation.
  - material properties of the portion A of the hopper tank sloping plate to be not less than those of the inner side plating.

OIL TANKERS

AREA 6: Lower part of inner side	Connection of hopper tank sloping plates with inner side – Radiused construction	Sheet 6.6





Section a - a

A = distance to be taken not less than the spacing of side transverses

Hot spot stresses:

- At hot spot A: $\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX}$
- At hot spot B: $\Delta\sigma_{SY} = K_{SY} \cdot \Delta\sigma_{nY} + K_{SXY} \cdot \Delta\sigma_{nX}$

t = minimum among:

– thickness of member above hopper tank top plate,
– thickness of member below hopper tank top plate,
– t_2.

SCANTLINGS:

- Inner radius of the bent plate to be between 3,5 and 5 times the thickness of the bent plate and to be indicated in the approved plan.
- $d \leq 40$ mm.
- $t_2 \geq t_1$.
- $t_3 \geq t_1$ in portion A.
- Thickness of members above and below hopper tank top plate to be not less than that of side transverses.

FATIGUE:

Fatigue check to be carried out for $L \geq 150$ m:

– $K_{SX} = 4,5$
– $K_{SY} = 1,3$
– $K_{SXY} = 5,6$

CONSTRUCTION:

- Misalignment (median lines) between members above and below hopper tank top plate $\leq t / 3$.
- If not full penetration welding of hopper tank top plate to inner side, the weld preparation is to be indicated on the approved drawings.
- Butt welds between inner side and hopper tank sloping plate at a distance greater than 500 mm from the hopper tank top plate.

NDE:

The following NDE are required:

– VE 100%,
– UE 25% of full penetration welds, if any, for absence of cracks, lack of penetration and lamellar tears.

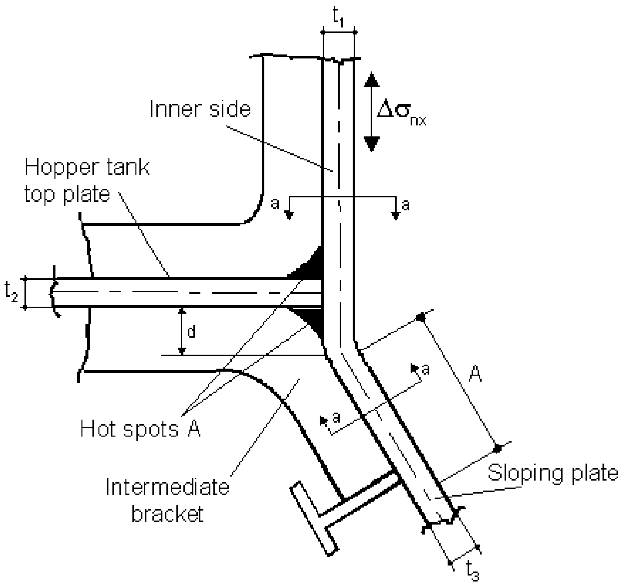
WELDING AND MATERIALS:

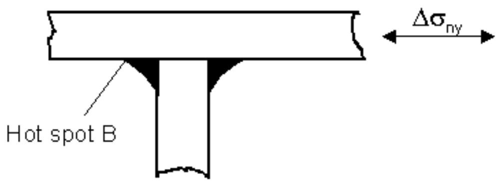
Material requirements:

– where hopper tank top plate is welded within the bent area, folding procedure to be submitted to the Society for review, with evidence given that the mechanical properties and, in particular, the impact properties are not deteriorated by the folding operation,
– material properties of the portion A of the hopper tank sloping plate to be not less than those of the inner side plating.

OIL TANKERS

AREA 6: Lower part of inner side	Connection of hopper tank sloping plates with inner side in way of intermediate brackets - Radiused construction	Sheet 6.7





Section a - a

A = distance to be taken not less than the spacing of side transverses

Hot spot stresses:

- At hot spot A: $\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX}$
- At hot spot B: $\Delta\sigma_{SY} = K_{SY} \cdot \Delta\sigma_{nY} + K_{SXY} \cdot \Delta\sigma_{nX}$

t = minimum among:

– thickness of member above hopper tank top plate,
– thickness of intermediate bracket,
– t_2.

SCANTLINGS:

- Inner radius of the bent plate to be between 3,5 and 5 times the thickness of the bent plate and to be indicated in the approved plan.
- $d \leq 40$ mm.
- $t_2 \geq t_1$.
- $t_3 \geq t_1$ in portion A.
- Thickness of intermediate brackets and members above hopper tank top plate to be not less than that of side transverses.

FATIGUE:

Fatigue check to be carried out for $L \geq 150$ m:

– $K_{SX} = 3{,}85$
– $K_{SY} = 1{,}3$
– $K_{SXY} = 4{,}5$

CONSTRUCTION:

- Misalignment (median lines) between intermediate bracket and member above hopper tank top plate $\leq t/3$.
- If not full penetration welding of hopper tank top plate to inner side, the weld preparation is to be indicated on the approved drawings.
- Intermediate brackets to be fitted in place and welded after the welding of the joint between the hopper tank top plate and the inner side plating.
- Butt welds between inner side and hopper tank sloping plate at a distance greater than 500 mm from the hopper tank top plate.

NDE:

The following NDE are required:

– VE 100%,
– UE 25% of full penetration welds, if any, for absence of cracks, lack of penetration and lamellar tears.

WELDING AND MATERIALS:

Material requirements:

– where hopper tank top plate is welded within the bent area, folding procedure to be submitted to the Society for review, with evidence given that the mechanical properties and, in particular, the impact properties are not deteriorated by the folding operation,
– material properties of the portion A of the hopper tank sloping plate to be not less than those of the inner side plating.