Rules for the Classification of Floating Offshore Units at Fixed Locations and Mobile Offshore Drilling Units

Effective from 1 January 2024

Part B

Hull and Stability

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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 G overnments.

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 reinstatemen t. 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 th e 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 p art 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 certificati on 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 seaw orthiness, structural integrity, quality or fitness for a particular purpose or service of any Ship, structure, 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 certification 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, the 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 statutory 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.

EXPLANATORY NOTE TO PART B

1. Reference edition

TThe reference edition of these Rules is the edition effective from 01 January 2015.

2. Effective date of the requirements

2.1 All requirements in which new or amended provisions with respect to those contained in the reference edition have been introduced are followed by a date shown in brackets.

The date shown in brackets is the effective date of entry into force of the requirements as amended by the last updating. The effective date of all those requirements not followed by any date shown in brackets is that of the reference edition.

2.2 Item 5 below provides a summary of the technical changes from the preceding edition. In general, this list does not include those items to which only editorial changes have been made not affecting the effective date of the requirements contained therein.

3. Rule Variations and Corrigenda

Until the next edition of the Rules is published, Rule Variations and/or corrigenda, as necessary, will be pub-lished on the Tasneef web site (www.Tasneef.ae). Except in particular cases, paper copies of Rule Variations or cor-rigenda are not issued.

4. Rule subdivision and cross-references

4.1 Rule subdivision

The Rules are subdivided into six parts, from A to F.

Part A: Classification and Surveys

Part B: Hull and Stability

Part C: Machinery, Systems and Fire Protection

Part D: Materials and Welding

Part E: Service Notations

Part F: Additional Class Notations

Each Part consists of:

- Chapters
- Sections and possible Appendices
- Articles
- Sub-articles
- Requirements

Figures (abbr. Fig) and Tables (abbr. Tab) are numbered in ascending order within each Section or Appendix.

5.2 Cross-references

Examples: Pt A, Ch 1, Sec 1, [3.2.1]or Pt A, Ch 1, App 1, [3.2.1]

- Pt A means Part A

The part is indicated when it is different from the part in which the cross-reference appears. Otherwise, it is not indicated.

- Ch 1 means Chapter 1

The Chapter is indicated when it is different from the chapter in which the cross-reference appears. Otherwise, it is not indicated.

- Sec 1 means Section 1 (or App 1 means Appendix 1)

The Section (or Appendix) is indicated when it is different from the Section (or Appendix) in which the cross-reference appears. Otherwise, it is not indicated.

- [3.2.1] refers to requirement 1, within sub-article 2 of article 3.

Cross-references to an entire Part or Chapter are not abbreviated as indicated in the following examples:

- Part A for a cross-reference to Part A
- Part A, Chapter 1 for a cross-reference to Chapter 1 of Part A.

5. Summary of amendments

Foreword

The date of entry into force of each new or amended item is shown in brackets after the number of the item concerned.

RULES FOR THE CLASSIFICATION OF FLOATING OFFSHORE UNITS AT FIXED LOCATIONS AND MOBILE OFFSHORE DRILLING UNITS

Part B
Hull and Stability

Chapters 1 2 3 4 5 6 7 8 9 10 11 12 13

CHAPTER 1
GENERAL

CHAPTER 2
GENERAL ARRANGEMENT DESIGN

CHAPTER 3
STABILITY

Appendix 2 Trim and Stability Booklet

CHAPTER 4
STRUCTURE DESIGN PRINCIPLES

CHAPTER 5
DESIGN LOADS

Section 1 General

Section 2 Hull Girder Loads

Section 3 Unit Motions and Accelerations

CHAPTER 6
HULL GIRDER STRENGTH

CHAPTER 7
HULL SCANTLINGS

CHAPTER 8
OTHER STRUCTURES

Section 5 Arrangement of Hull and Superstructure Openings

CHAPTER 9
MOORING SYSTEM (ANCHORING)

Section 1 General

Section 2 Turret Structures and Yoke Arms

Section 3 Equipment for Mooring and Anchoring

CHAPTER 10
FOUNDATIONS

Section 1 General

Section 2 Pile Foundations

Section 3 Gravity Type Foundations

Section 4 Anchor Foundations

Appendix 1 Determination of Parameters Relating to the Formulae for the Bearing Capacity

CHAPTER 11
TOPSIDE STRUCTURES AND LOADING ARMS

CHAPTER 12
CORROSION DETECTION AND LOADING INFORMATION

CHAPTER 13
CONSTRUCTION AND TESTING

Section 1 Welding and Weld Connections

Section 2 Special Structural Details

Part B
Hull and Stability

Chapter 1
GENERAL

SECTION 1 APPLICATION

1 General

1.1 Structural requirements

1.1.1 *(1/7/2015)*

Part B contains the requirements for determination of the minimum hull scantlings, applicable to offshore floating units with a ship or a barge hull form made in welded steel construction and intended for oil/gas storage and production by having one of the service notations **FSO**, **FPSO** or **FSRU**. These requirements are to be integrated with those specified in Part E, for any individual service notation, and in Part F, as applicable, depending on the additional class notations assigned to the unit.

For units with the notations **FSO CSR** and **FPSO CSR**. The "Common Structural Rules for Bulk Carriers and Oil Tankers" 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 5, Sec 6, [2.2] and [2.3] - for the calculation of impact pressures in tanks in the case of resonance
- Pt B, Ch 11, Sec 2, [4] of the Rules for the Classification of Ships - for the requirements concerning the loading instruments
- Pt B, Ch 12, Sec 3, [1], [2] and [3] of the Rules for the Classification of Ships - for the requirements concerning testing.

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

1.1.3 Units whose hull materials are different than those given in [1.1.2] and units 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 units 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.

1.1.6 Units engaged in offshore drilling operations will be subject to structural requirements of Pt E, Ch 4, Sec 2 applicable to service notation **MODU**.

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

1.2.2 The fixed parts of lifting appliances and their connections to the unit'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 Hull parts

2.1.1 General

For the purpose of application of the Rules, the unit 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 foreward peak 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 foreward peak bulkhead and the after peak bulkhead.

Where the flat bottom foreward area or the bow flare area extend aft of the forward peak 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 hull parts

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

2.3 Rules applicable to other unit items

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

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

Part	Applicable Chapters and Sections	
	General	Specific
Fore part	Chapter 1 Chapter 2 Chapter 3 Chapter 4 Chapter 8 **(1)**, excluding: • Ch 8, Sec 1 • Ch 8, Sec 2 Chapter 12 Chapter 13	Ch 8, Sec 1
Central part		Chapter 5 Chapter 6 Chapter 7
Aft part		Ch 8, Sec 2
(1) See also [2.3].		

2.3.2 Machinery spaces, if fitted, have to comply with the requirements of Pt B, Ch 9, Sec 3 of the Rules for the Classification of Ships.

2.3.3 Rudders and propeller shaft brackets, if fitted, have to comply with the requirements of Pt B, Ch 10, Sec 1 and 3 respectively, of the Rules for the Classification of Ships.

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
Superstructures and deckhouses	Ch 8, Sec 4
Hull outfitting	Ch 8, Sec 3 Ch 8, Sec 6

SECTION 2 SYMBOLS AND DEFINITIONS

1 General

1.1

1.1.1 *(1/1/2022)*

The applicable requirements in Pt B, Ch 1, Sec 2 of the Rules for the Classification of Ships are to be complied with.

SECTION 3 DOCUMENTATION TO BE SUBMITTED

1 Documentation to be submitted for all units

1.1 Units 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 unit, 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 13, 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.

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.

2 Further documentation to be submitted for units 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 unit, 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 units to which it is not assigned, when this is deemed necessary by the Society on the basis, inter alia, of the unit 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 units *(1/7/2022)*

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 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 Pt B, Ch 11, Sec 2 of the Rules for the Classification of Ships
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, where fitted	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)
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
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
Derricks and cargo gear Cargo lift structures	Design loads (forces and moments) Connections to the hull structures
Sea chests, other recesses	
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 or document	Containing also information on
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 for towing and equipment for ship-to-unit mooring	List of equipment Construction and breaking load of steel wires Material, construction, breaking load and relevant elongation of synthetic ropes
Site-specific and transit	See Ch 5, Sec 1, [1.8]
Seakeeping calculations	See Ch 5, App 2, [1.2]
Mooring Loads	See Ch 5, App 3, [2]
Ship-to-unit mooring analysis	See Ch 8, App 1, [2]
Plans of position mooring system	Anchors, anchor lines and equipments Winches, windlasses Buoys, if any Mechanical details Hull interface
Sea bed foundations	See Ch 10, Sec 1, [1.1]

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

Service notations	Plans or documents
FSO, FPSO	Arrangement of pressure/vacuum valves in cargo tanks Cargo temperatures
FSRU	Arrangement of pressure/vacuum valves in cargo tanks Heat transfer analysis Distribution of steel qualities For units with independent tanks: • cargo tank structure • connection of the cargo tanks to the hull structure • anti-floating and anti-collision arrangements
FPSO, FSO, FSRU	Topside structures for process and off-loading facilities and hull interface
MODU	See Pt E, Ch 4, Sec 2 [1.2]

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

Additional class notation	Plans or documents
DMS	See Pt F, Ch 6, Sec 5, [1.2]
ICE CLASS IA SUPER **ICE CLASS IA** **ICE CLASS IB** **ICE CLASS IC** **ICE CLASS ID**	Refer to Part F, Ch 9 of the Rules for Classification of Ships
MON-HULL	See Pt F, Ch 5, Sec 1, [1.2]

Additional class notation	Plans or documents
POLAR CLASS	Refer to Part F, Ch 10 of the Rules for Classification of Ships
HELIDECK **HELIDEC-H**	See Pt F, Ch 5, Sec 1, [1.2]

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 unit'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.

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

- one foreward peak bulkhead
- one after peak bulkhead
- where applicable, two bulkheads forming the boundaries of the machinery space in units with machinery amidships, and a bulkhead forward of the machinery space in units with machinery aft. In the case of units 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

Transverse bulkheads are to be adequately spaced and in general not less in number than indicated in Tab 1.

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

Table 1 : Number of bulkheads

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

1.2 Height of transverse watertight bulkheads

1.2.1 Transverse watertight bulkheads other than the foreward peak bulkhead and the after peak bulkhead are to extend watertight up to the freeboard deck.

1.2.2 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.

2 Openings in watertight bulkheads and decks

2.1 General

2.1.1 The number of openings in watertight subdivisions is to be kept to a minimum compatible with the design and proper working of the unit. 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 unit is not impaired.

2.1.2 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.

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

2.1.4 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 [2.2] and [2.3] are specified in Tab 2.

2.1.5 *(1/7/2021)*
The cable transits seal systems in watertight bulkheads and decks are to be type approved regarding watertightness. The pressure for which these cable transits seal systems are to be certified is to be greater than or equal to the one taken for the determination of the scantlings of the structural plate where they are located.

2.2 Openings in the watertight bulkheads below the freeboard deck

2.2.1 Openings normally open with unit in operation

Doors provided to ensure the watertight integrity of internal openings which are used during operation 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	X						
		Normally closed **(2)**		X			X **(3)**		
		Remain closed **(2)**			X **(4)**			X **(4)**	X **(4)**
Weathertight / watertight **(1)**	Above the freeboard deck	Open	X						
		Normally closed **(2)**		X			X		
		Remain closed **(2)**						X **(4)**	

(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".
(3) Units of 150 m and upwards 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) A device which prevents unauthorised opening is to be fitted.

2.2.2 Openings normally closed

Access doors and access hatch covers normally closed, 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.

2.2.3 Openings permanently kept closed

Other closing appliances which are kept permanently closed 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.

2.3 Openings in the bulkheads above the freeboard deck

2.3.1 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.

2.3.2 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.

2.3.3 Doors normally closed

The doors normally closed 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.

2.3.4 Openings kept permanently closed

The doors kept closed are to be hinged doors. Such doors and the other closing appliances which are kept closed 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 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 Pt B, Ch 12, Sec 3, [2] of the Rules for the Classification of Ships.

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 Where a double bottom is fitted, its depth is to satisfy the provisions of Pt B, Ch 4, Sec 4, [4.2] of the Rules for the Classification of Ships.

4 Compartments forward of the foreward peak bulkhead

4.1 General

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

5 Watertight ventilators and trunks

5.1 General

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

6 Fuel oil tanks

6.1 General

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

6.1.2 As far as practicable, fuel oil tanks are to be part of the unit'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.

6.1.3 Fuel oil tanks may not be located where spillage or leakage therefrom can constitute a hazard by filling 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.

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

7 Accommodation Spaces

7.1 General

7.1.1 Accommodation spaces or living quarters are to be located outside of hazardous areas and may not be located above or below cargo storage tanks or process areas.

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 unit.

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 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 unit'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.

Part B
Hull and Stability

Chapter 3
STABILITY

SECTION 1 GENERAL

1 General

1.1 Application

1.1.1 General

All units 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 and in Part E, depending on Service Notations to be assigned to the units under consideration. In any case, the level of intact stability is not to be less than that provided by the Rules.

For classification purposes, units having the service notation **MODU** are also to comply with damage stability criteria set out in Part E, Chapter 4, Section 3.

1.1.2 Approval of the Administration

When the Administration of the State whose flag the unit is entitled to fly has issued specific rules covering stability, the Society, due regard being given to the requirement set out in [1.1.1], 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 unit.

2 Examination procedure

2.1 Documents to be submitted

2.1.1 List of documents

a) The plans to be submitted to the Society for examination are those listed in Tab 1. Other documentation may be requested depending on the unit's characteristics.

b) The attention of the Interested Parties is drawn to possible additional details, provisions and requirements of Flag Administration set forth depending on the size, type and intended service of the units.

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

Table 1 : Documentation to be submitted

No	I/A **(1)**	Document
1	I	General arrangement
2	I	Capacity plan, indicating the volume and position of the centre of gravity of all compartments and tanks
3	I	Lines plan
4	I	Hydrostatic curves
5	I	Lightweight distribution
6	A	Inclining test report **(2)**
7	A	Trim and stability booklet
8	A	Loading computer documentation, if applicable **(3)**

(1) A : to be submitted for approval, in four copies
I : to be submitted for information, in duplicate.

(2) In cases listed below, this documentation may be substituted by:

- where the stability data is based on a unit which is identical by design , the inclining test report of that unit along with the lightship measurement report for the unit in question (for Mobile Offshore Drilling Units see also Part E, Chapter 4, Sect 3); or
- where lightship particulars are determined by methods other than inclining of the unit or units which are identical by design , the lightship measurement report of the unit in question along with a summary of the method used to determine those particulars as indicated in [2.2.4].

(3) See Sec 2, item [1.1.2]

2.1.2 Provisional documentation

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

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

2.1.3 Final documentation

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

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

- 2% for the displacement, and,
- 1% of the length, (as defined in the 1966 Load Line Convention, as amended) of the unit for the longitudinal position of the centre of gravity

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

2.2 Inclining test/lightweight check

2.2.1 Definitions

a) Lightship

The lightship is a unit 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 unit. By using this information and applying basic naval architecture principles, the unit'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 unit at the time of the inclining test so that the observed condition of the unit 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 unit at the time of the inclining test as determined by measuring the freeboard or verified draught marks of the unit, the unit's hydrostatic data and the sea water density.

2.2.2 General

Any unit 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 [2.2.4]) 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.

2.2.3 Inclining test

The inclining test is required in the following cases:

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

2.2.4 Lightweight check

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

a) an individual unit, provided basic stability data are available from the inclining test of a unit which is identical by design and a lightweight check is performed in order to prove that the sister unit corresponds to the prototype unit. The lightweight check is to be carried out upon the unit's completion. The final stability data to be considered for the unit which is identical by design 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% or a deviation from the lightship longitudinal centre of gravity exceeding 0,5% of length is found, the unit is to be inclined.

b) special designs, provided that:

- a detailed list of weights and the positions of their centres of gravity is submitted
- a lightweight check is carried out, showing accordance between the estimated values and those determined adequate stability is demonstrated in all the loading conditions reported in the trim and stability booklet.

2.3 Detailed procedure

2.3.1 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, [1.1.9].

SECTION 2 INTACT STABILITY

1 General

1.1 Information for the Master

1.1.1 Stability booklet

Each unit is to be provided with a stability booklet, approved by the Society, which contains sufficient information to enable the Master to operate the unit in compliance with the applicable requirements contained in this Section. Where any alterations are made to a unit so as to materially affect the stability information supplied to the Master, amended stability information is to be provided. If necessary the unit is to be re-inclined. Stability data and associated plans are to be drawn up in the official language or languages of the issuing country. If the language used is not English the text is to include a translation into this language

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

1.1.2 Loading instrument

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

A simple and straightforward instruction manual is to be provided.

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

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

2 Permanent ballast

2.1

2.1.1 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 unit or relocated within the unit without the approval of the Society. Permanent ballast particulars are to be noted in the unit's stability booklet. Permanent solid ballast is to be installed under the supervision of the Society.

3 Design criteria

3.1 General intact stability criteria

3.1.1 General

The intact stability criteria specified inPart E depending on the Service Notation to be assigned to the unit under consideration are to be complied with for the loading conditions mentioned in App 2, [1.2].

3.1.2 Elements affecting stability

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

3.1.3 Elements reducing stability

Provisions are to be made for a safe margin of stability at all stages of any operational condition, regard being given to additions of weight, such as those due to absorption of water and icing and to losses of weight such as those due to consumption of fuel and stores.

4 Effects of free surfaces of liquids in tanks

4.1 General

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

4.2 Consideration of free surface effects

4.2.1 Free surface effects are to be considered whenever the filling level in a tank is less than 98% of full condition. Free surface effects need not be considered where a tank is nominally full, i.e. filling level is 98% or above. Free surface effects for small tanks may be ignored under the condition in [4.9.1].

4.2.2 For units having cargo tanks with a breadth greater than 60% of the unit's maximum beam, the free surface effects when the tanks are filled at 98% or above may not be neglected.

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 in any operational condition, the free surfaces effect is to be calculated to take account of the most onerous transitory stage relating to such operation.

4.6 Liquid transfer operations

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

4.7 GM_0 and GZ curve corrections

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

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

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

- Correction based on the actual moment of fluid transfer for each angle of heel calculated; corrections may be calculated according to the categories indicated in [4.3.1]
- Correction based on the moment of inertia, calculated at 0 degrees angle of heel, modified at each angle of heel calculated; corrections may be calculated according to the categories indicated in [4.3.1]
- Correction based on the summation of M_{fs} values for all tanks taken into consideration, as specified in [4.8.1].

4.7.4 Whichever method is selected for correcting the righting lever curve, only that method is to be presented in the unit'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 Free surface moment

4.8.1 The values for the free surface moment at any inclination in m.t for each tank may be derived from the formula:

$$M_{fs} = v b \rho k \sqrt{\delta}$$

where:

- v : Tank total capacity, in m^3
- b : Tank maximum breadth, in m
- ρ : Mass density of liquid in the tank, in t/m^3
- k : Dimensionless coefficient to be determined from Tab 1 according to the ratio b/h. The intermediate values are determined by interpolation.
- δ : Tank block coefficient, equal to:

$$\delta = \frac{v}{b \ell h}$$

- ℓ : Tank maximum length, in m
- h : Tank maximum height, in m.

4.9 Small tanks

4.9.1 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:

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

where:

- Δ_{min} : Minimum unit displacement, in t, calculated at d_{min}
- d_{min} : Minimum mean service draught, in m, of unit without cargo, with 10% stores and minimum water ballast, if required.

4.10 Remainder of liquid

4.10.1 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 Icing

5.1 Application

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

5.1.2 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.

5.2 Guidance relating to ice accretion

5.2.1 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) 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.

5.2.2 For units operating where ice accretion may be expected:

- within the areas defined in a), c), d) and e) of [5.2.1] known to having icing conditions significantly different from those described in [5.3], ice accretion requirements of one half to twice the required allowance may be applied;
- within the area defined in b), where ice accretion in excess of twice the allowance required by [5.3] may be expected, more severe requirements than those given in [5.3] may be applied.

Table 1 : Values of coefficient k for calculating free surface corrections

$$k = \frac{\sin\theta}{12}\cdot\left(1+\frac{(\tan\theta)^2}{2}\right)\cdot\frac{b}{h}\ ,\qquad \text{where}\qquad \cot\theta \geq \frac{b}{h}$$

$$k = \frac{\cos\theta}{8}\cdot\left(1+\frac{\tan\theta}{b/h}\right) - \frac{\cos\theta}{12\cdot(b/h)^2}\cdot\left(1+\frac{(\cot\theta)^2}{2}\right),\qquad \text{where}\qquad \cot\theta < \frac{b}{h}$$

θ b/h	5°	10°	15°	20°	30°	40°	45°	50°	60°	70°	75°	80°	85°	θ b/h
20	0,11	0,12	0,12	0,12	0,11	0,10	0,09	0,09	0,09	0,05	0,04	0,03	0,02	20
10	0,07	0,11	0,12	0,12	0,11	0,10	0,10	0,09	0,07	0,05	0,04	0,03	0,02	10
5,0	0,04	0,07	0,10	0,11	0,11	0,11	0,10	0,10	0,08	0,07	0,06	0,05	0,04	5,0
3,0	0,02	0,04	0,07	0,09	0,11	0,11	0,11	0,10	0,09	0,08	0,07	0,06	0,05	3,0
2,0	0,01	0,03	0,04	0,06	0,09	0,11	0,11	0,11	0,10	0,09	0,09	0,08	0,07	2,0
1,5	0,01	0,02	0,03	0,05	0,07	0,10	0,11	0,11	0,11	0,11	0,10	0,10	0,09	1,5
1,0	0,01	0,01	0,02	0,03	0,05	0,07	0,09	0,10	0,12	0,13	0,13	0,13	0,13	1,0
0,75	0,01	0,01	0,01	0,02	0,02	0,04	0,04	0,05	0,09	0,16	0,18	0,21	0,16	0,75
0,5	0,00	0,01	0,01	0,02	0,02	0,04	0,04	0,05	0,09	0,16	0,18	0,21	0,23	0,5
0,3	0,00	0,00	0,01	0,01	0,01	0,02	0,03	0,03	0,05	0,11	0,19	0,27	0,34	0,3
0,2	0,00	0,00	0,00	0,01	0,01	0,01	0,02	0,02	0,04	0,07	0,13	0,27	0,45	0,2
0,1	0,00	0,00	0,00	0,00	0,00	0,01	0,01	0,01	0,02	0,04	0,06	0,14	0,53	0,1

5.3 Calculation assumptions

5.3.1 For units 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 unit above the water plane
- the projected lateral area of discontinuous surfaces of rail, sundry booms, spars (except masts) and rigging 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%.

5.3.2 Units 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.

APPENDIX 1 INCLINING TEST AND LIGHTWEIGHT CHECK

1 Inclining test and lightweight check

1.1 General

1.1.1 Application

This Appendix 1 provides the criteria and methods that generally are to be applied for carrying out the inclining test and lightweight check. However, the adoption of criteria and/or methods alternative to those described in the following may be considered by the Society.

1.1.2 General condition of the unit

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

- the weather conditions are to be favourable;
- the unit is to be moored in a quiet, sheltered area free from extraneous forces, such as to allow unrestricted heeling. The unit is to be positioned in order to minimise the effects of possible wind, stream and tide;
- the unit is to be transversely upright and the trim is to be taken not more than 1% of the length of the unit. 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 unit;
- the unit 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.

1.1.3 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 units provided that the requirement on pendulum deflection or U-tube difference in height specified in [1.1.5] is complied with. Test weights are to be compact and of such a configuration that the VCG (vertical centre of gravity) of the weights can be accurately determined. Each weight is to be marked with an identification number and its weight. Re-certification of the test weights is to be carried out prior to the incline. A crane of sufficient capacity and reach, or some other means, is to be available during the inclining test to shift weights on the deck in an expeditious and safe manner. Water ballast is generally not acceptable as inclining weight.

1.1.4 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;
- tanks are to be directly opposite to maintain unit's trim;
- specific gravity of ballast water is to be measured and recorded;
- pipelines to inclining tanks are to be full. If the unit's piping layout is unsuitable for internal transfer, portable pumps and pipes/hoses may be used;
- blanks must be inserted in transverse manifolds to prevent the possibility of liquids being "leaked" during transfer. Continuous valve control must be maintained during the test;
- all inclining tanks must be manually sounded before and after each shift;
- vertical, longitudinal and transverse centres are to be calculated for each movement;
- accurate sounding/ullage tables are to be provided. The unit'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 amidunits (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.

1.1.5 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. 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 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.

1.1.6 Means of communications

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

1.1.7 Documentation

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

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

1.1.8 Determination of the displacement

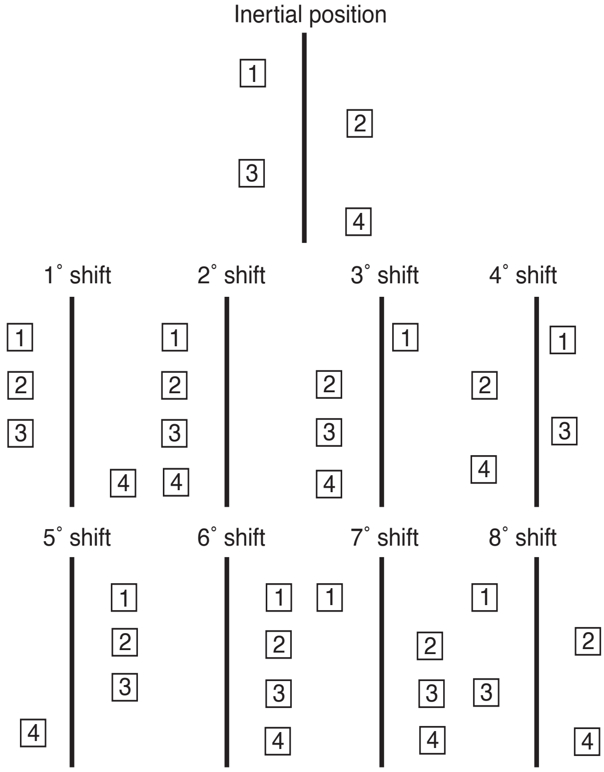
The Society's Surveyor is to carry out all the operations necessary for the accurate evaluation of the displacement of the unit at the time of the inclining test, as listed below:

- 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 unit'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 units, it is recommended that samples of the sea water be taken forward, midship and aft, and the readings averaged. For small units, 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 unit's trim and the position of air pipes, and also taking into account the provisions of [1.1.2]
- 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 unit is to be surveyed in order to identify all items which need to be added, removed or relocated to bring the unit 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.

1.1.9 The incline

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

Figure 1 : Weight shift procedure



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

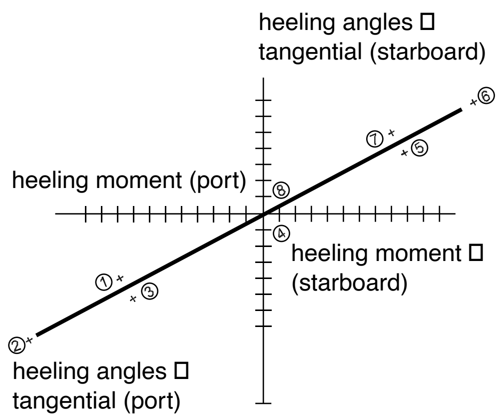
After each weight shifting, the new position of the transverse centre of gravity of the weights is to be accurately determined.

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

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

During the reading, no movements of personnel are allowed.

Figure 2 : Graph of resultant tangents



APPENDIX 2 TRIM AND STABILITY BOOKLET

1 Trim and stability booklet

1.1 Information to be included in the trim and stability booklet

1.1.1 General

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

The format of the stability booklet and the information included vary depending on the unit 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 unit, including:
  - the unit's name and the Society classification number
  - the unit 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 unit's perpendiculars, if applicable;
- hydrostatic curves or tables corresponding to the design trim, and, if significant trim angles are foreseen during the normal operation of the unit, 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, [2.2], including lightship displacement, centre of gravity co-ordinates, place and date of the inclining test, as well as the Society approval details specified in the inclining test report. It is suggested that a copy of the approved test report be included.

  Where the above-mentioned information is derived from a unit which is identical by design, the reference to this unit is to be clearly indicated, and a copy of the approved inclining test report relevant to this unit 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] 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 unit;
- 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:

a) lightship unit

b) unit fully loaded corresponding to the freeboard centre disc or to the given draught, the cargo being evenly distributed in each area to which it has been assigned, fully equipped, without liquid ballast

c) unit with half the cargo

d) unit in ballast condition.

Furthermore, the stability characteristics are to be calculated for the loading conditions, including loading, unloading and ballasting conditions, derived from those stated by the Owner in relation to the unit's actual use, which could prove to be less favourable than those mentioned above.

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

1.3 Stability curve calculation

1.3.1 General

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

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

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

Enclosed superstructures complying with Pt B, Ch 1, Sec 2, [3.10] of the Rules for the Classification of Ships may be taken into account.

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

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

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

Deckhouses, the doors of which do not comply with the requirements of Ch 8, Sec 4, [1.5.4], are not to be taken into account.

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 unit would sink due to flooding through any openings, the stability curve is to be cut short at the corresponding angle of flooding and the unit 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 GENERAL REQUIREMENTS

1 General

1.1

1.1.1 *(1/1/2022)*

The applicable requirements in Pt B, Ch 4 of the Rules for the Classification of Ships are to be complied with, except for Pt B, Ch 4, Sec 2 of the Rules for the Classification of Ships that is to be replaced by Sec 2 of this Chapter.

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.

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 unit 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 Pt B, Ch 4, Sec 3, [3.1.2] of the Rules for the Classification of Ships, 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	0,070	0,4
$w_G > 200$ cm^3	0,035	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

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 m^3, calculated on the basis of the gross scantlings proposed by the Designer.

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

2.2 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 m^3, calculated on the basis of the net scantlings proposed by the Designer

Z_{GD} : Gross midship section modulus, in m^3, calculated on the basis of the gross scantlings proposed by the Designer.

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

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].

For units having design life greater than 20 years, the values of corrosion additions are to be agreed with the Society.

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, the scantling criteria are generally to be applied considering the value of corrosion addition applicable at the lowest point of the element.

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 **(4)**
Cargo tank and fuel oil tank	Plating of horizontal surfaces	0,75	1,00 in upper zone **(4)**
	Plating of non-horizontal surfaces	0,50	1,00 in upper zone **(4)**
	Ordinary stiffeners	0,75	1,00 in upper zone **(4)**
Cargo tank of units with service notation **FSRU** **(3)**		0,00	
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) The corrosion addition t_C specified for cargo tanks is to be applied when required in IGC, 4.5.2.
(4) Upper zone: area within 1,5 m below the top of the tank. This is not to be applied to tanks in the double bottom.
Note 1: Values of corrosion additions apply to units having design life ≤ 20 years, in other cases see [3.1.1].

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.

Part B
Hull and Stability

Chapter 5
DESIGN LOADS

Symbols used in chapter 5

T_1 : Draught, in m, defined in Sec 1, [2.5.3] or Sec 1, [2.6.3], 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] of the Rules for the Classification of Ships.

SECTION 1 GENERAL

1 Definitions

1.1 Still water loads

1.1.1 Still water loads are those acting on the unit at rest in calm water.

1.2 Wave loads

1.2.1 Wave loads are those due to wave pressures and unit 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 Mooring loads

1.4.1 Mooring loads are those acting on the unit induced by the positional mooring systems.

1.5 Local loads

1.5.1 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 unit spaces.
- Wave local loads are constituted by the external sea pressures due to waves and the inertial pressures and forces induced by the unit accelerations applied to the weights carried in the unit spaces.
- Dynamic local loads are constituted by the impact and sloshing pressures.
- Mooring loads are constituted by the forces transmitted by the positional mooring system to the hull.

1.5.2 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.

1.6 Hull girder loads

1.6.1 Hull girder loads are (still water, wave and dynamic) forces and moments which result as effects of local loads acting on the unit as a whole and considered as a girder.

1.7 Loading condition

1.7.1 A loading condition is a distribution of weights carried in the unit spaces arranged for their storage.

1.8 Environmental conditions

1.8.1 Environmental conditions are defined by means of sets of environmental data regarding the specific site of operation; these are to be documented by adequate statistical data and mathematical models reporting the range of pertinent expected variations of the environmental parameters (wave, wind, current). A minimum return period (period of recurrence) of 100 years for the environmental conditions is required for floating installations.

Specifically, the following environmental data are normally to be provided:

a) Wave scatter diagram assigning probability of occurrence to all sea states, characterised by a significant wave height and a wave period, which can be expected in the considered site of operation. The precision of the scatter diagrams is to be at least 10^{-5} corresponding to 20-years sea-state observations.

   Definition of any adopted parameter characterizing sea-states and scatter diagrams are to be provided.

b) Extreme events of 100-, 10- and 1-year return period data for wind speeds, significant wave height and current. A range of associated wave periods is to be given for each considered significant wave height. Both winter storms and tropical cyclones (hurricanes or typhoons), if any, need to be considered. Wind spectrum and speed variation through height (profile) should be indicated.

c) Directional data and angular separation for extreme values of wind, waves and current.

d) Waves, wind and current joint probabilities (including relative direction).

e) Wave energy spectral shape formulation and spreading function.

f) Current speed and directional variation through the water depth.

g) Long-term wave statistics by direction.

h) Ice, iceberg and snow, if any.

All data are to be fully documented with the sources and estimated reliability of data noted.

Probabilistic methods for short-term, long-term and extreme-value prediction are to be based on statistical distributions appropriate to the environmental phenomena being considered.

Generally, environmental data and analyses supplied by recognized consultants will be accepted as the basis for design. If available for the location of interest, published design standards and data may be cited as documentations.

Shorter return periods may be considered by the Society for units with design life of 10 years or less.

For transit conditions, wind speed and significant wave height of 10-year return period are to be considered as a minimum.

1.9 Load case

1.9.1 A load case is a state of the unit 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 units

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) according to the requirements in Chapter 6 and Chapter 7.

2.1.2 Requirements applicable to specific unit types

The design loads applicable to specific unit 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 unit's characteristics, intended service and site-specific environmental conditions. 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 Mooring loads

2.3.1 The mooring loads to be considered for units operating afloat with positional mooring systems are specified in App 3. Effects of mooring loads on the hull are to be considered on the following:

- the hull girder strength, according to the requirements of Chapter 6, and
- the local scantling of structural elements where the mooring forces are transmitted to the hull, according to the requirements in Chapter 9.

2.4 Local loads

2.4.1 Load cases

The local loads defined in [1.5] 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.

2.4.2 Unit motions and accelerations

The wave local loads are to be calculated on the basis of the reference values of unit motions and accelerations specified in Sec 3.

2.4.3 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 unit motions and accelerations

are specified in Sec 5 for sea pressures and in Sec 6 for internal pressures and forces.

2.4.4 Flooding conditions

The still water and wave pressures in flooding conditions are specified in Sec 6, [6]. The pressures in flooding conditions applicable to specific unit types are to be defined in accordance with the requirements in Part E.

2.5 Load definition criteria to be adopted in structural analyses based on plate or isolated beam 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:

- plating, according to Ch 7, Sec 1 of the Rules for the Classification of Ships
- ordinary stiffeners, according to Pt B, Ch 7, Sec 2 of the Rules for the Classification of Ships
- primary supporting members for which a three dimensional structural model is not required, according to Pt B, Ch 7, Sec 3, [3] of the Rules for the Classification of Ships.

2.5.2 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 unit 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.

2.5.3 Draught associated with each cargo and ballast distribution

Local loads are to be calculated on the basis of the unit's draught T_1 corresponding to the cargo or ballast distribution considered according to the criteria in [2.5.2]. The unit 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) 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 unit'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 unit's draught in light ballast condition may be obtained, in m, from the following formulae:
  - $T_B = 0,03L \le 7,5$ m for units with the service notation **FSRU**
  - $T_B = 2 + 0,02L$ for units with one of the service notations **FSO** and **FPSO**.

2.6 Load definition criteria to be adopted in structural analyses based on three dimensional structural models

2.6.1 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 Pt B, Ch 7, Sec 3, [4] of the Rules for the Classification of Ships.

2.6.2 Loading conditions

For all unit types for which analyses based on three dimensional models are required according to Pt B, Ch 7, Sec 3, [4] of the Rules for the Classification of Ships, 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 unit loading manual.

Further criteria applicable to specific unit types are specified in Part E.

2.6.3 Draught associated with each loading condition

Local loads are to be calculated on the basis of the unit's draught T_1 corresponding to the loading condition considered according to the criteria in [2.6.2].

2.7 Environmental coefficients

2.7.1 The environmental coefficients, which appear in the formulae of this Chapter for the definition of wave hull girder and local loads are defined as the ratio between the response of the unit as a fixed installation in the intended site and the response of the unit as a seagoing unit in unrestricted navigation.

An environmental coefficient equal to 1,0 corresponds to a seagoing trading unit in unrestricted navigation; a value lower than 1,0 indicates less severe environment than the unrestricted case.

The environmental coefficients are in all cases to be determined by means of direct calculations according to the provisions in App 2.

Alternative methods used for the computation of environmental coefficients will be considered by the Society on a case by case provided that suitable background documentation relevant to the applied method is provided.

In no case a value lower than 0,5 can be applied to the environmental coefficients.

2.7.2 Transit condition

The environmental coefficients in transit condition are defined in App 2.

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 units having the following characteristics:

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

Units not having one or more of these characteristics and units 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 unit 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 unit 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 units, 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, when applicable, 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 effect of mooring loads is to be taken into account as equivalent weight distributions positioned at the actual locations where in each loading condition as equivalent weight distributions positioned at the actual locations where mooring forces are transferred into the hull, considering, in each condition, the value associated to the most severe effect on the hull girder strenght.

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 on-site operations and transit conditions and, where applicable, into departure and arrival conditions, on which the approval of hull structural scantlings is based.

For all units, 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, and 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) transit conditions

g) short voyage or harbour conditions, where applicable

h) loading and unloading transitory conditions, where applicable

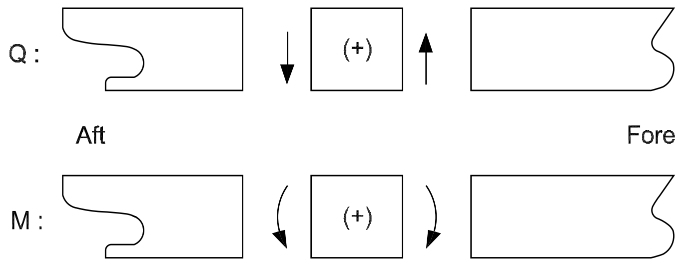
i) docking condition afloat

j) ballast exchange at sea, if applicable

k) on-station tank inspection condition.

Part E specifies other loading conditions which are to be considered depending on the unit type.

Figure 1 : Sign conventions for shear forces Q and bending moments M



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 2, for units with one of the service notations **FSO, FPSO**, or
- Fig 3, for other unit types,

may be considered.

In Fig 2 and Fig 3, 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:

$$M_{SWM,H} = 175 e_{S1} C L^2 B (C_B + 0{,}7) 10^{-3} - M_{WV,H}$$

- sagging conditions:

$$M_{SWM,S} = 175 e_{S1} C L^2 B (C_B + 0{,}7) 10^{-3} + M_{WV,S}$$

where $M_{WV,H}$, $M_{WV,S}$ are the vertical wave bending moments, in kN.m, defined in [3.1].

e_{S1} : environmental coefficient for design still water bending moment to be calculated according to the Tab 1.

Table 1 : Environmental coefficient e_{S1}

e_{WV} **(1)**	e_{S1}
< 0,70	0,85
0,70 to 1,0	0,5 (1 + e_{WV})
> 1,0	1,0
(1) e_{WV} : environmental coefficient defined in [3.1.1]	

Figure 2 : Preliminary still water bending moment distribution for FSOs and FPSOs

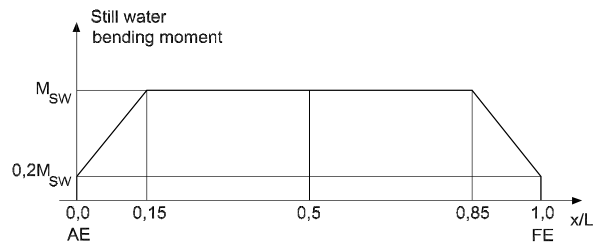
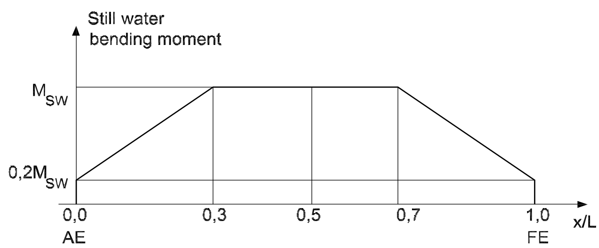


Figure 3 : Preliminary still water bending moment distribution for other unit types



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:

$$M_{WV,H} = 190 F_M e_{WV} C L^2 B C_B 10^{-3}$$

- sagging conditions:

$$M_{WV,S} = -110 F_M e_{WV} C L^2 B (C_B + 0,7) 10^{-3}$$

where:

F_M : Distribution factor defined in Tab 2 (see also Fig 4).

e_{WV} : environmental coefficient for vertical wave bending moment to be calculated according to the provisions in App 2.

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:

$$M_{WH} = 1,6 F_M e_{WH} L^{2,1} T C_B$$

where:

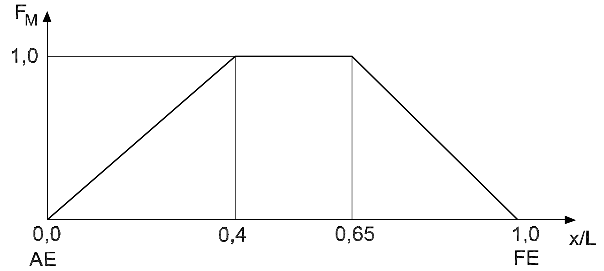
F_M : Distribution factor defined in [3.1.1].

e_{WH} : environmental coefficient for horizontal wave bending moment to be calculated according to the provisions in App 2.

Table 2 : 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 4 : 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 unit in two different conditions:

- condition 1: unit direction forming an angle of 60° with the prevailing sea direction
- condition 2: unit 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:

$$M_{WT} = \frac{HL}{4} e_{WT} (F_{TM} C_M + F_{TQ} C_Q d)$$

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 3 for unit conditions 1 and 2 (see also Fig 5 and Fig 6)

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.

e_{WT} : environmental coefficient for wave torque to be calculated according to the provisions in App 2.

Table 3 : Distribution factors F_{TM} and F_{TQ}

Unit 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 5 : Unit condition 1 - Distribution factors F_{TM} and F_{TQ}

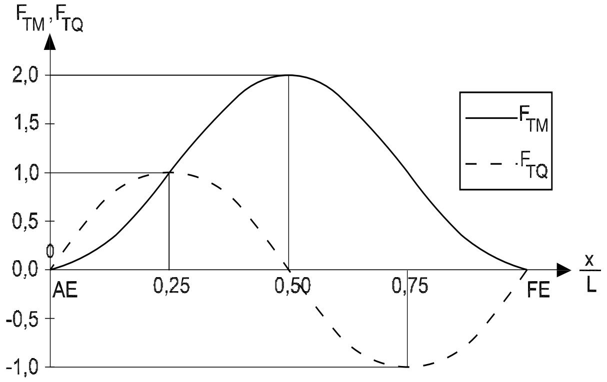
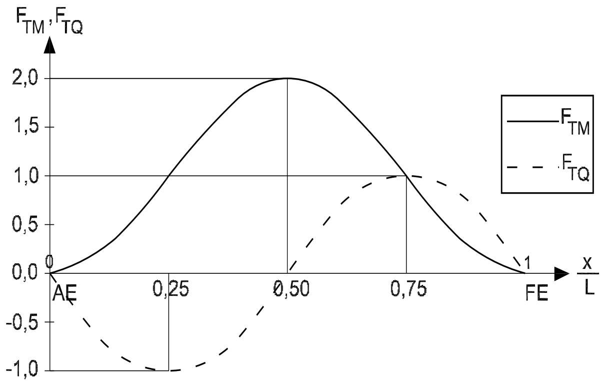


Figure 6 : Unit condition 2 - Distribution factors F_{TM} and F_{TQ}



3.4 Vertical wave shear force

3.4.1 The vertical wave shear force at any hull transverse section is obtained, in kN, from the following formula:

$$Q_{WV} = 30 F_Q e_{WQ} C L B (C_B + 0{,}7) 10^{-2}$$

where:

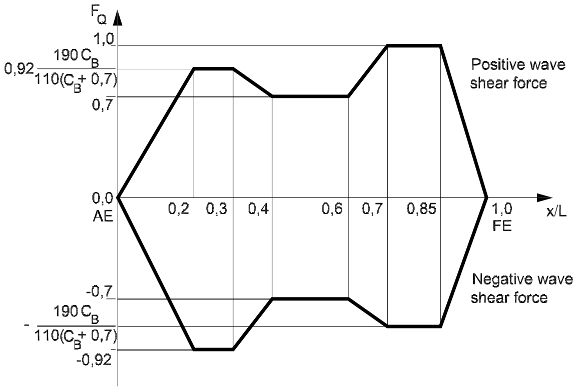
F_Q : distribution factor defined in Tab 4 for positive and negative shear forces (see also Fig 7).

e_{WQ} : environmental coefficient for vertical wave shear force to be calculated according to the provisions in App 2.

Table 4 : 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: $A = \frac{190 C_B}{110(C_B + 0{,}7)}$		

Figure 7 : Distribution factor F_Q



SECTION 3 UNIT 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:

$$a_B = 0{,}0691 + 1{,}875\frac{h_W}{L}$$

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

Unit motions and accelerations are defined, with their signs, according to the reference co-ordinate system in Pt B, Ch 1, Sec 2, [4] of the Rules for the Classification of Ships.

1.1.2 Unit 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 unit motions and accelerations derived from direct calculations, when justified on the basis of the unit's characteristics and intended service. In any case, the calculations, including the assumed sea scatter diagrams and spectra, are to be submitted to the Society for approval.

2 Unit absolute motions and accelerations

2.1 Surge

2.1.1 The surge acceleration a_{SU} is to be taken equal to $0{,}5 \cdot e_{SU}$ m/s², where:

e_{SU} : environmental coefficient for surge acceleration to be calculated according to the provisions in App 2.

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
$0{,}72\sqrt{L}$	$0{,}775\ a_B \cdot e_{sw}\ g$

e_{sw} : environmental coefficient for sway acceleration to be calculated according to the provisions in App 2.

2.3 Heave

2.3.1 The heave acceleration is obtained, in m/s², from the following formula:

$$a_H = a_B \cdot e_H g$$

where:

e_H : environmental coefficient for heave acceleration to be calculated according to the provisions in App 2.

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
$a_B \cdot e_R\sqrt{E}$	$2{,}2\frac{\delta}{\sqrt{GM}}$	$A_R\left(\frac{2\pi}{T_R}\right)^2$

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 unit'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 units with one of the service notations **FSO** and **FPSO**

δ : roll radius of gyration, in m, for the loading considered; when δ is not known, the following values may be assumed, in general equal to:

δ = 0,35 B

e_R : environmental coefficient for roll amplitude to be calculated according to the provisions in App 2.

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
$0{,}328a_B \cdot e_p\left(1{,}32 - \frac{h_W}{L}\right)\left(\frac{0{,}6}{C_B}\right)^{0{,}75}$	$0{,}575\sqrt{L}$	$A_p\left(\frac{2\pi}{T_p}\right)^2$

e_p : environmental coefficient for pitch amplitude to be calculated according to the provisions in App 2.

2.6 Yaw

2.6.1 The yaw acceleration is obtained, in rad/s², from the following formula:

$$\alpha_Y = 1{,}581\frac{a_B e_Y g}{L}$$

e_Y : environmental coefficient for yaw acceleration to be calculated according to the provisions in App 2.

3 Unit relative motions and accelerations

3.1 Definitions

3.1.1 Unit relative motions

The unit relative motions are the vertical oscillating translations of the sea waterline on the unit 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 unit motions defined in [2.1] to [2.6].

3.2 Unit conditions

3.2.1 General

Unit relative motions and accelerations are to be calculated considering the unit in the following conditions:

- upright unit condition
- inclined unit condition.

3.2.2 Upright unit condition

In this condition, the unit encounters waves which produce unit motions in the X-Z plane, i.e. surge, heave and pitch.

3.2.3 Inclined unit condition

In this condition, the unit encounters waves which produce unit motions in the X-Y and Y-Z planes, i.e. sway, roll and yaw.

3.3 Unit relative motions

3.3.1 The reference value of the relative motion in the upright unit 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 unit condition

Location	Reference value of the relative motion h_1 in the upright unit condition, in m
x = 0	$e_{h1A}0{,}7\left(\frac{4{,}35}{\sqrt{C_B}} - 3{,}25\right)h_{1,M}$ if $C_B < 0{,}875$ $e_{h1A}h_{1,M}$ 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 ≤ x ≤ 0,7L	$0{,}42e_{h1M}C(C_B + 0{,}7)$ 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	$e_{h1F} \cdot \left(\frac{4{,}35}{\sqrt{C_B}} - 3{,}25\right)h_{1,M}$

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

e_{1hM} : environmental coefficient for relative motion in upright condition amidship to be calculated according to the provisions in App 2.

e_{1hF} : environmental coefficient for relative motion in upright condition at fore end to be calculated according to the provisions in App 2

e_{h1A} : environmental coefficient for relative motion in upright condition at aft end to be calculated according to the provisions in App 2.

3.3.2 The reference value, in m, of the relative motion in the inclined unit 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 unit, 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 unit conditions.

Table 5 : Reference values of the accelerations a_X, a_Y and a_Z

Direction	Upright unit condition	Inclined unit 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 unit relative motion in the upright unit condition, defined in Sec 3, [3.3]

h_2 : Reference value of the unit relative motion in the inclined unit condition, defined in Sec 3, [3.3]

a_{X1},a_{Y1},a_{Z1}: Reference values of the accelerations in the upright unit condition, defined in Sec 3, [3.4]

a_{X2},a_{Y2},a_{Z2}: Reference values of the accelerations in the inclined unit 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 unit 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 unit modelling. They are:

- the analyses of plating (see Ch 7, Sec 1 of the Rules for the Classification of Ships)
- the analyses of ordinary stiffeners (see Pt B, Ch 7, Sec 2 of the Rules for the Classification of Ships)
- the analyses of primary supporting members analysed through isolated beam structural models or three dimensional structural models (see Pt B, Ch 7, Sec 3 of the Rules for the Classification of Ships)
- the fatigue analysis of the structural details of the above elements (see Ch 7, Sec 2).

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 unit 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 unit in inclined conditions (see Sec 3, [3.2]), i.e. having sway, roll and yaw motions.

2 Load cases

2.1 Upright unit conditions (Load cases "a" and "b")

2.1.1 Unit condition

The unit 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 unit 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"

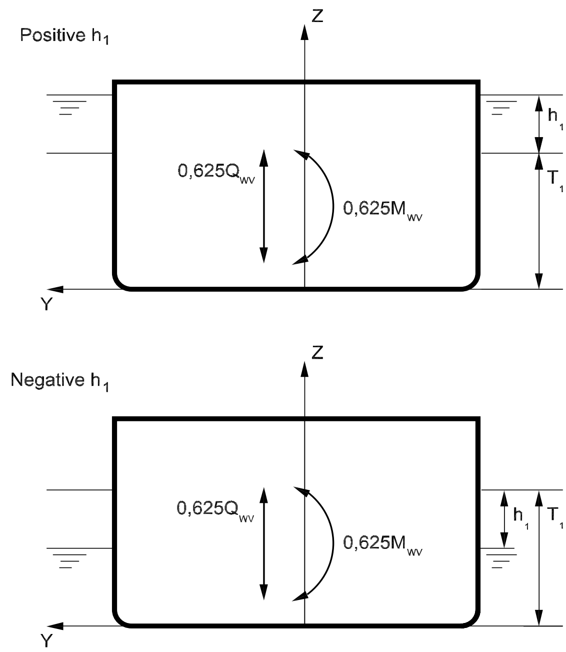
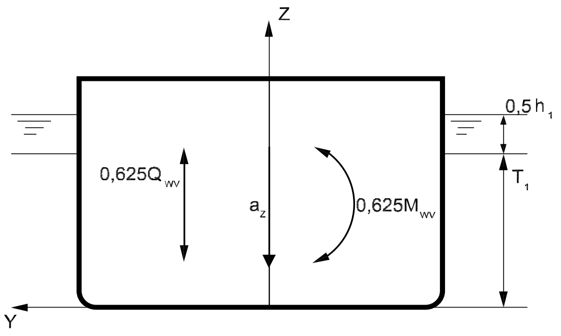


Figure 2 : Wave loads in load case “b”



2.2 Inclined unit conditions (Load cases “c” and “d”)

2.2.1 Unit condition

The unit 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 unit 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 unit 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”

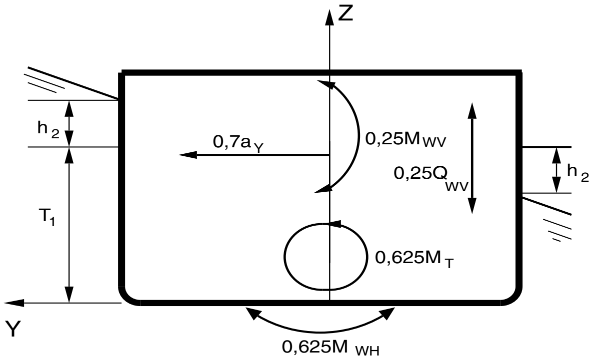
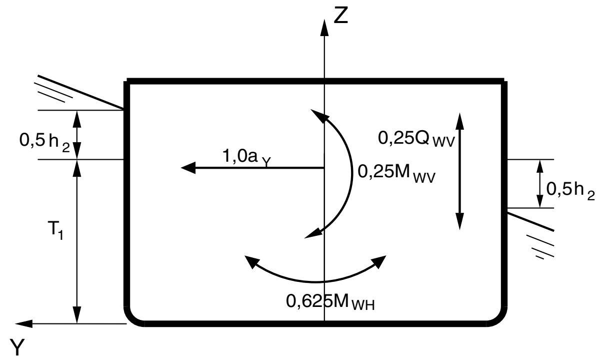


Figure 4 : Wave loads in load case “d”



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

Unit 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 unit 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 unit 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

Unit 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 unit relative motions in the upright unit condition, defined in Sec 3, [3.3]

h_2 : Reference values of the unit relative motions in the inclined unit conditions, defined in Sec 3, [3.3].

1 Still water pressure

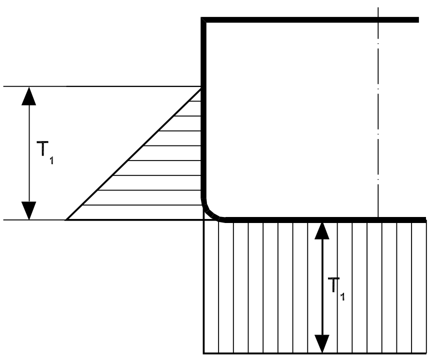
1.1 Pressure on sides and bottom

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 ($z \le T_1$)	$\rho g(T_1 - z)$
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
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

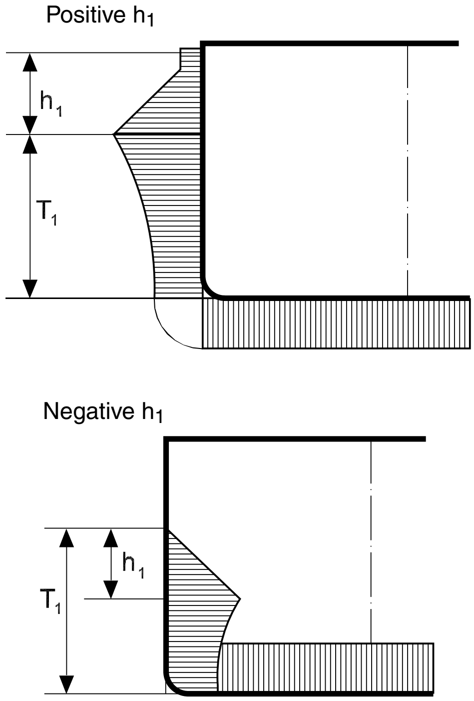
2 Wave pressure

2.1 Upright unit 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"



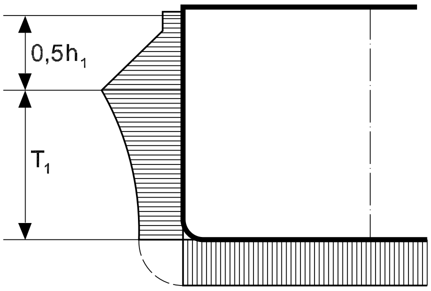


Figure 3 : Wave pressure in load case “b”

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 unit 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”).

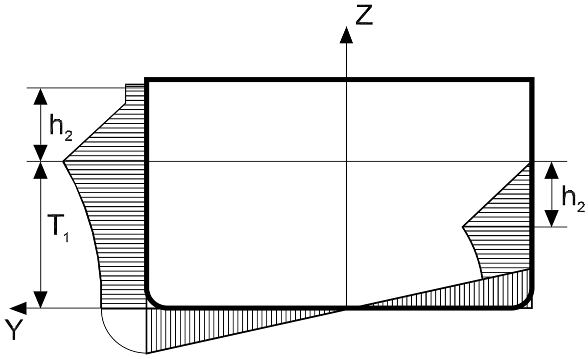


Figure 4 : Wave pressure in load case “c”

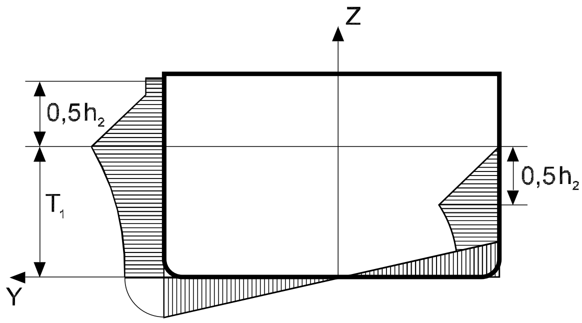


Figure 5 : Wave pressure in load case “d”

Table 3 : Wave pressure on sides and bottom in upright unit 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: $z \le T_1 - h$	$C_1 \rho g h e^{\frac{-2\pi(T_1 - z)}{L}}$	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 2.

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 unit conditions (load cases “a” and “b”)

Location	Wave pressure p_W, in kN/m²
$0 \le x \le 0,5\ L$	$17,5 e_{pW} \varphi$
$0,5\ L < x < 0,75\ L$	$\left\{17,5 + \left[\frac{19,6\sqrt{H_F} - 17,5}{0,25}\right]\left(\frac{x}{L} - 0,5\right)\right\} e_{pW} \varphi$
$0,75\ L \le x \le L$	$19,6 e_{pW} \varphi \sqrt{H}$

Note 1:

$$H = 3,6 \cdot C_{F1}\left[2,66\left(\frac{x}{L} - 0,7\right)^2 + 0,14\right]\sqrt{\frac{L}{C_B}} - (z - T_1)$$ 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”

e_{pW} : environmental coefficient for wave pressure on exposed decks in upright condition to be calculated according to the provisions in App 2.

Table 5 : Wave pressure in inclined unit conditions (load cases “c” and “d”)

Location	Wave pressure p_W, in kN/m²	C_2 (negative roll angle)	
		$y \ge 0$	$y < 0$
Bottom and sides below the waterline with: $z \le T_1 - h$	$C_2 C_{F2} \rho g \left[\frac{y}{B_W} h_1 e^{\frac{-2\pi(T_1 - z)}{L}} + A_R y e^{\frac{-\pi(T_1 - z)}{L}}\right]$	1,0	1,0
Sides below the waterline with: $T_1 - h < z \le T_1$	$C_2 C_{F2} \rho g \left[\frac{y}{B_W} h_1 e^{\frac{-2\pi(T_1 - z)}{L}} + A_R y e^{\frac{-\pi(T_1 - z)}{L}}\right]$	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/m^3, of the liquid 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

a_{X1}, a_{Y1}, a_{Z1}: Reference values of the accelerations in the upright unit condition, defined in Sec 3, [3.4], calculated in way of the centre of gravity of the compartment, in general

a_{X2}, a_{Y2}, a_{Z2}: Reference values of the accelerations in the inclined unit condition, defined in Sec 3, [3.4], calculated in way of the centre of gravity of the compartment, in general

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 unit 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 Pt B, Ch 4, Sec 7, [5] of the Rules for the Classification of Ships

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 Pt B, Ch 4, Sec 7, [5] of the Rules for the Classification of Ships

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/m^2, 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/m^2, 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/m^2, 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].

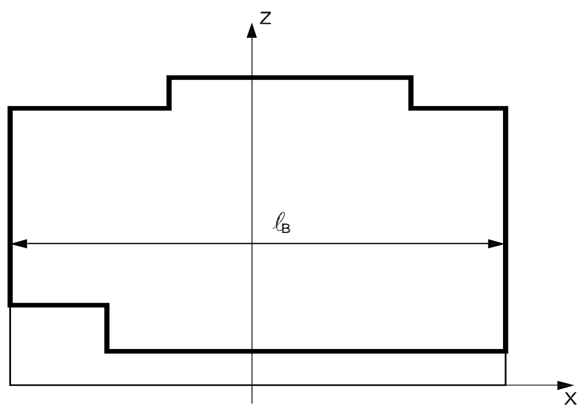
For typical tank arrangements, see also App 1.

Table 1 : Liquids - Inertial pressure

Unit 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 unit 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.

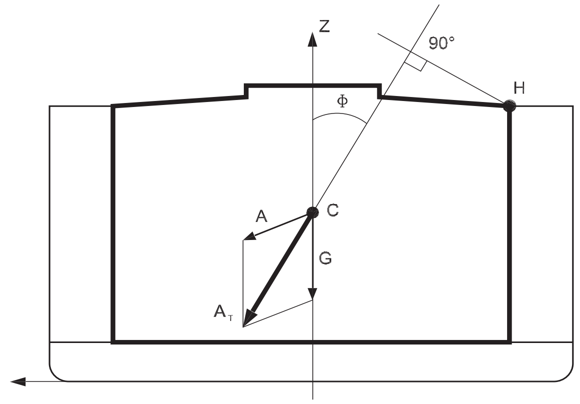
Table 2 : Inclined unit conditions Y and Z components of the total acceleration vector and angle Φ it forms with the z direction

Components (negative roll angle)		Angle Φ, in rad
a_{TY}, in m/s²	a_{TZ}, in m/s²	
$0,7C_{FA}a_{Y2}$	$-0,7C_{FA}a_{Z2} - g$	$\operatorname{atan}\frac{a_{TY}}{a_{TZ}}$

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 unit 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 unit 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 $0,1H \le d_F \le 0,95H$, the risk of resonance between:

- the unit pitch motion and the longitudinal motion of the liquid inside the tank, for upright unit condition
- the unit sway and roll motion and the transverse motion of the liquid inside the tank, for inclined unit 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

Unit 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 unit 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 Pt B, Ch 4, Sec 7, [5] of the Rules for the Classification of Ships

b_S : Breadth, in m, of the free surface of the liquid, measured horizontally with the unit at rest and depending on the filling level d_F, as shown in Fig 4 for units without longitudinal watertight or wash bulkheads; for units 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 Pt B, Ch 4, Sec 7, [5] of the Rules for the Classification of Ships)

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].

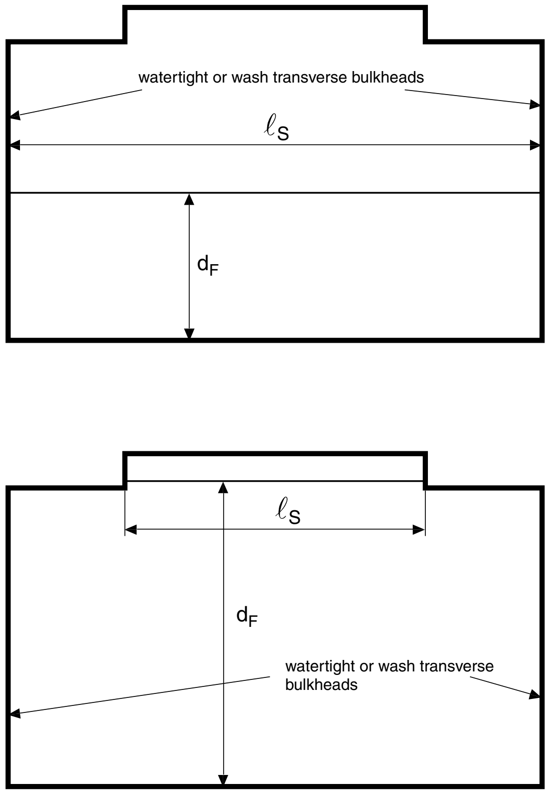
2.1.2 The Society may accept that the risk of resonance is evaluated on the basis of dynamic calculation procedures, where deemed necessary in relation to the tank's dimensions and the unit's characteristics. The calculations are to be submitted to the Society for approval.

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 unit's characteristics.

Figure 3 : Length ℓ_S of the free surface of the liquid



2.2.2 Risk of resonance in upright unit condition

Where there is a risk of resonance in upright unit 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.

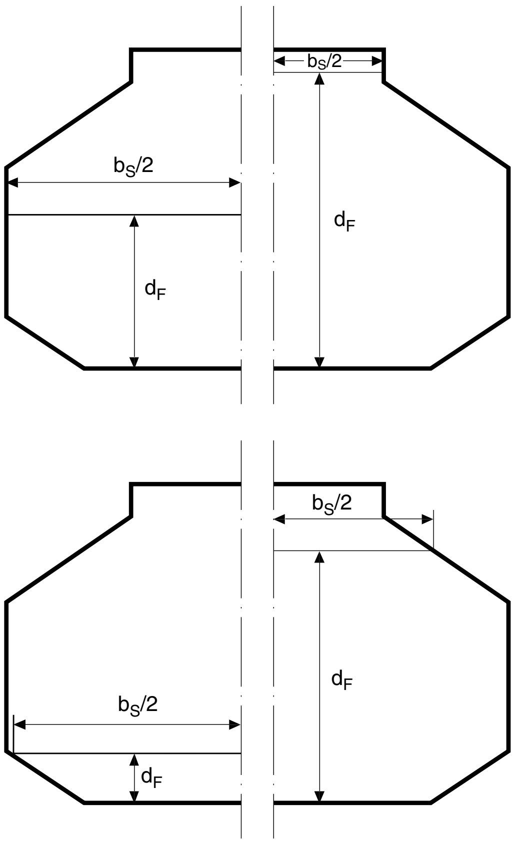
The Society may also require the sloshing pressure to be considered when there is no risk of resonance, but the tank arrangement is such that $\ell_C/L > 0,15$.

2.2.3 Risk of resonance in inclined unit condition

Where there is a risk of resonance in inclined unit 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 units 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 unit conditions.

2.2.5 Sloshing pressure on tank bottom transverses in the case of resonance in upright unit condition

Where there is a risk of resonance in upright unit condition, the sloshing pressure to be considered as acting on tank bottom transverses is obtained, in kN/m², from the following formula:

$$p_{SL,W} = 0,8 \rho_L g (1,95 - 0,12 n)(z - d_{TB})$$

where n is the number of bottom transverses in the tank.

Figure 5 : Breadth b_S of the free surface of the liquid, for units with longitudinal bulkheads

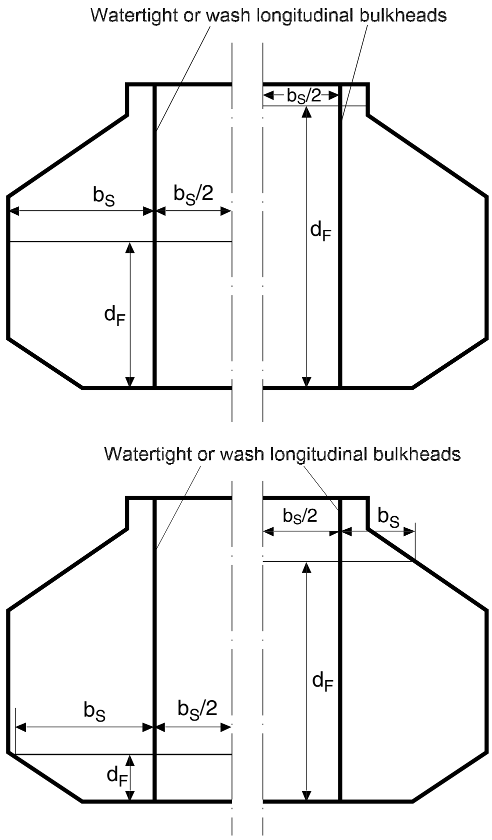


Figure 6 : Sloshing pressure p_{SL} in the case of no restrictions on the filling level

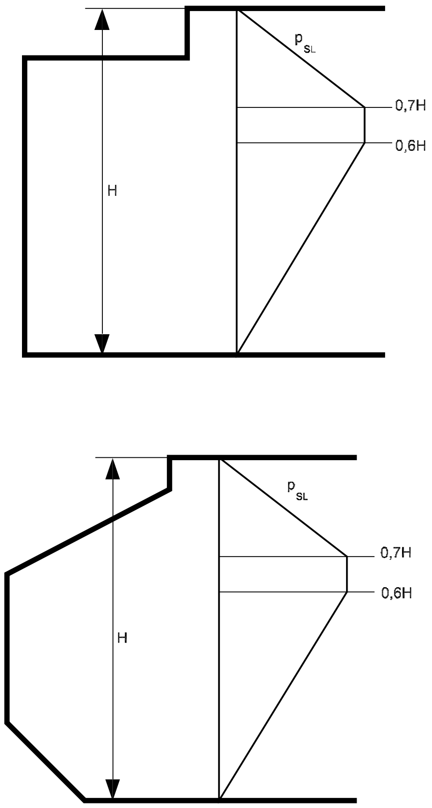


Table 4 : Reference pressure for calculation of sloshing pressures

Unit condition	Reference pressure p_0 , in kN/m²	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 unit condition

Where there is a risk of resonance in upright unit 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 $\ell_C/L > 0{,}15$.

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/m², from the following formula:

$$p_{I,U} = \varphi_U \rho_L g \ell_C A_P\left(0{,}9 + \frac{\ell_C}{L}\right)(2{,}6 + 0{,}007L)$$

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 unit condition

Where there is a risk of resonance in inclined unit 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/m², 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 unit'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 unit condition

Where there is a risk of resonance in upright unit 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 unit condition

Where there is a risk of resonance in inclined unit 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:

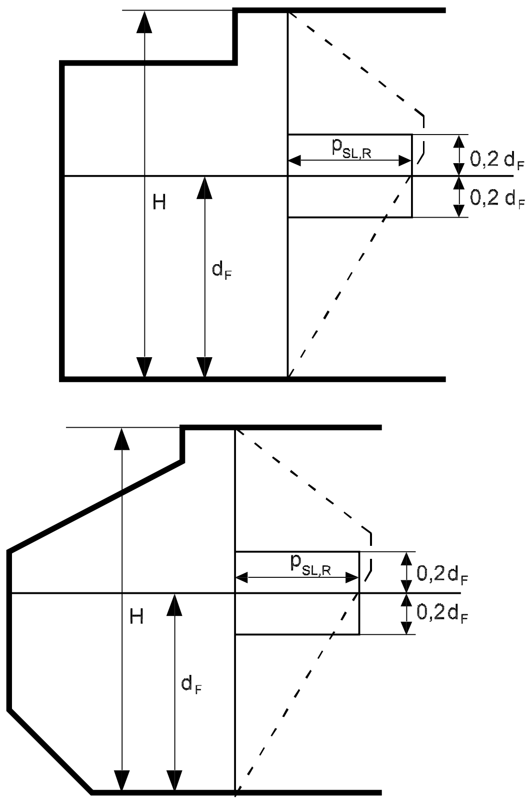
$$p_{SL,R} = \frac{d_F}{0{,}6H} p_0 \qquad \text{for} \quad d_F < 0{,}6H$$

$$p_{SL,R} = p_0 \qquad \text{for} \quad 0{,}6H \le d_F \le 0{,}7H$$

$$p_{SL,R} = \frac{H - d_F}{0{,}3H} p_0 \qquad \text{for} \quad d_F > 0{,}7H$$

where p_0 is the reference pressure defined in Tab 4 for upright and inclined unit 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 unit conditions, respectively.

The Society may also require the impact pressure for upright unit condition to be considered when there is no risk of resonance, but the tank arrangement is such that $\ell_C/L > 0{,}15$.

3 Production facilities

3.1

3.1.1 The still water and inertial forces due to on deck production facilities transmitted to the hull are to be determined on the basis of the forces obtained, in kN, as specified in Tab 5.

Wind loads are to be added to still water and wave loads in the most unfavourable combination that might occur.

For units designed for operations in geographic areas where the design temperature is less than 0°C the static forces due to ice accumulation on production facilities are to be properly accounted in addition to the still water loads.

Table 5 : Production facilities
Still water, inertial and wind forces

Unit condition	Load case	Still water force F_S, inertial force F_W, Wind force, 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 $F_{W,Z} = MC_{FA}a_{Z2}$ in z direction
	"d"	
Wind		$W = 0,5\ C_S\ C_H\ \rho_a\ V_w^2\ A\ 10^{-3}$

Note 1:
- M : mass in tonnes of a production module including the mass of fluids, when applicable.
- C_S : shape coefficient depending on the shape of the structural member exposed to wind, see Tab 6
- C_H : height coefficient depending on the height above sea level of the structural member exposed to wind, see Tab 7
- ρ_a : air density to be assumed equal to 1,222 kg/m³
- V_W : most probable sustained wind speed relevant to applicable return period as per Sec 1, [1.8], in m/s, to be assumed not less than 51,5 m/s. Sustained wind speed is defined as the average wind speed during a time interval of 1 minute, measured at a height of 10 m above the mean still water level. For particularly repaired sites, the Society may take into consideration reduction of wind speed which, for the unit in operating and/or transit conditions, shall in no case be taken less than 25,8 m/s.
- A : projected area of all exposed surfaces, in m²

Table 6 : Values of the shape coefficient C_S

Shape	C_S
Spherical	0,4
Cylindrical	0,5
Large flat surfaces (hull, deckhouse, smooth, underdeck areas)	1,0
Drilling derrick	1,25
Wires	1,2
Exposed beams and girders under deck	1,3
Small parts	1,4
Isolated shapes (crane, beam, etc..)	1,5
Clustered deckhouses or similar structures	1,1

Table 7 : Values of the height coefficient C_H

Height above sea level (m)	C_H
0 - 15,3	1,00
15,3 - 30,5	1,10
30,5 - 46,0	1,20
46,0 - 61,0	1,30
61,0 - 76,0	1,37
76,0 - 91,5	1,43
91,5 - 106,5	1,48
106,5 - 122,0	1,52
122,0 - 137,0	1,56
137,0 - 152,5	1,60
152,5 - 167,5	1,63
167,5 - 183,0	1,67
183,0 - 198,0	1,70
198,0 - 213,5	1,72
213,5 - 228,5	1,75
228,5 - 244,0	1,77
244,0 - 256,0	1,79
above 256,0	1,80

4 Accommodation and work spaces

4.1 Still water and inertial pressures

4.1.1 The still water and inertial pressures transmitted to the deck structures are obtained, in kN/m², as specified in Tab 8.

5 Machinery

5.1 Still water and inertial pressures

5.1.1 The still water and inertial pressures transmitted to the deck structures are obtained, in kN/m², as specified in Tab 10.

Table 8 : Accommodation and work spaces Still water and inertial pressures

Unit 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 9 depending on the type of the 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 9 : Still water deck pressure in accommodation and work spaces

Type of accommodation compartment	p_S, in kN/m²
Storage areas	13,0
Working areas	9,0
Crew spaces, accommodation spaces, walkway areas	4,5
Cabins	3,0
Other compartments	2,5

Table 10 : Machinery Still water and inertial pressures

Unit 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"	

6 Flooding

6.1 Still water and inertial pressures

6.1.1 Unless otherwise specified, 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 11.

Table 11 : 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 freeboard deck at side in way of the transverse section considered. Where the results of damage stability calculations are available, the deepest equilibrium waterline may be considered in lieu of the freeboard deck; in this case, the Society may require transient conditions to be taken into account
- d_0 : Distance, in m, to be taken equal to:
  - $d_0 = 0{,}02L$ for $90\ m \le L < 120\ m$
  - $d_0 = 2{,}4$ for $L \ge 120\ m$.

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 unit 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

Unit condition	Load case	Inertial pressure p_W , in kN/m²
Inclined (negative roll angle)	"c"	$0,7 C_{FA} \rho_L (a_{Y2} b_L + a_{Z2} d_H)$
	"d"	

Note 1:

C_{FA} : Combination factor, to be taken equal to:
- C_{FA} = 0,7 for load case "c"
- C_{FA} = 1,0 for load case "d"

ρ_L : Density, in t/m³, of the liquid cargo carried

a_{Y2}, a_{Z2} : Reference values of the acceleration in the inclined unit 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

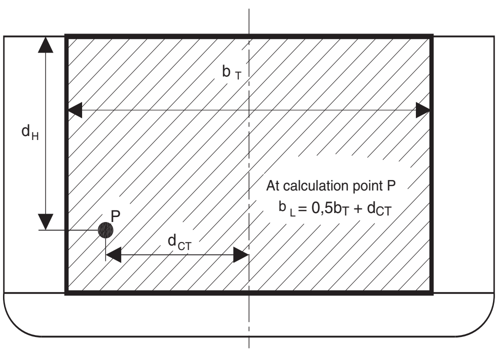


Figure 2 : Distances b_L and d_H

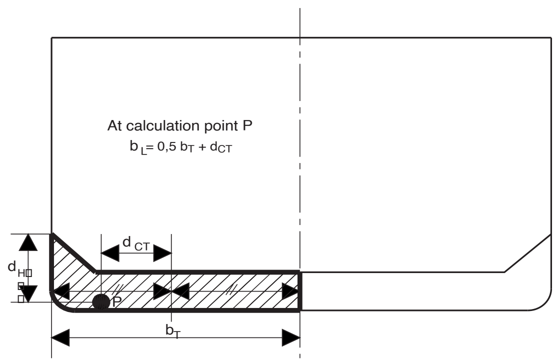


Figure 3 : Distances b_L and d_H

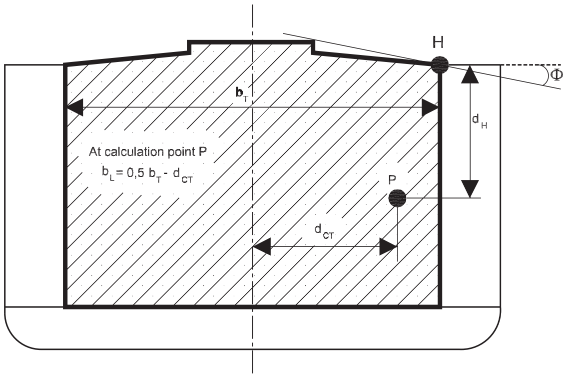


Figure 4 : Distances b_L and d_H

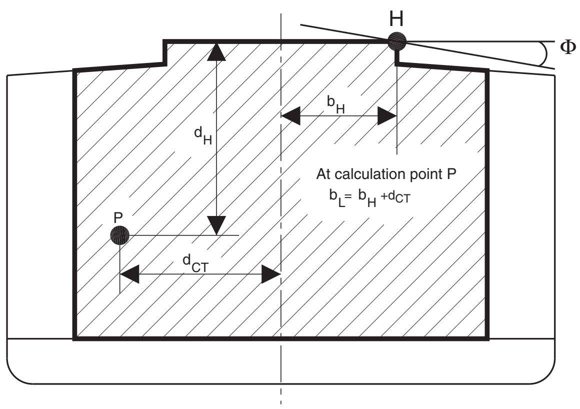


Figure 5 : Distances b_L and d_H

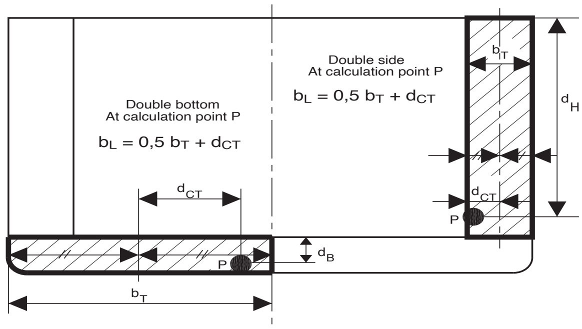
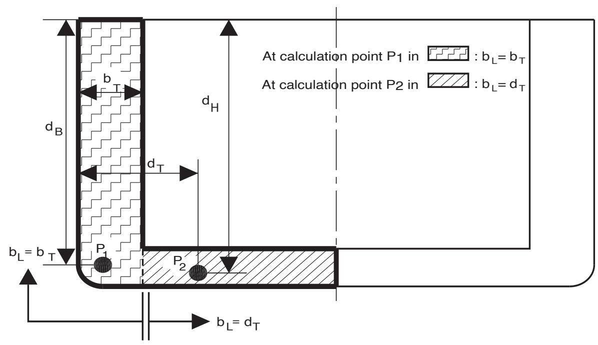


Figure 6 : Distances b_L and d_H



APPENDIX 2 DIRECT CALCULATION OF ENVIRONMENTAL COEFFICIENTS

1 On-site

1.1 Application

1.1.1 The requirements of this appendix apply for the analysis criteria, hydrodynamic and environmental modelling and for the calculation of environmental coefficients.

This appendix deals with the hydrodynamic and seakeeping analysis of wave frequencies induced motion and loads.

1.2 Information required

1.2.1 Vessel data

- Lines Plan
- Loading manual
- Mass and inertia distribution calculation
- Site specific environmental information (see Chapter 5, Sec 1, [1.8])
- Mooring and anchoring arrangement.

1.2.2 Presentation of the results

Motion Analysis report should include, at least:

- Description of the software used for the calculation and theory associated
- Description of the hydrodynamic model
- Calibration/comparison with model tests (or with previous experience) and model test evaluation
- RAO of the variables described in [1.4] (with input parameters specification in case of non-linear/linearized analysis)
- Scatter diagram used in the calculation
- Long term results of the variables described in [1.4]
- Assumptions and simplifications
- Description of additional viscous damping, if applied.

1.3 Hydrodynamic Model

1.3.1 The hydrodynamic model shall reproduce, as close as possible, the wetted hull shapes and, in case of non linear analysis, all the hull shapes that will be wetted during the simulation.

A diffraction-radiation panel method should be used in order to calculate the motions of the unit; in case of slender bodies (units with L/B>5) a strip theory method may be accepted.

Mass characteristics for each loading condition shall be represented as close as possible to the designed unit.

1.4 Output parameters

1.4.1 The following parameters are to be calculated by means of seakeeping direct assessment for the vessel as Sailing Ship and as Site Moored Unit:

- Maximum vertical wave bending moment M_{WV}
- Maximum vertical wave shear force Q_{WV}
- Maximum horizontal wave bending moment M_{WH}
- Maximum wave torque M_Q
- Surge acceleration at Center of Gravity a_{GX}
- Sway acceleration at Center of Gravity a_{GY}
- Heave acceleration at Center of Gravity a_{GZ}
- Roll amplitude ϑ_4
- Pitch amplitude ϑ_5
- Yaw acceleration α_{Yaw}
- Relative motion between unit and sea surface at midship h_{wMid}
- Relative motion between unit and sea surface at F_{pp} h_{wFpp}
- Relative motion between unit and sea surface at A_{pp} h_{wAFpp}

In particular, for each of the above mentioned values the following cases are to be considered:

E_{Site} : extreme value based on site-specific environment with 100-year return period, calculated according to [1.5].

$E_{SailingShip}$: extreme value based on unrestricted service environment with 20- year return period calculated according to [1.6].

1.5 Calculation of E_{Site}

1.5.1 The following assumptions are to be considered in the calculation of E_{Site}:

- Long term probabilistic approach
- Heading angle:
  - Considering the most critical heading angle for each E_{Site} parameter, according to meteo-marine data

directional related distribution of wind, current and waves, if detailed information are available
  - Considering only the most critical heading angle for each E_{Site} parameter, in case no detailed directional meteo-marine data are available.
- Spreading function as per meteo-marine data, taking in consideration low drift yawing of the unit (for weather vaning units)
- Scatter diagram according to meteo-marine data of the specific site.

For the long term assessment response the following procedure should be followed, if a linear analysis is performed:
- Calculation of the RAO for the variable E_{Site}
- Calculation of the RMS = σ^2 : Root Mean Square of the response E
- Selection of the heading angle that gives the Maximum response $E_{Site\ ijk}$ for each cell of the scatter diagram and for each heading angle (considering possible headings in case joint distribution about direction of wind, wave and current is available in the meteo-marine data)
- Calculation of the short term distribution response: Rayleigh (narrow band stochastic process)
- Calculation of the directional long term probability distribution of response for each heading angle:

$$LT_{ESite} = \sum_{ii} p_{ij} R_{ij}$$

- With p_{ij} : probability of occurrence of each cell of the scatter diagram
- Calculation of the Maximum Expected Value of the variable E_{Site} corresponding to the design probability of exceedance (see Tab 2).

1.6 Calculation of $E_{SailingShip}$

1.6.1 The following assumptions are to be considered in the calculation of $E_{SailingShip}$:
- Long term probabilistic approach
- Scatter diagram as per IACS REC 034
- Equally distributed probability of wave main heading angle
- Spreading function: $\cos^4 \theta$
- Zero advance speed.

For the long term assessment response the following procedure should be followed, if a linear analysis is performed:
- Calculation of the RAO for the variable $E_{SailingShip}$ for each heading angle
- Calculation of the RMS = σ^2 : Root Mean Square of the response $E_{SailingShip\ ijk}$ for each cell of the scatter diagram and for each heading angle
- Calculation of the short term distribution response: Rayleigh (narrow band stochastic process)
- Calculation of the long term probability distribution of response

$$LT_{ESite} = \sum_{ijk} p_k p_{ij} R_{ijk}$$

with:

p_K : probability of occurrence of each heading angle

p_{ij} : probability of occurrence of each cell of the scatter diagram

- Calculation of the Maximum Expected Value of the variable $E_{SailingShip}$ corresponding to the reference probability of exceedance (see Tab 2 for return periods of the single variables).

Note 1: in case of linear analyses hydrodynamic calculation of RAO can be performed only once (and not repeated for the vessel in Sailing Ship condition and on Site condition; only long term post processing work is to be performed).

1.7 Calculation of the environmental coefficients

1.7.1 The environmental coefficients are to be calculated according to Tab 1 with the definitions contained in Tab 2 for both full load and ballast, and applied depending on the considered loading condition

Table 1

ID	Description	Environmental coefficient	Formula
1	Vertical wave bending moment	e_{wv}	$M_{WVSite}/M_{WVSailingShip}$
2	Horizontal wave bending moment	e_{wh}	$M_{WHSite}/M_{WHSailingShip}$
3	Wave torque	e_{wt}	$M_{QSite}/M_{QSailingShip}$
4	Vertical wave shear force	e_{wq}	$Q_{WVSite}/Q_{WVSailingShip}$
5	Surge acceleration	e_{su}	$a_{GXSite}/ a_{GXSailingShip}$
6	Sway acceleration	e_{sw}	$a_{GYSite}/ a_{GYSailingShip}$
7	Heave acceleration	e_h	$a_{GZSite}/ a_{GZSailingShip}$
8	Roll amplitude	e_r	$\vartheta_{4Site}/\vartheta_{4SailingShip}$

ID	Description	Environmental coefficient	Formula
9	Pitch amplitude	e_p	$\vartheta_{5Site}/\vartheta_{4SailingShip}$
10	Yaw acceleration	e_y	$\alpha_{YawSite}/\alpha_{YawSailingShip}$
11	Relative motion in upright condition in way of Midship perpendicular	e_{h1M}	$h_{wMidSite}/ h_{wMidSailingShip}$
12	Relative motion in upright condition in way of Fore perpendicular	e_{h1F}	$\frac{h_{wFppSite}}{h_{wFppSailingShip}} \cdot \frac{1}{e_{h1M}}$
13	Relative motion in upright condition in way of Aft perpendicular	e_{h1A}	$\frac{h_{wAFppSite}}{h_{wAFppSailingShip}} \cdot \frac{1}{e_{h1M}}$
14	Wave pressure on exposed decks in upright cond.	e_{pw}	$h_{wFppSite}/ h_{wFppSailingShip}$

Table 2

	Symbol	Description	Probability of exceedance
1A	M_{WVSite}	Maximum vertical wave bending moment over the length of the unit on site	10^{-9}
1B	$M_{WVSailingShip}$	Maximum vertical wave bending moment over the length of the unit as sailing ship	10^{-8}
2A	$M_{WHVSite}$	Maximum horizontal wave bending moment over the length of the unit on site	10^{-9}
2B	$M_{WHVSailingShip}$	Maximum horizontal wave bending moment over the length of the unit as sailing ship	10^{-8}
3A	M_{QSite}	Maximum wave torque over the length of the unit on site	10^{-9}
3B	$M_{QSailingShip}$	Maximum wave torque over the length of the unit as sailing ship	10^{-8}
4A	Q_{WVSite}	Maximum vertical wave shear force over the length of the unit on site	10^{-9}
4B	$Q_{WVSailingShip}$	Maximum vertical wave shear force over the length of the unit as sailing ship	10^{-8}
5A	a_{GXSite}	Surge acceleration at the centre of gravity of the unit on site	10^{-6}
5B	$a_{GXSailingShip}$	Surge acceleration at the centre of gravity of the unit as sailing ship	10^{-5}
6A	a_{GYSite}	Sway acceleration at the centre of gravity of the unit on site	10^{-6}
6B	$a_{GYSailingShip}$	Sway acceleration at the centre of gravity of the unit as sailing ship	10^{-5}
7A	a_{GZSite}	Heave acceleration at the centre of gravity of the unit on site	10^{-6}
7B	$a_{GZSailingShip}$	Heave acceleration at the centre of gravity of the unit as sailing ship	10^{-5}
8A	ϑ_{4Site}	Roll Angle on site	10^{-6}
8B	$\vartheta_{4SailingShip}$	Roll Angle as sailing ship	10^{-5}
9A	ϑ_{5Site}	Pitch Angle on site	10^{-6}
9B	$\vartheta_{5SailingShip}$	Pitch Angle as sailing ship	10^{-5}
10A	$\alpha_{YawSite}$	Yaw acceleration amplitude on site	10^{-6}
10B	$\alpha_{YawSailingShip}$	Yaw acceleration amplitude as sailing ship	10^{-5}
11A	$h_{wMidSite}$	Relative motion between the unit and the water surface in way of the Midship Perpendicular (Centre line) on site	10^{-6}
11B	$h_{wMidSailingShip}$	Relative motion between the unit and the water surface in way of the Midship Perpendicular (Centre line) as sailing ship	10^{-5}
12A	$h_{wFppSite}$	Relative motion between the unit and the water surface in way of the Fore Perpendicular (Centre line) on site	10^{-6}

	Symbol	Description	Probability of exceedance
12B	$h_{wFppSailingShip}$	Relative motion between the unit and the water surface in way of the Fore Perpendicular (Centre line) as sailing ship	10^{-5}
13A	$h_{wAFppSite}$	Relative motion between the unit and the water surface in way of the Aft Perpendicular (Centre line) on site	10^{-6}
13B	$h_{wAFppSailingShip}$	Relative motion between the unit and the water surface in way of the Aft Perpendicular (Centre line) as sailing ship	10^{-5}

1.8 Roll damping

1.8.1 Reliable seakeeping models should take into account properly viscous effects on roll damping.

It is to be noted that roll damping is in general a quadratic damping; when linearized seakeeping methods (for instance frequency domain method) are used, particular care is to be taken in the linearization of the roll damping (response and linearization method).

2 Transit

2.1 Environmental coefficients in transit

2.1.1 For transit condition the environmental coefficients are defined in Tab 3 depending on the applicable navigation notation during transit. For navigation notations refer to Part A Chapter 1 Section 2 [5] of Rules for the Classification of Ships.

Table 3 : Environmental coefficient in transit condition

Navigation for transit	All environmental coefficients except e_{S1}	e_{S1}
Unrestricted navigation	0,97	1,00
Summer zone	0,87	0,95
Tropical zone	0,77	0,90
Coastal area	0,77	0,90
Sheltered area	0,63	0,80

In alternative the Society may consider different environmental coefficients derived from direct calculations carried out for the actual transit condition.

APPENDIX 3 MOORING LOADS

1 General

1.1 Application

1.1.1 Mooring loads are to be calculated from a direct mooring analysis conducted with appropriate recognized software calibrated and verified by model tests; in such cases where documented experience of previous similar projects does not require calibration/verification of the software, model tests could be omitted.

2 Required documentation

2.1 Unit and mooring data

2.1.1 The following information are required in order to assess the mooring analysis:

- Mooring system
  - Number of lines
  - Type of line segments
  - Weight of the chain
  - Dimensions
  - Material
  - Line length from fairlead to anchor point
  - Anchor pattern
  - Anchor type
  - Initial pretensions
  - Horizontal distance between fairleads and anchor point
  - Position of buoyancy elements and buoyancy of the elements
  - Position of weight elements and weight of the elements
  - Shackles, D-shackles
  - Anchor design including anchor size, weight and material
- Unit
  - Lines plan
  - Loading conditions
  - Characteristics of weight distribution (Moments of Inertia)
  - Arrangement of the fairleads for mooring lines
  - Fairleads and chain stopper drawings.

2.2 Presentation of the results

2.2.1 Mooring Analysis report should include, at least:

- Description of the software for the calculation and theory associated
- Description of the hydrodynamic model and mechanical model
- Calibration/comparison with model tests (or with previous experience) and model test evaluation
- RAO of the vessel motions (with input parameters specification in case of non-linear/linearized analysis) and Quadratic Transfer Function of the unit
- Environmental data and wind combination matrix
- Assumptions and simplification
- Description of additional viscous damping, if applied
- Statistics of the results
- Spectral analyses of the results
- Time histories of the results.

3 Analysis methods

3.1 Mooring Analysis

3.1.1 The analysis is to reproduce as close as possible the real behaviour of the system during its operative life.

Hypotheses assumed and simplifications done are to be clearly indicated and explained.

For the calculation of the forces induced by the mooring system to the unit the following analyses are required:

- Quasi Static Analysis
- Dynamic Analysis

3.1.2 Dynamic analysis can be:

- Frequency domain analysis (linear analysis) when non linear effect are considered negligible
- Time domain analysis

Dynamic analysis is to be performed in the following conditions:

- Intact condition
- Broken line condition
- Transient broken line (required on a case by case basis)

The following effects shall be taken into account and sensitivity analysis shall be performed:

- Installation tolerances
- Chain length/pretension tolerances
- Chain corrosion
- Marine growth
- Water dept (tide/bathymetry) variation
- Waves period variation
- Seabed friction variation

3.1.3 Additional analyses can be required by the Society when deemed necessary.

4 Loads

4.1

4.1.1 The following effects are to be duly taken into account for the mooring analysis:

- Static loads
- Wind
- Current
- Waves (slow frequency and wave frequency motions)

The effects of wind, current and waves, considered as acting simultaneously, as described in 5, are to be considered.

4.1.2 The effects of wind, current and waves, considered as acting simultaneously, as described in 5, are to be considered.

4.2 Static loads

4.2.1 Static loads are the loads that act on the turret and on the hull in still water condition and with no wind and no current. Loads transmitted to the unit by external structures are due the weight of the risers and to the pretension of the mooring lines.

4.3 Wind Loads

4.3.1 Wind loads may be determined by drag formulation considering drag coefficients according to recognised standard (such as OCIMF), where applicable, or through wind tunnel test or flow analysis.

For time domain analysis, time series of squalls according to wind spectrum, indicated in the meteo-marine data should be considered.

4.4 Current Loads

4.4.1 The current loads may be determined according to recognised standard (such as OCIMF), where applicable, or through wind tunnel test or flow analysis. For the evaluation of the current loads, current profile according to the information contained in the meteo-marine data is to be considered.

4.5 Wave loads

4.5.1 The loads resulting from the interaction between waves and floating unit can be divided as follows:

- Wave frequency loads/motions
- Slow drift varying loads/motions
- Mean drift loads/mean displacement

If no specific wave spectrum is indicated in the meteo-marine data, JONSWAP spectrum with spreading function $\cos^4$ may be used. Peakedness parameter may be taken equal to 3.3 if no otherwise specified in the meteo-marine data.

5 Environmental conditions

5.1

5.1.1 All possible combinations of waves, current and wind that results in the most severe loading cases are to be accounted, as follows:

- 100-year waves with associated wind and current,
- 100-year wind with associated waves and current,
- 100-year current with associated waves and wind.

5.1.2 The data and the mutual direction of wind, waves and current should be extracted from meteo-marine data; if no data on the relative directions of wind, wave and current are available, different tests using conservative hypotheses (extreme cases) are to be considered.

6 Results and maximum expected value

6.1

6.1.1 A short term analysis of the most critical cases is to be considered for the computation of the mooring loads.

The Characteristic Value of mooring load to be considered for the strength assessment is the Maximum Expected Value for 3 hours return period in the most critical situation; a 3 parameter Weibull distribution may be used in order to fit the distribution of the "maxima between two mean-up-zero-crossing". The 3 parameter Weibull cumulative distribution function is represented by the following formula:

$$W(x) = 1 - \exp\left[-\left(\frac{x-m}{q}\right)^p\right]$$

Several 3 hours simulations with different random seeds or a long simulation should be run in order to provide a good statistical confidence.

For the strength analysis according to Ch 7, 8 and 10, the most critical load combinations of hull girder loads, local loads and mooring loads are to be applied (dynamic loads characteristic values can be considered as equivalent static loads).

As guidance, the allowable displacement of the top of the riser should be not less than the maximum horizontal displacement of the unit.

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 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 Ch 5, Sec 2, [2.2], when the unit 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 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 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 [2.1.8].

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 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.

2.1.3 Longitudinal ordinary stiffeners or girders welded above the decks

Longitudinal ordinary stiffeners or girders welded above the decks (including the deck of any trunk fitted as specified in [2.1.2]) may be included in the hull girder transverse sections.

2.1.4 Longitudinal bulkheads with vertical corrugations

Longitudinal bulkheads with vertical corrugations may not be included in the hull girder transverse sections.

2.1.5 Members in materials other than steel

Where a member contributing to the longitudinal strength is made in material other than steel with a Young's modulus E equal to 2,06 10^5 N/mm², the steel equivalent sectional area that may be included in the hull girder transverse sections is obtained, in m², from the following formula:

$$A_{SE} = \frac{E}{2{,}06{,}10^5} A_M$$

where:

A_M : Sectional area, in m², of the member under consideration.

2.1.6 Large openings

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.

2.1.7 Small openings

Smaller openings than those in [2.1.6] in one transverse section in the strength deck or bottom area need not be deducted from the sectional areas included in the hull girder transverse sections, provided that:

$$\Sigma b_S \le 0{,}06(B - \Sigma b)$$

where:

Σb_S : Total breadth of small openings, in m, in the strength deck or bottom area at the transverse section considered, determined as indicated in Fig 1

Σb : Total breadth of large openings, in m, at the transverse section considered, determined as indicated in Fig 1

Where the total breadth of small openings Σb_S does not fulfil the above criteria, only the excess of breadth is to be deducted from the sectional areas included in the hull girder transverse sections.

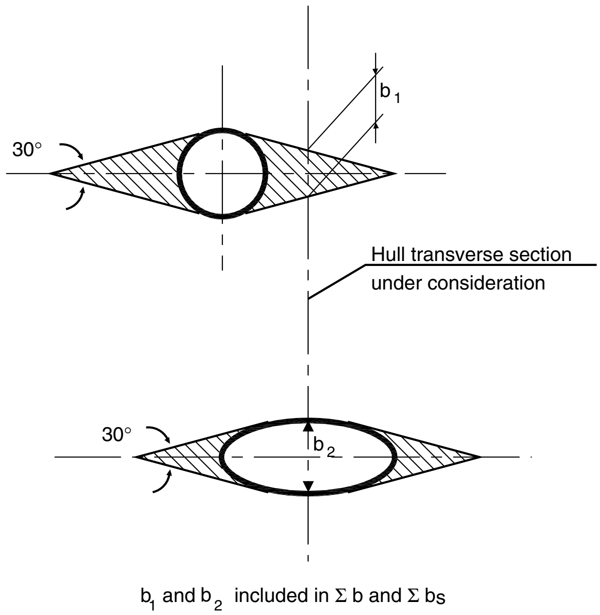
2.1.8 Lightening holes, draining holes and single scallops

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 Pt B, Ch 4, Sec 3 of the Rules for the Classification of Ships.

Otherwise, the excess is to be deducted from the sectional area or compensated.

Figure 1 : 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 unit, 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 2):

ℓ_P : Longitudinal distance, in m, between the frames beside the opening

h : Height, in m, of openings

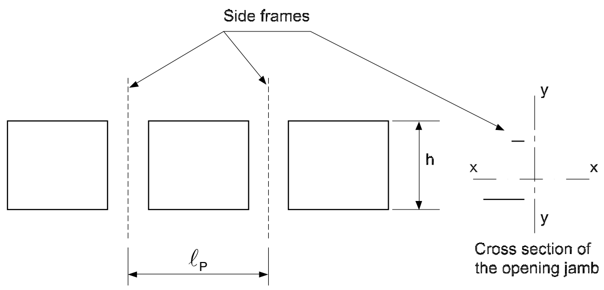
I_J : Moment of inertia, in m^4, of the opening jamb about the transverse axis y-y

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/mm², of the material used for the opening jamb, to be taken equal to:

- for steels:
  G = 8,0.10⁴ N/mm²
- for aluminium alloys:
  G = 2,7.10⁴ N/mm².

Figure 2 : Side openings



2.3 Section modulus

2.3.1 *(1/1/2022)*

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 m^4, 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 Pt B, Ch 1, Sec 2, [4] of the Rules for the Classification of Ships

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 Pt B, Ch 1, Sec 2, [4] of the Rules for the Classification of Ships.

2.3.2 *(1/1/2022)*

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 Pt B, Ch 1, Sec 2, [4] of the Rules for the Classification of Ships

- 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 Pt B, Ch 1, Sec 2, [4] of the Rules for the Classification of Ships; 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 Pt B, Ch 1, Sec 2, [4] of the Rules for the Classification of Ships.

2.4 Moments of inertia

2.4.1 The moments of inertia I_Y and I_Z, in m^4, are those, calculated about the horizontal and vertical neutral axes, respectively, of the hull transverse sections defined in [2.1].

2.5 First moment

2.5.1 The first moment S, in m^3, at a level z above the baseline is that, calculated with respect to the horizontal neutral axis, of the portion of the hull transverse sections defined in [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 Pt B, Ch 4, Sec 1, [2.3] of the Rules for the Classification of Ships

x : X co-ordinate, in m, of the calculation point with respect to the reference co-ordinate system defined in Pt B, Ch 1, Sec 2, [4] of the Rules for the Classification of Ships

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]

e_{S1} : Environmental coefficient defined in Ch 5, Sec 1, Tab 1

C : Wave parameter defined in Ch 5, Sec 2.

1 Application

1.1

1.1.1 The requirements of this Section apply to units having the following characteristics:

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

Units not having one or more of these characteristics and units 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, [2.1.5], 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, [2.1.5].

2.2 Normal stresses induced by torque and bending moments

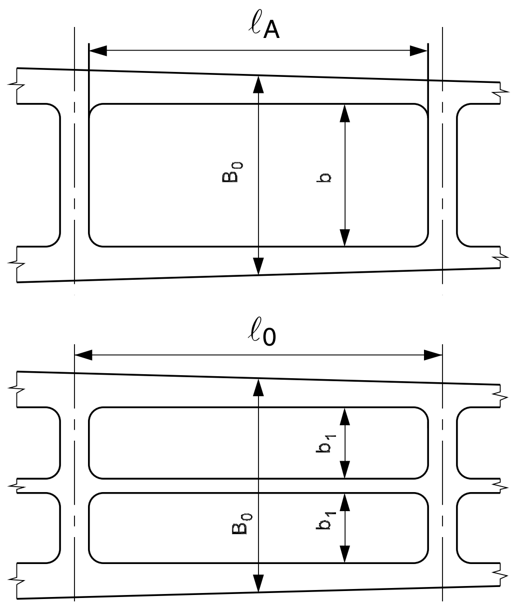
2.2.1 Units having large openings in the strength deck

The normal stresses induced by torque and bending moments are to be considered for units having large openings in the strength decks, i.e. units 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 : Units with large openings



2.2.2 Normal stresses *(1/1/2022)*

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 Pt B, Ch 1, Sec 2, [4] of the Rules for the Classification of Ships.

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 units, the vertical shear forces Q_{SW} and Q_{WV}
- for units having large openings in the strength decks, also the torque M_{WT} as specified in [2.2].

When deemed necessary by the Society on the basis of the unit'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 Units 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

Unit typology	Location	t, in mm	δ	Meaning of symbols used in the definition of δ
Single side units without effective longitudinal bulkheads - see Fig 3 (a)	Sides	t_S	0,5	
Double side units without effective longitudinal bulkheads - see Fig 3 (b)	Sides	t_S	(1- Φ) / 2	$\Phi = 0{,}275 + 0{,}25\,\alpha$ $\alpha = t_{ISM} / t_{SM}$
	Inner sides	t_{IS}	Φ / 2	
Double side units with one effective longitudinal bulkhead - see Fig 3 (c)	Sides	t_S	(1- Φ)Ψ / 2	$\Phi = 0{,}275 + 0{,}25\,\alpha$ $\alpha = t_{ISM} / t_{SM}$
	Inner sides	t_{IS}	ΦΨ / 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- χ	$\alpha_0 = \frac{0{,}5t_{BM}}{t_{SM} + t_{ISM}}$ $\beta = \frac{0{,}75}{3\delta + \alpha_0 + 1}$ $\gamma = \frac{2\delta + 1}{4\delta + 1 + \frac{1}{\alpha_0}}$ $\delta = \frac{B}{2D}$

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 units with double bottom in alternate loading conditions:

$$\Delta Q_C = \alpha\left|\frac{P}{B_H\ell_C} - \rho T_1\right|$$

- for other units:

$$\Delta Q_C = 0$$

$$\alpha = g\frac{\ell_0 b_0}{2 + \varphi\frac{\ell_0}{b_0}}$$

$$\varphi = 1{,}38 + 1{,}55\frac{\ell_0}{b_0} \le 3{,}7$$

ℓ_0, b_0 : Length and breadth, respectively, in m, of the flat portion of the double bottom in way of the tank considered; b_0 is to be measured on the hull transverse section at the middle of the tank

ℓ_C : Length, in m, of the tank considered, measured between transverse bulkheads

B_H : Unit's breadth, in m, measured on the hull transverse section at the middle of the tank considered

P : Total mass of cargo, in t, in the transversely adjacent tanks in the section considered

ρ : Sea water density, in t/m³:

$\rho = 1{,}025$ t/m³

T_1 : Draught, in m, measured vertically on the hull transverse section at the middle of the tank considered, from the moulded baseline to the waterline in the loading condition considered.

Figure 2 : Shear force correction ΔQ_C

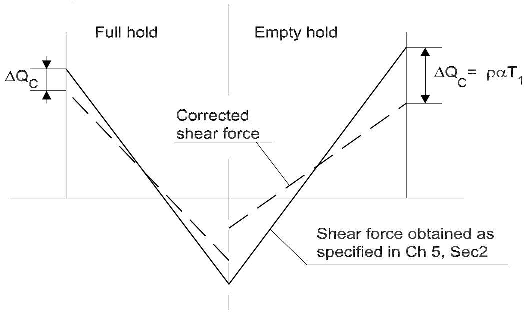
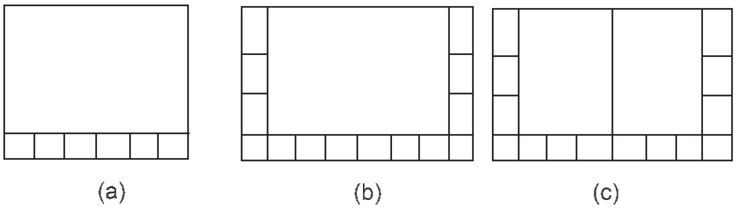


Figure 3 : Unit typologies (with reference to Tab 2)



2.4.2 Units 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

$$\varepsilon_Q = \operatorname{sgn}\left(\frac{Q_F - Q_A}{\ell_C}\right)$$

Q_F, Q_A : Value of Q_{SW}, in kN, in way of the forward and aft transverse bulkhead, respectively, of the tank considered

ℓ_C : Length, in m, of the tank 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:

$$\Delta Q = \frac{g\varepsilon(p_C - p_W)\ell_C b_C}{4}\left[\frac{2n}{3(n+1)} - \Phi\right]$$

$$\varepsilon = \operatorname{sgn}(Q_{SW})$$

p_C : Pressure, in kN/m², acting on the inner bottom in way of the centre tanktank in the loading condition considered

p_W : Pressure, in kN/m², acting on the inner bottom in way of the wing tank in the loading condition considered, to be taken not greater than p_C

b_C : Breadth, in m, of the centre tank, measured between longitudinal bulkheads

n : Number of floors in way of the centre tank

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:

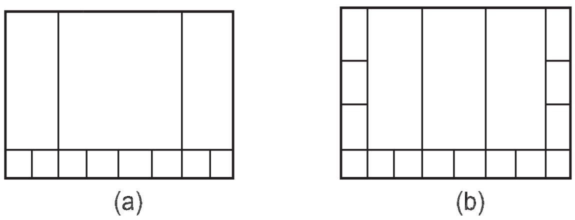
$\tau_{1,ALL} = 110/k$ N/mm².

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.

Figure 4 : Unit typologies (with reference to Tab 3)



4.2 Section modulus within 0,4L amidships

4.2.1 For units 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:

- $Z_{R,MIN} = e_{S1} C L^2 B (C_B + 0,7) k 10^{-6}$
- $Z_R = \frac{M_{SW} + M_{WV}}{175/k} 10^{-3}$

where e_{S1} is the environmental coefficient for design still water bending moment as defined in Ch 5, Sec 2, [2.2.2].

4.2.2 For units 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:

$$Z_{R,MIN} = e_{S1} C L^2 B (C_B + 0,7) k 10^{-6}$$

where e_{S1} is the environmental coefficient for design still water bending moment as defined in Ch 5, Sec 2, [2.2.2].

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, [2.1.7], 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 8.

4.4 Midship section moment of inertia

4.4.1 The gross midship section moment of inertia about its horizontal neutral axis is to be not less than the value obtained, in m⁴, from the following formula:

$$I_{YR} = 3 Z'_{R,MIN} L 10^{-2}$$

where $Z'_{R,MIN}$ is the required midship section modulus $Z_{R,MIN}$, in m³, calculated as specified in [4.2.1], but assuming k = 1.

4.5 Extent of higher strength steel

4.5.1 *(1/1/2022)*

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 Pt B, Ch 1, Sec 2, [4] of the Rules for the Classification of Ships
- 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 Pt B, Ch 1, Sec 2, [4] of the Rules for the Classification of Ships
- 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 in on-site and transit conditions

5.1 Permissible still water bending moment

5.1.1 The permissible still water bending moment at any hull transverse section in on-site and transit conditions, 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 $\tau = 110/k$ N/mm² in the most stressed point of the hull transverse section, taking into account the shear force correction ΔQ_C and ΔQ in accordance with [2.4.1] and [2.4.2], respectively.

5.2.2 Units 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 Units 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].

Table 3 : Shear stresses induced by vertical shear forces

Unit typology	Location	t, in mm	δ	Meaning of symbols used in the definition of δ
Single side units with two effective longitudinal bulkheads - see Fig 4 (a)	Sides	t_S	$(1-\Phi)/2$	$\Phi = 0{,}3 + 0{,}21\,\alpha$ $\alpha = t_{BM} / t_{SM}$
	Longitudinal bulkheads	t_B	$\Phi/2$	
Double side units with two effective longitudinal bulkheads - see Fig 4 (b)	Sides	t_S	$(1-\Phi)/4$	$\Phi = 0{,}275 + 0{,}25\,\alpha$ $\alpha = \dfrac{t_{BM}}{t_{SM} + t_{ISM}}$
	Inner sides	t_{IS}	$(1-\Phi)/4$	
	Longitudinal bulkheads	t_B	$\Phi/2$	

Note 1:
t_S, t_{IS}, t_B : Minimum thicknesses, in mm, of side, inner side and longitudinal bulkhead plating, respectively
t_{SM}, t_{ISM}, t_{BM} : Mean thicknesses, in mm, over all the strakes of side, inner side and longitudinal bulkhead plating, respectively. They are calculated as $\Sigma(\ell_i t_i)/\Sigma\ell_i$, where ℓ_i and t_i are the length, in m, and the thickness, in mm, of the ith strake of side, inner side and longitudinal bulkheads.

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 units 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

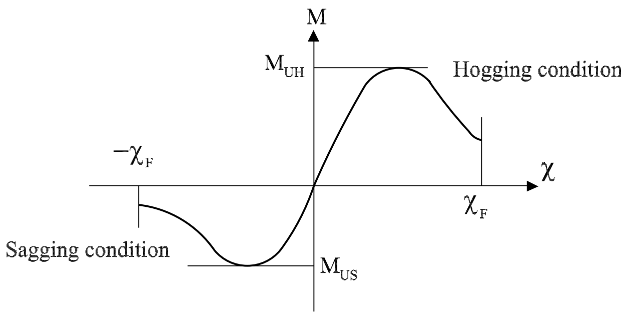
3.2.1 Curve M-χ

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 Pt B, Ch 6, App 1 of the Rules for the Classification of Ships.

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].

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] of the Rules for the Classification of Ships,

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] of the Rules for the Classification of Ships, for steel,
- Pt B, Ch 4, Sec 1, [4.4] of the Rules for the Classification of Ships, 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 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 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 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] of the Rules for the Classification of Ships,

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 Rules for the Classification of Ships, 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 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 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 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 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 Ch 5, Sec 2, [3.1],

M_{WH} : Horizontal wave bending moment, in kN.m, at the hull transverse section considered, defined in Ch 5, Sec 2, [3.2],

M_{WT} : Wave torque, in kN.m, at the hull transverse section considered, defined in Ch 5, Sec 2, [3.3].

SECTION 1 GENERAL REQUIREMENTS

1 General

1.1

1.1.1 *(1/1/2022)*

The applicable requirements in Pt B, Ch 7 of the Rules for the Classification of Ships are to be complied with, except for Pt B, Ch 7, Sec 4 of the Rules for the Classification of Ships that is to be replaced by Sec 2 of this Chapter.

SECTION 2 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/m^2, see [2.2]

s : Spacing, in m, of ordinary stiffeners

ℓ : Span, in m, of ordinary stiffeners, measured between the supporting members, see Pt B, Ch 4, Sec 3, [3.2] of the Rules for the Classification of Ships

w : Net section modulus, in cm^3, of the stiffener, with an attached plating of width b_p , to be calculated as specified in Pt B, Ch 4, Sec 3, [3.4] of the Rules for the Classification of Ships

K_h, $K\ell$: Stress concentration factors, defined in Ch 13, 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 13, 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 *(1/1/2022)*

The requirements of Pt B, Ch 7, App 1, [6] of the Rules for the Classification of Ships 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 13, 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).

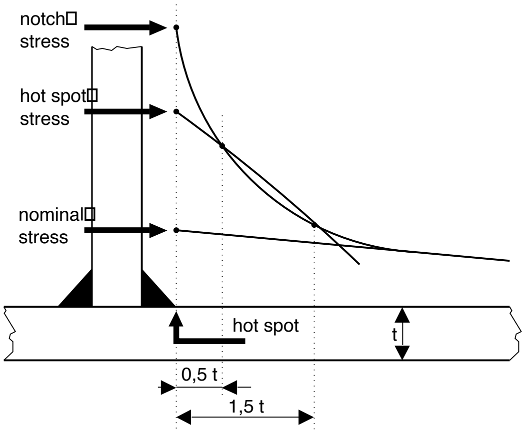
1.3.3 Hot spot stress

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, [2.5] and Ch 5, Sec 1, [2.6]).

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 *(1/1/2022)*

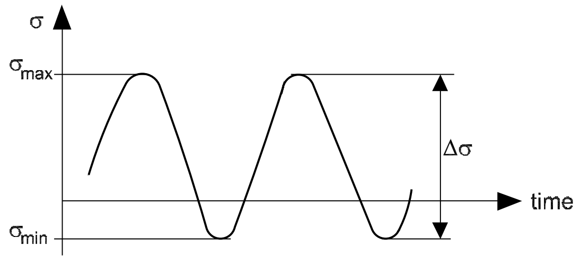
Unless otherwise specified, design loads are to be determined at points defined in:

- Pt B, Ch 7, Sec 2, [1.3] of the Rules for the Classification of Ships for ordinary stiffeners
- Pt B, Ch 7, Sec 3, [1] of the Rules for the Classification of Ships 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, [2.6].

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, [2.5].

2.1.5 Spectral fatigue analysis

For units 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 unit and the site-specific environmental conditions.

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 unit 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 $a_{Z1} < 0$

2.2.3 Inclined unit 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.

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

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 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	$\sigma_{WV,H}$	$\left\|\frac{0{,}625M_{WV,H}}{I_Y}(z-N)\right\|10^{-3}$
Vertical wave bending moment in sagging	$\sigma_{WV,S}$	$\left\|\frac{0{,}625M_{WV,S}}{I_Y}(z-N)\right\|10^{-3}$
Horizontal wave bending moment	σ_{WH}	$\left\|\frac{0{,}625M_{WH}}{I_Z}y\right\|10^{-3}$

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 13, 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 13, 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 *(1/1/2022)*

The elementary hot spot stress range $\Delta\sigma_{S,ij}$ is to be obtained, in N/mm², in accordance with:

- Pt B, Ch 7, App 1, [6] of the Rules for the Classification of Ships 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:

$$\Delta\sigma_{N,ij} = 0{,}7K_FK_mK_{C,ij}\Delta\sigma_{S,ij}$$

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]

$$K_{C,ij} = \frac{0{,}4R_y}{\Delta\sigma_{S,ij}} + 0{,}6 \quad \text{with} \quad 0{,}8 \le K_{C,ij} \le 1$$

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 13, 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:

$$\Delta\sigma_{N,eq} = (\alpha\Sigma_{3N,F} + (1-\alpha)\Sigma_{3N,B})^{1/3}$$

where:

α : Part of the unit’s life in full load condition, given in Tab 8 for various service notations.

Table 8 : Part of the unit’s life in full load condition

Service notation	Coefficient α
FSO, FPSO, FSRU	0,5

$$\Sigma_{3N,F} = \alpha_u \max(\mu_{aF}\Delta\sigma^3_{N,aF};\mu_{bF}\Delta\sigma^3_{N,bF}) + (1-\alpha_u)\max(\mu_{cF}\Delta\sigma^3_{N,cF};\mu_{dF}\Delta\sigma^3_{N,dF})$$

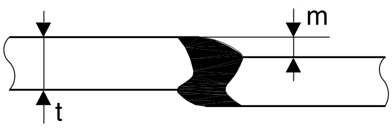
$$\Sigma_{3N,B} = \alpha_u \max(\mu_{aB}\Delta\sigma^3_{N,aB};\mu_{bB}\Delta\sigma^3_{N,bB}) + (1-\alpha_u)\max(\mu_{cB}\Delta\sigma^3_{N,cB};\mu_{dB}\Delta\sigma$$

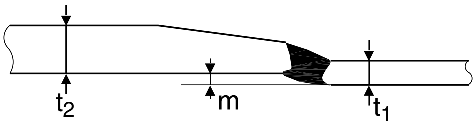
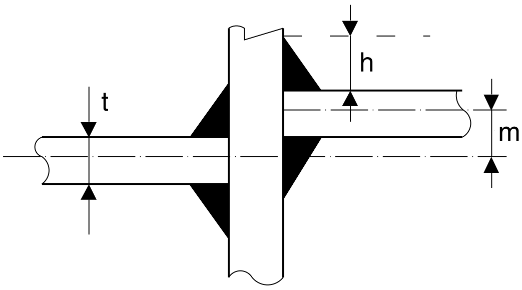
α_υ : Fraction of the unit's life in upright condition to be taken equal to:

- 0,9 for turret-moored installations
- 0,7 for spread-moored installations

If actual heading information is available, the actual heading probability may be used in alternative to the above values.

Table 9 : Stress concentration factor K_m for misalignment

Geometry	K_m
Axial misalignment between flat plates 	$1 + \frac{3(m - m_0)}{t}$
Note 1: m : Actual misalignment between two abutting members m_0 : Permissible misalignment for the detail considered, given in Ch 13, Sec 2.	

Geometry	K_m
Axial misalignment between flat plates of different thicknesses 	$1 + \frac{6(m - m_0)}{t_1} \frac{t_1^{3/2}}{t_1^{3/2} + t_2^{3/2}}$
Axial misalignment in fillet welded cruciform joints 	$1 + \frac{m - m_0}{t + h}$
Note 1: m : Actual misalignment between two abutting members m_0 : Permissible misalignment for the detail considered, given in Ch 13, Sec 2.	

$\Delta\sigma_{N,aF}$, $\Delta\sigma_{N,bF}$, $\Delta\sigma_{N,cF}$, $\Delta\sigma_{N,dF}$: 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

$$\nu_{ij} = \left(\frac{S_q}{\Delta\sigma_{N,ij}}\right)^{\xi} \ln N_R$$

$$S_q = (K_p 10^{-7})^{1/3}$$

$$K_p = 5{,}802\left(\frac{16}{t}\right)^{0,9} 10^{12}$$

$N_R = 5 \cdot 10^5$ (in transit condition $N_R = 5 \cdot 10^4$)

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

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
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:

$$N_t = (31,53\cdot 10^6)\frac{\alpha_0\cdot L_Y}{T_A}$$

T_A : Average period, in seconds, to be taken equal to:

$$T_A = 4\log L$$

$\Gamma_C[X+1]$: Complete Gamma function, defined in [3.3.2] and calculated for $X = 3/\xi$.

α_0 : 1

L_Y : Design life of the unit, in years, excluding any eventual prior lifetime in the case of converted ships, to be taken nor less than 10. If a design life is not specified, 20 years should be used.

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

X	Γ_C [X+1]
3,5	11,632
3,6	13,381

5 Checking criteria

5.1

5.1.1 The fatigue check is to be carried out in accordance with the criteria in [5.3.1] or [5.4.2].

5.2 Fatigue damage

5.2.1 Equivalent fatigue damage

The equivalent fatigue damage is to be obtained from the following formula:

$D_f = \alpha \cdot D_F + (1 - \alpha) \cdot D_B$

where:

$D_F = \alpha_u \cdot \max(D_{aF}; D_{bF}) + (1 - \alpha_u) \cdot \max(D_{cF}; D_{dF})$

$D_B = \alpha_u \cdot \max(D_{aB}; D_{bB}) + (1 - \alpha_u) \cdot \max(D_{cB}; D_{dB})$

α, α_u : coefficients defined in [3.3.2]

$D_{aF}; D_{bF}; D_{cF}; D_{dF}$: elementary fatigue damages in full load during on-site service, corresponding to load cases, "a", "b", "c", "d" as defined in Ch 5 Sec 4, to be calculated according to [5.1.3]

$D_{aB}; D_{bB}; D_{cB}; D_{dB}$: elementary fatigue damages in ballast condition during on-site service, corresponding to load cases, "a", "b", "c", "d" as defined in Ch 5 Sec 4, to be calculated according to [5.1.3]

5.2.2 Elementary fatigue damage

The elementary fatigue damage is to be obtained from the following formula:

$$D_{ij} = \frac{N_t \cdot \mu_{ij} \Delta\sigma^3_{N,ij} \cdot \Gamma_c\left[\frac{3}{\xi} + 1\right]}{K_p \cdot (\ln N_R)^{3/\xi}}$$

where:

i,j : indices defined in [3.3.1]

N_t : parameter defined in [4.1.1]

μ_{ij} : parameter defined in [3.3.2]

$\alpha_{N,ij}$: elementary notch stress range, defined in [3.3.1]

Γ_C [x + 1]: parameter defined in [4.1.1]

K_P : parameter defined in [3.3.2]

N_R : parameter defined in [3.3.2]

ξ : parameter defined in [3.3.2]

5.3 Fatigue check

5.3.1 The equivalent fatigue damage D_f, calculated according to [5.2.1], is to comply with the following formula:

$$D_F \leq \frac{\eta}{\gamma_R}$$

η : Permissible damage factor to be identified based on the accessibility of the detail for inspection and repair and the consequences of damage. Due consideration to the risk of fatigue failure is to be given in cases of substantial consequences, such as related to:

- loss of human life
- significant pollution
- collision
- sinking
- major economical consequences.

Maximum values of permissible damage are given in Tab 12 depending on the different degree for the consequence of failure.

The substantial consequence is to be applied in case of bottom structures of tanks of single bottom units and side structures of tanks of single side skins.

5.4 Fatigue life

5.4.1 The fatigue life of the unit L_F, in years, is to be calculated according to the following formula:

$$L_F \leq \frac{L_Y \cdot \eta}{D_f \cdot \gamma_R}$$

Table 12 : Permissible damage factor for details with non-substantial and substantial consequence of failure

Structural detail position	η	
	Non-Substantial	Substantial
Internal, accessible and not welded directly to the submerged part	1,0	0,5
External, accessible for regular inspection and repairs in dry and clean conditions	1,0	0,5
Internal, accessible and welded directly to the submerged part	0,5	0,25
External not accessible for inspection and repair in dry and clean conditions	0,5	0,25
Non-accessible, areas not planned to be accessible for inspection and repair during operation	0,33	0,1

5.4.2 The checking criteria expressed in terms of fatigue life, as alternative to that in [5.3.1], is:

$$L_F \geq L_Y$$

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:

$$\Delta\sigma_{h,eq} = (\alpha_u \max(\Delta\sigma_{h,a};\Delta\sigma_{h,b})^3 + (1-\alpha_u)\max(\Delta\sigma_{h,c};\Delta\sigma_{h,d})^3)^{1/3}$$

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 13.

Table 13 : 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:

$$\Delta P_{W,eq} = (\alpha\Sigma_{3P,F} + (1-\alpha)\Sigma_{3P,B})^{1/3}$$

where:

α : Part of the unit's life in full load condition, given in Tab 8

$$\Sigma_{3P,F} = \alpha_u \max(\Delta P_{W,aF};\Delta P_{W,bF})^3 + (1-\alpha_u)\max(\Delta P_{W,cF};\Delta P_{W,dF})^3$$

$$\Sigma_{3P,B} = \alpha_u \max(\Delta P_{W,aB};\Delta P_{W,bB})^3 + (1-\alpha_u)\max(\Delta P_{W,cB};\Delta P_{W,dB})^3$$

$\Delta P_{W,ij}$: 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:

$$\Delta\sigma_{h,eq} < \frac{\Delta\sigma_{p0}}{0,287 K_F K_m K_h \gamma_R^{1/3}} \cdot \eta^{1/3}$$

Moreover, the stiffener net section modulus is to be not less than the value obtained, in cm³, from the following formula:

$$w = 0,7 K_F K_m K_G K_\ell \frac{\beta_b \gamma_{W2} \Delta P_{W,eq}}{12\left(\frac{\Delta\sigma_{p0} \cdot \eta^{1/3}}{0,41\gamma_R^{1/3}} - 0,7 K_F K_m K_h \Delta\sigma_{h,eq}\right)} \cdot \left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$$

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 cm³, 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.

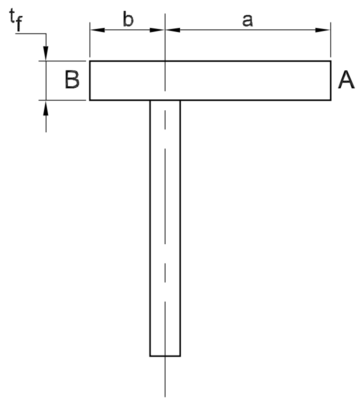
6.3.2 Longitudinal ordinary stiffeners not contributing to the hull girder longitudinal strength and transverse stiffeners

The stiffener net section modulus is to be not less than the value obtained, in cm³, from the following formula:

$$w = 0{,}287 K_F K_m K_G K_\ell \frac{\beta_b \gamma_{W2} \gamma_R^{1/3} \Delta P_{W,eq}}{12 \Delta\sigma_{p0} \cdot \eta^{1/3}}\left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$$

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 *(1/1/2022)*

The stiffener net section modulus is to be not less than the value obtained, in cm³, from the following formula:

$$w = 0{,}287 K_F K_m K_G K_\ell \frac{\beta_b \lambda_{bW} \gamma_{W2} \gamma_R^{1/3} \Delta P_{W,eq}}{12 \Delta\sigma_{p0} \cdot \eta^{1/3}}\left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$$

where:

K_G, β_b : Coefficients defined in [6.3.1]

λ_{bW} : Coefficient defined in Pt B, Ch 7, Sec 2, [3.4.5] of the Rules for the Classification of Ships.

7 Fatigue of converted units

7.1 General

7.1.1 The fatigue strength is based on a cumulative damage theory; therefore, in case of converted ships, the fatigue damage experienced prior to conversion is to be counted, in addition to the fatigue damage that the unit will experience in service as a fixed unit at the intended site.

The following separate contributions are to be considered for the assessment of the total fatigue damage:

- Fatigue damage cumulated during prior service as a trading vessel, to be calculated according to [7.2]
- Fatigue damage cumulated during the transit to the installation site, to be calculated according to [7.3]
- Fatigue damage cumulated at the intended site of operation including operational loading and unloading cycles, to be calculated according to [7.4].

Fatigue assessment for converted units is to be carried out through calculation of fatigue damages expressed as adimensional values ranging from 0 and 1.

The total cumulated damage, to be calculated according to [7.5], is to be in compliance with the checking criteria in [7.6]. In no case fatigue damage at any structural detail could be greater than 1; in such a case renewals or reinforcements are to be carried out.

7.1.2 Effect of corrosion

The use of scantlings which differ from the net values required for the fatigue assessment as per [1.1.1], in order to reflect actual corrosions, is to be verified on a case by case basis and subjected to the Society.

7.2 Fatigue during prior service as a trading vessel

7.2.1 Fatigue calculation relevant to the period of service as a trading vessel is to be performed according to Pt B, Ch 7, Sec 4 of the Rules for the Classification of Ships, with reference to the navigation notation reported in the Class certificate of the ship. In absence of information regarding actual trading routes, the unrestricted navigation is to be applied.

Fatigue damage during prior service as a trading vessel is given by D_s, to be calculated according to [7.7].

7.2.2 *(1/1/2022)*

In alternative, when wave environments in the actual route experienced are deemed less severe than those of the applicable navigation notation, the direct calculation approach of Ch 5, App 2 for route-specific loads might be applicable, provided that all documentation and calculation report are submitted for review.

7.3 Fatigue during transit condition

7.3.1 Fatigue calculation relevant to the transit to the installation site is to be performed according to Pt B, Ch 7, Sec 4 of the Rules for the Classification of Ships, with reference to a proper navigation notation; such navigation notation, defined according to Pt A, Ch 1, Sec 2, [5] of the Rule for the Classification of Ships has to reflect the intended route and shall be subjected to the Society for review.

Fatigue damage during transit condition is given by D_t, to be calculated according to [7.8].

7.3.2 *(1/1/2022)*

In alternative, when wave environments in the actual transit route are deemed less severe than those of the applicable navigation notation, the direct calculation approach of Ch 5, App 2 for route-specific loads might be applicable, provided that all documentation and calculation report are submitted for review.

7.4 Fatigue on-site

7.4.1 Fatigue calculation relevant to the on-site operation is to be performed according to Sec 4.

Fatigue damage on-site is given by D_f, to be calculated according to [5.2].

7.5 Total fatigue damage of converted units

7.5.1 Total fatigue damage of converted units is given by the following formula:

$D_{tot} = D_s + D_t + D_f$

where:

- D_s : fatigue damage during prior service as a trading vessel, defined in [7.2]
- D_t : fatigue damage during transit condition, defined in [7.3]
- D_f : fatigue damage on-site, defined in [7.4].

In case of multiple conversions, each of the terms related to a distinct service shall be repeated accordingly, on a case by case basis.

7.6 Checking criteria

7.6.1 The total fatigue damage D_{tot} calculated according to [7.5], is to comply with the following formula:

$D_{tot} \leq \eta / \gamma_R$

where:

- η : permissible damage factor, defined in [5.3.1]
- γ_R : partial safety factor on resistance, defined in [1.4.1].

7.6.2 Residual fatigue life

The residual fatigue life at the time of conversion L_{FR}, in years, is to be calculated according to the following formula:

$$L_{FR} = \frac{L_Y}{D_f} \cdot \left(\frac{\eta}{\gamma_R} - D_s - D_t\right)$$

where:

- L_Y : defined in [4.1.1]
- D_f : defined in [5.2.1]
- D_s : defined in [7.5.1]
- D_t : defined in [7.5.1]

7.6.3 The checking criteria expressed in terms of fatigue life, as alternative to that in [7.6.1], is:

$L_{FR} \geq L_Y$

7.7 Calculation of fatigue damage applicable to D_s (trading vessel)

7.7.1 This paragraph applies to fatigue assessment to be conducted in accordance to the provisions of Pt B, Ch 7, Sec 4 of the Rules for the Classification of Ships, being representative of period of lifetime of the unit as a trading ship (ship phase).

7.7.2 Ship-rule service elementary fatigue damage

The elementary fatigue damage for rule-based ships, is to be obtained from the following formula:

$$D_{ij} = \frac{N_t \cdot \mu_{ij} \Delta\sigma^3_{N,ij} \cdot \Gamma_c\left[\frac{3}{\xi} + 1\right]}{K_p \cdot (\ln N_R)^{3/\xi}}$$

where:

- i,j : indices defined in Rules for the Classification of Ships Pt B, Ch 7, Sec 4, [3.3.1]
- N_t : parameter defined in Rules for the Classification of Ships Pt B, Ch 7, Sec 4, [4.1.1]
- T_A : parameter defined in Rules for the Classification of Ships Pt B, Ch 7, Sec 4, [4.1.1]
- $\mu_{i,j}$: parameter defined in Rules for the Classification of Ships Pt B, Ch 7, Sec 4, [3.3.2]
- $\sigma_{N,i,j}$: elementary notch stress range, defined in Rules for the Classification of Ships Pt B, Ch 7, Sec 4, [3.3.1]
- $\Gamma_C[x + 1]$: parameter defined in Rules for the Classification of Ships Pt B, Ch 7, Sec 4, [4.1.1]
- K_p : parameter defined in Rules for the Classification of Ships Pt B, Ch 7, Sec 4, [3.3.2]
- N_R : parameter defined in Rules for the Classification of Ships Pt B, Ch 7, Sec 4, [3.3.2]
- ξ : parameter defined in Rules for the Classification of Ships Pt B, Ch 7, Sec 4, [3.3.2].

7.7.3 Rule service equivalent fatigue damage

The cumulated equivalent damage, based on a 20 years service, is to be obtained from the following formula:

$$D_{20} = \frac{\alpha}{2} \cdot D_F + \frac{1 - \alpha}{2} \cdot D_B$$

where:

- α : coefficient defined in Rules for the Classification of Ships Pt B, Ch 7, Sec 4, [3.3.2]

$D_F = \max(D_{aF}; D_{bF}) + \max(D_{cF}; D_{dF})$

$D_B = \max(D_{aB}; D_{bB}) + \max(D_{cB}; D_{dB})$

$D_{aF}; D_{bF}; D_{cF}; D_{dF}$: elementary fatigue damages in full load during trading ship navigation, corresponding to load cases, "a", "b", "c", "d" as defined in Rules for the Classification of Ships Pt B, Ch 5, Sec 4, to be calculated according to [7.7.2]

D_{aB}; D_{bB}; D_{cB}; D_{dB}: elementary fatigue damages in ballast condition during trading ship navigation, corresponding to load cases, "a", "b", "c", "d" as defined in Rules for the Classification of Ships Pt B, Ch 5, Sec 4, to be calculated according to [7.7.2].

7.7.4 Equivalent fatigue damage in actual ship service

The cumulated damage during actual number of years of service is to be obtained from the following formula:

$$D_S = D_{20} \cdot \frac{L_S}{17,4}$$

where:

L_S : ship service lifetime, to be taken equal to number of years of service as a trading vessel, from the date of delivery up to end of service, after deducing any time needed for loading/unloading operations, repairs, inactivity, etc.; in the absence of precise information, a total inactivity of up to 15% over the whole period comprised between the dates of delivery and service end can be assumed.

D_{20} : cumulated damage as a trading ship based on a 20 years service, to be calculated according to [7.7.3] with navigation corresponding to actual Class navigation of the ship-phase.

7.8 Calculation of fatigue damage applicable to D_t (unit in transit condition)

7.8.1 This paragraph applies to fatigue assessment to be conducted in accordance to the provisions of Pt B, Ch 7, Sec 4 of the Rules for the Classification of Ships, being representative of period necessary to transfer the unit from the shipyard to the intended-site of operation.

7.8.2 Ship-rule service elementary fatigue damage

The elementary fatigue damage for rule-based ships, is to be obtained from the following formula:

$$D_{ij} = \frac{N_t \cdot \mu_{ij} \Delta\sigma_{N,ij}^3 \cdot \Gamma_C\left[\frac{3}{\xi}+1\right]}{K_p \cdot (\ln N_R)^{3/\xi}}$$

where:

i,j : indices defined in Rules for the Classification of Ships Pt B, Ch 7, Sec 4, [3.3.1]

N_t : parameter defined in Rules for the Classification of Ships Pt B, Ch 7, Sec 4, [4.1.1]

T_A : parameter defined in Rules for the Classification of Ships Pt B, Ch 7, Sec 4, [4.1.1]

μ : parameter defined in Rules for the Classification of Ships Pt B, Ch 7, Sec 4, [3.3.2]

$\alpha_{N,ij}$: elementary notch stress range, defined in Rules for the Classification of Ships Pt B, Ch 7, Sec 4, [3.3.1]

Γ_C [x + 1]: parameter defined in Rules for the Classification of Ships Pt B, Ch 7, Sec 4, [4.1.1]

K_P : parameter defined in Rules for the Classification of Ships Pt B, Ch 7, Sec 4, [3.3.2]

N_R : parameter defined in Rules for the Classification of Ships Pt B, Ch 7, Sec 4, [3.3.2]

ξ : parameter defined in Rules for the Classification of Ships Pt B, Ch 7, Sec 4, [3.3.2].

7.8.3 Rule service equivalent fatigue damage

The cumulated equivalent damage, based on a 20 years service, corresponding to the transit condition is to be obtained from the following formula:

$$D_{t20} = \frac{\alpha}{2} \cdot D_F + \frac{1-\alpha}{2} \cdot D_B$$

where:

α : coefficient defined in Rules for the Classification of Ships Pt B, Ch 7, Sec 4, [3.3.2]. This coefficient can be set to either 0 or 1 as applicable for the actual loading condition during transit.

$D_F = \max(D_{aF}; D_{bF}) + \max(D_{cF}; D_{dF})$

$D_B = \max(D_{aB}; D_{bB}) + \max(D_{cB}; D_{dB})$

D_{aF}; D_{bF}; D_{cF}; D_{dF}: elementary fatigue damages in full load during transit navigation, corresponding to load cases, "a", "b", "c", "d" as defined in Rules for the Classification of Ships Pt B, Ch 5, Sec 4, to be calculated according to [7.8.2]

D_{aB}; D_{bB}; D_{cB}; D_{dB}: elementary fatigue damages in ballast condition during transit navigation, corresponding to load cases, "a", "b", "c", "d" as defined in Rules for the Classification of Ships Pt B, Ch 5, Sec 4, to be calculated according to [7.8.2]

7.8.4 Equivalent fatigue damage in transit condition

The cumulated damage in transit condition is to be obtained from the following formula:

$$D_t = D_{t20} \cdot \frac{D_t}{6976}$$

where:

D_t : actual duration, in days, of the transit voyage

D_{t20} : cumulated damage in transit based on a 20 years service, to be calculated according to [7.8.3] with navigation corresponding to actual navigation of transit.

Part B
Hull and Stability

Chapter 8
OTHER STRUCTURES

SECTION 1 FORE PART

Symbols

L_1, L_2 : Lengths, in m, defined in Pt B, Ch 1, Sec 2, [2.1.1] of the Rules for the Classification of Ships

e_{pw} : Environmental coefficient, defined in Ch 5, App 2

h_1 : Reference value of the unit relative motion, defined in Ch 5, Sec 3, [3.3]

a_{Z1} : Reference value of the vertical acceleration, defined in Ch 5, Sec 3, [3.4]

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

g : Gravity acceleration, in m/s^2:

$g = 9,81$ m/s^2

x, y, z : X, Y and Z co-ordinates, in m, of the calculation point with respect to the reference co-ordinate system defined in Pt B, Ch 1, Sec 2, [4] of the Rules for the Classification of Ships

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 Pt B, Ch 4, Sec 1, [2.3] of the Rules for the Classification of Ships

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:

$$c_r = 1 - 0,5s/r$$

to be taken not less than 0,75

r : Radius of curvature, in m

β_b, β_s : Coefficients defined in Pt B, Ch 7, Sec 2, [3.7.3] of the Rules for the Classification of Ships

λ_{bS}, λ_{bW}, λ_{sS}, λ_{sW}: Coefficients defined in Pt B, Ch 7, Sec 2, [3.4.5] of the Rules for the Classification of Ships

c_E : Coefficient to be taken equal to:

$c_E = 1$ for $L \leq 65$ m

$c_E = 3 - L / 32,5$ for $65 \text{ m} < L < 90$ m

$c_E = 0$ for $L \geq 90$ 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 foreward peak 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.

1.1.3 Where the structure is subjected to concentrated mooring loads from the mooring system (i.e. mooring arms or yokes, external turrets or mooring hawsers etc.), the scantlings and arrangements are to be specially considered. Finite element analysis of attachments to the hull is to be carried out, according to applicable provisions of Chapter 9.

1.2 Connections of the fore part with structures located aft of the foreward peak bulkhead

1.2.1 Tapering

Adequate tapering is to be ensured between the scantlings in the fore part and those aft of the foreward peak 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 foreward peak bulkhead, side girders are to be fitted as specified in Pt B, Ch 4, Sec 5, [2.2] or Pt B, Ch 4, Sec 5, [3.2] of the Rules for the Classification of Ships, 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)**	$19{,}6 e_{pw} \varphi \sqrt{H}$

(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

$$H = 3{,}6\left[2{,}66\left(\frac{x}{L} - 0{,}7\right)^2 + 0{,}14\right]\sqrt{\frac{L}{C_B}} - (z - T)$$

without being taken less than 0,8

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 foreward peak 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 foreward peak 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: $t = 14{,}9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y}}$ • for inner bottom: $t = 14{,}9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y}}$	Net minimum thickness, in mm: • in general: $t = c_F(0,038L + 7,0)(sk)^{1/2} - c_E$ • for inner bottom: $t = 2 + 0{,}017 L k^{1/2} + 4{,}5 s$
Ordinary stiffeners	Net section modulus, in cm³: $w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{8 R_y} \left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$	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 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 foreward peak 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 foreward peak 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 foreward peak 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 foreward peak 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.

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.		

2.7.5 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.

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 Pt B, Ch 7, Sec 3 of the Rules for the Classification of Ships, considering the loads in [2.3].

The partial safety factors to be used are those defined in Pt B, Ch 7, Sec 3, [1.3] of the Rules for the Classification of Ships.

2.9 Platforms

2.9.1 Non-tight platforms

Non-tight platforms located inside the peak are to be provided with openings having a total area not less than 10% of that of the platforms. Moreover, the thickness of the plating and the section modulus of ordinary stiffeners are to be not less than those required in [2.10] for the non-tight central longitudinal bulkhead.

The number and depth of non-tight platforms within the peak is considered by the Society on a case by case basis.

The platforms may be replaced by equivalent horizontal structures whose scantlings are to be supported by direct calculations.

2.9.2 Platform transverses

The net sectional area of platform transverses, calculated considering a width of attached plating whose net sectional area is equal to that of the transverse flange, is to be not less than the value obtained, in cm^2, from the following formula:

$$A = 10\gamma_R\gamma_m\frac{\gamma_{S2}p_S + \gamma_{W2}p_W}{C_P R_y}d_S h_S$$

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 unit'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 unit's length.

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:

$$p_{BI} = 25C_e\left[0{,}004 - \left(\frac{T_F}{L}\right)^2\right]\frac{L_1 L}{T_F}$$

where T_F is the draught defined in [3.1.2] and C_e is the coefficient defined in [4.3.1].

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.

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.

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.

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: $t = 13{,}9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{W2} p_{BI}}{R_y}}$	Net minimum thickness, in mm: $t = c_F(0,038L + 7,0)(sk)^{1/2} - c_E$
Ordinary stiffeners	Net section modulus, in cm³: $w = \gamma_R \gamma_m \beta_b \frac{\gamma_{W2} p_{BI}}{16 c_P R_y}\left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$	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: $A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{W2} p_{BI}}{R_y}\left(1 - \frac{s}{2\ell}\right) s \ell$	
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.		

3.5 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 foreward peak 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 Pt B, Ch 4, Sec 4 of the Rules for the Classification of Ships 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 all units.

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/m^2, from the following formula:

$$p_{FI} = C_e C_S C_L C_Z (0{,}22 + 0{,}15 \tan\alpha)(3{,}2 \sin\beta + 0{,}6\sqrt{L})^2$$

where:

C_e : Coefficient depending on environmental factor e_{pw}:
- $C_e = e_{pw}$ for $e_{pw} \le 1$
- $C_e = e^2_{pw}$ for $e_{pw} > 1$

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 unit's length:
- $C_L = 0{,}0125\ L$ for $L < 80$ m
- $C_L = 1{,}0$ for $L \ge 80$ m

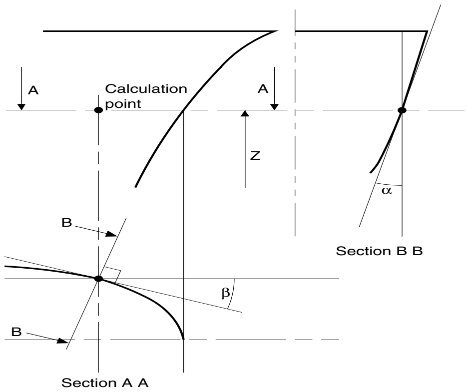
C_Z : Coefficient depending on the distance between the summer load waterline and the calculation point:
- $C_Z = C - 0{,}5\ (z-T)$ for $z \ge 2\ C + T - 11$
- $C_Z = 5{,}5$ for $z < 2\ C + T - 11$

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.

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 Pt B, Ch 7, Sec 3 of the Rules for the Classification of Ships, 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: $t = 11c_a c_r s\sqrt{\gamma_R \gamma_m \frac{\gamma_{W2} p_{FI}}{R_y}}$	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: • $t = 1,5L_2^{1/3}k^{1/6}$ • the thickness of the attached plating.
	Net shear sectional area, in cm²: $A_{Sh} = 10\gamma_R \gamma_m \beta_s \frac{\gamma_{W2} p_{FI}}{R_y}\left(1 - \frac{s}{2\ell}\right) s \ell$	
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 : Unit'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 cm², 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 13, Sec 1, [3.3].

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 Pt B, Ch 1, Sec 2, [2.1.1] of the Rules for the Classification of Ships

h_1 : Reference value of the unit relative motion, defined in Ch 5, Sec 3, [3.3]

a_{Z1} : Reference value of the vertical acceleration, defined in Ch 5, Sec 3, [3.4]

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 Pt B, Ch 1, Sec 2, [4], of the Rules for the Classification of Ships

p_S, p_W : Still water pressure and wave pressure defined in [1.2]

k : Material factor, defined in Pt B, Ch 4, Sec 1, [2.3] of the Rules for the Classification of Ships

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 Pt B, Ch 7, Sec 2, [3.7.3] of the Rules for the Classification of Ships

λ_{bS}, λ_{bW}, λ_{sS}, λ_{sW}: Coefficients defined in Pt B, Ch 7, Sec 2, [3.4.5] of the Rules for the Classification of Ships

c_E : Coefficient to be taken equal to:

$c_E = 1$ for $L \leq 65$ m

$c_E = 3 - L/30$ for $65\text{ m} < L < 90$ m

$c_E = 0$ for $L \geq 90$ m

c_F : Coefficient:

$c_F = 0,8$ for poop sides

$c_F = 1,0$ in other cases.

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.

1.1.3 In cases where rudder and propulsion axis are fitted, their supporting structures are to be in compliance with the applicable provisions of Pt B, Ch 9 of the Rules for the Classification of Ships.

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)**	$17{,}5 e_{pw}\,\varphi$

(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	$p_S \dfrac{a_{Z1}}{g}$

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 unit, 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 Pt B, Ch 7, Sec 3 of the Rules for the Classification of Ships, considering the loads in [1.2].

The partial safety factors to be used are those defined in Pt B, Ch 7, Sec 3, [1.3] of the Rules for the Classification of Ships.

Table 6 : Net thickness of plating

Plating location	Net thickness, in mm	Net minimum thickness, in mm
Bottom, side and transom	$14{,}9c_a c_r s\sqrt{\gamma_R\gamma_m\dfrac{\gamma_{S2}p_S+\gamma_{W2}p_W}{R_y}}$	$t = c_F(0{,}038L+7{,}0)(sk)^{1/2}-c_E$
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 cm³: $w = \gamma_R\gamma_m\beta_b\dfrac{\gamma_{S2}p_S+\gamma_{W2}p_W}{8R_y}\left(1-\dfrac{s}{2\ell}\right)s\ell^2 10^3$	Web net minimum thickness, in mm, to be not less than the lesser of: • $t = 1{,}5L_2^{1/3}k^{1/6}$ • the thickness of the attached plating.
	Net shear sectional area, in cm²: $A_{Sh} = 10\gamma_R\gamma_m\beta_s\dfrac{\gamma_{S2}p_S+\gamma_{W2}p_W}{R_y}\left(1-\dfrac{s}{2\ell}\right)s\ell$	
Deck	Net section modulus, in cm³: $w = \gamma_R\gamma_m\beta_b\dfrac{\gamma_{S2}p_S+\gamma_{W2}p_W}{mR_y}\left(1-\dfrac{s}{2\ell}\right)s\ell^2 10^3$	
	Net shear sectional area, in cm²: $A_{Sh} = 10\gamma_R\gamma_m\beta_s\dfrac{\gamma_{S2}p_S+\gamma_{W2}p_W}{R_y}\left(1-\dfrac{s}{2\ell}\right)s\ell$	
Platform and wash bulkhead	Net section modulus, in cm³: $w = 3{,}5s\ell^2k(z_{TOP}-z_M)$	

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.

SECTION 3 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 unit, 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 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 Sec 5, [5] are to be fitted.

1.2.5 In units 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 Sec 5, [4.3.1] are to be fitted.

1.2.6 In units 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 Sec 5, [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 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 unit, 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 unit, 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.

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 units 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 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 Pt B, Ch 1, Sec 2, [4] of the Rules for the Classification of Ships

s : Spacing, in m, of ordinary stiffeners

k : Material factor, defined in:

- Pt B, Ch 4, Sec 1, [2.3] of the Rules for the Classification of Ships, for steel
- Pt B, Ch 4, Sec 1, [4.4] of the Rules for the Classification of Ships, 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 *(1/1/2022)*

The lowest tier is normally that which is directly situated above the freeboard deck.

Where the freeboard exceeds one standard superstructure height, defined in Pt B, Ch 1, Sec 2, Tab 2 of the Rules for the Classification of Ships 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 5.

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/m^2, 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 unit 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, [4].

Moreover, when the deck is a tank boundary, the lateral pressure constituted by the still water internal pressure (p_S) and the inertial pressure (p_W), defined in Ch 5, Sec 6, [1] is also to be considered.

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 unit, 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, 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:

$$t = 0,95 s\sqrt{kp} - t_c$$

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, 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 Pt B, Ch 7, Sec 2 of the Rules for the Classification of Ships.

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 cm³, from the following formula:

$$w = 0{,}35\varphi ks\ell^2 p(1 - \alpha t_c) - \beta t_c$$

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/m², 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 Pt B, Ch 7, Sec 2 of the Rules for the Classification of Ships.

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 Pt B, Ch 7, Sec 3 of the Rules for the Classification of Ships.

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 Pt B, Ch 7, Sec 3 of the Rules for the Classification of Ships, 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 Pt B, Ch 7, Sec 3 of the Rules for the Classification of Ships.

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/m^2.

6.2.2 Checking criteria

It is to be checked that the equivalent stress σ_{VM}, calculated according to Pt B, Ch 7, App 1, [5.1.2] or Pt B, Ch 7, App 1, [5.2.2] of the Rules for the Classification of Ships, as applicable, is in compliance with the following formula:

$$\frac{R_y}{\gamma_R \gamma_m} \geq \sigma_{VM}$$

where:

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

γ_R : Partial safety factor covering uncertainties regarding resistance, to be taken equal to:

- 1,10 in general
- 1,40 for checking locking devices

γ_m : Partial safety factor covering uncertainties regarding material, to be taken equal to 1,02.

SECTION 5 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.

1.2 Definitions

1.2.1 Standard height of superstructure (1/1/2022)

The standard height of superstructure is that defined in Pt B, Ch 1, Sec 2, Tab 2 of the Rules for the Classification of Ships.

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 unit'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 unit'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 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.

2.1.3 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 unit and provided that the safety of the unit is not impaired.

2.1.4 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 unit.

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, are to be of such construction as to prevent effectively any person opening them without the consent of the Master of the unit.

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.

3.2.2 Cargo spaces

No sidescuttles may be fitted in any spaces which are appropriated exclusively for the storage of cargo.

3.2.3 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 units subject to damage stability regulations
- where they are fitted outside the space considered flooded and are below the final waterline for those units where the freeboard is reduced on account of subdivision characteristics.

3.2.4 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.

3.2.5 Automatic ventilating scuttles

Automatic ventilating sidescuttles, fitted in the shell plating below the freeboard deck, are considered by the Society on a case by case basis.

3.2.6 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.

3.3 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 mm^2	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.

3.4 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 unit'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 summer load line. The deadlights may be portable in crew accommodation, unless the deadlights are required by the International Convention on Load Lines in force to be permanently attached in their proper positions. Such portable deadlights are to be stowed adjacent to the sidescuttles they serve.

3.4.3 Openings at the side shell in the second tier

Sidescuttles and windows at the side shell in the second tier superstructure, protecting direct access to an opening loading 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 unit.

4.1.2 Inboard opening of ash-shoot, rubbish-shoot, etc.

The inboard opening of each ash-shoot, rubbish-shoot, etc. is to be fitted with an efficient cover.

If the inboard opening is situated below the freeboard deck, the cover is to be watertight, and in addition an automatic non-return valve is to be fitted in the shoot in an easily accessible position above the summer 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 unit 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 ≤ 80	7,0
80 < d < 180	7,0 + 0,03 (d - 80)
180 ≤ d ≤ 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.

Table 5 : Freeing port area in bulwark located on freeboard deck

Unit types or unit particulars	Area A of freeing ports, in m^2	Applicable requirement
Type A	0,33 ℓ_B h_B	[5.5.2]
Units fitted with a trunk included in freeboard calculation and/or breadth ≥ 0,6B	0,33 ℓ_B h_B	[5.3.1]
Units fitted with continuous or substantially continuous trunk and/or hatch coamings	A_2	[5.3.1]
Units fitted with non-continuous trunk and/or hatch coamings	A_3	[5.3.2]
Units fitted with open superstructure	A_S for superstructures A_W for wells	[5.4.2] [5.4.3]
Other units	A_1	[5.2.1]

Note 1:
ℓ_B : Length, in m, of bulwark in a well at one side of the unit
h_B : Mean height, in m, of bulwark in a well of length ℓ_B.

5.1.3 Freeing port arrangement

Where a sheer is provided, two thirds of the freeing port area required is to be provided in the half of the well nearer the lowest point of the sheer curve.

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.

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 units, 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 unit for each well is to be not less than that obtained, in m^2, in Tab 6.

In units 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 m^2	
	$\ell_B \le 20$	$\ell_B > 20$
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 m^2, 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 unit 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 unit 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 unit 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

5.3.1 Freeing area for continuous trunk

Where the unit is fitted with a continuous trunk not included in the calculation of freeboard, the freeing port area is to be not less than that obtained, in m^2, from Tab 7.

Where the unit 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 m^2
$B_H \le 0,4B$	$0,2\ \ell_B\ h_B$
$0,4B < B_H < 0,75B$	$\left[0,2 - 0,286\left(\frac{B_H}{B} - 0,4\right)\right]\ell_B h_B$
$B_H \ge 0,75B$	$0,1\ \ell_B\ h_B$

Note 1:

ℓ_B : Length, in m, of bulwark in a well at one side of the unit

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 unit is impeded due to the presence of a non-continuous trunk, 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 m^2, from Tab 8.

Table 8 : Freeing port area in a well contiguous to non-continuous trunk or hatchways

Free flow area f_P, in m^2	Freeing port area A_3, in m^2
$f_p \le A_1$	A_2
$A_1 < f_P < A_2$	$A_1 + A_2 - f_P$
$f_P \ge A_2$	A_1

Note 1:

f_P : Free flow area on deck, equal to the net area of gaps between hatchways, and between hatchways and superstructures and deckhouses up to the actual height of the bulwark

A_1 : Area of freeing ports, in m^2, to be obtained from Tab 6

A_2 : Area of freeing ports, in m^2, to be obtained from Tab 7.

5.4 Freeing port area in an open space within superstructures

5.4.1 General

In units 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 unit for the open superstructure is to be not less than that obtained, in m^2, from the following formula:

$$A_S = A_1 c_{SH}\left[1-\left(\frac{\ell_W}{\ell_T}\right)^2\right]\left(\frac{b_0 h_S}{2\,\ell_T h_W}\right)$$

where:

ℓ_T : Total well length, in m, to be taken equal to:

$\ell_T = \ell_W + \ell_S$

ℓ_W : Length, in m, of the open deck enclosed by bulwarks

ℓ_S : Length, in m, of the common space within the open superstructures

A_1 : Freeing port area, in m^2, required for an open well of length ℓ_T , in accordance with Tab 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 unit for the open well is to be not less than that obtained, in m^2, from the following formula:

$$A_W = A_1 c_{SH}\left(\frac{h_S}{2\,h_W}\right)$$

A_1 : Freeing port area, in m^2, 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 units of Type A

5.5.1 Freeing arrangement for Type A units

Type A units 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 units

Machinery casings on Type A units 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 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 unit'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, 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 units of not more than 100 m in length

In units 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 units of more than 100 m in length

Where, in units 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 unit’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 unit side or through enclosed superstructures are considered by the Society on a case by case basis. If such ventilators are led overboard more than 4,5 m above the freeboard deck, closing appliances may be omitted provided that satisfactory baffles and drainage arrangements are fitted.

8.2 Coamings

8.2.1 General

Ventilators in positions 1 or 2 to spaces below freeboard decks or decks of enclosed superstructures are to have coamings of steel or other equivalent material, substantially constructed and efficiently connected to the deck.

Ventilators passing through superstructures other than enclosed superstructures are to have substantially constructed coamings of steel or other equivalent material at the freeboard deck.

8.2.2 Scantlings

The scantlings of ventilator coamings exposed to the weather are to be not less than those obtained from Tab 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 unit, for units 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 (1/1/2022)

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 Pt B, Ch 4, Sec 1, [2] of the Rules for the Classification of Ships. 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) of the Rules for the Classification of Ships.

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.

Spurling pipes through which anchor chains are led are to be provided with permanently attached closing appliances to minimise water ingress. Examples of acceptable closing appliance arrangements are:

- steel plates with cut-outs to accommodate chain links,
- canvas hoods with a lashing arrangement that maintains the cover in the secured position.

Figure 1 : Separate chain lockers

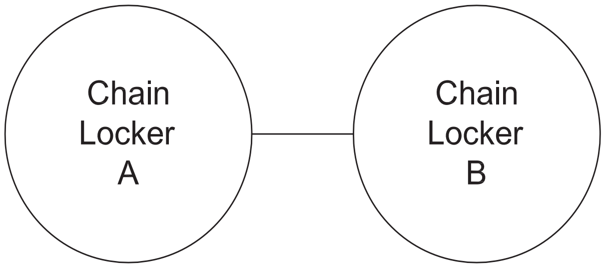


Figure 2 : Chain locker with a common boundary

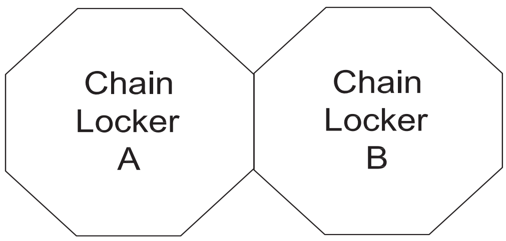


Table 10 : 900 mm Ventilator Pipe Thickness and Bracket Standards

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.

Note 1: For other ventilator heights, the relevant requirements in [8.3.4] are to be applied.

SECTION 6 EQUIPMENT

1 General

1.1 General

1.1.1 The requirements in [2] apply to temporary mooring of a unit engaged in ship-to-unit transfer operations.

Therefore, the equipment complying with the requirements in [2] is not intended for permanent mooring (to which provisions in Ch 9 apply) or for stopping a unit which is moving or drifting.

1.1.2 For the purpose of this Section, disconnectable self-propelled units are subject to the provisions of the Pt B, Ch 10, Sec 4 of the Rules for the Classification of Ships.

2 Equipment

2.1 Shipboard fittings and supporting hull structures

2.1.1 Application

The requirements of [2.1] apply to bollards, bitts, fairleads, stand rollers, chocks used for mooring the unit during ship-to-unit transfer operations and similar components used for towing the unit in the following events:

- wet towing to operating location
- escort towing (for disconnectable non self-propelled units).

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 towing and mooring operations are also covered by [2.1].

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.

2.1.2 Net scantlings

The net minimum scantlings of the supporting hull structure are to comply with the requirements in [2.1.8] and [2.1.14]. 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 [2.1.3], to t_{net}.

2.1.3 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.

2.1.4 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 unit is to be in accordance with [2.1.13].

2.1.5 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.

2.1.6 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 [2.1.7], acting through the arrangement of connection to the shipboard fittings.

2.1.7 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 and is not to be less than 750 kN:

a) for wet towing operations, 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 Pt B, Ch 10, Sec 4, [3.1.7] of the Rules for Classification of Ships.

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).

2.1.8 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.

2.1.9 Safe Working Load (SWL)

The SWL used for wet towing operations is not to exceed 80% of the design load as per [2.1.7] a) and the SWL used for other towing operations (e.g. escort) is not to exceed the design load as per [2.1.7] b). For fittings used for wet and other towing operations, the greater of the design loads of [2.1.7] a) and [2.1.7] 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 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 [2.1.16] is to define the method of use of towing lines.

2.1.10 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 unit is to be in accordance with [2.1.13].

2.1.11 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.

2.1.12 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 [2.1.13], acting through the arrangement of connection to the shipboard fittings.

2.1.13 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 [3.2.1].

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.

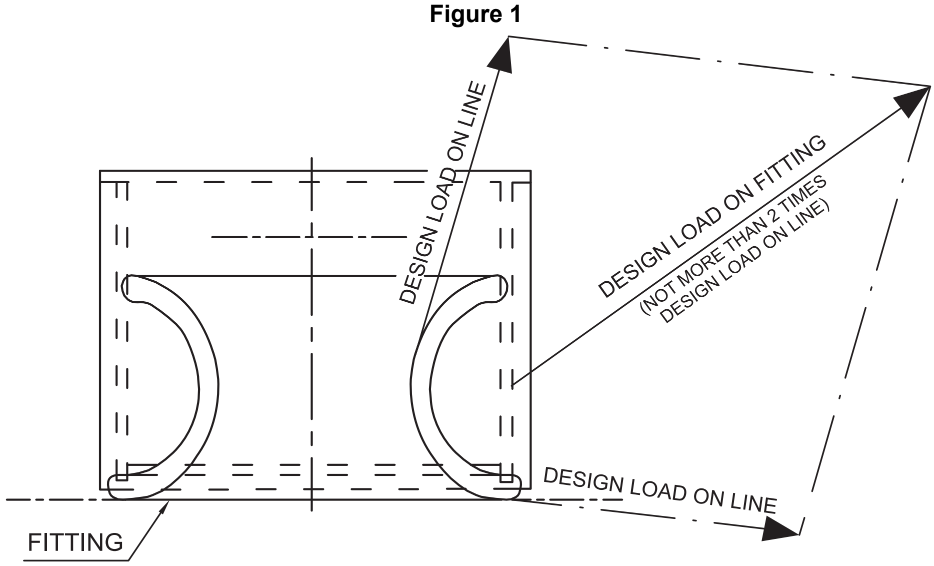
c) This force is to be considered as acting on the shipboard fittings at the attachment point of the mooring line or at a change in its direction, as applicable.

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.

Figure 1



2.1.14 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.

2.1.15 Safe Working Load (SWL)

The SWL is not to exceed 80% of the design load as per [2.1.13] a).

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 [2.1.16] is to define the method of use of mooring lines.

2.1.16 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 unit;
- fitting type;
- SWL;
- purpose (ship-to-unit mooring / wet towing / escort towing); and
- manner of applying towing or mooring line load including limiting fleet angles.

2.2 Mooring lines

2.2.1 General

The mooring lines, when provided on board the unit, are to be designed, selected and tested according to provisions in OCIMF Mooring Equipment Guidelines, as amended.

2.2.2 Minimum breaking load

Minimum breaking load of mooring lines is to be determined according to safety factors defined in OCIMF Mooring Equipment Guidelines that are to be applied on the maximum working loads during mooring operations. Such maximum working loads are to be obtained from the ship-to-unit mooring analysis carried out according to provisions in App 1.

2.2.3 Materials

Mooring lines may be of wire, natural synthetic fibre or a mixture of wire and fibre. The material is to be the same as that utilized for the mooring loads calculations mentioned in [2.2.2].

Steel wires and fibre ropes are to be tested in accordance with the applicable requirements in Pt D, Ch 4, Sec 1 of the Rules for the Classification of Ships.

Steel wires are to made of flexible galvanized steel and are to be of types defined in Tab 1.

2.3 Fenders

2.3.1 General

Fenders are to be selected in accordance with ISO Standards.

Table 1 : 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

SECTION 7 STEERING NOZZLES

1 General

1.1

1.1.1 The requirements of this Article apply to scantling steering nozzles for which the power transmitted to the propeller, P, is less than the value P_0 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.

1.1.2 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.

1.1.3 Care is to be taken in the manufacture of the nozzle to ensure the welded connection between plating and webs.

1.1.4 The internal part of the nozzle is to be adequately protected against corrosion.

2 Nozzle plating and internal diaphragms

2.1

2.1.1 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 [1.1.1].

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.

2.1.2 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 [2.2.1] and, in any case, not less than 7 mm.

2.1.3 The thicknesses of ring webs and longitudinal webs are to be not less than (t_F - 7) mm, where t_F is defined in [2.2.1], 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.

3 Nozzle stock

3.1

3.1.1 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:
$A_{1N} = L_M\ d_M$

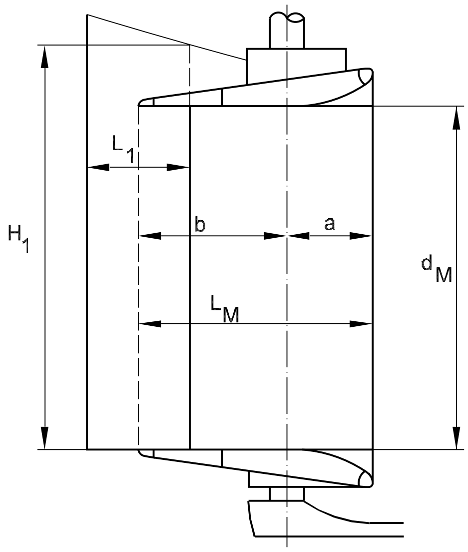
A_{2N} : area, in m², equal to:
$A_{2N} = L_1\ H_1$

a, b, L_M, d_M, L_1, H_1 : geometrical parameters of the nozzle, in m, defined in Fig. 1.

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 1 : Geometrical parameters of the nozzle



4 Pintles

4.1

4.1.1 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 [3.1.1].

4.1.2 The net pintle length h_A, in mm, is to be not less than 1,2 d_A, where d_A is defined in [4.1.1].

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:

$p_F \leq p_{F,ALL}$

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 [3.1.1],

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 1.

In any case, h_A is to be not less than d_A.

Table 1 : 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.

5 Nozzle coupling

5.1

5.1.1 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 [3.1.1],

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 [3.1.1], 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.

5.1.2 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 [3.1.1],

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.

5.1.3 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:

- $6,2\dfrac{M_{TR}\eta\gamma}{c d_M t_S \mu_A \beta}$
- $16\dfrac{M_{TR}\eta\gamma}{c t_S^2 \beta}\sqrt{\dfrac{d_{NTF}^6 - d_{NT}^6}{d_{NT}^6}}$

$$\Delta_1 = \frac{2\eta + 5}{1,8}\,\frac{\gamma d_0 R_{eH}}{10^6 c(1+\rho_1)}$$

$$\rho_1 = \frac{80\sqrt{d_{NTF}^6 - d_{NT}^6}}{R_{eH} d_M t_S^2\left[1 - \left(\dfrac{d_0}{d_{NTF}}\right)^2\right]}$$

d_{NTF} : nozzle stock diameter, in mm, to be obtained from the formula in [3.1.1], considering k_1=1

d_{NT} : nozzle stock diameter, in mm, to be obtained from the formula in [3.1.1], 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:

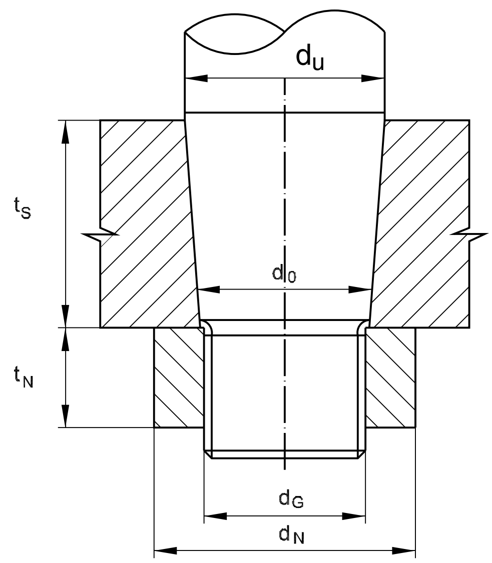
- for rudder stocks and bosses made of steel: $\mu = 0,15$; $\gamma = 1$
- for rudder stocks made of steel and bosses made of SG iron: $\mu = 0,13$; $\gamma = 1,24 - 0,1\ \beta$

t_S, d_U, d_0 : defined in Fig 2

R_{eH} : yield stress, in N/mm², of the steel used, and not exceeding the lower of 0,7 R_m and 450 N/mm²

Rm : minimum ultimate tensile strength, in N/mm², of the steel used.

Figure 2 : Geometrical of cone coupling



5.1.4 Locking device

A suitable locking device is to be provided to prevent the accidental loosening of nuts.

APPENDIX 1 SHIP-TO-UNIT MOORING ANALYSIS

1 General

1.1 Shuttle carriers to be considered

1.1.1 The mooring analysis is to be carried out considering the range of shuttle carriers that, according to the design, are intended to be moored with the unit in order to carry out ship-to-unit cargo transfer operations.

A selected sample of representative shuttle carriers is to be identified, and agreed with the Society, on the basis of which the mooring analysis is to be carried out and the mooring loads are to be calculated.

1.1.2 A selected sample of representative shuttle carriers is to be identified, and agreed with the Society, on the basis of which the mooring analysis is to be carried out and the mooring loads are to be calculated.

1.2 Mooring Assessment

1.2.1 Mooring analysis

Ship-to-unit mooring loads are to be calculated by means of a direct analysis to be carried out with recognized software.

1.2.2 Model tests

With the exemptions specified below, the software is to be calibrated and verified by model tests.

In case of tandem transfer operations, the Society may accept, on a case by case basis, that model tests are not carried out, taking into account the possible available documentation for similar designs.

1.2.3 Society's attendance to model tests

The Society may require that the model tests are attended by a Surveyor of the Society, on a case by case basis. To this scope, the Society is to be provided, well in advance of the execution of the model tests, with:

- a detailed description of the testing laboratory, with the specification of previous experience for the same model tests,
- the technical specification of the model tests program,
- the methodology of the software validation through experimental results.

1.2.4 Agreement on the overall methodology

In any case, the overall methodology for the ship-to-unit mooring analysis (sample of shuttle carriers to be considered, model tests, numerical calculations and software verification) is to be agreed with the Society at the first phase of the design.

2 Mooring Analysis

2.1 Units and mooring data

2.1.1 The following information are to be provided, as a minimum requirement, in order to assess the ship-to-unit mooring analysis:

a) description of the mooring system of the unit with the seabed,

b) ship-to-unit mooring system:
   - mooring arrangement,
   - detailed description of mooring fittings, mooring lines, fenders (mechanical characteristics and geometrical description),

c) unit:
   - loading conditions during ship-to-unit transfer operations,
   - characteristics of weight distribution (moments of inertia) in the various loading conditions,

d) for each shuttle carrier considered in the analysis:
   - general characteristics,
   - lines plans,
   - loading conditions during ship-to-unit transfer operations,
   - characteristics of weight distribution (moments of inertia) in the various loading conditions,
   - mooring fitting arrangement.

2.2 Design conditions for ship-to-unit mooring

2.2.1 The design limit environmental conditions for ship-to-unit mooring operations are to be specified.

The following information on the design meteomarine conditions are to be provided for the specific location:

- wave height,
- wave period (range or maximum),
- wave spectrum,
- wind speed,
- current speed,
- directionality information for wind, wave and current.

The data assumed for the mooring analysis are to be consistent with the data provided in the meteomarine analysis report.

The design performances in terms of allowable failures of the mooring system are to be specified by the Designer.

2.3 Loads

2.3.1 The loads on the system caused by the following primary factors are to be taken into account for the mooring analysis:

- static loads (ex. pretension in mooring lines),
- wind,
- current,
- waves (slow frequency and wave frequency motions).

The analysis is to cover all the most critical cases envisaged, according to the design meteomarine conditions for ship-to-unit operations. The effects of wind, current and waves, considered as acting simultaneously are to be considered, according to [2.2].

2.4 Analysis methods

2.4.1 The analysis is to reproduce as close as possible the actual behaviour of the system during its operative life, considering mechanical and hydrodynamic issues. In general, fully coupled, non linear, time domain simulations are required. Simplifications may be accepted by the Society, on a case by case basis.

Hypotheses assumed and simplifications done are to be clearly indicated and explained.

A sensitivity analysis is to be performed in order to check the robustness of the calculations.

Assessments and calculations considering the allowable failure of mooring fittings and mooring lines are to be carried out, when operations in such conditions are envisaged in the design conditions.

A clash study in order to avoid any collision between the unit and the shuttle carrier is to be carried out.

Additional analyses may be required by the Society, when deemed necessary on the basis of the system and unit characteristics.

2.5 Presentation of the results

2.5.1 Ship-to-unit Mooring Analysis report is to include, at least:

- a detailed description of the software for the calculation and the associated theory,
- a description of the hydrodynamic and mechanical models,
- a calibration and comparison with model tests (or with previous experience, when acceptable),
- RAO's of the vessels motions, with input parameters specification in case of non-linear/linearized analysis, and Quadratic Transfer Function of the unit,
- environmental data and wind/current combination matrix,
- assumptions and simplifications,
- a description of additional viscous damping, if applicable,
- statistics of the results (motions, velocities, accelerations, tensions on the lines and loads on the fenders),
- spectral analyses of the results,
- time histories of the results.

3 Model tests

3.1 General

3.1.1 When required, according to [1.2.2], model tests are to be carried out to calibrate and verify the numerical model and the software used for the mooring analysis.

The model scale of the test is to be chosen in order to avoid, as much as possible, any scale effect.

3.2 Documentation required

3.2.1 The following documentation is to be provided to the Society:

- model test evaluation,
- model test data and technical specification,
- model test results.

Part B
Hull and Stability

Chapter 9
MOORING SYSTEM (ANCHORING)

SECTION 1 GENERAL

1 Application

1.1 General

1.1.1 The structural requirements of this Chapter apply to devices pertaining to the mooring system which are devoted to the mooring function and are interested by the transmission of mooring loads. Such structures are located between the sea bed foundations (excluded, being covered by provisions of Ch 10) and the structural reinforcements or the mooring equipment (included), depending on the arrangement of mooring system, interfacing the unit and the mooring system itself.

The application also covers the load carrying mechanical components of turrets but excludes piping, machinery and electrical devices.

1.1.2 Other types of mooring systems not covered by present Chapter will be specially considered.

2 Definitions

2.1

2.1.1 Spread Mooring: an offshore system for mooring the unit at a fixed site based on multiple catenary mooring lines anchored to piles or drag anchors at the sea bed. The other end of each line is individually attached to winches or stoppers on the unit through fairleads as necessary. The spread mooring maintains the unit on an approximately fixed heading.

2.1.2 Single Point Mooring (SPM): an offshore system for mooring the unit at a fixed site based on a single tower or a single buoy. A SPM system allows the unit to weathervane.

The system, which includes the stiffening structures on the unit, the articulated system which anchors the unit to the sea-bed and the foundation and/or anchoring system, may be associated with the transfer of oil or gas to and from the unit.

A SPM system can be arranged in one of the following types:

- **CALM**: catenary anchor leg mooring system consisting of a large buoy anchored by catenary mooring lines. The installation is moored to the buoy by single or multiple soft hawsers or a rigid Yoke structure
- **SALM**: single anchor leg system consisting of an anchoring structure with built-in buoyancy at or near the water surface and itself anchored to the sea bed by an articulated connection.
- **Turret mooring**: system consisting of a number of mooring legs attached to a turret that is designed to act as part of the installation, allowing only angular relative movement of the installation to the turret. The turret may be mounted internally within the installation or externally from the installation bow or stern. Typically, a spread mooring arrangement connects the turret to the seabed.

2.1.3 York arm: a Yoke arm is a structure connecting one end of the installation to a SPM that allows only angular relative movement between the installation and the mooring attachment to the sea bed. A Yoke is normally employed for permanently moored units.

2.1.4 Mooring buoys: a floating mooring device constrained by flexible tethers to the sea bed.

2.1.5 Mooring hawser : a mooring rope permanently connecting the unit to a single point mooring or buoy.

2.1.6 Splash zone: portion of the installation between the following heights measured from the sea bottom:

a) sea depth plus the maximum tide and 65% of the wave height having recurrence frequency equal to 0,01;

b) sea depth minus the minimum tide and 35% of the above wave height.

3 Structure design principles

3.1 General

3.1.1 Mooring system shall be designed so as to minimize its sensitivity to environmental factors and to operational demands and so as to make easier its construction and inspection.

3.1.2 The design of the mooring system as a whole and of its components shall be such as to avoid that normal operational conditions be adversely affected by vibrations of structures.

3.1.3 Mechanical components shall be designed in compliance with international recognized Codes and Standards.

3.1.4 Supplementary Codes or Standards used for the design of the mooring system shall be previously submitted to the Society for approval.

3.1.5 Secondary structures such as fenders, gangway ladders, mooring eye-bolts, etc. shall be designed such as to avoid that their possible failure, due to accidental overloading, may result in damages to primary structures of the mooring system and to personnel.

3.1.6 Connections and structural joints shall be designed so as to avoid, as far as practicable, complex structures and sharp section variations which may give rise to dangerous stress concentrations. The transfer of normal tensile stresses through the plate thickness is also to be avoided as far as practicable.

3.1.7 Mooring systems constructed to operate in locations where extremely low ambient temperature may be encountered shall be designed adopting solutions such as to minimize ice accumulation on structures and machinery.

3.1.8 Buoys and buoyant devices in general are to be adequately compartmented by watertight divisions in order to have sufficient stability.

3.2 Materials

3.2.1 Material grades of the mooring system are to be in compliance with Ch 4 Sec 1; structural categories and material Classes, as defined in Ch 4 Sec 1, are to be applied in connection with Tab 1 and [3.2.2].

Table 1 : Application of material classes and grades in mooring system

Structural member category	Material Class
SECONDARY	I
PRIMARY	II
SPECIAL	III

3.2.2

In addition to provisions of Ch 4, Sec 1, the following categorization applies to structural members of the mooring system.

SECONDARY members:

- walkways
- guard rails
- minor fittings and attachments

PRIMARY members:

- turret bearing support structure
- supporting structures to external turret
- external shell plating of turret
- swivel gantry support structure
- chain tables
- anchor line fairleads and chain stoppers and their supporting structures
- heavy substructures and equipment supports

SPECIAL members:

- structure in way of critical load transfer points which are designed to receive major concentrated loads in way of mooring systems, including Yokes and similar structures, and supports to hawsers to mooring installations including external hinges, complex padeyes, brackets and supporting structures
- intersections of structures which incorporate novel construction including the use of steel castings
- highly stressed structural elements of anchor-line attachments.

3.2.3

Chains are to be of offshore Grades R3, R3S, R4, R4S and R5 are to comply with Pt D, Ch 1, Sec 2, [1.1.2].

4 Design loads

4.1 General

4.1.1 The following loads are to be considered for the scantlings of the mooring system, as appropriate:

- mooring loads arising from the mooring analysis described in Ch 5, App 3. The maximum values from the dynamic analysis are to be adopted for the final design of the system; quasi static loads might be adopted for early design scope,
- local static and dynamic sea pressures, defined in accordance with Ch 5, Sec 5 or Ch 8 Sec 1, as applicable
- gravity loads and internal forces, as defined in Ch 5, Sec 6
- hull girder loads, as defined in Ch 5, Sec 6, where applicable for the scantlings of structures in main hull constituting the interface with the mooring system.

4.1.2 Design loads are to be applied in the worst combination to which the system may be subjected during the life of the unit, including transit.

4.1.3 Due account is to be given to wave slamming and accidental loads, like impact with floating objects (ice blocks, etc.).

4.1.4 Proper cyclic loads, corresponding to dynamic components of applicable loads are to be accounted where fatigue analysis is required, on a case by case basis. Local vibrations caused by vortex shedding according to Pt E, Ch 4, Sec 2 [3.4.5] shall be considered, where appropriate.

4.1.5 For systems using the SALM arrangement, the loading conditions with one broken line is not relevant and the damaged condition is to be described by considering loss of buoyancy due to damage in a compartment.

5 Scantlings

5.1 General

5.1.1 Structural checks to be carried out in general for the verification of structural scantlings of mooring systems and its attachment to the unit are yielding, buckling and fatigue checks.

5.1.2 Due consideration is to be given to the detail design in fatigue sensitive areas like turret structures including structural supports in way of bearings and highly stressed structural elements of mooring line attachments, chain stoppers and supporting structures, mooring arms, articulated and sliding joints.

5.2 Net scantlings

5.2.1 Turret structures and Yoke arms

For structural members within the "splash zone" as defined [2.1.6], all scantlings are net i.e. the thickness reduction due to corrosion is to be considered.

The amount of such reduction is to be decided case by case depending on the specific environmental factors, the materials used and the arrangements adopted for corrosion prevention, but in no case it is to be assumed less than 5 mm.

For elements located above the mean still water level the above mentioned reduction may be shortened up to zero, provided that in the Operating Manual periodical maintenance of the splash zone protective coating is foreseen which is suitable in the opinion of the Society for preventing coating deterioration and the protective coating is not subject to removal risks due to impacts or abrasions.

5.2.2 Anchor lines

Scantling assessment of anchor lines is to be based on net values. The values of corrosion margins based on current industry standards (refer for example to API RP 2SK) might be adopted and applied to anchor lines with respect to the service life of the installation.

6 Protection against corrosion

6.1 General

6.1.1 Provisions for protections against corrosion of the mooring system are given in Ch 12, Sec 1.

6.1.2 For permanent systems, corrosion of wire ropes at connection to sockets is to be prevented: it is recommended that either the wire be electrically isolated from socket or that the socket be isolated from the adjacent component.

SECTION 2 TURRET STRUCTURES AND YOKE ARMS

1 General

1.1

1.1.1 Provisions of this chapter apply to the structures of the turret or Yoke arm fitted on a single point mooring arrangement and to the supporting structures at the interface of such components with the main hull of the installation.

2 Arrangement

2.1

2.1.1 A cofferdam or equivalent has to be fitted between turret spaces and cargo tanks. A pump room, void space or water ballast tank might be adopted in lieu of a cofferdam.

2.1.2 Adequate arrangements for inspection during service of turret/Yoke structures and mechanical components are to be provided. A planned inspection scheme is to be also provided.

2.1.3 The primary hull strength of the unit is to be maintained in way of turret openings and suitable compensation is to be fitted, as necessary. Continuity of primary structural elements has to be maintained as far as practicable in way of turret/Yoke openings and mooring support structure.

2.1.4 Proper arrangement shall be given at ends of longitudinal and well side bulkheads. In general, bulkheads are to be connected to bottom and deck girders by means of large, suitably shaped brackets in such a way to optimize stress distributions at their connections with girders and bulkheads.

2.1.5 The structural arrangement in way of the turret/Yoke mooring system interface is to be capable of withstanding the loads transmitted from the mooring systems to the unit and has to be adequately reinforced.

3 Scantlings

3.1

3.1.1 The requirements of this Article apply for the strength check of plating, ordinary stiffeners and primary supporting members.

3.2 Structural model

3.2.1 Local scantlings of structural elements of the turret system subject to lateral pressure loads are in general to be analysed according to the provisions and checking criteria defined in Ch 7, or Ch 8, as applicable.

Plates and ordinary stiffeners are to be checked also with respect to wave slamming loads, according to provisions and checking criteria of Ch 8 Sec 1.

3.2.2 Global strength due to global response of the system subject to mooring loads is to be assessed according to the provisions and checking criteria defined, in Pt B, Ch 7, App 1 of the Rules for the Classification of Ships and provisions in [3.3] by means of direct calculation with three-dimensional beam models or finite element models.

3.2.3 For units fitted with an internal turret, due consideration is to be given to bottom slamming in transit condition to avoid possible damage to the turret supports and bearings.

3.3 Finite Element model

3.3.1 A Finite Element model of the turret/Yoke and its integration with the hull is to be constructed for yielding, buckling and fatigue assessment.

3.3.2 The Finite Element has to extend to a reasonable distance of the installation to minimize the effects due to the boundary conditions.

3.3.3 In general for turret installations such extension shall be identified as follows:

- For turrets arranged at fore end of the unit, the model will extend longitudinally from the fore end of the unit up to, at least, a section immediately abaft the after end of the closer cargo tank. The model can be considered fixed at its aft end.
- For turrets arranged at aft end of the unit, the model will extend longitudinally from the aft end up to, at least, a section immediately forward the fore end of the closer cargo tank. The model can be considered fixed at its fore end.
- For turret arranged internally to the hull of the unit, a three cargo holds model according to the provisions of Pt B, Ch 7, App 1 of the Rules for the Classification of Ships is to be constructed, with the turret positioned in the central tank of the model

3.3.4 For arrangements with Yoke arms, the model extension shall be evaluated on a case by case basis.

3.4 Plating and ordinary stiffeners

3.4.1 Load model for local strength

The following loads are to be considered:

- the still water and wave sea pressures, defined in accordance with Ch 5 Sec 5 or Ch 8, Sec 1 or Ch 8, Sec 2, as applicable
- installations in fore part: the bow impact pressure, in exposed areas, defined in accordance with Ch 8 Sec 1 [4.3].

3.4.2 The internal pressures, if any, are to be defined in accordance with Ch 5, Sec 6.

3.4.3 Sea pressure and bow impact pressure are to be considered mutually exclusive.

3.4.4 Load model for global strength

The following loads are to be considered, as appropriate:

- the mooring loads, see Sec 1 [4.1.1]
- gravity loads due to uniform and/or concentrated loads (non-structural parts, equipment, etc.), in accordance with Ch 5, Sec 6.

3.4.5 The Internal pressures, if any, are to be defined in accordance with Ch 5, Sec 6.

3.4.6 For buckling checks of plating and ordinary stiffeners contributing to the global strength of the turret, global stresses due to global response shall be obtained by direct FEM analysis (see [3.3]).

3.5 Fatigue

3.5.1 Permissible damage factors η for fatigue checks of structural elements pertaining to turret/Yoke, to be carried out according to Ch 7, Sec 2, [5.1.1], are in general to be taken as:

- 0.33 for not accessible details
- 0.5 for accessible details within and below the splash zone
- 1.0 for accessible details above the splash zone.

4 Bearings

4.1 Arrangement

4.1.1 The turret bearing support structure is to be integrated into the hull structure.

4.1.2 The mooring loads and loads applied to the external turret structure have to be efficiently transferred through its bearing system into the unit. In general in turret arrangements, a roller bearing is located near the installation deck level, and radial sliding bearing is located near the keel of the installation.

4.2 General

4.2.1 Bearings are to be selected according to industrial standards and proven Manufacturers' design recommendations; a report showing the bearing design and the compliance with Manufacturer's requirements in terms of service loads, installation, maintenance, etc. is to be submitted for approval.

4.2.2 The time interval N, in years, between two subsequent bearing replacements is to be such that the bearing is able to properly operate for a time not less than that shown in Tab 1.

Table 1

Bearing location	Accessibility for inspection and repair	Required time
Above the "splash zone"	Accessible	N years
	Not accessible	3N years
Within and below the "splash zone"	Accessible	3N years
	Not accessible	10N years

SECTION 3 EQUIPMENT FOR MOORING AND ANCHORING

1 Anchors

1.1 General

1.1.1 Anchors employed in mooring systems are to be of an approved type and are to be in accordance with the provisions of Pt D, Ch 4, Sec 1 [1] of the Rules for the Classification of Ships and Pt D, Ch 1, Sec 2 [1]. Either drag embedment anchors or plate anchors (vertically loaded drag anchors - VLA) can be adopted for the anchoring arrangement on the specific field. Different anchor arrangement will be subject to special consideration.

1.2 Holding capacity, penetration and drag

1.2.1 The ultimate holding capacity (UHC) of a drag anchor in a particular soil condition is the maximum steady pull which can be resisted by the anchor at continuous drag.

1.2.2 Proper data regarding UHC, penetration and drag of drag anchors are to be submitted by the Designer, reflecting the anchor performance in the specific soil and based on empirical design data for the specific anchor. Due account will be given to previous applications of the anchor under similar conditions.

1.2.3 The results of analytical predictions of anchor performance might be used to complement the anchor selection, provided that the reliability of such methods is demonstrated against experience.

1.2.4 Exact holding power is to be determined after the anchor is deployed and test loaded in accordance with [1.4.1].

1.3 Foundations

1.3.1 Anchor foundations are to be in accordance with Ch 10, Sec 4.

1.4 Proof test on field

1.4.1 All anchors have to be test loaded at installation field to the satisfaction of Tasneef Surveyor. The proof test load has to be equal to the maximum mooring load in intact condi-tion as per Sec 1, [4.1] and has to be maintained for a mini-mum duration of 30 minutes. The test load is not however to exceed 50% of the minimum breaking strength of the anchor line.

2 Anchor lines

2.1 General

2.1.1 Anchor lines fitted in the mooring system can be realized through either chain cables, steel wire ropes or fibre ropes.

2.2 Arrangement

2.2.1 Adequate clearances from subsea devices are to be assured.

2.2.2 Suitable device is to be fitted on the mooring system for detecting eventual tension loss.

2.2.3 Installation of the mooring line should include precautions to be followed in order to avoid possible twisting of the chains during installation.

2.3 Strength principles

2.3.1 Chains fitted in the mooring system are to be in compliance with the provisions of Pt D, Ch 4, Sec 1, [2] or Pt D, Ch 4, Sec 1, [3] of the Rules for the Classification of Ships as applicable.

2.3.2 Steel wire ropes fitted in the mooring system are to be in compliance with the provisions of Pt D, Ch 4, Sec 1 [4] of the Rules for the Classification of Ships.

2.3.3 Fibre ropes fitted in the mooring system are to be in compliance with the provisions of Pt D, Ch 4, Sec 1, [5] of the Rules for the Classification of Ships.

2.4 Factor of safety

2.4.1 Factors of safety of anchor lines, defined as the ratio between the minimum breaking strength and the maximum line tension, have to be in compliance with Tab 1.

Table 1 : Factors of safety of anchor lines

	Intact condition	Damaged condition
Quasi-static	2,0	1,43
Dynamic	1,67	1,25

2.5 Fatigue

2.5.1 Fatigue assessment of mooring lines is to be carried out according to recognized method and is to be submitted for approval.

The T-N approach is to be applied in general (for example method in API RP 2SK), giving the number of cycles to failure for the mooring component as a function of constant normalized tension range, based on fatigue test data and regression analysis.

The Miner's Rule is to be used to calculate the cumulative fatigue damage.

2.5.2 Permissible damage factors η for fatigue checks of mooring lines, to be carried out according to Ch 7, Sec 2, [5.1.1], are in general to be taken as:

- 0,33 for inspectable areas
- 0,1 for non inspectable and critical areas.

3 Chain stoppers

3.1 Strength principles

3.1.1 Chain stoppers used in the mooring system and supporting structure are to be capable of withstanding a load not less than the breaking strength of the chain.

3.1.2 Permissible damage factors η for fatigue checks of chain stoppers, to be carried out according to Ch 7, Sec 2, [5.1.1], are in general to be taken as:

- 0,33 for inspectable areas
- 0,1 for non inspectable and critical areas.

4 Fairleads and cable stoppers

4.1 Arrangement

4.1.1 Arrangement and design of fairleads and cable stoppers are to be such to prevent excessive bending and wear of the anchor lines.

4.2 Strength principles

4.2.1 Design load is equal to the maxim design load of the mooring line or to the minimum breaking strength of the anchor line, as applicable.

A minimum wrap angle equal to 90° has to be applied for strength assessment.

4.2.2 Diameter of wire rope fairleads is in general to be not less than 16 times that of the wire rope.

4.2.3 Diameter of chain fairleads is in general to be not less than 7 times that of the chain.

5 Hawsers

5.1 Arrangement

5.1.1 Flexible arrangements using mooring hawsers can be adopted for connecting the unit to the buoy in CALM and SALM arrangements.

5.2 Strength principles

5.2.1 Mooring hawser and chafe chain assemblies are to be built in accordance with recognized Standards (for example by OCIMF).

5.2.2 Minimum breaking strength of the hawser is to be not less than 2 times the maximum mooring load.

5.2.3 In case two separate hawser lines are fitted, running to two separate fairleads, the minimum breaking strength of each hawser is to be not less than 1.5 times the maximum mooring load.

Part B
Hull and Stability

Chapter 10
FOUNDATIONS

SECTION 1 GENERAL

1 General

1.1 Investigation on location

1.1.1 The requirements of this Chapter apply to pile, gravity and anchor foundations.

The design of foundations is to be based on information taken from the actual location, considering an area of sufficient extent to take account of tolerances due to errors in positioning the platform during the investigations and the installation.

1.1.2 The results of investigation on location are to be submitted to the Society for consideration and are to include:

a) information on when the investigation was carried out and by whom;

b) comprehensive description of equipment and procedures used for field and laboratory investigation;

c) results of the above investigation;

d) critical examination of possible sources of errors and limitations in the applicability of the results.

1.1.3 For each platform to be installed, a sea bed investigation is to be carried out for the purpose of revealing the presence of natural obstructions (rocks, deposits, etc.) or other types of obstructions (anchors, wrecks, etc.), the soil waviness height and the possible occurrence of sand dune displacements or sea bed alterations.

1.1.4 The investigation on location is to be sufficiently extensive to include all the soil layers and rock deposits which may influence the behaviour of the platform foundation.

The investigation may be carried out by one or a combination of the following principal methods:

a) geophysical methods;

b) in site tests;

c) borings with sampling for laboratory tests.

The investigation is to supply data for the classification and description of deposits and parameters to be used in the check calculations for the most important soil layers.

1.2 General design principles

1.2.1 General

The analysis of foundations is to aim to prevent their total failure and local overstressing of members of the base structure.

The possibility of excessive deformations is to be independently evaluated.

Any type of analysis is to take account of scour.

The calculations are to cover both the installation and operation phases.

1.2.2 Characteristic properties of soil

The characteristic properties of each layer of soil are to be carefully evaluated on the basis of the results of in site and laboratory tests, taking account of stress conditions in the sample during the tests and of the actual stress conditions in the layer considered.

1.2.3 Effects of pulsating loads

Where deemed necessary, the influence of load fluctuations on the soil properties is to be evaluated.

The effects of wave induced forces are to be considered for the following conditions:

a) a design storm during the installation phase and the consolidation period;

b) the 100-year storm;

c) the cumulative effect of several storms, including the 100-year storm.

Realistic assumptions are to be made regarding the duration and intensity of such storms.

In the case of platforms installed in seismically active areas, the possible deterioration of soil properties due to the cyclic characteristic of the seismic actions is to be taken into consideration.

Such deterioration generally results in a reduction of shear strength of soil, which is to be considered in the design.

1.2.4 Stability

The soil stability is to be evaluated by one of the following methods:

a) an effective stress stability analysis based on effective strength parameters of the soil and realistic estimates of the pore water pressures in the soil. Such method requires laboratory shear tests with pore pressure measurements;

b) total stress stability analysis based on total shear strength of the soil evaluated on representative soil samples which are to be subjected, as far as practicable, to the same loading conditions as corresponding elements in the soil.

1.2.5 Settlements and displacements

This Settlements and displacements analysis is generally to consider:

a) initial and secondary settlements;

b) differential settlements;

c) permanent horizontal displacements;

d) dynamic motions due to load fluctuations.

The evaluation of settlements of structures is essential for the design of foundation piles, risers, etc.

The tilt of the platform consequent to differential settlements of the foundation system, due to variations in the soil characteristics and/or preferential direction of application of external loads, is not to exceed the tilt which can be allowed for the serviceability and safety of the platform.

1.2.6 Soil-structure interactions

The evaluation of sectional forces and moments, as well as of dynamic motions in the members of the foundation system, is to be based on an integrated analysis of the soil-structure interaction.

The analysis is to be based on realistic assumptions regarding the soil stiffness and the transfer to the soil of loads from structural members resting on the sea bed or penetrating into it.

1.3 Stability of sea bed

1.3.1 Slope stability

The analysis of slope stability is to consider the natural slopes, those due to the installation or the presence of the platform, the possible future variations of existing slopes during the design life and the effects of wave loads on the sea bed.

The slope stability is to be carefully evaluated in the presence of layers of soft clays and loose deposits of silt or sands as well as in seismically active geographic areas.

1.3.2 Hydraulic stability

In the case of platforms whose foundations are on soils subject to erosion and softening (reduction in the modulus of elasticity due to fluctuating loads), the possibility is to be analysed of:

a) reduction of soil bearing capacity due to hydraulic gradients and seepage forces;

b) formation of piping channels and consequent erosion in the soil;

c) local surface erosion in areas under the foundation due to hydraulic pressure variations resulting from environmental loads.

1.3.3 Scour

The risk of scour around the foundation is always to be taken into account, unless it can be proved that the foundation soil is not subject to scour for the expected range of water particle velocities.

To prevent the effects of scour, one of the following measures is to be taken:

a) materials placed around the platform as early as possible after the installation;

b) foundation system designed considering all materials which are not resistant to scour as having been removed;

c) direct inspection of sea bed close to platform foundations and provision of suitable means to quickly stop the development of any scour detected.

Materials placed on the sea bed to prevent scour are to have adequate weight and dimensions, such that they are not removed by currents and that they prevent soil erosion though without impairing the draining of overpressure caused on the layers by the loads imposed.

SECTION 2 PILE FOUNDATIONS

1 General

1.1

1.1.1 In the design of piles for foundations it is necessary to take account of the method used for their installation.

Where the transfer of loads from one pile to another or from a pile to the foundation soil is achieved by grouting, the surfaces are to be free from rust scales or other imperfections which may reduce the capacity of load transfer.

The design pile penetration is to be sufficient to provide adequate capacity to withstand the design compressive and tensile loads with an adequate safety coefficient.

The ultimate bearing capacity of piles may be evaluated in accordance with the requirements of [2], [3] and [4] or by other recognised methods. The allowable bearing capacity is obtained by dividing the total ultimate bearing capacity by a safety factor which is to be not less than

- 1,5 for combined loads in damaged conditions;
- 2,0 for combined loads in intact conditions.

The design bearing capacity of piles is to be limited to penetrations which have proved to be consistently obtained by experience; before installation, alternative solutions are also to be foreseen to be applied where design penetration cannot be obtained.

2 Axial bearing capacity of piles

2.1

2.1.1 Ultimate bearing capacity

The ultimate bearing capacity of pile Q, in kN, is given by the equation:

$$Q = Q_s + Q_p$$

where:

Q_s : skin friction resistance of pile, in kN, equal to:

$$\sum f_i \cdot A'_{si}$$

Q_p : total end bearing capacity of pile, in kN, = the lower of:

$$q \cdot A_p$$

and

$$q \cdot \pi / 4 \cdot (D_e^2 - D_i^2) + \sum f_i \cdot A'_{si}$$

f_i : unit skin friction capacity in the i layer, in kN/m²;

A_{si} : external side surface area of pile in the i layer, in m²;

q : unit end bearing capacity of pile, in kN/m²;

A_p : gross end area of pile, in m²;

D_e : pile end external diameter, in m;

D_i : pile end internal diameter, in m;

A'_{si} : internal side surface area of pile in the i layer, in m².

In determining the ultimate bearing capacity of piles, consideration is to be given, when appropriate, to the weight of pile-soil plug system and to hydrostatic uplift.

Where a pilot hole is drilled, its end bearing area is to be discounted in computing the area A_p.

As a rule, for pile-bell systems the skin friction resistance of a portion of pile above the bell-shaped area having length of 3 pile diameters is to be neglected.

If the pile is laterally loaded by cyclic loads and deformations imposed on the soil are rather high (higher than the quantity y_c defined in [4.1.2]), the friction resistance relevant to those layers of soil affected by such deformations is to be reduced or annulled.

2.1.2 Skin friction and end bearing capacity of piles in clay soils

a) For piles driven through clay, the unit skin friction capacity f is generally not to exceed the values given in Tab 1 as a function of the undrained shear strength of the clay soil, c.

For piles driven in undersized drilled holes or jetted (drilled by jetting of fluid under pressure) holes and for drilled and grouted piles in normally consolidated clay soils, f values are to be determined by reliable methods based on the evaluation of soil disturbance resulting from installation.

In any case, the values given in Tab 1 are not to be exceeded.

For drilled and grouted piles in over-consolidated clay soils, f values may exceed those given in Tab 1.

In this case, careful consideration is to be given to the strength of the soil-grout and grout-pile skin interfaces (see item [7]) also in relation to the amount and quality of drilling mud used.

b) The unit end bearing capacity of piles in clay soils q, in kN/m², may be determined, in general, by the equation:

$$q = 9\,c$$

Special consideration is to be given where the value of the shear strength of the soil in layers under the end of piles changes in an uneven way.

Table 1

c (kN/m²)	f (kN/m²)
$c \le 24$	$f = c$
$24 < c < 72$	$f = \left(1,25 - \frac{c}{96}\right) \cdot c$
$c \ge 72$	$f = 0,5\ c$

2.1.3 Skin friction and end bearing capacity of piles in sandy and silty soils

The unit skin friction capacity f, in kN/m², of piles driven in sandy and silty soils may be determined by the following equation:

$$f = K \cdot p_o \cdot tg\delta$$

where:

K : coefficient of lateral soil pressure;

p_o : effective overburden pressure of soil round pile, in kN/m²;

δ : friction angle between the soil and pile wall, in degrees.

Such f values may be adopted even for piles driven in drilled and grouted holes.

For piles driven in undersized drilled holes or jetted holes, f values are to be determined by reliable methods based on the evaluation of soil disturbance resulting from installation and are not to exceed those for driven piles.

The unit end bearing capacity of piles q, in kN/m², in sand and silt soils may be determined by the following equation:

$$q = p_o\ N_q$$

where:

N_q : bearing capacity factor.

K coefficient varies between 0,5 and 1 with the increase of the grade of sand density, while δ and N_q values depend on the angle of internal friction of soil Φ in degrees, in accordance with data given in Tab 2.

For deep foundations, f and q values may be lower than those given above.

For layered soils, N_q may be limited to values lower than those given in Tab 2 and are to be determined on the basis of considerations regarding the local soil conditions.

Table 2

SOIL TYPE	Φ (°)	δ (°)	N_q
Clean sand	35	30	40
Silty sand	30	25	20
Sandy silt	25	20	12
Silt	20	15	8

2.1.4 Skin friction and end bearing capacity of piles grouted in rock

a) The unit skin friction capacity f, in kN/ m², of grouted piles in rock may theoretically have an upper limit equal to the shear strength of the rock or of the grout. In actual fact, the f value may be reduced considerably in relation to the installation procedure and to the type of rock or of drilling fluid used.

   An upper limit of f value for this kind of pile may be given by the allowable bond stress between the pile wall and the grout mentioned in [7].

b) The end bearing capacity of the rock is to be determined from the shear strength of the rock itself and an appropriate bearing capacity factor, but in any case it is not to exceed 10000 kN/m².

3 Pile capacity for axial pullout loads

3.1

3.1.1 The ultimate axial pullout capacity of pile is not to exceed the total skin friction of pile Q_s.

The effective weight of the pile, including the soil plug and hydrostatic uplift, is to be considered.

For clay soils, the unit skin friction capacity f is to have the same values given in [2.1.2].

For sandy and silty soils, the same considerations given in [2.1.3], are applicable, except that K = 0,5 is to be used.

For rock, see [2.1.4].

The safety factors applicable to the ultimate axial pullout capacity of pile are to be the same as those given in [1.1.1].

4 Lateral resistance of pile

4.1

4.1.1 General

The behaviour of the soil-pile system subjected to lateral loads is to be analysed on the basis of realistic relationships which relate the deformations to the soil reactions.

Such relationships, generally represented by (p-y) (soil reaction lateral deflection) curves, are characteristic of the type of soil, pile dimensions and loading application conditions (static, cyclic or impact loads).

The (p-y) curves may be constructed using the results of laboratory tests on soil samples; the influence of scour in proximity to the sea bottom and the disturbance caused by pile installation on the soil characteristics are to be taken into account.

In the absence of criteria which are more appropriate to the individual practical cases, the (p-y) curves may be constructed according to indications given in [4.1.2] and [4.1.3].

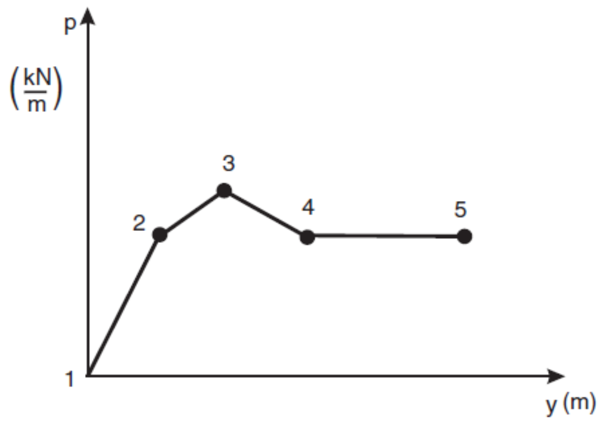
4.1.2 (p-y) curves for clay soils

a) For soft clay soils, the (p-y) curve for the layer of soil located at a depth z, in m, from the sea bottom may be represented by the broken line shown in Fig 1, generated by the values specified in Tab 3.

b) For stiff clay soils (c >10 kN/m²) and for static loads, the same considerations in item a) above are applicable.

Instead, for cyclic loads a rapid deterioration of soil characteristics occurs due to high deformations, which result in considerable reduction of ultimate resistance p_u of soil.

Figure 1



4.1.3 (p-y) curves for sand soils

The (p-y) curve of the layer located at depth z is as shown in Fig 2 generated by abscissa and ordinate of the points u, m and k, which may be computed as follows:

point u:

$$\begin{cases} y_u = \frac{3}{80}D \quad (m) \\ p_u = A \cdot p_c \ (kN/m) \end{cases}$$

where:

D : pile diameter, in m

A : empirical coefficient according to Fig 3

p_c : to be taken equal to p_{cs} if $z \le z_t$ or equal p_{cu} if $z > z_t$, in kN/m

$$p_{cs} = \gamma \cdot z\left[\frac{k_o \cdot z \cdot tg\Phi \cdot sen\beta}{tg(\beta - \Phi) \cdot cos\alpha} + \frac{tg\beta}{tg(\beta - \Phi)}(D + z \cdot tg\beta \cdot tg\alpha) + \right.$$
$$\left. + k_o \cdot z \cdot tg\beta(tg\Phi \cdot sen\beta - tg\alpha) - k_a \cdot D\right]$$

$$p_{cp} = D \cdot \gamma \cdot z[k_a \cdot (tg^8\beta - 1) + k_o \cdot tg\Phi \cdot tg^4\beta]$$

z_t : depth below soil surface to bottom, obtained when p_{cs} is equal to p_{cp}, in m;

γ : effective specific gravity of sand (in water), in kN/m³;

Φ : angle of internal friction of sand, in degrees;

α : $\frac{\Phi}{2}$ in degrees;

β : $45 + \frac{\Phi}{2}$ in degrees;

k_o : 0,4;

k_a : $tg^2\left(45 - \frac{\Phi}{2}\right)$

point m:

$$\begin{cases} y_m = \frac{1}{60}D \quad (m) \\ p_m = Bp_c \quad (kN/m) \end{cases}$$

B being an empirical coefficient according to Fig 4.

point k:

determined by the intersection of the two lines given by the equations:

$$p = K\ z\ y \quad (kN/m)$$

$$p = C\ y^{1/n} \quad (kN/m)$$

where:

K : coefficient depending on the grade of sand density, given in Tab 4:

$$C = \frac{p_m}{y_m^{1/n}}$$

$$n = \frac{p_m}{m \cdot y_m}$$

$$m = \frac{p_u - p_m}{y_u - y}$$

Therefore, the abscissa and ordinate of point k are:

$$y_k = \left(\frac{C}{K \cdot z}\right)^{\frac{n}{n-1}} \quad (m)$$

$$p_k = K \cdot z \cdot y_k \quad (kN/m)$$

For some combinations of the parameters involved, the K value may result in a deflection y_k greater than y_m, in which case the parabolic portion of the (p-y) curve is to be omitted.

Table 3

Static load		
Point	p / p_u	y / y_c
1	0	0
2	0,5	1,0
3	0,75	3,0
4	1,00	8,0
5	1,00	∞
Cyclic load for $z \geq z_R$		
Point	p / p_u	y / y_c
1	0	0
2	0,5	1,0
3	0,72	3,0
$4 \equiv 5$	0,72	∞
Cyclic load for $z \leq z_R$		
Point	p / p_u	y / y_c
1	0	0
2	0,5	1,0
3	0,72	3,0
4	$0{,}72\ z / z_R$	15,0
5	$0{,}72\ z / z_R$	∞

Note 1:

yc, in m, is given by the following equation:

$yc = 2{,}5 \cdot \varepsilon_c \cdot D$

where:

- D : pile diameter, in m;
- ε_c : strain which occurs at one half the maximum stress on laboratory undrained compression tests of undisturbed soil samples;
- z_R : depth of reduced strength zone, in m, given by the following formula:

$$z_R = \frac{6D}{\frac{\gamma D}{c} + J}$$

where:

- γ : effective specific gravity of soil (in water), in kN/m³;
- c : undrained shear strength of soil, in kN/m²;
- J : empirical coefficient, whose values are between 0,5 and 0,25 (in the absence of reliable information, 0,25 is to be used);
- p_u : ultimate soil resistance, in kN/m (force/unit length of pile), given by the following formulae:

$$p_u = \left(\frac{6c}{z_R} \cdot z + 3c\right) \cdot D \qquad \text{for } z \leq z_R$$

$$p_u = 9 \cdot D \cdot c \qquad \text{for } z > z_R$$

5 Group effects

5.1

5.1.1 The axial and lateral bearing capacity of a group of piles depends on several factors such as pile spacing, type and strength of soil, sequence of soil layers, pile installation method, etc.

The knowledge on this subject is rather limited and therefore the strength calculation of the group is to be carried out on the basis of conservative assumptions, due consideration being given to the possibility that the actual spacing of piles is less than that assumed for the design due to a non-perfect installation.

Where more reliable data are not available, the following considerations are applicable:

a) the end bearing capacity of the group in homogeneous soils may be taken equal to the sum of the single pile contributions;

b) the skin friction capacity of the pile group is to be taken equal to the sum of the single pile contributions multiplied by a reduction factor R, given by the following formula:

$$R = \frac{p}{\sum_{i=1}^{N} \pi \cdot D_i}$$

p : external perimeter of the group, in m

D_i : diameter of the i-pile, in m

N : number of the piles.

Such a reduction is required in any case for sandy soils, while it may be neglected for clay soils when the ratio of the minimum spacing of piles to the pile diameter exceeds the value 0,785 ($N^{0,5}$ + 1).

If R > 1, is to be assumed R = 1.

Table 4

DENSITY	K (kN/m³)
loose	5400
medium	16300
dense	33900

Figure 2

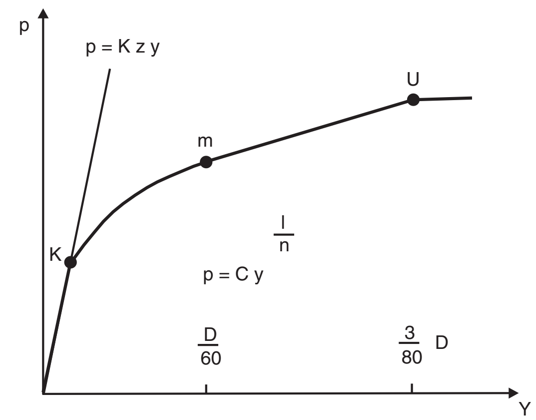


Figure 3

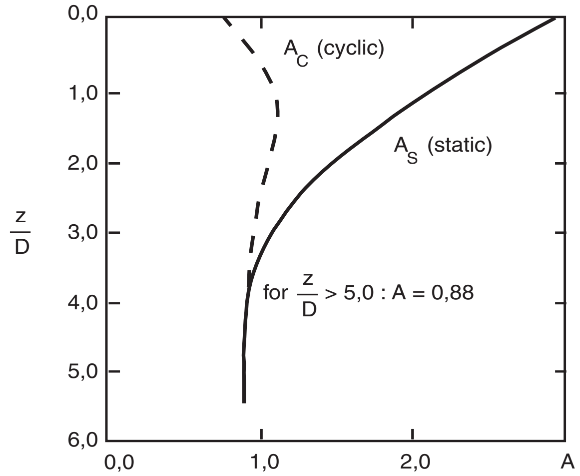
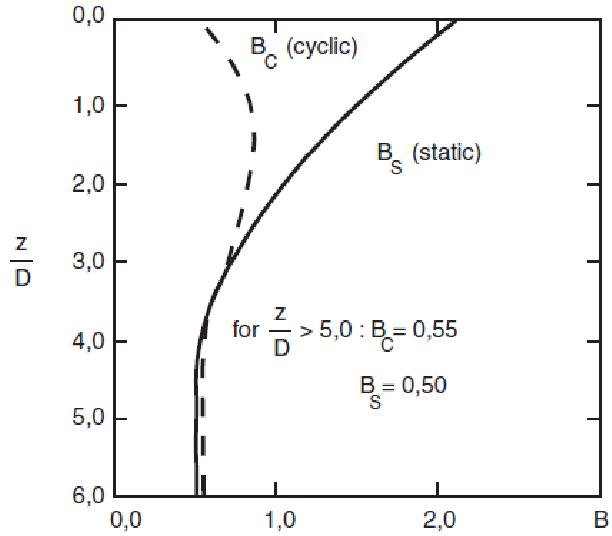


Figure 4



6 Pile design

6.1

6.1.1 Structural analysis

The foundation pile is to be analysed on the basis of loads imposed by the platform and those due to its installation.

a) As regards the loads imposed by the platform, the analysis is to consider the maximum values of axial and lateral loads and the actual restraint conditions of the soil.

The soil lateral reactions are to be represented by the (p-y) curves mentioned in [4], due account being taken of scour effects.

The transfer of the axial load from pile to soil may be assumed as proportional to the friction resistance between them, divided by the safety factors specified in [1.1.1], taking into account the provisions of [2.1.1] regarding the high deformations due to cyclic lateral loads.

In general, the instability analysis of the pile is not required unless there are justified reasons for considering that the pile is without lateral support on account of considerable scour phenomena, the presence of particularly yielding soils, high calculated lateral deformation, etc.

b) The structural analysis of the pile during the installation phase is to include realistic evaluation of stresses induced by the various systems used.

In particular, for driven piles it is necessary to consider the static loads due to driving equipment weight and dynamic loads induced during driving operations, due attention being paid to bending moment caused by axial load eccentricity and to lateral deformation of the pile, magnified when high resistance layers are encountered or when the blow frequency of the hammer approaches the natural frequency of the pile-hammer elastic system.

6.1.2 Scantlings

a) The D/t ratio of pile diameter to thickness is to be such as to preclude the possibility of occurrence of local buckling during the installation operations and the operation life of the foundation.

For guidance, it can be specified that the D/t ratio for piles driven in high strength soils is to comply with the following formula:

$$t \geq 6,35 + \frac{D}{100}$$

where:

D : pile diameter, in mm

t : pile wall thickness, in mm

b) In general, the pile wall thickness is not constant for the entire length of the pile, but varies with the anticipated stress level, which is normally highest in the portion close to the sea bed. It is recommended that the heavy wall thickness of the pile is extended for a reasonable length to take account of the two possibilities of not achieving the foreseen penetration or of being compelled to exceed it in order to reach a layer with high bearing capacity.

c) It is recommended that the end of the pile is provided with a driving shoe having a thickness increased by 50% in respect of that mentioned in item a) above.

7 Bonding between pile and structure

7.1

7.1.1 Platform loads are generally transferred to foundation piles by filling the annulus between the pile and relevant housing in the structure by cement grout in such a way that the axial load transferred by the structure to the pile is transferred through the bond action between the pile surface and the cement grout.

Instead, the lateral force results in a compression of the cement grout annulus whose effect is generally negligible.

7.1.2 The bonding action between pile and cement grout (and between cement grout and pile housing) is affected by several factors, such as:

a) type of cement grout (cement, water, additives, etc.);

b) temperature;

c) method of installation;

d) movements of platform while the cement grout is setting.

7.1.3 In general, in the absence of reliable data on the subject concerned, the tangential stress, obtained by dividing the axial load acting on the pile by the surface on which the bonding force is developed, is not to exceed 140 kN/m^2, for combined loads in damaged condition, and 184 kN/m^2, for combined loads in intact condition.

Such value may be increased when special grouts are used ensuring a better bonding strength, on the basis of significant tests carried out.

Where mechanical devices are provided to avoid the pile axial load being transferred by friction between steel and cement grout only, for instance by fitting welded circumferential rings between the outer surface of pile and the inner surface of its housing, it will be necessary to verify the connection taking into account the geometry realised and the compressive strength of the portion of the grout close to the rings

SECTION 3 GRAVITY TYPE FOUNDATIONS

1 General

1.1

1.1.1 Gravity type foundations are characterised by a low ratio of the maximum penetration depth to the horizontal extent of the foundation base.

The design of such type of foundation is to include consideration of the following:

a) stability;

b) static deformation;

c) hydraulic instability;

d) dynamic behaviour;

e) installation feasibility.

2 Stability

2.1

2.1.1 General

The foundation system is to ensure stability in respect of overturning, bearing capacity and lateral resistance.

2.1.2 Overturning

The ratio of the moment of righting forces to that of overturning forces acting on the platform and computed at the extreme position of possible application points of soil reaction resultant is generally to exceed 1,3.

Different values of such ratio, justified by particular requirements or conditions, will be specially considered.

The righting and overturning moments are to include all loads acting on the platform in their most unfavourable combination which may be reasonably presumed.

The extreme position of possible application points of soil reactions is to be evaluated according to the provisions in [2.1.3]. In particular, for platforms resting on several perimetrical foundation bases, the possible application points of the resultant of soil reactions may be assumed to be located within the polygon whose vertices are the single base centres.

2.1.3 Bearing capacity and sliding resistance

The bearing capacity and sliding resistance of the foundation system are to be evaluated considering the following:

a) the shape of the foundation base;

b) loads acting on the foundations and their variation over time;

c) characteristics of sea bottom;

d) geophysical characteristics of the soil layers concerned;

e) possible rupture surfaces in the soil in relation to measures adopted against sliding (see Fig 1);

f) possible softening phenomena in the soil due to alternating loads;

g) pore pressure variation corresponding to the actual stress level of the soil.

Where conditions given in [4], occur, the analysis may be performed by the bearing capacity formulae which give the values of ultimate horizontal and vertical loads leading to the collapse of foundation soil.

Such method of analysis may include the following two cases:

- undrained analysis;
- drained analysis.

The first type of analysis applies when loading and its variation occur so rapidly that no drainage and hence no dissipation of excess pore pressure occur.

Such type of analysis, also called "short-term analysis", considers the angle of internal friction of the soil $\Phi = 0$ and the undrained shear strength of the soil c is essentially involved.

Where, on the contrary, the rate of loading is sufficiently slow, complete drainage occurs and excess pore pressures are not developed.

In this ("long-term") condition, the behaviour of the soil is controlled by its friction angle Φ' and by the cohesion intercept c' of the Mohr-Coulomb effective stress failure envelope.

2.1.4 Undrained analysis

a) The maximum bearing capacity Q, in kN, is given by the following formula:

$$Q = (c\, N_c\, K_c + \gamma\, d) \cdot A'$$

where:

c : undrained shear strength of soil, in kN/m^2;

N_c : dimensionless constant equal to 5,14 for $\Phi = 0$;

Φ : angle of internal friction of undrained soil to be taken equal to 0, in degrees;

γ : total unit weight of soil, in kN/m^3;

d : penetration depth of foundation, in m;

A' : effective area of the foundation depending on the load eccentricity (see App 1), in m^2;

K_C : correction factor which accounts for load inclination, shape of footing, penetration depth, and inclination of the foundation base and of ground surface (see App 1).

In the quite frequently encountered cases of:

- vertical centric load
- horizontal foundation base
- horizontal sea bed,

the above formula may be reduced as follows:

1) for infinitely long rectangular footing, the bearing capacity per unit length Q_o, in kN/m, may be given by the simplified formula:

   $Q_o = 5{,}14 \cdot c \cdot A_o$

   A_o being the actual foundation area per unit length, in m^2/m

2) for circular or square footing, the bearing capacity Q_o , in kN, may be given by the simplified formula:

   $Q_o = 6{,}17 \cdot c \cdot A$

   A being the actual foundation area, in m^2.

b) The maximum horizontal soil reaction at failure H, in kN, is given by the following formula:

   $H = c \cdot A$

2.1.5 Drained analysis

The maximum bearing capacity Q', in kN, is given by the following formula:

$$Q' = \left(c' \cdot N_c \cdot K_c + q' N_q \cdot K_q + \frac{1}{2} \cdot \gamma' \cdot B \cdot N_\gamma \cdot K_\gamma\right) \cdot A'$$

where:

c' : effective cohesion intercept of Mohr-Coulomb envelope, in kN/m^2;

N_c : $(N_q - 1) \cdot \text{cotg}\,\Phi'$ (see Fig 2);

N_q : $e^{\pi \cdot tg\Phi'} \cdot tg^2\left(45° + \frac{\Phi'}{2}\right)$

N_γ : $2(N_q + 1) \cdot tg\Phi'$

Φ' : effective friction angle of Mohr-Coulomb envelope, in degrees

γ ' : effective unit weight of soil (in water), in kN/m^3

q : $\gamma' \cdot d$, in kN/m^2

d : penetration depth of foundation, in m

B : minimum lateral foundation dimension, in m

A' : effective area of foundation (see App 1), in m^2

K_c, K_q, K_γ: correction factors (see App 1).

Also in this case, in the presence of soil having c' = 0 (sand) and of applied centric load, simplified formulae may be used, as follows:

a) for infinitely long rectangular footing, the bearing capacity per unit length Q_o in kN/m, may be expressed by the formula:

   $Q_o = 0,5 \cdot \gamma' \cdot B \cdot N_\gamma \cdot A_o$

b) for circular or square footing, the bearing capacity Q, in kN, may be expressed by the formula:

   $Q = 0,3 \cdot \gamma' \cdot B \cdot N_\gamma \cdot A$

   where A_o and A have the same meaning specified in [2.1.4].

The maximum drained horizontal soil reaction at failure H, in kN, is given by the formula:

$H = c' \cdot A + Q \cdot tg\Phi'$

while the maximum horizontal reaction H' which can be supplied by soil in correspondence with the actual vertical load V acting on the footing is given by:

$H' = c' \cdot A + V \cdot tg\Phi'$

2.1.6 Safety factors

The foundation system is to have an adequate margin of safety against failure under the design loading conditions.

In general such margin may be given by the safety factors in Tab 1.

Table 1

Type of failure	Safety factor
bearing failure	2,0
sliding failure	1,5

Such values are to be used after cyclic loading effects have been taken into account and may be increased when geotechnical data are particularly uncertain.

2.1.7 Filling of voids

To ensure sufficient platform stability, filling of voids between the platform structure and the sea bed may be necessary. In such case the stresses induced by filling pressures are to be kept within acceptable limits.

The materials used for filling are to be capable of maintaining sufficient strength during the whole design life of the platform under the deteriorating effects of repeated loads, chemical action and possible defects in the placement of filling materials themselves.

3 Static deformations

3.1

3.1.1 The evaluation of possible short-term and long-term deformations is to be performed by recognised methods deemed appropriate by the Society.

It is very important to determine such deformations for the safety both of the structural members of the platform and of the components which pass through the contact surface between the foundation base and ground (risers, etc.) or which join the sea bed to the platform itself (pipelines, etc.).

For the condition where the structure base is circular, rigid, subject to static loads or to loads which may be considered as static, and rests on isotropic and homogeneous soil, the short-term (undrained) deformations may be evaluated by the following formulae:

$$u_v = \frac{1 - \nu}{4 \cdot G \cdot R} Q$$

$$u_h = \frac{7 - 8 \cdot \nu}{32 \cdot (1 - \nu) \cdot G \cdot R} \cdot H$$

$$\vartheta_f = \frac{3 \cdot (1 - \nu)}{8 \cdot G \cdot R^3} \cdot M$$

$$\vartheta_t = \frac{3}{16 \cdot G \cdot R^3} \cdot M_t$$

where:

u_v , u_h : vertical and horizontal deformations, in m;
Q, H : vertical and horizontal loads, in kN;
ϑ_f , ϑ_t : overturning and torsional rotations, in rad;
M, M_t : bending and torsional moments, in kN m;
G : elastic shear modulus of the soil, in kN/m^2;
ν : Poisson's ratio of the soil;
R : radius of the base, in m.

These formulae may also be used for square base of equal area.

4 Limits of application of the formulae for the determination of the bearing capacity

4.1

4.1.1 The application of the formulae for the determination of the bearing capacity is subject to the following limiting conditions:

a) homogeneous, isotropic and fully plastic soil;
b) low ratios of horizontal to vertical loads;
c) low torsional stress levels;
d) regular foundation geometry;
e) presence of suitably spaced skirts so that, if lateral instability occurs, a horizontal failure plane in the soil is ensured rather than a failure at the base structure-soil interface.

Where the above conditions are not satisfied, more conservative methods of analysis and increased safety factors are to be used or more refined techniques are to be adopted, such as:

- limit analysis to determine bounds on collapse loads and relative sensitivity of collapse loads to parameters of interest;
- numerical analysis such as finite differences or finite elements;
- properly scaled model tests such as centrifuge tests.

Special consideration is also to be given to the effects of cyclic loading on pore pressures and to the possibility that soil softening may occur.

5 Hydraulic instability

5.1

5.1.1 This type of foundation failure may occur in the presence of soils which are easily subject to erosion and softening.

The risks of reduction of bearing capacity due to hydraulic gradients, with consequent seepage (i.e. constant flow of water through pores), of formation of piping channels, with consequent erosion of soil beneath the foundation, and of scour are to be considered.

To prevent erosion beneath the foundation, scour skirts may be provided penetrating through erodible layers and extending their influence up to those layers which are not subject to erosion.

As far as scour around the edges of the foundation is concerned, the considerations in Sec 1, [1.3.3] are applicable.

Figure 1 : Schemes of some possible failure modes of soil due to sliding

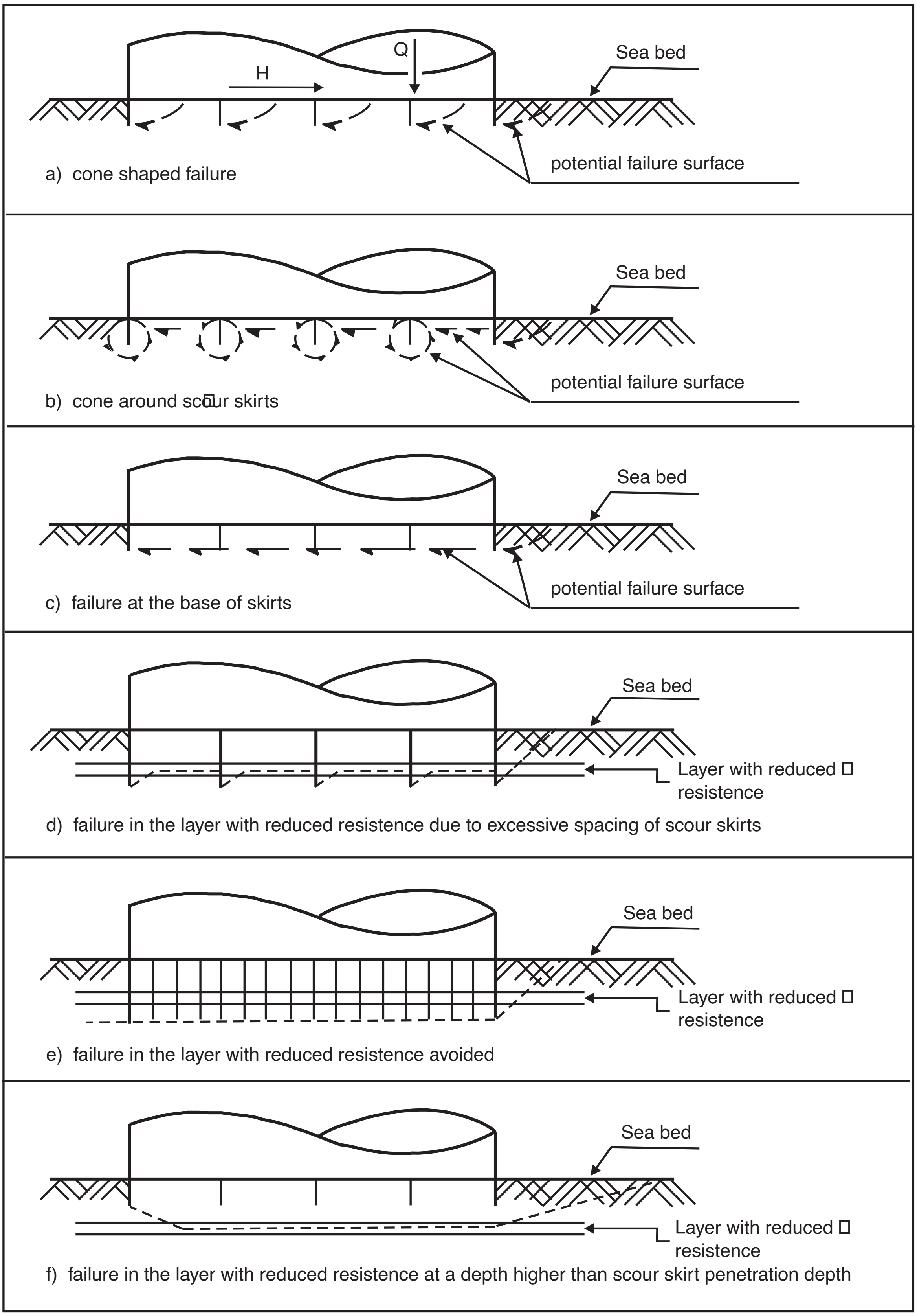
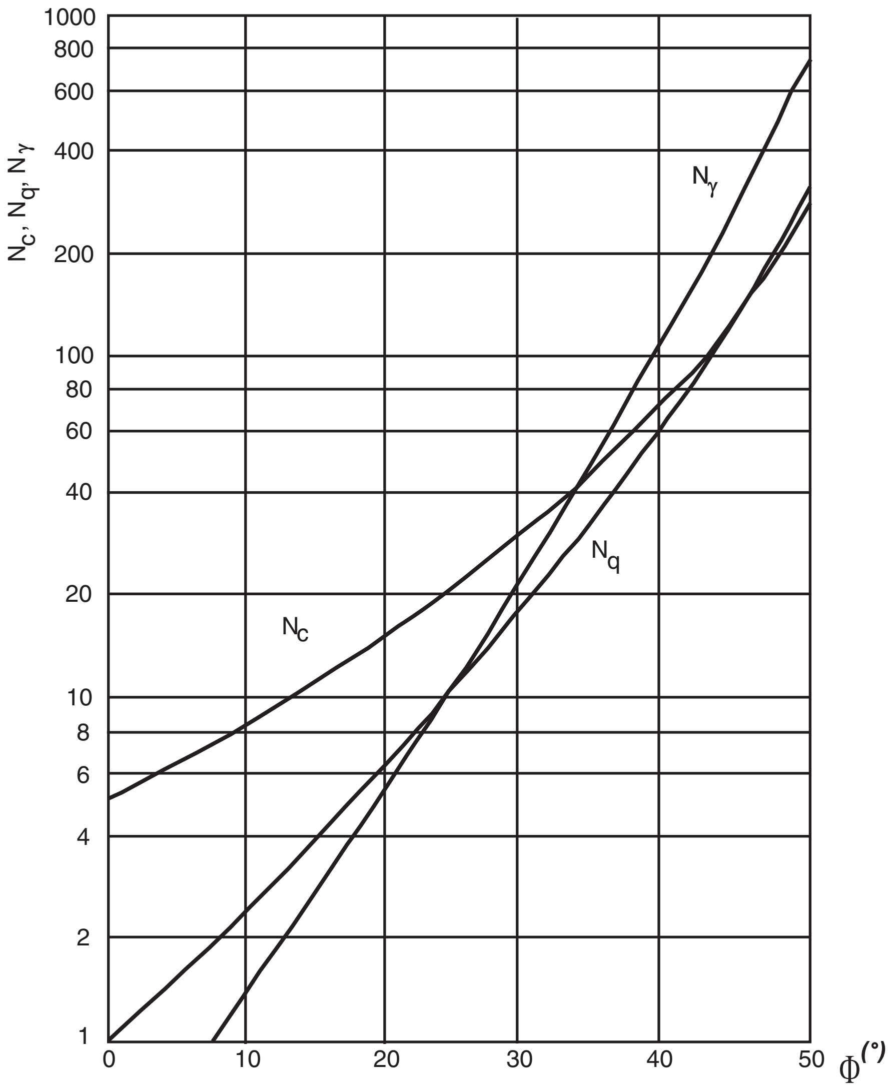


Figure 2 : Bearing capacity factors



6 Dynamic behaviour

6.1

6.1.1 The construction of a model which satisfactorily represents the dynamic behaviour of gravity foundations, when the stress level is quite low, is generally performed by the continuous "half space" approach, which is based on the assumption of linear elastic behaviour of the soil considered as homogeneous.

In real cases of anisotropy, of layered soil with energy radiated from the footing reflected by the interfaces between the layers and, especially, of non-linearity of stiffness and damping characteristics of soil and their frequency dependence, more appropriate analyses are required.

7 Installation feasibility

7.1

7.1.1 The gravity foundations are frequently provided with scour skirts to improve stability and prevent scour and with dowels (hollow pipes of large diameter) to facilitate orienting and positioning operations.

The estimate of resistance to penetration of these devices is of great interest for the purpose of scantlings of the ballasting system, so that proper installation of the structure base on the sea bed can be ensured.

For its determination it is necessary to identify the soil layers by means of soil samples and laboratory tests and to measure by a cone penetrometer the average resistance to penetration among the values obtained by tests carried out on various soil layers.

7.1.2 The resistance to penetration R, in kN, of scour skirts is given by their end resistance and skin friction resistance, and is calculated by the following formula:

$$R = K_P(d) \cdot A_P \cdot q_c(d) + A_S \int_0^d K_f(z) \cdot q_c(z) \cdot dz$$

where:

z : depth of the soil layer under consideration, in m;

d : penetration depth, in m;

K_p : empirical coefficient relating to end resistance;

K_f : empirical coefficient relating to skin friction;

q_c : resistance to penetration measured by cone penetration, in kN/m^2;

A_p : end area of scour skirt, in m^2;

A_s : skin area of scour skirt per unit penetration depth, in m^2/m.

The empirical coefficients K_p and K_f may be selected in Tab 2, which are the highest expected values of the resistance to penetration.

For penetration depth lower than 1 to 1,5 m, the values shown in Tab 2 should be reduced by 25 to 50 per cent due to local piping or lateral movements of the platform.

Table 2

Type of soil	K_p	K_f
Clay	0,6	0,05
Sand	0,6	0,003

SECTION 4 ANCHOR FOUNDATIONS

1 General

1.1

1.1.1 Anchor foundation system can be of based on one of the following types:

- traditional drag embedment anchor
- plate anchor (drag embedded or direct embedded)

The ultimate holding capacity (UHC) of a drag embedment anchor in a particular soil condition is the maximum horizontal steady pull that can be resisted by the anchor at continuous drag.

Plate anchor system is in general to be preferred to traditional drag embedment anchors in all cases where deeper penetration into the seafloor and high vertical holding capacity are required.

The ultimate pull-out capacity (UPC) of plate anchor is defined as the load at failure for the soil around the anchor, the exceedance of which determines the plate anchor to start moving through the soil.

The UPC is governed by the soil undrained shear strength at the anchor fluke, projected area of the fluke, fluke shape, bearing capacity factor and penetration depth.

The bearing capacity factor has to be based on test data from reliable sources and from any investigations and references for such type of anchors, the effect of capacity reduction factors is to be accounted for the disturbance of the soil due to soil failure mode.

Penetration depth of plate anchors is in general in the range of 2 to 5 times the fluke width, depending on the undrained shear strength of the soil, in order to generate a deep failure mode. If the final depth does not generate a deep failure mode, a suitable reduction in bearing capacity factor is to be adopted.

Anchor creep under long-term static loads and the effect of cyclic loading shall be taken into account by reducing the actual anchor capability.

1.1.2 After the installation, the anchoring system is to be subjected to a load test in accordance to Ch 9, Sec 3, [1.4.1].

1.1.3 The penetration depth of anchors shall be checked after the installation. The position of anchors on the seabed, to verify their possible shifting, shall be periodically checked, in particular after the first period of service of the mooring system and following to severe sea conditions encountered by the structure.

2 Safety factors

2.1

2.1.1 Anchor foundation is to have an adequate margin of safety against failure under the design loading conditions; values of safety factor, defined as the ratio of the anchor holding capacity and the maximum anchor load, are in general to be in accordance with those reported in Tab 1 and Tab 2 for drag anchors and plate anchors respectively.

Higher safety factors of drag embedded plate anchors respect to drag anchors are due to the different failure mode: in case of overloading, drag anchors have the general tendency to proceed dragging and further penetrate, without generating additional holding capacity, differently from plate anchor for which overloading causes pullout. For plate anchors that exhibit similar overloading behaviour as drag anchor, consideration may be given to using drag anchor safety factors, provided that such behaviour is verified by significant field tests and experience.

Table 1 : Safety factors for drag embedment anchor foundations

	Quasi-static analysis	Dynamic analysis
Permanent mooring	-	• 1,0 for damaged condition • 1,5 for intact condition
Mobile mooring	1,0	0,8

Table 2 : Safety factors for plate anchor foundations

	Quasi-static analysis	Dynamic analysis
Permanent mooring	-	• 1,5 for damaged condition • 2,0 for intact condition
Mobile mooring	-	• 1,2 for damaged condition • 1,5 for intact condition

APPENDIX 1 DETERMINATION OF PARAMETERS RELATING TO THE FORMULAE FOR THE BEARING CAPACITY

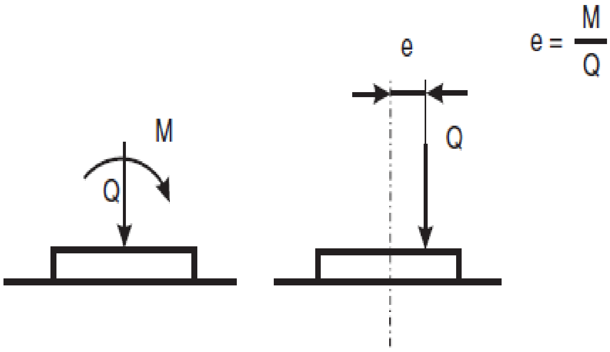
1 Effective area and correction factors

1.1 Effective area

1.1.1 Load eccentricity in respect of the geometrical axis of the footing leads to the decrease of the bearing capacity of the foundation.

This effect is accounted for through the reduction of the actual area of the footing by introducing an effective area A', function of the load eccentricity e, which is defined as the ratio of the bending moment M to the vertical load Q acting on the foundation (see Fig 1).

Figure 1



For rectangular base area of length L, in m, and width B, in m, and load eccentricity e, having components e_1 and e_2 along the length and width, respectively, the following results (see Fig 2):

$$A' = L' \cdot B' \qquad (\text{in } m^2)$$

where:

$$L' = L - 2e_1 \qquad (\text{in m})$$

$$B' = B - 2e_2 \qquad (\text{in m})$$

For circular base with radius R and load eccentricity e, the following results (see Fig 2):

$$A' = 2\left[R^2 \cdot \text{arc cos}\left(\frac{e}{R}\right) - e\sqrt{R^2 - e^2}\right]$$

where arc cos (e/R) is expressed in radians.

1.2 Correction factors

1.2.1 Correction factors K_c, K_q and K_γ are usually written:

$$K_c = i_c\ s_c\ d_c\ b_c\ g_c$$

$$K_q = i_q\ s_q\ d_q\ b_q\ g_q$$

$$K_\gamma = i_\gamma\ s_\gamma\ d_\gamma\ b_\gamma\ g_\gamma$$

where i, s, d, b and g are individual correction factors related to load inclination, foundation shape, penetration depth, base inclination and ground surface inclination, respectively.

Their recommended values are:

a) Inclination factors

$$\left.\begin{aligned} i_q &= \left[1 - \frac{H}{Q + B' \cdot L' \cdot c \cdot \text{cotg}\Phi}\right]^m \\ i_\gamma &= \left[1 - \frac{H}{Q + B' \cdot L' \cdot c \cdot \text{cotg}\Phi}\right]^{m+1} \end{aligned}\right\} \qquad \Phi > 0$$

$$i_c = i_q - \frac{1 - i_q}{N_c \cdot \text{tg}\Phi} \qquad \Phi > 0$$

$$i_c = 1 - \frac{mH}{B' \cdot L' \cdot c \cdot N_c} \qquad \Phi = 0$$

where:

- H : projection of the load resultant on the plane of the footing, in kN
- m : $m_L \cdot \cos^2\vartheta + m_B \cdot \text{sen}^2\vartheta$

where:

$$m_L = \frac{2 + \dfrac{L'}{B'}}{1 + \dfrac{L'}{B'}} \qquad m_B = \frac{2 + \dfrac{B'}{L'}}{1 + \dfrac{B'}{L'}}$$

- ϑ : angle between the longitudinal axis of the footing and the direction of H
- N_c : (see Sec 3, [2.1.4])

b) Shape factors

- Rectangular base

$$s_c = 1 + \left(\frac{B'}{L'}\right) \cdot \left(\frac{N_q}{N_c}\right)$$

$$s_q = 1 + \left(\frac{B'}{L'}\right) \cdot \text{tg}\Phi$$

$$s_\gamma = 1 - 0,4 \cdot \frac{B'}{L'}$$

N_q : (see Sec 3, [2.1.5]).

- Circular base with centric load:

$$s_c = 1 + \frac{N_q}{N_c}$$

$$s_q = 1 + \text{tg}\Phi$$

$$s_\gamma = 0,6$$

For circular base with eccentric load, the formulae for an equivalent rectangular base are to be used.

c) Depth factors

$$d_q = 1 + 2 \cdot tg\Phi(1 - sen\Phi)^2 \cdot \frac{d}{B'}$$

$$d_\gamma = 1,0$$

$$d_c = d_q - \frac{1 - d_q}{N_c\ tg\Phi}$$

d) Base and ground surface inclination factors

$$\left.\begin{aligned} b_q &= b_\gamma = (1 - \alpha\ tg\Phi)^2 \\ b_c &= b_q - \frac{1 - b_q}{N_c\ tg\Phi} \end{aligned}\right\} \quad \Phi > 0$$

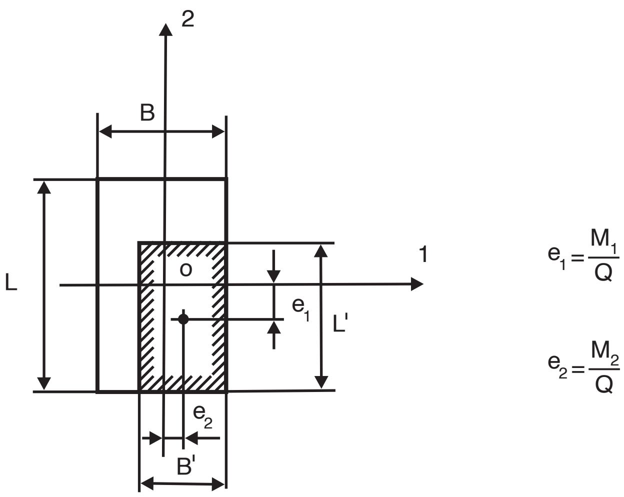
$$b_c = 1 - \frac{2\alpha}{N_c} \qquad \Phi = 0$$

$$\left.\begin{aligned} g_q &= g_\gamma = (1 - tg\beta)^2 \\ g_c &= g_q - \frac{1 - g_q}{N_c\ tg\Phi} \end{aligned}\right\} \quad \Phi > 0$$

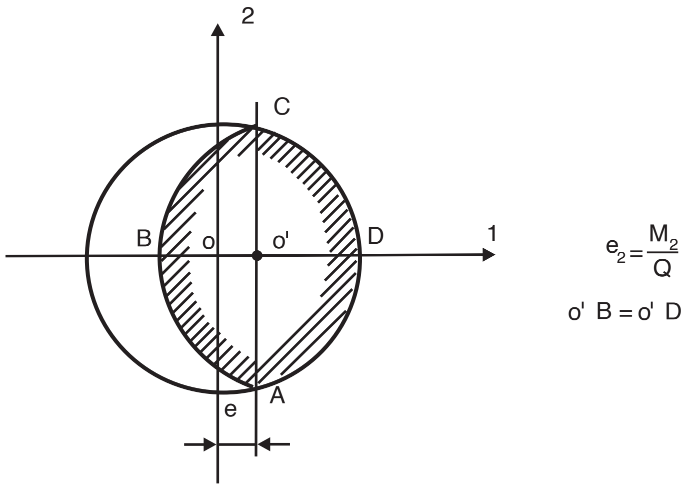
$$g_q = 1 - \frac{2\beta}{N_c} \qquad \Phi = 0$$

where α and β are base and ground inclination angles, in radians, in respect of the horizontal axis.

Figure 2 : Footings with eccentric load



Reduced base area for rectangular base



Reduced base area for circular base

Part B
Hull and Stability

Chapter 11
TOPSIDE STRUCTURES AND LOADING ARMS

SECTION 1 GENERAL

1 Application

1.1 General

1.1.1 The structural requirements of this Chapter apply to topside structures (deck mounted topside modules and loading arms) and their attachment to the hull.

Other types of topside structures not covered by present Chapter will be considered on a case by case basis.

2 Arrangement

2.1 General

2.1.1 The design of process plant support structure and loading arms has to integrate with the primary hull underdeck structure.

2.1.2 Adequate underdeck reinforcements are to be provided in the way of the welded connections of the topsides support structure to the main hull. Special attention is to be given to alignment of primary members.

2.1.3 Appropriate measures shall be introduced to minimise the effects of green water on the topside structures, such as bow shape design, bow flare, bulwarks and other protective structure. Adequate drainage arrangements shall be provided.

2.1.4 Bulwark and guardrails fitted on topside structures up to the level corresponding to first tier of superstructure are to in compliance with requirements of Ch 8, Sec 3.

SECTION 2 TOPSIDE MODULES

1 Structure design principles

1.1

1.1.1 Sufficiently stiff arrangement is to be provided in order to prevent excessive deformations. In framed arrangements, the following checking criteria might be adopted, for maximum displacements:

- lateral deflection on top of module: H/500
- vertical deflection of horizontal members (supported at both ends): L/300
- vertical deflection of horizontal members (cantilevers): L/150

where:

H : overall height of the topside structure

L : span of horizontal member.

2 Design Loads

2.1

2.1.1 The following loads are to be considered for the scantlings of the topside structures, as appropriate

- loads due to production facilities (including self weights), as defined in Ch 5, Sec 6
- wind load, as defined in Ch 5, Sec 6
- green sea loads, as defined in Ch 8, Sec 4
- snow and ice loads, as defined in Pt E, Ch 4 Sec 2 [3.4.6] and [2.1.5]
- hull girder loads, as defined in Ch 5, Sec 6, where applicable (integration with the hull).

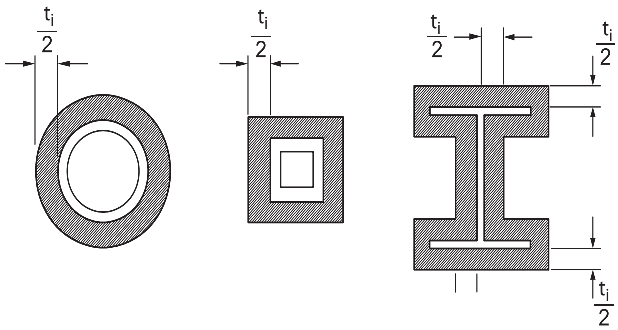
2.1.2 Design loads are to be applied in the worst combinations to which the structure may be subjected during the life of the unit, including transit.

2.1.3 Due account is to be given to functional loads due to process (like piping reactions, thermal loads, etc.) and hull girder displacements, where applicable, to be defined on a case by case basis.

2.1.4 Proper cyclic loads, corresponding to dynamic components of applicable loads are to be accounted in fatigue analysis, to be defined on a case by case basis.

2.1.5 The overall distribution of snow and/or ice on topside structure is to be taken as a thickness t_i on the upper and windward faces of the member under consideration, where t_i is the basic thickness obtained from the meteorological data. The distribution of ice on individual members may be assumed to be as shown in Fig 1.

Figure 1 : Assumed distribution of ice on individual members



2.2 Loading conditions of topside structures

2.2.1 Topside production facility modules are to be considered in wet-condition for on-site conditions and in dry-condition for transit.

2.2.2 All relevant loading conditions are to be assessed including those for lifting, mounting and removal of equipment, as deemed appropriate.

3 Scantlings

3.1 General

3.1.1 The structural checks to be carried out in general for the verification of structural scantlings of topside structures and their attachment to the hull are yielding, buckling and fatigue.

3.2 Materials

3.2.1

Material grades of the topside structures are to be in compliance with Pt B, Ch 4, Sec 1 of the Rules for the Classification of Ships; structural categories and material Classes, as defined in Pt B, Ch 4, Sec 1 of the Rules for the Classification of Ships, are to be applied in connection with Tab 1 and [3.2.2].

Table 1 : application of material classes and grades in topside structures

Structural Member Category	Material Class
SECONDARY	I
PRIMARY	II

3.2.2 The following categorization applies to structural members of the topside structures.

Main load bearing members and elements subjected to high tensile or shear stresses, like module's main frame members and deck support stools, are to be considered as PRIMARY members. All other structures are to be considered as SECONDARY members. Where fitted, foundation bolts are to be considered as PRIMARY members.

3.3 Net scantlings

3.3.1 All scantlings are net i.e. the thickness reduction due to corrosion is to be considered according to Ch 4 Sec 2.

3.3.2 Thickness reduction in topside structures may be shortened up to zero, provided that in the Operating Manual periodical maintenance of the protective coating is foreseen which is suitable in the opinion of the Society for preventing coating deterioration and the protective coating is not subject to removal risks due to impacts or abrasions.

3.4 Structural model

3.4.1 Local and global scantlings of structural elements of the topside structures subject to pressure loads are in general to be analysed according to the provisions and checking criteria defined in Ch 8, [3], [4] and [5]. In alternative or for other type of loads (i.e. concentrated forces), other recognized structural models according to linear-elastic theory might be adopted, subject to Society's approval.

3.4.2 The strength of the attachments of topside structures to the main hull is to be checked by direct calculation with three-dimensional beam models or finite element models in accordance with provisions of Pt B, Ch 7, App 1 of the Rules for the Classification of Ships and [3.5].

3.4.3 Due consideration is to be given to the detail design in fatigue sensitive areas like primary connections of the topside structures, integration with the hull and other connections subjected to significant dynamic loading.

3.4.4 Structural model and scantling check of tubular joints are to be performed according to the provisions of the Rules for The Classification of Steel Fixed Offshore Platforms, Ch 8, [4]. For fatigue analysis, stress concentration factors are to be calculated according to recognized Codes or Standards or by direct calculation.

3.5 Integration with the hull - Finite Element model

3.5.1 The Finite Element has to extend to a reasonable distance of the installation to minimize the effects due to the cut boundary conditions.

SECTION 3 LOADING ARMS

1 General

1.1 Arrangement

1.1.1 Detailed description of the whole system and all possible configurations including emergency conditions is to be provided together with the general arrangement and structural plans.

2 Structure design principles

2.1 General

2.1.1 Loading arms for liquefied gas have to comply with international Standard EN 1474 "Installation and equipment for liquefied natural gas - Design and testing of marine transfer systems", as amended. Application of other Codes or Standards will be subject to special consideration by the Society.

2.1.2 Risks of potential structural failures connected to installation, operation and maintenance of loading arms have to be identified by risk assessment methods conducted in accordance with the provisions in Pt C, Ch 7. Suitable structural analyses shall be undertaken, where deemed appropriate, to prove the safety of the design under such risks.

2.1.3 Suitable mechanical devices (swivel joints) are to be arranged on the loading arm for uncoupling the motions of the unit from those of the shuttle vessel, in such a way that any transmission of load (i.e. stress) between the two units does not occur throughout the arm.

2.1.4 When deemed necessary, the main dynamic response parameters from a mathematical model of arm's kinematic (rigid body) may be required by the Society.

3 Design Loads

3.1 General

3.1.1 In addition to loads defined in EN 1474 Standard, the following loads are to be considered:

- inertial loads due to motions of the unit, to be evaluated with ship-to-unit mooring analysis in accordance with Ch 8, App 1 and/or model testing
- green sea loads, as defined in Ch 8, Sec 4.

3.1.2 Due account shall be given to accidental loads and any transient condition which may give rise to elevated dynamic forces in operation and emergency.

4 Scantlings

4.1 General

4.1.1 Structural checks to be carried out in general for the verification of structural scantlings of mooring systems and its attachment to the unit are yielding, buckling and fatigue checks.

4.1.2 Load models, load cases and allowable stresses are to be applied in accordance with EN 1474.

4.2 Structural model

4.2.1 Local scantlings of structural elements of the loading arm subject to lateral pressure loads are in general to be analysed according to the applicable structural models defined in Ch 8 [3] and [4] in addition to requirements in [4.1.2].

4.2.2 Global response of the loading arm subject to loads defined in [3.1] is to be assessed by means of direct calculation according to the structural models defined in [4.3], in addition to requirements in [4.1.2].

4.3 Finite Element model

4.3.1 Finite Element analysis with three-dimensional beam models or finite element models in compliance with provisions in Pt B, Ch 7, App 1 of the Rules for the Classification of Ships, as applicable, is required for strength and fatigue checks of the structures of the loading arms and their integration with the main hull.

Part B
Hull and Stability

Chapter 12
CORROSION DETECTION AND LOADING INFORMATION

SECTION 1 CORROSION DETECTION

1 General

1.1 Application

1.1.1 All structural steel structures are to be suitably protected against corrosion by means, for example, of coating systems, corrosion allowances, cathodic protection or other methods which can be applied alone or in combination with others.

It is the responsibility of the shipbuilder and the Owner to choose the corrosion protection systems and have them applied in accordance with the manufacturer's requirements.

The selected protection system is to be suitable for the zone of structure to be protected.

2 Definition of the structures to be protected

2.1

2.1.1 The external structures can be divided in the following zones:

a) Submerged zone: part of the external structure below the maximum design operating draught.

b) Boot topping: part of the external structure between the maximum design operating draught and the light design operating draught.

c) Topside and superstructures: the part of the external structure above the boot topping zone.

2.1.2 The internal zones consist of ballast tanks, cargo tanks, liquid storage tanks and other compartments.

3 Internal zones

3.1 Coating systems

3.1.1 All salt water ballast tanks are to have a corrosion protective coating, epoxy or equivalent, applied in accordance with the manufacturer's requirements.

3.1.2 Corrosion protective coating is required for internal surfaces of spaces intended for the storage of products which may be corrosive.

3.1.3 In general, corrosion protective coating is not required for internal surfaces of spaces intended for the storage of cargo oil or fuel oil. Anyway, the effect of possible water deposit in the bottom of such tanks is to be considered.

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

3.1.5 In deep draught caisson units and other units with combined oil storage and ballast tanks which remain full during the service life of the unit, special consideration will be given to the requirement for internal corrosion protection of the tanks.

3.2 Cathodic protection

3.2.1 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. In this case, the coating system is to be compatible with the cathodic protection.

3.2.2 Details concerning the type of anodes used and their location and attachment to the structure are to be submitted to the Society for approval.

4 External zones

4.1

4.1.1 The external surface in the submerged zone is to be suitably protected by means of a cathodic protection system or of a combination of coating and cathodic protection systems.

Increased scantlings may be considered as supplementary protection system in special areas.

4.1.2 External surfaces in the boot topping, topside and superstructures zones are to be protected by means of a coating system.

5 Protection against galvanic corrosion

5.1

5.1.1 here connections between different types of metallic materials are foreseen in the structures, suitable insulation is to be provided in order to avoid galvanic corrosion. Insulation details are to be submitted for approval.

SECTION 2 RISER SYSTEMS

1 General

1.1

1.1.1 Riser systems are to be suitably protected against corrosion. It is recommended that this be achieved using a coating combined with a cathodic protection system. Account should be taken of possible temperature effects. Other equivalent methods of protection will be considered.

1.1.2 The boot topping zone of risers is to be specially considered. A corrosion allowance will be required in addition to any coatings. Risers in J-tubes, etc. will require separate assessment of protection.

1.1.3 Where the cathodic protection system is designed to compensate for loss of protective coating, the system should be based on an initial loss of coating of between 5 and 10 per cent. Due allowance should be made for further breakdown during the service life.

2 External coatings

2.1

2.1.1 Paint or protective coatings are generally to be chosen in conjunction with the system of cathodic protection.

2.1.2 The performance of the coating materials used should be proven by previous service or by extensive and documented laboratory testing.

2.1.3 Preparation of the riser surface before coating is to comply with the approved specification.

3 Internal protection

3.1

3.1.1 The method of internal protection is to take into account the corrosivity, bacterial content, solids/abrasive content, flow characteristics and temperature and pressure.

3.1.2 Materials or systems (e.g. liners) are to be evaluated against the service nature of the product to be conveyed. Relevant specifications and in-service history are to be submitted to the Society.

3.1.3 Where internal protection is proposed by use of corrosion inhibitors, the properties, compatibility and effect on product conveyed are all to be documented and submitted.

4 Cathodic protection systems

4.1

4.1.1 Cathodic protection systems are to comply with the requirements of Section 4.

4.1.2 Measurements of potential are to be taken and any deficiencies corrected by the addition of extra sacrificial anodes.

4.1.3 Measurements are to be taken to confirm that there is no over-protection.

4.1.4 Stray currents from ships, other vessels or installations in the vicinity are to be evaluated and appropriate measures taken.

SECTION 3 INFORMATION TO BE SUBMITTED

1 Cathodic protection systems

1.1

1.1.1 The following plans and information are to be submitted to the Society:

a) A surface area breakdown for all areas to be protected including secondary steelwork and details of appurtenances.
b) The resistivity of the sea water.
c) All current densities used for design purposes.
d) The type and location of any reference electrodes and their methods of attachment.
e) Full details of any coatings used and the areas to which they are to be applied.
f) Details of any electrical bonding.

2 Sacrificial anode systems

2.1

2.1.1 In addition to the information required by [1] the following plans and information are to be submitted:

a) The design life of the system in years.
b) Anode material and minimum design capacity of anode material, in Ah/kg.
c) The dimensions of anodes including details of the insert and its location.
d) The nett and gross weight of the anodes, in kg.
e) The means of attachment.
f) Plans showing the location of the anodes.
g) Calculation of anodic resistance, as installed and when consumed to their design and utilisation factor, in ohms.
h) Closed circuit potential of the anode material, in volts.
i) Details of any computer modelling.
j) The anode design utilization factor.

3 Impressed current systems

3.1

3.1.1 In addition to the information required by [1], the following plans and information are to be submitted:

a) The anode composition and where applicable the thickness of the plated surface, consumption and life data.
b) Anode resistance, limiting potential and current output.
c) Details of construction and attachment of anodes and reference electrodes.
d) Size, shape and composition of any dielectric shields.
e) Diagram of the wiring system used for the impressed current and monitoring systems including details of cable sizes, underwater joints, type of insulation and normal working current in circuits, and the capacity, type and make of the protected devices.
f) Details of glands and size of steel conduits.
g) Plans showing the locations of the anodes and reference electrodes.
h) If the system is to be used in association with a coating system then a statement is to be supplied by the coating manufacturer that the coating is compatible with the impressed current cathodic protection system.

4 Coating systems

4.1

4.1.1 The following plans and information are to be submitted:

a) Coating products technical data sheets and Type Approval certificates, if any. Technical data sheets have to include the following information:
   1) Materials, components and composition of the coating products
   2) Weldability properties of the shop primer and its compatibility with the coating system
   3) Number of coats and minimum/maximum dry film thickness
   4) Application methods and relevant equipment
   5) Surface preparation methods and standard of surface condition
   6) Environmental conditions
b) Procedures for inspection and repair of coating system during unit construction
c) Details of the areas to be coated.
d) Procedures for maintenance and repair of coating system during unit's service.

5 Inhibitors and biocides

5.1

5.1.1 Where it is proposed to use inhibitors, biocides, or other chemicals for the protection of storage tanks, full details, including compatibility with each other and evidence of satisfactory service experience or suitable laboratory test results or any other data to substantiate the suitability for the intended purpose are to be submitted for consideration.

SECTION 4 CATHODIC PROTECTION SYSTEMS

1 General requirements

1.1 Objective

1.1.1 The cathodic protection system for the external submerged zone is to be designed for a period commensurate with the design life of the structure or the drydocking interval and it should be capable of polarizing the steelwork to a sufficient level in order to minimize corrosion.

This may be achieved using either sacrificial anodes or an impressed current system or a combination of both.

1.2 Electrical continuity

1.2.1 All parts of the structure are to be electrically continuous and where considered necessary appropriate bonding straps should be fitted across such items as propellers, thrusters, rudders and legs, etc., and the joints of articulated structures are to be efficiently completed to the Surveyor's satisfaction.

1.2.2 Where bonding straps are not fitted then a supplementary cathodic protection system is to be considered.

1.2.3 Consideration should be given to the influence of any connecting structures, such as risers and pipelines, on the efficiency of the cathodic protection system.

1.3 Criteria for cathodic protection

1.3.1 The cathodic protection system is to be capable of polarizing the steelwork to potentials measured with respect to a silver/silver chloride/sea-water (Ag/AgCl) reference electrode to within the following ranges:

a) -0,80 to -1,10 volts for aerobic conditions.

b) -0,9 to -1,10 volts for anaerobic conditions.

1.3.2 Potentials more negative than -1,10 volts Ag/AgCl must be avoided in order to minimize any damage due to hydrogen absorption and reduction in the fatigue life. For steel with a tensile strength in excess of 700 N/mm2 the maximum negative potential should be limited to -0,95 volt.

But where the steel is prone to hydrogen assisted cracking the potential should not be more negative than -0,83 volt (Ag/AgCl reference cell).

1.3.3 High strength fastening materials should be avoided because of the possible effects of hydrogen, and the hardness of such bolting materials should be limited to a maximum of 300 Vickers.

1.3.4 The potential for steels with surfaces operating above 25°C should be 1 mV more negative for each degree above 25°C.

2 Sacrificial anodes

2.1 General

2.1.1 Sacrificial anodes intended for installation on units are to be manufactured in accordance with the requirements of this Section.

2.1.2 Plans showing anode nominal dimensions, tolerances and fabrication details are to be submitted for approval prior to manufacture.

2.2 Anode materials

2.2.1 The anode materials are to be approved alloys of zinc or aluminium with a closed circuit potential of at least -1,00 volt (Ag/AgCl reference electrode). Magnesium-based anodes may be used for short-term temporary protection of materials not susceptible to hydrogen embrittlement.

2.3 Steel insert

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

2.4 Anode identification

2.4.1 The manufacturer is to adopt a system of identification of the anodes to enable the material to be traced back to its original cast.

2.4.2 The anodes are to be clearly marked with the following:

a) Name or initials of the anode manufacturer.

b) Number and/or initials to identify the batch.

c) Agreed identification mark for the anode material.

2.4.3 Where the anodes are heat treated they are also to be marked with the appropriate heat treatment batch number.

2.5 Anode inspection

2.5.1 All anodes are to be cleaned and adequately prepared for inspection. The surfaces are not to be hammered, peened or treated in any way which may obscure defects. However, any flash or other protrusions should be removed prior to inspection.

2.5.2 Anodes are to be inspected prior to the application of any coating which may be applied to the underside of the anode or to the exposed steelwork.

2.5.3 The surface should be free of any significant slag or dross or anything that may be considered detrimental to the satisfactory performance of the anodes.

2.5.4 Shrinkage depressions should not exceed the smaller of 10 per cent of the nominal depth of the anode or 50 per cent of the depth to the anode insert.

2.5.5 Cracks in the longitudinal direction are not acceptable. Small transverse cracks may be permitted provided:

a) They are not more than 5 mm in width,

b) They are within the section wholly supported by the steel insert,

c) They do not extend around more than two faces or 180° of the anode circumference.

2.5.6 Cold shuts or surface laps should not exceed a depth of 10 mm or extend over a total length equivalent to more than three times the width of the anode. All material is to be completely bonded to the bulk material.

2.6 Dimensions

2.6.1 Anode nominal dimensions, tolerances and fabrication details are to be shown on manufacturing plans prepared by the manufacturer and submitted for approval.

2.6.2 The accuracy and verification of dimensions is the responsibility of the manufacturer unless otherwise agreed.

2.7 Anode weight

2.7.1 Anodes are to be weighed and individual anodes should be within ±5 per cent of the nominal weight for anodes less than 50 kg or ±3 per cent of the nominal weight for anodes 50 kg and over.

2.7.2 No negative tolerance is permitted on the total contract weight and the positive tolerance should be limited to two per cent of the nominal contract weight.

2.8 Bonding and internal defects

2.8.1 It will be necessary for the manufacturer to demonstrate that there is a satisfactory bond between anode material and the steel insert and that there are no significant internal defects. This may be carried out by sectioning of an anode selected at random from the batch or by other approved means.

2.8.2 Where sectioning is carried out, at least one anode or at least 0,5 per cent of each production run is to be sectioned transversely at 25 per cent, 33 per cent and 50 per cent of the nominal length of the anode or at other agreed locations for a particular anode design.

2.8.3 The cut surfaces are to be essentially free from slag or dross.

2.8.4 Small isolated gas holes and porosity may be accepted provided their surface area is not greater than two per cent of the section.

2.8.5 No section is to show more than 10 per cent lack of bond between the insert and the anode material.

2.9 Electrochemical testing

2.9.1 Electrochemical performance testing is to be carried out by the manufacturer in accordance with previously approved procedures designed to demonstrate batch consistency of the as cast electrochemical properties.

2.10 Certification

2.10.1 The manufacturer is to provide copies of the Material Certificate or shipping statement for all acceptable anodes.

2.10.2 The certificate is to include at least the following information:

a) Name of manufacturer.

b) Description of anode, alloy designation or trade name.

c) Cast identification number.

d) Chemical composition.

e) Details of heat treatment where applicable.

f) Results of electrochemical test.

g) Weight data.

h) Purchaser's name and order number, and the name of the structure for which the material is intended.

2.10.3 The manufacturer is to confirm that the tests have been carried out with satisfactory results in accordance with the approved specification and the Rules.

2.11 Anode installation

2.11.1 The location and means of attachment of anodes are to be submitted for approval.

2.11.2 The anodes are to be attached to the structure in such a manner that they remain secure throughout the service life.

2.11.3 Where bracelet anodes are proposed the tightness of the anodes are not to rely on the anode material being in direct contact with the structure.

2.11.4 The location and attachment of anodes are to take account of the stresses in the members concerned. Anodes are not to be directly attached to the shell plating of main hull columns or primary bracings.

2.11.5 The anode supports may be welded directly to the structure in low stress regions provided they are not attached in way of butts, seams, nodes or any stress raisers. They are not to be attached to separate members which are capable of relative movement.

2.11.6 The attachment of all anodes to primary bracing members and nodes is to be submitted for approval. Anodes are not to be welded directly to the structure and the supports are to be welded to small doubler plates which are attached by continuous welds to the structure.

2.11.7 All welding is to be carried out by qualified welders using an approved welding procedure.

2.11.8 The welds are to be examined using magnetic particle inspection or other acceptable means of nondestructive testing.

2.11.9 Anodes attached to studs 'fired' into the structure are not permitted.

2.11.10 The anodes are to be located on the structure to ensure rapid polarization of highly stressed areas such as node welds and with due regard to a possible reduction in throwing power in re-entrant angles.

2.11.11 Anodes should not be located in positions where they may be damaged by craft coming alongside.

2.11.12 Magnesium anodes are not to be used in way of higher tensile steel or coatings which may be damaged by the high negative potentials unless suitable dielectric shields are fitted.

3 Impressed current anode systems

3.1 General

3.1.1 Impressed current anode materials may be of leadsilver alloy or platinum over such substrates as titanium, niobium, tantalum, or of mixed oxides activated titanium.

3.1.2 The design and installation of electrical equipment and cables is to be in accordance with the requirements of Pt C, Ch 2.

3.1.3 All equipment is to be suitable for its intended location. Cables to anodes are not to be led through tanks intended for the storage of low flash point oils. Where cables are led through cofferdams of oil storage units they are to be enclosed in a substantial steel tube of about 10mm thickness.

3.1.4 The arrangement for glands, where cables pass through shell boundaries, are to include a small cofferdam.

3.1.5 Cable and insulating material should be resistant to chloride, hydrocarbons and any other chemicals with which they may come into contact.

3.1.6 The electrical connection between the anode cable and the anode body is to be watertight and mechanically and electrically sound.

3.1.7 Where the power is derived from a rectified a.c. source adequate protection is to be provided to trip the supply in the event of:

a) A fault between the input or high voltage windings of the transformer (i.e. main voltage) and the d.c. output of the associated rectifier; or

b) The ripple on the rectified d.c. exceeding five per cent.

3.1.8 Anodes may be installed by mounting in insulating holders attached directly to the submerged structural member provided the general requirements given in [2.11] regarding attachments to the structure are complied with.

3.1.9 Suitable dielectric shields are to be fitted in order to avoid high negative potentials.

3.1.10 A warning light or other warning indicator is to be arranged at the control position from which divers are controlled to indicate that the impressed current cathodic protection system has been switched off when divers are in the water.

3.2 Protection after launching and during outfitting

3.2.1 Where protection is primarily by an impressed current cathodic protection system, sufficient sacrificial anodes are to be fitted, capable of polarizing the critical regions of the structure from the time of initial immersion until full commissioning of the impressed current system.

4 Fixed potential monitoring systems

4.1 General

4.1.1 A permanent monitoring system is to be installed on structures protected by an impressed current cathodic protection system, and although not essential such a monitoring system is recommended for use in conjunction with sacrificial anodes.

4.1.2 Zinc or Ag/AgCl reference electrodes should be used.

4.1.3 The location and attachment of the reference electrodes are to take account of the stresses in the members concerned and they should not be attached in highly stressed areas or in way of butts, seams, nodes or any stress raisers.

4.1.4 The location of the reference electrodes should be such as to enable the performance of the cathodic protection system to be adequately monitored.

4.1.5 The reference electrodes may be connected to the top side display and control equipment by suitable cabling or by any other agreed means.

4.1.6 Provision is to be made for the regular recording at an agreed interval of the potential of the steelwork and log sheets are to be made available for inspection when required by the Surveyors.

5 Cathodic protection in tanks

5.1 General

5.1.1 Impressed current cathodic protection systems are not to be fitted in any tank.

5.2 Sacrificial anodes

5.2.1 Particular attention is to be given to the locations of anodes in tanks that can contain explosive or other inflammable vapour, both in relation to the structural arrangements and openings of the tanks.

5.2.2 Aluminium anodes are only permitted in tanks that may contain explosive or flammable vapour, and in tanks adjacent to tanks that may contain explosive or flammable vapour, where the potential energy of the anode does not exceed 275 J (28 kgm). The height of the anode is to be measured from the bottom of the tank to the centre of the anode, and its weight of the anode is to be taken as the weight at the time of installation, including any inserts and fitting devices. However, where aluminium anodes are located on wide horizontal surfaces from which they cannot fall, the height of the anode may be measured from this surface.

5.2.3 Aluminium anodes are not to be located under tank hatches or other openings unless protected by adjacent structure.

5.2.4 Magnesium or magnesium alloy anodes are permitted only in tanks intended solely for water ballast, in which case adequate venting must be provided.

5.2.5 Anodes fitted internally should preferably be attached to stiffeners, or aligned in way of stiffeners on plane bulkhead plating. Where they are welded to asymmetrical stiffeners, they are to be connected to the web with the welding at least 25mm away from the edge of the web.

5.2.6 In the case of stiffeners or girders with symmetrical face plates, the connection may be made to the web or to the centreline of the mild steel face plate but well clear of the free edges. Where higher tensile steel face plates are fitted the anodes are to be attached to the webs.

5.2.7 Anodes are not to be attached directly to the shell plating of main hulls, columns or primary bracings.

6 Potential surveys

6.1 General

6.1.1 Potential surveys of the external submerged zones are to be carried out at agreed intervals.

6.1.2 Should the results of any potential survey measured with respect to a Ag/AgCl reference cell indicate values more positive than -0,8 volt for aerobic conditions or -0,9 volt for anaerobic conditions then remedial action is to be carried out at the earliest opportunity.

7 Retrofits

7.1 General

7.1.1 Where it is proposed to fit additional anodes or replace existing ones then full details are to be submitted for consideration.

7.1.2 Where it is necessary to weld anodes to the structure then only approved welding procedures and consumables are to be used.

7.1.3 The welding procedure is to be qualified under fully representative conditions.

SECTION 5 COATING SYSTEMS

1 General requirements

1.1 General

1.1.1 The coating specification is to be submitted for approval, see Sec 3, [4.1.1].

1.1.2 Paints, varnishes and similar preparations having nitrocellulose or other highly flammable base are not to be used in accommodation or machinery spaces or in other areas with an equal or higher fire-risk.

1.1.3 Where a coating is to be applied in accommodation spaces and areas of similar fire-risk the coating is to have low flame spread characteristics.

1.1.4 Paints or other similar coatings containing aluminum should not be used in positions where flammable vapours may accumulate, unless it has been shown by appropriate tests that the paint to be used does not increase the incendive sparking hazard.

1.1.5 Any sheathing or composition to protect decks is to be applied in such a manner that corrosion will not occur unseen beneath the covering.

1.1.6 Deck coatings or coverings used on decks forming the crown of spaces with a high fire-risk (such as helidecks, machinery and accommodation spaces) or which are within accommodation spaces, control rooms, emergency escape routes, etc., are to be of a type which will not readily ignite.

1.1.7 Paints or other coatings are to be suitable for the intended purpose in the locations where they are to be used.

1.1.8 Coatings are to be applied to blast cleaned surfaces prepared to at least an equivalent of ISO 8501-1 Sa 21/2. All resulting dust is to be removed from the surface prior to the application of any paint.

SECTION 6 PREFABRICATION PRIMERS

1 General

1.1

1.1.1 Primers are to have proper weldability and to be compatible with other coating products subsequently applied. Weldability products are to be tested according the provisions of Pt D, Ch 5, Sec 3 of the Rules for the Classification of Ships.

SECTION 7 LOADING MANUAL AND LOADING INSTRUMENTS

1 General

1.1

1.1.1 *(1/1/2022)*
The applicable requirements in Pt B, Ch 11, Sec 2 of the Rules for the Classification of Ships are to be complied with.

Part B

Hull and Stability

Chapter 13

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 of the Rules for the Classification of Ships. 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 of the Rules for the Classification of Ships.

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 of the Rules for the Classification of Ships.

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 Pt B, Ch 4, Sec 1, Tab 3 and Tab 8, as applicable, of the Rules for the Classification of Ships.

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] of the Rules for the Classification of Ships); 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] of the Rules for the Classification of Ships.

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:

$$\frac{p}{d} \le \varphi$$

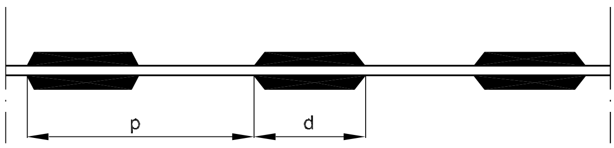
where the coefficient φ is defined in Tab 2 and Tab 3 for the different types of intermittent welding, depending on the type and location of the connection.

In general, staggered welding is not allowed for connections subjected to high alternate stresses.

In addition, the following limitations are to be complied with:

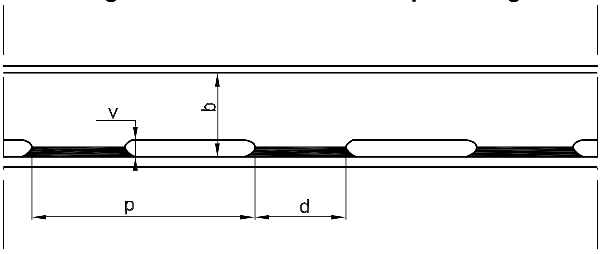
- chain welding (see Fig 1):
  $d \ge 75$ mm
  $p-d \le 200$ mm

Figure 1 : Intermittent chain welding



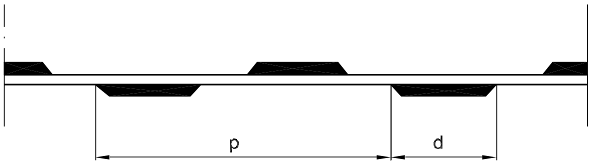
- scallop welding (see Fig 2):
  $d \ge 75$ mm
  $p-d \le 150$ mm
  $v \le 0,25b$, without being greater than 75 mm

Figure 2 : Intermittent scallop welding



- staggered welding (see Fig 3):
  $d \geq 75$ mm
  $p\text{-}2d \leq 300$ mm
  $p \leq 2d$ for connections subjected to high alternate stresses.

Figure 3 : Intermittent staggered welding



2.3.5 Throat thickness of fillet weld T connections

The throat thickness of fillet weld T connections is to be obtained, in mm, from the following formula:

$$t_T = w_F t \frac{p}{d}$$

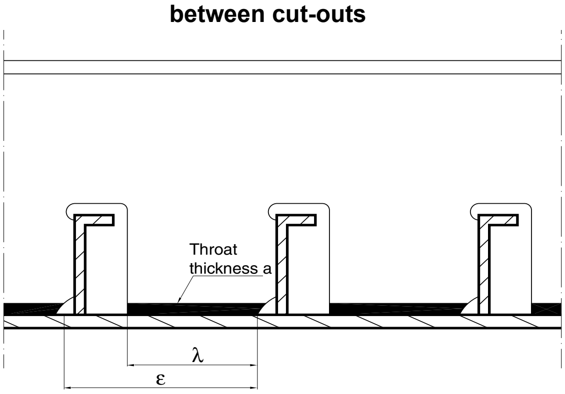
where:

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 unit types, the values of w_F specified in Part E for these unit 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 $8 \leq t \leq 16$ mm.

For thicknesses t less than 8 mm, the values of p_1 may be increased, with respect to those in Tab 2, by:

- 10 mm for chain or scallop welding
- 20 mm for staggered welding

without exceeding the limits in [2.3.4].

For thicknesses t greater than 16 mm, the values of p_1 are to be reduced, with respect to those in Tab 2, by:

- 10 mm for chain or scallop welding
- 20 mm for staggered welding.

Figure 5 : Intermittent scallop fillet welding between cut-outs

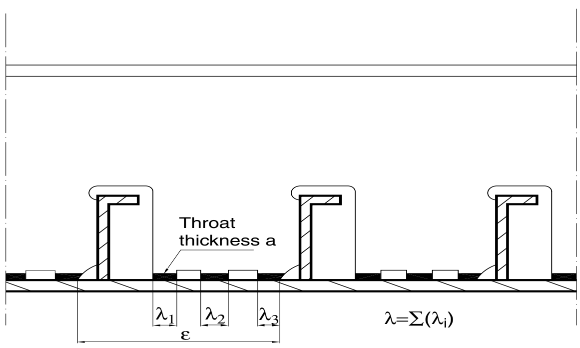


Table 2 : Welding factors w_F and coefficient φ for the various hull structural connections

Hull area	Connection of	Connection to		w_F **(1)**	φ **(2) (3)** CH	SC	ST	p_1, in mm (see [2.3.6]) **(3)**
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
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 units	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

Hull area	Connection of	Connection to		w_F **(1)**	φ **(2)** **(3)** CH	SC	ST	p_1, in mm (see [2.3.6]) **(3)**
Bulkheads	tank bulkhead structures	tank bottom	plating and ordinary stiffeners (plane bulkheads)	0,45				
			vertical corrugations (corrugated bulkheads)	Full penetration welding				
		boundaries other than tank bottom		0,35				
	watertight bulkhead structures	boundaries		0,35				
	non-watertight bulkhead structures	boundaries	wash bulkheads	0,20	2,2	2,2		CH/SC 160
			others	0,13	3,5	3,0	4,6	ST 260
	ordinary stiffeners	bulkhead plating	in general **(5)**	0,13	3,5	3,0	4,6	ST 260
			at ends (25% of span), where no end brackets are fitted	0,35				
Structures located forward of 0,75 L from the AE **(6)**	bottom longitudinal ordinary stiffeners	bottom plating		0,20	2,2			CH 160
	floors and girders	bottom and inner bottom plating		0,25	1,8			CH 130
	side frames in panting area	side plating		0,20	2,2			CH 160
	webs of side girders in single side skin structures	side plating and face plate	A< 65 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				
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
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				

(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 cm².

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 $0{,}35t_W$, 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/m², acting on the ordinary stiffener, defined in Pt B, Ch 7, Sec 2, [3.3.2] of the Rules for the Classification of Ships

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				

(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.

Primary supporting member	Connection			w_F (1)	φ (2) (3)			p_1, in mm (see [2.3.6]) (3)
	of	to			CH	SC	ST	
In tanks, where A ≥ 65 cm^2	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 cm^2.

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

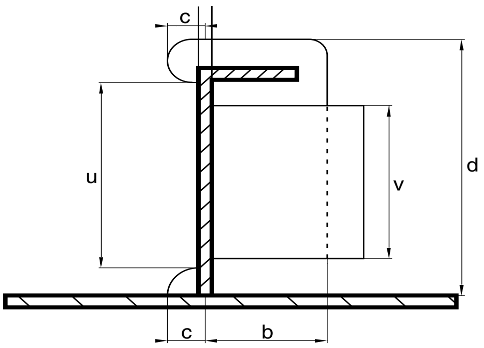


Table 4 : Required throat thickness

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 unit 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

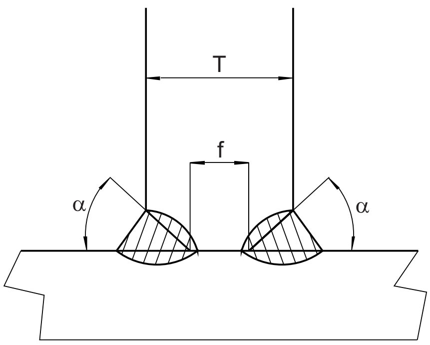


Figure 8 : Partial penetration weld

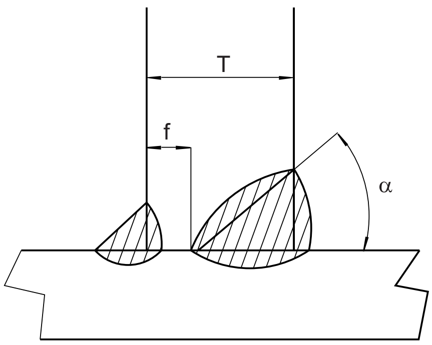


Figure 9 : Full penetration weld

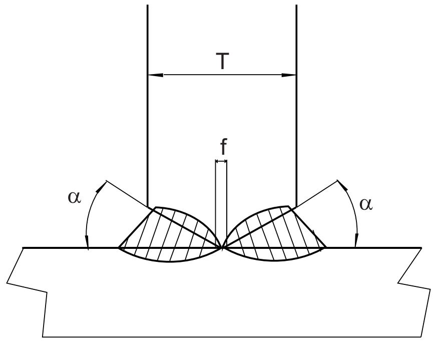
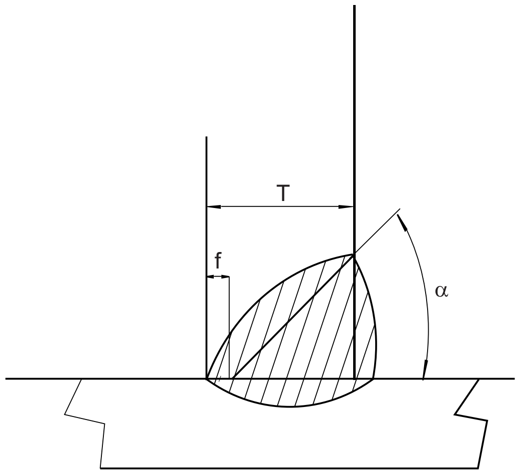


Figure 10 : Full penetration weld



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 Pt B, Ch 4, Sec 3, [2.1] of the Rules for the Classification of Ships.

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 Bilge keel connection to the hull will be considered on a case-by-case basis.

3.3 Bar stem connections

3.3.1 The bar stem is to be welded to the bar keel generally with butt welding.

The shell plating is also to be welded directly to the bar stem with butt welding.

3.4 Additional welding factors

3.4.1 Additional values for welding factors w_F for fillet welds not covered by [2.3.5] are reported in Tab 5.

For items indicated in Tab 5 continuous fillet welding is to be adopted.

Table 5 : Additional welding factors

Item	w_F,
Turrets and swivel supports structures **(1)**	0,45
Topsides and process plant structures to deck **(1)**	0,34
Mooring equipment seats, fairleads and chain stoppers **(1)**	0,44
(1) full penetration welding may be required	

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 of the Rules for the Classification of Ships.

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.

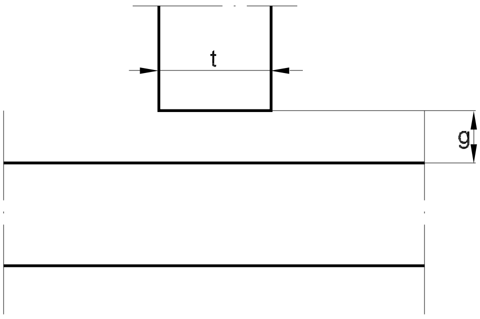
4.3.5 Gap in fillet weld T connections

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 unit types. Recommendations are also given in the "Guide for welding".

In any event, the gap g may not exceed 4 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 3 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 unit types.

The Society may require lower misalignment to be adopted for cruciform connections subjected to high stresses.

Figure 12 : Plate misalignment in butt connections

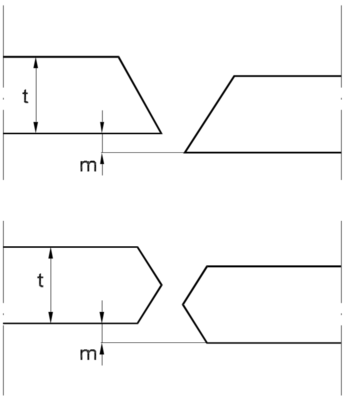
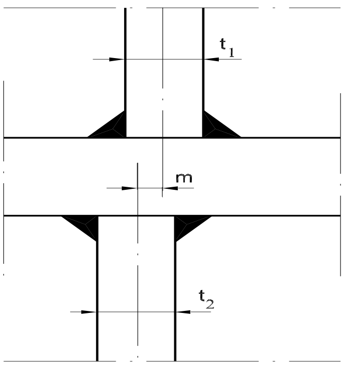


Figure 13 : Misalignment in cruciform connections



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 unit 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 unit launching and with the unit 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-unit'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 : Unit's draft in light ballast condition, see Ch 5, Sec 1, [2.5.3].

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 unit 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 for structural scantling
- Chapter 13, Sec 1 for construction and welding requirements
- the applicable requirements in Part E and Part F.

1.2 Design requirements

1.2.1 General requirements *(1/1/2022)*

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 Pt B, Ch 7, Sec 2 of the Rules for the Classification of Ships.

1.2.2 Fatigue check requirements *(1/1/2022)*

Where a fatigue check is to be carried out, the design requirements specify see Pt B, Ch 7, Sec 2, [3] of the Rules for the Classification of Ships:

- the locations (hot spots) where the stresses are to be calculated and the fatigue check performed
- the direction in which the normal stresses are to be calculated
- the stress concentration factors K_h and K_l to be used for calculating the hot spot stress range.

1.3 Constructional requirements

1.3.1 Constructional requirements specify the allowable misalignment and tolerances, depending on the detail arrangement and any local strengthening.

1.4 Material requirements

1.4.1 Material requirements specify the material quality to be used for specific elements which constitute the detail, depending on their manufacturing procedure, the type of stresses they are subjected to, and the importance of the detail with respect to the unit 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 unit 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 units with longitudinally framed sides

2.2.1 The special structural details relevant to all types of longitudinally framed units are listed and described in Tab 1.

2.3 FSOs and FPSOs

2.3.1 The special structural details relevant to units with the service notation **FSO** and **FPSO** are listed and described in Tab 2 for various hull areas.

When the structural arrangement in a certain area is such that the details considered in Tab 2 are not possible, specific requirements are defined by the Society on a case by case basis, depending on the arrangement adopted.

2.4 FRSUs

2.4.1 The special structural details relevant to units with the service notation **FRSU** are listed and described in Tab 3 for various hull areas.

When the structural arrangement in a certain area is such that the details considered in Tab 3 are not possible, specific requirements are defined by the Society on a case by case basis, depending on the arrangement adopted.

Table 1 : Units with longitudinally framed sides - Special structural details *(1/1/2022)*

Area reference number	Area description	Detail description	Fatigue check	Reference sheet *
1	Part of side extended: • longitudinally, between the after peak bulkhead and the foreward peak 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
Note 1: *Reference sheets are those in Pt B, Ch 12, App 1 of the Rules for the Classification of Ships, taking into account that: • the reference sheets for oil tankers and chemical tankers apply to FSOs and FPSOs • the reference sheets for liquefied gas carriers apply to FSRUs.				

Table 2 : FSOs and FPSOs - Special structural details *(1/1/2022)*

Area reference number	Area description	Detail description	Fatigue check	Reference sheet *
1	Part of side extended: • longitudinally, between the after peak bulkhead and the foreward peak 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

Area reference number	Area description	Detail description	Fatigue check	Reference sheet *
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
Note 1: *Reference sheets are those in Pt B, Ch 12, App 1 of the Rules for the Classification of Ships, taking into account that: • the reference sheets for oil tankers and chemical tankers apply to FSOs and FPSOs • the reference sheets for liquefied gas carriers apply to FSRUs.				

Table 3 : FSRUs - Special structural details *(1/1/2022)*

Area reference number	Area description	Detail description	Fatigue check	Reference sheet *
1	Part of side extended: • longitudinally, between the after peak bulkhead and the foreward peak 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
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 cofferdam bulkheads	For L≥150m	Sheet 3.5
4	Double bottom in way of hopper tanks	Connection of inner bottom with hopper tank sloping plates	For L≥150m	Sheets 4.5 to 4.7
6	Lower part of inner side	Connection of hopper tank sloping plates with inner side	For L≥150m	Sheets 6.8, 6.9
Note 1: *Reference sheets are those in Pt B, Ch 12, App 1 of the Rules for the Classification of Ships, taking into account that: • the reference sheets for oil tankers and chemical tankers apply to FSOs and FPSOs • the reference sheets for liquefied gas carriers apply to FSRUs.				