INDIAN REGISTER OF SHIPPING

Rules and Regulations for the Construction and Classification of Floating Offshore Units

July 2018

IRCLASS
Indian Register of Shipping

General Information

This consolidated version of the ‘Rules and Regulations for the Construction and Classification of Floating Offshore Units’ (July, 2018) supersedes the July 2017 edition of the Rules and includes amendments published in the ‘Rule Change Notice No.1 January, 2018’.

A summary of additions and amendments incorporated in this consolidated version are indicated in Table 1.

RULES AND REGULATIONS FOR THE CONSTRUCTION AND CLASSIFICATION OF FLOATING OFFHSORE UNITS, JULY 2018

TABLE 1 – AMENDMENTS INCORPORATED IN THIS EDITION

These amendments will come into force as indicated in the Table

Section / Clause	**Subject / Amendments**
Chapter 1: Regulations *The amendments are applicable to units contracted for construction on or after 01 July 2018*	
2/2.6.5.3 and 2.6.5.4	Reference to Chapter 8, that provides requirements for topside production facilities associated with FPUs and FPSOs, is introduced.
7/7.8.1	It is clarified that design philosophy document is to be provided for information and structural integrity assessment of riser systems depicting ultimate strength and fatigue assessment is to be submitted for review only.
7/7.9.1	Documents, plans and calculations to be submitted for appraisal of topside production facilities for FPUs and FPSOs, are listed.
Chapter 8: Topside Production Facilities (New Chapter) *The amendments are applicable to units contracted for construction on or after 01 July 2018*	
Sec 1 to 7	New chapter providing the requirements for topside production facilities have been added to the rules.

Indian Register of Shipping

Rules and Regulations for the Construction and Classification of Floating Offshore Units – July 2018

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Section 1

General Information

1.1 Indian Register of Shipping

1.1.1 Indian Register of Shipping (hereinafter referred to as "IRS") was incorporated in 1975 as a Public Limited Company of the Indian Companies Act for the purpose of providing amongst other things a faithful and accurate classification of mercantile shipping classed with it, to approve designs of, to survey and to issue reports on mercantile and non-mercantile ships, hovercrafts, hydrofoils etc.; all within the scope of classification described in the Rules. This Section contains General Regulations which have been adopted by IRS for its governance.

1.1.2 The management of the affairs of IRS are carried out by the Managing Director (MD)and the Jt. Managing Director (JMD) under the direction and control of the Board of Directors (hereinafter referred to as the 'Board'), in accordance with the provisions of its Memorandum and Articles of Association.

1.1.3 Information regarding the Board of Directors and Technical Committee of IRS is given in Part 1, Chapter 1, of IRS Rules and Regulations for the Construction and Classification of Steel Ships.

1.2 Fees

1.2.1 Fees will be charged for all surveys and for other services rendered by IRS or any of its publications in accordance with established scales. Traveling expenses incurred by the Surveyors in connection with such services are also chargeable.

1.3 Survey Reports

1.3.1 All reports of survey are to be made by the Surveyors according to the form prescribed and submitted for consideration of the Board or the Sub-Committee of Classification, but the character assigned by the latter is to be reported to the Board. The Board may, in specified instances, vest in the Managing Director/Jt. Managing Director discretionary powers to act on its behalf, and all such actions being reported to the Board at its subsequent meeting.

1.3.2 The reports of the Surveyors shall, subject to the approval of the Managing Director/Jt. Managing Director, be open to inspection of the Owner and any other person authorized in writing by the Owner. Copies of the reports will, subject to the approval of the Managing Director/ Jt. Managing Directors, be supplied to Owners or their representatives

1.4 Register Book

1.4.1 A Register book is available on-line on the IRCLASS Website which contains the names, character of class and notations assigned together with other relevant useful information for Ships & Units classed with IRS. The FOUs classed with IRS are displayed in the Register Book with the assigned classification notations.

1.5 Liability

1.5.1 Whilst Indian Register of Shipping, a Classification Society, along with its subsidiaries and associates (hereinafter referred to as the Society) and its Board/Committees use their best endeavors to ensure that the functions of the Society are properly carried out, in providing services, information or advice, neither the Society nor any of its servants or agents warrants the accuracy of any information or advice supplied. Except as set out herein, neither the Society nor any of its servants or agents (on behalf of each of whom the Society has agreed this clause) shall be liable for any loss damage or expense whatever sustained by any person due to any act or omission or error of whatsoever nature and howsoever caused of the Society, its servants or agents or due to any inaccuracy of whatsoever nature and howsoever caused in any information or advice given in any way whatsoever by or on behalf of the Society, even if held to amount to a breach of warranty. Nevertheless, if any person uses services of the Society, or relies on any information or advice given by or on behalf of the Society and suffers loss damage or expenses thereby which is proved to have been due to any negligent act omission or error of the Society its servants or agents or any negligent inaccuracy in information or advice given by or on behalf of the Society then the Society will pay compensation to such person for his proved loss up to but not exceeding the amount of the fee charged by the Society for that particular service, information or advice.

1.5.2 Any notice of claim for loss, damage or expense as referred to in 1.5.1 shall be made in writing to Head Office within six months of the date when the service, information or advice was first provided, failing which all the rights to any such claim shall be forfeited and the Society shall be relieved and discharged from all liabilities.

1.6 Audits and Assessments by external organizations

1.6.1 The surveys required by the regulations and conducted by IRS may be subject to Audit by an independent Accredited Certification Body (ACB) as per requirements of ISO 9001: 2008 standard, Quality Management System Certification Scheme (QSCS) of IACS or audits of relevant third party regimes. For this purpose, ACB auditors are to be given the necessary access to the FOU, shipyard and works when requested by IRS.

1.6.2 Access is also to be given to auditors or inspectors accompanying the Surveyors as required by other external organizations

1.7 Access of Surveyors to Floating Offshore Units, Shipyard or works

1.7.1 The Surveyors are to be given free access to FOUs classed with IRS as well as to shipyards, sub-contractors work/premises, etc. so as to perform their duties, and are to receive adequate assistance for this purpose.

1.8 Requirements for Service Suppliers

1.8.1 Firms providing services on behalf of the Owner, the results of which are used by Surveyors in making decision affecting classification and/or affecting statutory certifications, are to be approved by IRS in accordance with the laid down procedures. (Also refer to Part 1, Chapter 1 of Rules and Regulations for the Construction and Classification of Steel Ships).

1.9 Responding to Port State Control

1.9.1 When requested by Port State and upon concurrence by the FOU's owner/master, IRS surveyors would attend onboard the unit in order to assist in the rectification of deficiencies or other discrepancies that affect or may affect the classification or the statutory certificates issued by IRS. The owners and the FOU's flag state will be notified of such attendance and survey. IRS surveyors will also co-operate with Port states by providing inspectors with background information.

Section 2

Classification Regulations

2.1 Application

2.1.1 The Rules and Regulations for Construction and Classification of Floating Offshore units (hereinafter referred to as "Rules") are applicable to Ship-shaped offshore Units which are engaged for operations such as the production, storage and offloading of oil but excluding the ship types defined the Rules and Regulations for Construction and Classification of Steel Ships and Rules for Bulk Carriers and Oil Tankers.

2.1.2 When an FOU is assigned a specific character of class by IRS, it implies IRS has been satisfied that the said FOU meets, for this particular class with the Rules thereto. The FOU will continue to be classed with IRS so long as it is found upon examination at the prescribed surveys, to be maintained in a fit and efficient condition and in accordance with the Survey Requirement of the Rules.

2.1.3 Compliance with the following IMO conventions, codes and resolutions as amended and as applicable is a pre-requisite of classification.

- International Convention on Loadlines (ILLC)
- International Convention for the Safety of Life at Sea (SOLAS)
- International Convention for the Prevention of Pollution from Ships (MARPOL)
- Fire Test Procedures (FTP code)
- International Regulations for preventing Collisions at Sea (COLREGS)
- Related Resolutions of the IMO assembly, Maritime Safety Committee and the Marine Environment Protection Committee of IMO

2.1.4 Compliance with the requirements of National Authority and Administration of the site where the FOU would be operational may be required in addition to the IMO conventions (as specified in 2.1.3)

2.1.5 Classification of an FOU with IRS is under the premises that the FOU will be not be operated outside the conditions or areas for which it has been designed.

2.1.6 Where an FOU holds dual classification with IRS and the classification requirements of the other society differ from the Rules, IRS may accept the application of the requirements of the other society provided IRS is satisfied that these are no less stringent than the IRS rules

2.1.7 When an FOU is detained by Port State Control, IRS is to be immediately notified by the owner / operator for arranging attendance by a surveyor

2.1.8 Unless otherwise directed by IRS, no new Regulations or amendments to the rules relating to the character of classification or class notation is to be applied to existing FOUs in class.

2.1.9 Unless otherwise directed by IRS no new Rules & Regulations or amendments to the existing Rules become applicable within 6 months after date of issue.

2.2 Scope of Classification

2.2.1 Provision of services by IRS does not assess compliance with any standards or rules other than applicable IRS rules, international regulations and standards agreed in writing.

2.2.2 The scope of items for classification includes the following to the extent as specified within the Rules:

a) Hull
b) Marine Machinery & Systems
c) Marine Electrical Equipment
d) Safety systems
e) Mooring systems

Topside production facilities are not required to be classed; however, on request of the owner, an optional descriptive note can be assigned for applicable facilities compliant with the requirements for the applicable notation (see 2.6.5).

2.2.3 Though Topside production facilities do not constitute a mandatory scope of classification; aspects of Topside Production Facilities which may affect the integrity and safety of the Unit as a whole need to be compliant with requirements as specified in these Rules.

2.2.4 Upon request, Topsides installation or any specific installations on the FOU may be classed by IRS.

2.3 Interpretations of the Rules

2.3.1 The correct interpretation of the Rules is the sole responsibility and is at the sole discretion of IRS. Any discrepancy in the meaning of the Rules must be referred to IRS for clarification

2.4 Definitions

2.4.1 Clear Water: Water having sufficient depth to permit the normal development of wind generated waves.

2.4.2 Fetch: The extent of clear water across which a wind has blown before reaching the ship.

2.4.3 Sheltered Water: Water where the fetch is six nautical miles or less.

2.4.4 Floating Offshore Unit: Unit with its mooring system which operates at a fixed geographical location.

2.4.5 Position mooring: Mooring system utilized for maintaining the position of the FOU at a fixed location.
In the event that the mooring system is independent of the unit (e.g. a mooring buoy or tower to which the FOU is moored); such mooring system is also to be considered as a part of the FOU. IRS may require such a mooring system to be classed or may specially consider such system if classed by IACS member classification societies.

2.4.6 Reasonable Weather: Reasonable weather is assumed to exclude winds exceeding Beaufort force six associated with sea states resulting in green water being frequently taken on board the FOU's deck. However, it is realised that this is largely a matter of judgment and good seamanship and can vary for particular ships.

2.4.7 Type Notation : A notation indicating that the FOU has been designed and constructed complying with the Rules applicable to that type of FOU, e.g. FPSO

2.4.8 Special Feature Notation: A notation indicating that the FOU incorporates special features which significantly affect the design.

2.4.9 Service Restriction Notation: A notation indicating that a FOU has been classed on the understanding that it will be operated only in suitable areas or conditions which have been agreed to by IRS.

2.4.10 Topside Production Facility(ies): Facility(ies) provided onboard FOU for processing of the fluids extracted from the Subsea wells.

2.5 Character of Classification

2.5.1 Character **SUL** shall be assigned to FOUs indicating that the hull, appendages and equipment meet the Rule requirements for assignment of this character of class.

2.5.2 Character **IY** shall be assigned to self-propelled FOUs indicating that the machinery meets the Rule requirements for assignment of this character of class.

2.5.3 The distinguishing mark 卐 inserted before a character of class is assigned to new units where the hull (and its appendages, equipment) and the machinery as appropriate are constructed under special survey of IRS in compliance with the Rules to the satisfaction of IRS. This also applies to FOUs converted from existing oil tankers under special survey of IRS in compliance with Rules to the satisfaction of IRS.

2.6 Class Notations

2.6.1 In addition to the character of class assigned by IRS, the FOU will also be assigned applicable Class Notations as given below:

a. Type Notation
b. Service Restrictions Notation
c. Additional Notations
E.g. A typical class notation is as follows:

卐 SUL, IY, FPSO, Indian Ocean – Unrestricted Navigation & Transit, POSMOOR – Spread Mooring, IWS

2.6.2 **Type Notation –** A notation indicating the functional purpose of the FOU. The following Type Notations may be assigned, as applicable

- **FOU**: Floating offshore unit (Ship Shaped)
- **FSO**: Floating Storage Offloading Unit (Ship Shaped)
- **FPU**: Floating Production System Unit with offloading facilities (Ship Shaped)
- **FPSO**: Floating Production Storage & Offloading Unit (Ship Shaped)

2.6.3 Service Restrictions – This notation specifies the operational limitations of the FOU considering its steady operation sites as well as navigation & transit between sites. The following are the applicable notations:

- Unrestricted
- [Site (s) of Operation] – Unrestricted Navigation & Transit]
- [Site (s) of Operation] – [Specific Criteria for Navigation & Transit]

2.6.4 Additional Notations as listed in Section 6 may be assigned if the FOU is in compliance with the relevant requirements stipulated within the Rules.

2.6.5 With reference to the type notations in 2.6.2, the scope of classification are as given in the following:

.1 FOU: The FOU hull, machinery, electrical systems, safety systems, mooring installations, offloading systems & equipment. Topside Production Facility is not required to be within the scope of classification; however, the safety systems for the electrical equipment on the Topside production facilities and the associated safety systems are to be included in the classification scope.

.2 FSO: The FOU hull, machinery, electrical systems, safety systems, mooring installations & Offloading equipment & systems. These type of units are not provided with a Topside Production Facility.

.3 FPU: The FOU hull, machinery, electrical systems, safety systems, mooring installations, Offloading equipment & systems and Topside Production facilities. This type of installation may not have the storage capacity for the processed fluids.
For the FPU type notation, the requirements for topside facilities are given in Chapter 8.

.4 FPSO: The FOU hull, machinery, electrical systems, safety systems, mooring installations, Offloading equipment & systems and Topside Production facilities.
For the FPSO type notation, the requirements for topside facilities are given in Chapter 8.

2.7 Materials, Components, Equipment and Machinery

2.7.1 The requirements of Rules & Regulations for Construction and Classification of Steel Ships, Part 1, Chapter 1, Section 2.9 are applicable for FOUs.

2.8 Request for Surveys

2.8.1 It is the responsibility of the Builders or Owners, as applicable, to inform the Surveyors of IRS in the port at which the surveys for supervision during new construction or FOUs in service are to be undertaken and to ensure that all surveys for issue of class certificate for new construction, and maintenance of class for FOUs in service are carried out.

2.9 Repairs

2.9.1 Any repairs to Hull, Machinery, Equipment, Mooring system, Topsides facilities including process equipment either as a result of damage or wear and tear which are required for the maintenance of the FOU's classification are to be carried out under the inspection and to the satisfaction of the IRS surveyor.

2.9.2 Where a FOU is damaged to an extent resulting in towage outside port limits, it shall be the owners responsibility to notify IRS at the first practicable opportunity.

2.9.3 Where such repairs are effected at a port where there is no Surveyor of IRS, the FOU is to be surveyed by an IRS surveyor at the earliest opportunity.

2.9.4 Where repairs as listed in 2.9.1 are to be carried out by the FOU's crew, they are to be planned in advance. A complete repair procedure including the extent of proposed repairs and the need for Surveyor attendance at the time is to be submitted to and agreed upon by the Surveyor reasonably in advance. Failure to notify IRS in advance of the repairs may result in suspension of class.

2.9.5 Where in any emergency circumstances, repairs are to be effected immediately; the repairs should be documented in the FOU's log and submitted thereafter to IRS for use in determining further survey requirements.

2.10 Alterations

2.10.1 Any alterations proposed to be carried out to approved scantlings and arrangements of hull, machinery, equipment, mooring system or topsides facilities are to be with the approval of IRS. For this purpose, plans and technical particulars are to be submitted for approval in advance. Such approved alterations are to be carried out under the inspection of the IRS Surveyors to their satisfaction. If alterations are carried out on items which may affect the classification of the FOU without informing IRS, the class of the FOU will be liable to suspension except in the case of 2.9.5

2.11 Classification of New Constructions

2.11.1 The request for classification of new constructions is to be submitted to IRS by the builder or owner in the form provided by IRS. The request is to include complete details regarding class notations and statutory certificates required as applicable.

The IRS Rules in force on the date of contract for construction of the FOU (See Section 2.12) will be applicable for classification, in general. However, statutory requirements coming into force after the date of contract for construction may have to be complied with if they become applicable based on any other criteria such as the date on which FOU is constructed (keel laid).

2.11.2 Where orders for major machinery and equipment are placed on manufacturer or suppliers, IRS is to be informed. Responsibility for compliance with IRS Rules and Regulations shall be with the manufacturers/suppliers.

Where relevant, the date of application for certification of specific major machinery will also be considered in addition to the date of contract for construction of the FOU, for determining the applicable rules for such machinery.

2.11.3 Plans and particulars as specified in the Rules are to be submitted to IRS sufficiently in advance of commencement of construction. Any deviation from approved drawings is to be approved by IRS prior to execution of work.

2.11.4 IRS reserves the right to request for additional plans, information or particulars to be submitted.

Where it is proposed to use existing previously approved plans for a new contract, written application is to be made to IRS.

Approval of plans and calculations by IRS does not relieve the Builders of their responsibility for the design, construction and installation of the various parts, nor does it absolve the Builders from their duty of carrying out any alterations or additions to the various parts on board deemed necessary by IRS during construction or installation on board or trials.

2.11.5 IRS will assess the production facilities and procedures of the builder and other manufacturers as to whether they meet the requirements of the construction Rules.

Review of the construction facilities prior to any steel work or construction will be carried out under the following circumstances:

a) Where IRS has none or no recent experience of the construction facilities – typically after a one year lapse – or when significant new infrastructure has been added.
b) Where there has been a significant management or personnel re-structuring having an impact on the construction process, or
c) Where the builder contracts to construct a FOU of a different type or substantially different in design.

2.11.6 During construction of a FOU, IRS will ensure by surveys that parts of hull, machinery, mooring systems and topsides facilities requiring approval are in compliance with approved drawings, all required tests and trials are performed satisfactorily, workmanship is in compliance with current engineering practices and welded parts are produced by qualified welders.

2.11.7 All hull, machinery, electrical installations, mooring systems and items within the additional class notations (e.g. topsides, if requested) will be subjected to operational trials in the presence of IRS Surveyor.

2.11.8 On completion of the FOU, as fitted plans showing the FOU as built, essential certificates and records, loading manual etc. are to be submitted by the Builder generally prior to issuance of the Interim Certificate of Class.

2.11.9 For each new construction the builder is required to prepare and deliver a Construction portfolio containing documents / plans / manuals etc. for facilitating the future inspection, repair and maintenance as detailed in Section 7 in applicable sub-sections. Some of these documents may be directly supplied by other parties e.g. owner, for inclusion in the construction portfolio. The construction portfolio is to be maintained onboard each FOU.

2.12 Date of contract for construction/ conversion

2.12.1 The date of "contract for construction" of a vessel is the date on which the contract to build the FOU is signed between the prospective owner and the shipbuilder. This date and the construction numbers (i.e. hull numbers) of all the FOUs included in the contract are to be declared to IRS by the party applying for the assignment of class to a new building.

2.12.2 The date of "contract for construction" of a series of FOUs, including specified optional FOUs for which the option is ultimately exercised, is the date on which the contract to build the series is signed between the prospective owner and the shipbuilder. For the purpose of this requirement, FOUs built under a single contract for construction are considered a "series of FOUs" if they are built to the same approved plans for classification purposes. However, FOUs within a series may have design alterations from the original design provided:

a) Such alterations do not affect matters related to classification, or
b) If the alterations are subject to classification requirements, these alterations are to comply with the classification requirements in effect on the date on which the alterations are contracted between the prospective owner and the builder
c) Or, in the absence of the alteration contract, comply with the classification requirements in effect on the date on which the alterations are submitted to IRS for approval.

The optional FOUs will be considered part of the same series of FOUs if the option is exercised not later than 1 year after the contract to build the series was signed.

2.12.3 If a contract for construction is later amended to include additional FOUs or additional options, the date of "contract for construction" for such FOUs is the date on which the amendment to the contract, is signed between the prospective owner and the builder. The amendment to the contract is to be considered as a "new contract" to which 2.12.1 and 2.12.2 above apply.

2.12.4 If a contract for construction is amended to change the FOU type, the date of "contract for construction" of this modified FOU, or FOUs, is the date on which revised contract or new contract is signed between the Owner, or Owners, and the builder.

2.13 Date of Build

2.13.1 The date of completion of the special survey inspection will normally be taken as the date of build to be entered in the Register Book. Where there is a substantial delay between completion of construction survey and the FOU commencing service, the date of commissioning may be specified on the classification certificate. When modifications are carried out on a FOU, the initial date of build remains assigned to the FOU.

2.13.2 For conversions of existing tankers to FOUs, the provisions of 2.13.1 will apply as if the conversion were akin to construction of a new unit.

2.14 Appeal from Surveyor's recommend-dations

2.14.1 If the recommendations of the Surveyors are considered in any case to be unnecessary or unreasonable, appeal may be made to IRS, who may direct a special examination to be held.

2.15 Certificates

2.15.1 Certificates of Class will be issued to Builders or Owners when the required reports on completion of Special Surveys of new FOU or of existing FOUs submitted for classification have been received from the Surveyors and approved by IRS.

2.15.2 Certificates of class maintenance in respect of completed periodical special surveys of hull, machinery, mooring systems and applicable safety systems will also be issued to Owners.

2.15.3 The Surveyors are permitted to issue Interim Certificates to enable a FOU, classed with IRS, to commence service provided that, in their opinion, it is in a fit and efficient condition. Such Certificates will contain Surveyors' recommendations for continuance of Class, but in all cases are subject to confirmation by IRS.

2.15.4 Individual Certificates can also be issued for propelling machinery, boilers, equipments and fittings which have been manufactured under IRS Survey and in accordance with these Regulations

2.16 Suspension, Withdrawal and Deletion of Class

2.16.1 Suspension

2.16.1.1 The class of a FOU will be automatically suspended from the expiry date of the Certificate of Class or by the expiry date of any extension granted, if the special survey has not been completed by the due date and an extension (see also Chapter 2, Sections 1 – 4) has not been agreed to, or the FOUs not under attendance by the Surveyor with a view to complete the surveys prior to resuming service.

2.16.1.2 The class of a FOU will also be automatically suspended if the annual, intermediate survey becomes overdue. (See Rules and Regulations for Construction and Classification of Steel Ships, Part 1 Chapter 2, Table 1.1.1 for applicable due dates and window period).

2.16.1.3 When the surveys relating to specific additional notations of hull or equipment or machinery have not been complied with and thereby the FOU is not entitled to retain that notation, then the specific notation will be suspended till the related surveys are completed.

2.16.1.4 The class of a FOU will be subject to a suspension procedure if an item of continuous survey is overdue at the time of annual survey, unless the item is dealt with or postponed by agreement.

2.16.1.5 The class of the FOU will also be subject to a suspension procedure if recommendations and/or conditions of class are not dealt with by the due date or postponed by agreement, by the due date.

2.16.1.6 The class of a FOU is liable to be withheld or, if already granted may be withdrawn in case of any non-payment of fees or expenses chargeable for the service rendered.

2.16.1.7 Where any FOU proceeds to sea with less freeboard than that approved by IRS or when the freeboard marks are placed higher on the FOU's sides than the position assigned or approved by IRS, the FOU's class will be suspended.

2.16.1.8 When it is found that a FOU is being operated in a manner contrary to that agreed at the time of classification, or is being operated in conditions or in areas more onerous than those agreed, the class will be suspended.

2.16.1.9 The class of a FOU will be liable to be suspended if the Owner fails to notify IRS of any damage to the hull, machinery or equipment, mooring systems, safety systems, topside facilities and risers which may adversely affect classification of the FOU or subsequently fails to arrange for the survey as may be advised by IRS.

2.16.1.10 The class of a FOU will be suspended after a major casualty to the FOU, such as grounding, sinking or breaking up, if the Owner is unable to arrange for the FOU's survey by IRS and commence repairs within a reasonable period of the occurrence of the casualty, unless otherwise agreed to with IRS.

2.16.1.11 FOUs laid up in accordance with the Rules prior to surveys becoming overdue will not be suspended when surveys addressed above become overdue. However, FOU which are laid up after being suspended as a result of surveys becoming overdue, will remain suspended until the overdue surveys are completed.

2.16.1.12 When a FOU is intended for a demolition voyage with any periodical survey overdue, the FOU's class will not be suspended till completion of a single direct ballast voyage from the lay up to the demolition yard.

2.16.1.13 Force Majeure: If, due to exceptional circumstances the overdue surveys cannot be completed at the expiry of the periods allowed above, IRS may allow the FOU to sail, in class, directly to an agreed port at which the survey will be completed, provided:

a) Re-examination of the FOU's record is carried out by IRS,
b) IRS is satisfied that the FOU is in condition to sail for one trip to to a repair facility if necessary.

The scope of the overdue surveys will be based on the survey requirements applicable to the FOU at the original due date and not based on the age of the FOU when the survey is carried out. Such surveys will be credited from the date originally due.

If class has already been automatically suspended in such cases, it may be reinstated subject to the conditions prescribed above.

2.16.1.14 When a FOU is intended for a single voyage from laid-up position to repair yard with any periodical survey overdue, the FOU's class suspension may be held in abeyance and consideration may be given to allow the vessel to proceed on a single direct ballast voyage from the site of lay up to the repair yard, upon agreement with the Flag Administration, provided IRS finds the FOU in satisfactory condition after surveys, the extent of which are to be based on surveys overdue and duration of lay-up. A short-term Class Certificate with conditions for the intended voyage may be issued. This is not applicable to FOUs whose class was already suspended prior to being laid up.

2.16.1.15 Classification will be reinstated upon satisfactory completion of overdue survey. The scope of the overdue surveys will be based on the survey requirements applicable to the FOU at the original due date and not based on the age of the vessel when the survey is carried out. Such surveys will be credited from the date originally due. Such surveys will be credited from the date originally due. However, the FOU will remain dis-classed from the date of suspension until the date class is reinstated.

2.16.1.16 The Owners and the Flag State, where applicable, would be informed in writing, of the suspension and reinstatement of Classification.

2.16.2 Withdrawal

2.16.2.1 FOU's class will be withdrawn, at the end of six months of suspension, if the Owner has not commenced any action to reinstate the FOU's class. A longer suspension period may be granted when the FOU is not in service or in cases of lay-up awaiting attendance for reinstatement or disposition, in the event of a casualty.

2.16.2.2 When the class of a FOU holding IRS class, is withdrawn by IRS in consequence of a request from the Owners, the notation "Class withdrawn at Owners' request" (with date) will be made in the subsequent reprints of the Register of Ships. This entry will continue till the FOU's class is reinstated or deleted.

2.16.2.3 When the Regulations as regards surveys on the hull or equipment or machinery or mooring systems and items covered in assigned class notations have not been complied with and the FOU thereby is not entitled to retain her class, the class will be withdrawn and the notation "Class withdrawn" (with date) will be made in the subsequent reprints of the Register Of Ships. This entry will continue till the FOU's class is reinstated or deleted.

2.16.2.4 The withdrawal of a FOU from class will be confirmed in writing to the Owner and the Flag State, where applicable.

2.16.3 Deletion of Class

2.16.3.1 A FOU will be considered to "cease to exist" when it is destroyed by scrapping or by sinking to unsalvageable depths or abandoned by the owner.

2.16.3.2 A FOU can also be considered to "cease to exist" when it is broken up either by grounding or due to structural failure or due to actions of war or sabotage.

2.16.3.3 FOU's class will be deleted when it ceases to exist.

2.17 Reclassification

2.17.1 When Owners request for reclassification of a FOU for which the class previously assigned has been withdrawn, IRS will require a Special Survey for Reclassification to be held by the Surveyors. The extent of the survey will depend upon the age of the FOU and the circumstances of each case.

2.17.2 If the FOU is found or placed in good and efficient condition in accordance with the requirements of the Rules at the Special Survey for Reclassification, IRS may decide to reinstate her original class or assign such other class as considered appropriate.

2.17.3 The date of reclassification will appear in the supplement to the Register of Ships and the subsequent issue of Register of Ships.

2.18 Transparency of Classification and Statutory Information
2.18.1 Requirements within Rules and Regulations for Construction and Classification of Steel Ships, Part 1, Chapter 1, Section 2.21 are applicable.

Section 3

Classification of FOUs not built under the Survey of Indian Register of Shipping

3.1 General Procedure for classification of FOUs not built under survey of IRS
3.1.1 Plans of Hull, Machinery, Mooring system, Electrical installations, Safety Systems, Topside Production Facilities (as applicable) and applicable plans as per additional class notations requested are to be submitted for approval. It is preferable to have the plans approved before the commencement of classification survey.

3.1.2 If plans cannot be obtained or prepared by the owner, IRS may at its discretion consider collection of the required data and information. For this purpose IRS surveyors shall be provided access to the FOU. Additional Fees would be applicable as deemed by IRS.

3.1.3 Full special classification surveys would require to be carried out by IRS Surveyors in order to satisfy themselves regarding the workmanship and condition of the FOU and to verify the approved scantlings and arrangements. The scope of these surveys may, however, be modified in the case of FOUs built under the Special Survey and holding valid certificates of class of established classification societies or equivalent, if prior to commencement of survey by IRS, documentary evidence of all applicable classification surveys held by the other society subsequent to last special survey carried out by them could be produced. In such cases, a special survey notation will not be assigned in conjunction with the classification survey. The next special survey therefore would become due five years from the special survey held by the other society and not five years from classification with IRS.

3.1.4 In cases where the full special classification surveys would be performed over a period of time, issue of interim certificate may be considered based upon careful review of the merits case by case.

3.2 Plans and Information
3.2.1 The required plans and information for classification are detailed in Section 7. Additional plans and information may be requested as necessary.

3.2.2 It is expected that particulars of the process of manufacture and testing of material of construction are furnished. Consideration will however be given to waiving this where such particulars are not readily available, provided it can be established that the relevant FOU has been originally built under special survey of an IACS member classification society and continues to be so classed with an IACS member classification society. In the case of FOU which has been originally built under the special survey of an IACS member classification society but subsequently not maintaining class, it should additionally be possible to reasonably ascertain that no changes that would significantly affect the material specifications have taken place.

3.2.3 Calculations of torsional vibration characteristics of the main propelling machinery are to be furnished specially for self-propelled FOUs which have been in service for less than about 2 years.

Section 4

Alternative Certification Scheme based upon Quality Management systems

4.1 General

4.1.1 Alternative Certification Scheme will be in accordance with the requirements of Rules and Regulations for Construction and Classification of Steel Ships, Part 1, Chapter 1, Sec 4.

Section 5

Risk Assessment based Classification

5.1 General

5.1.1 Classification using Risk based assessment methods may be applied to the whole of the FOU or specific items if requested by the Owner. In such cases, the FOU will be applicable for the class notation 'RA' with descriptive notes specifying the extent of classification using Risk assessments.

5.1.2 The Risk assessments are to be submitted to IRS based upon acceptable techniques as mentioned in recognized standards e.g. ISO 17776, Norsok Z-013 etc.
The Risk assessment reports are to contain the following but not limited to:

- Scope of the Risk assessment
- Assumptions utilized within the Risk assessment reports
- Hazard identifications, Hazard operability studies, Fault tree analyses, Failure modes and effects analyses
- Accident Scenarios
- Frequency and Consequence assessments
- Risk acceptance criteria utilized
- Risk reduction measures
- Emergency procedures developed as a result of the Risk assessment.

5.1.3 IRS would also examine the operational manuals and procedures for the FOU which are relevant to the scope of the Risk assessment for classification.

5.1.4 IRS would also conduct surveys during the construction, installation and commissioning of the FOU to verify the realization of the basis on which classification was assigned to the unit.

5.1.5 IRS would conduct periodic surveys onboard the FOU to verify that the basis on which classification was assigned to the unit is being maintained during the service life. The frequency, scope and extent of such surveys would be decided by IRS.

Section 6

Additional Class Notations

6.1 INWATER SURVEY

6.1.1 This optional class notation may be assigned to FOUs where In-water survey is carried out in lieu of a dry docking survey. The FOU is to comply with applicable requirements as provided within Chapter 2, Section 2.

6.2 CSR

6.2.1 This optional class notation is to be assigned to FOUs the hulls of which have been designed in accordance with the IRS Rules for Bulk Carriers and Oil Tankers.

6.3 POSMOOR

6.3.1 This class notation is to be assigned to FOUs provided with position mooring arrangements (spread or single point) arrangements are in accordance with Chapter 2, Section 4 and Chapter 5, Section 1.

6.3.2 Descriptive notes "Spread Mooring" or "Single Point Mooring" may be assigned depending upon the type of the position mooring arrangement provided.

6.4 Thruster assisted mooring

6.4.1 This optional class notation may be assigned to FOUs provided with thruster units to assist in the position keeping in addition to the position mooring systems. The thrusters provided are to comply with requirements of Chapter 5, Section 2.5. The position mooring arrangements are to comply with Chapter 2 Section 4 and Chapter 5, Section 2 of the Rules.

6.5 DISCON

6.5.1 This optional class notation may be assigned to FOUs which have been provided with disconnect arrangements from the mooring and riser systems.

6.6 HELIDECK

6.6.1 This optional class notation may be assigned to FOUs provided with Helidecks.

6.6.2 The design and arrangement of Helideck and supporting facilities are to be in accordance with requirements provided for Helicopter decks and facilities within Rules & Regulations for Construction and Classification of Mobile Offshore Drilling Units. IRS may also consider design and arrangement based on other recognized standards such as CAP 437 and API RP 2L

6.6.3 Structural Design of the Helideck is to be verified in accordance with Chapter 5, Section 3.

6.6.4 Compliance with the relevant national regulations of the region where the FOU is to operate is also required.

6.7 JUS (Diving Support Vessel)

6.7.1 This optional class notation may be assigned to FOUs provided with arrangements and equipment for diving support in compliance with requirements provided in Rules and Regulations for Construction and Classification of Steel Ships, Part 5, Chapter 26

6.8 CCS

6.8.1 This optional class notation may be assigned to FOUs provided with propulsion and auxiliary machinery which can be controlled and monitored with continuous supervision from a centralized control station as provided within Rules and Regulations for Construction and Classification of Steel Ships, Part 4, Chapter 7.

6.9 NV

6.9.1 This class notation is to be assigned to FOUs provided with inert gas systems which are in accordance with Chapter 6, Section 9.

6.10 COW

6.10.1 This class notation is to be assigned to FOUs provided with crude oil washing systems certified by IRS.

6.11 ASCANT

6.11.1 This optional class notation may be assigned to FOUs provided with scantlings in excess of that required by the rules. For example notation of ASCANT (BTM – 1) can be provided to FOU whose bottom has been provided with an additional 1mm thickness over and above the rule requirements.

6.12 PMS
6.12.1 This optional class notation may be assigned to FOUs which have opted for planned maintenance scheme for the propulsion and auxiliary machinery. The requirements to be met for this notation are as per the Rules and Regulations for Construction and Classification of Steel Ships Part 1, Chapter 2.

6.13 SYJ
6.13.1 This class notation is to be assigned to FOUs in compliance with requirements within Rules and Regulations for Construction and Classification of Steel Ships, Part 5, Chapter 22.

6.14 RISER
6.14.1 This optional class notation may be assigned to riser systems installed for the FOU. The riser systems are to be in compliance with requirements in Chapter 5, Section 5. The class notation may be supplemented with the descriptive note "Flexible Riser" if flexible pipes are used for the risers.

6.15 RA
6.15.1 This optional class notation may be assigned to FOUs which are in compliance with requirements of risk assessment based classification in Section 5. Descriptive note detailing the scope and extent of the applicability of Class notation is to be assigned. For e.g. RA – Fire Safety Systems.

Section 7

Drawings and Information

7.1 General
7.1.1 Drawings and calculations are required to be submitted as provided within this section. This section is applicable to newbuild FOUs as well as FOUs built from conversions of existing vessels. For additional class notations; applicable drawings may be required by the corresponding Rules referred for those specific class notations.

7.1.2 The following plans are in general required to be submitted for information but not limited to:

- General arrangement of the FOU hull
- General arrangement of the FOU topsides facilities
- General layout of the mooring system
- List of machinery and electrical equipment including the topside process facilities
- Machinery layout and Equipment layout for the unit
- Loading manual
- Loading instrument details
- Capacity plan
- Lines plan
- Design brief/Design basis/Technical specification document for the FOU
- Risk analysis/FMEA/Hazop studies performed. (In case the RA notation is requested then these documents are to be submitted for approval)
- Operational manual (the manual will be reviewed in relation only to items relevant to class)
- Emergency shutdown procedures
- Emergency Preparedness
- Towing arrangements

7.2 Hull
7.2.1 The plans, informations and calculations for hull to be submitted for approval are listed in Rules and Regulations for Steel Ships, Part 3, Chapter 1, Section 3.4. Additional documentation required to be submitted is as described below:

- Hull structure i.w.o of supports for topside modules, mooring arrangements
- Hull structure i.w.o turret system (if applicable)
- Hull Structure support for flare towers
- Hull structure i.w.o riser systems
- Helideck Structure & support along with Hull structure i.w.o.
- Deckhouses and Accommodations
- Topside structural frames (structural details equipment skids may not be included; though their locations and weights are to be indicated with

information on the co-ordinates of the centre of gravity)

- Topside structural support stools/ connections to the decks.
- Trim & Stability booklet
- Corrosion protection and monitoring plan
- In-water survey plan (if applicable) as per Rules and Regulations for Construction and Classification of Steel Ships, Part 1, Chapter 2, Section 7.2.2.

7.2.2 Calculations in form of stress analysis computations, hydrodynamic and wind load computations, detailed cargo hold strength analyses; full ship analysis may accompany the plans as further support. For site specific evaluations, the analysis/calculations justifying the environmental safety factors (as defined in Chapter 4) are also required to be submitted. If deemed necessary by IRS, the finite element model files used for the various analyses or the hydrodynamic model files are to be submitted to IRS.

7.2.3 Where required, IRS may request additional details to ascertain the structural integrity of the hull.

7.3 Machinery

7.3.1 The following plans are to be submitted for approval but may not be limited to:

For self-propelled units

- Thrust, intermediate and propeller shafting
- Propeller
- Main engines, propulsion gears and clutch systems (or manufacturer make, model and rating information)
- Steam piping
- Bilge and Ballast piping system
- Wiring diagram
- Steering gear systems, piping arrangements and steering gear manufacturer make and model information
- Pumping arrangements at forward and aft ends and drainage of cofferdams and pump rooms
- General arrangement of cargo piping in tanks and decks
- Installation & Testing plan

For non-self-propelled units

- Power Generation equipment (or manufacturer make, model and rating information)
- Bilge and Ballast piping system
- Wiring diagram
- Pumping arrangements at forward and aft ends and drainage of cofferdams and pump rooms
- General arrangement of cargo piping in tanks and decks.
- Specification for pipes, valves and other components.
- Installation & Testing plan for various machinery.

7.4 Mooring system

7.4.1 The following plans and calculations are to be submitted for review and/or approval as may be applicable. These are applicable in general for position mooring systems as well as thruster assisted mooring systems.

- Environmental data (wind, waves, current) for site (for review)
- Geotechnical data for the seabed including reports and details of field and laboratory tests carried out.
- Detailed mooring lines layout (inclusive of mooring fittings such as fairleads, stoppers, accessories etc.)
- Mooring analysis calculations/report (in accordance with requirements in Chapter 5). This is to also include fatigue analysis calculations as specified in Chapter 5, Section 2.
- Motion analysis/report of the FOU considered for the mooring analysis calculations listed above.
- Mooring model tests (as applicable and in accordance with requirements in Chapter 5)
- Calculations for the foundations/anchor holding capacities. In addition or in lieu field test data may also be submitted.
- Specifications which may include test data for the materials of wire ropes, cables, chains, anchors, fairleads, stoppers and other miscellaneous accessories.
- Corrosion protection plan

- Alarms and monitoring systems for tensions in the mooring lines
- Alarms and monitoring systems for ship motions and excursions
- Survey & Inspection plan
- Installation & Test procedures
- Disconnection procedure

7.4.2 The following plans & calculations are to be submitted in addition to those specified in

7.4.1. if the turret mooring system is to be used for the position keeping of the installation; the following plans are to be submitted.

- General arrangement of the turret mooring system
- Turret structures
- Arrangement and specifications for the turret bearings, seals and swivel stacks bearings and seals.
- Relevant Machinery and Electrical systems
- Control and Monitoring systems including related alarms
- Piping arrangements within the turret system
- Buoys (if utilized)
- Installation & Test procedures
- Disconnect procedures
- Inspection plan

7.4.3 For thruster assisted mooring; the plan/documents/reports for machinery, electrical installations and control systems are to be submitted as per requirements in Rules and Regulations for Construction and Classification of Steel Ships, Part 5, Chapter 24, Section 1.5.

7.5 Electrical Installations

7.5.1 Documentation as required by Rules and Regulations for Construction and Classification of Steel Ships, Part 4, Chapter 8, Section 1.4 for approval. In addition, the following is also required to be submitted.

- Design basis/philosophy describing the power generation systems and their operation under normal and emergency modes. The documentation should also demonstrate the provisions of power supply for essential services. The documentation should encompass all utilities and services.
- Electrical equipment arrangement and plan in Hazardous areas (Hazardous areas are defined in Chapter 7, Section 3). A schedule of related electrical equipment is to be provided listing the certifying authority and the associated standards. Copies of the certificates also are to be provided.
- Documentation to support compliance with requirements within IEC 61892.
- Other miscellaneous documentation as may be referred to within the other chapters.
- In case of topside facilities being requested for classification with IRS; additional details for electrical equipment responsible for power supply to the process equipment are to be submitted. (see 7.9).
- IRS may request additional details if deemed necessary.

7.6 Safety & Control Systems

7.6.1 Documentation as required by Rules and Regulations for Construction and Classification of Steel Ships, Part 4, Chapter 7, Section 1.3 is to be submitted for approval. In addition, the following plans/documentation are also to submitted for approval

- Hazardous area plan of the unit (Hazardous areas are defined in Chapter 7, Section 3)
- Layout and arrangement of Emergency Shutdown systems
- Cargo Instrumentation diagram
- Design philosophy of the safety and control systems to demonstrate how the provided systems are adequate and effective during normal operations and emergency modes. The documentation should encompass safety and control systems for all utilities and services including those of the topside process equipment.
- Layout and arrangement of the control station(s) on the unit. In case of multiple control stations, the controls and monitoring by each control station and the modes of communication between the various control stations. The documentation is to also illustrate the ventilation arrangements for such control stations.
- Other miscellaneous documentation as may be referred to within the other chapters.

7.7 Fire Safety

7.7.1 Documentation required by Rules and Regulations for Construction and Classification of Steel Ships, Part 6, Chapter 1, Section 1.2 is to be submitted for approval.

7.7.2 Report demonstrating the effectiveness of the fire safety arrangements as required by Chapter 7, Section 4.8.

7.8 Riser Systems

7.8.1 The following documentation, plans and calculations are to be submitted for information/review/approval towards eligibility of assignment for RISER notation.

- Design basis/Design philosophy document (for information only)
- Arrangement of the riser systems along with components such as valves, flanges and other fittings. The arrangement is to also include details of buoyancy modules, clump weights and other components if utilized in the riser system.
- Details of connection to the FOU and the PLEM on seabed.
- Specifications for the materials for the riser lines and components such as valves, flanges, miscellaneous fittings.
- Analysis report for the structural integrity assessment of the riser systems depicting the ultimate strength and fatigue assessments (for information only).
- Control systems relevant to the risers
- Monitoring systems for risers (for gauging pressures, temperatures, flow, motions of the risers etc.)
- Installation & test procedures
- Inspection & maintenance plan.

7.9 Topsides Production Facilities

7.9.1 The following documentation, plans and calculations are to be submitted for information/review/approval of Topside Production facilities for Units to be assigned the FPSO/FPU type notation.

- Design basis/Design philosophy documents (for information only) clearly outlining the operating limits and the specifications for the fluids to be processed.
- General layout arrangement of the topside production equipments
- Hazardous area plan
- P & ID diagrams for the process systems
- Piping isometric drawings
- Material specifications for piping, valves and other components
- Equipment Specifications including design documentation, fabrication records, test records and certificates from the manufacturer as applicable
- Risk assessment report for topside production facilities (for review)
- FMEA reports for the various equipments (for review)
- Operating manuals (for information only)
- Structural plans for the skids and support foundations for the equipments
- Structural analysis reports for the skids and support foundations (for review only)
- Stress analysis report of the piping systems (for review only)
- Electrical installations plans (refer 7.5 for the detailed list of plans required)
- Fire safety arrangements (refer 7.7 for the detailed list of plans required)
- Control and monitoring systems arrangement and diagrams
- Emergency shutdown systems
- Safety analysis flow diagrams and safety analysis function evaluation (SAFE) charts (refer API RP 14C)
- Installation manuals (for information only)
- Equipment Maintenance plan
- Calculations for the sizing of pressure relief systems (including the flare systems)
- Ventilation plan
- Documentation as may be required by the standards/rules within chapter 8.
- Other documentation as deemed necessary by IRS to ascertain the safety of the topside production facilities.

Section 8

List of Recognized Standards, Rules and Guidelines

The following constitutes a list of recognized codes, standards, rules and guidelines to be used with the Rules.

ANSI/AISC 360-05	Specification for Structural Steel Buildings
API RP 2A	Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms— Working Stress Design
API RP 2FPS	Recommended Practice for Planning, Designing and Constructing Floating Production Systems
API RP 2FB	Recommended Practice for Design of Offshore Facilities against Fire and Blast Loading
API RP 2SK	Recommended Practice for Design and Analysis of Stationkeeping systems for Floating Structures
API RP 2L	Recommended Practice for Planning, Designing and Constructing Heliports for Fixed Offshore Platforms
API RP 2RD	Dynamic Risers for Floating Production Installations
API Spec 2C	Specification for Offshore-Pedestal mounted Cranes
API Spec 2F	Specification for Mooring Chain
API RP 2I	In-Service Inspection of Mooring Hardware for Floating Drilling Units
API RP 14F	Design, Installation and Maintenance of Electrical Systems for Fixed and Floating Offshore Facilities for Unclassified and Class 1, Division 1 and Division 2 Locations
API RP 17B	Recommended Practice for Flexible pipe
API Spec 17J	Specification for Unbonded Flexible pipe
API Spec 17K	Specification for Bonded Flexible pipe
ASME B31	Code for Pressure Piping
CAP 437	Standards for Offshore Helicopters landing areas
EN 12495	Cathodic Protection for Fixed Steel Offshore Structures
EN 13173	Cathodic Protection for Steel Offshore Floating Structures
EN 1993 / EC3	Design of Steel Structures
HSE	Offshore Installations: Guidance for Design, Construction and Certification.
NORSOK Standard Z-013	Risk and emergency preparedness analysis
ISO 2394	General principles on reliability for structures

ISO 4309	Cranes – Wire Ropes: Care, maintenance, inspection and Discard
ISO 9089	Marine Structures – Mobile Offshore Units: Anchor Winches
ISO 13628	Design and Operation of Subsea Production Systems
ISO 13702	Petroleum and natural gas industries – Control and mitigation of fires and explosions on Offshore Production installations – Requirements and Guidelines
ISO 17776	Petroleum and natural gas industries – Offshore Production Installations: Guidelines on tools and techniques for hazard identification and risk assessment
ISO 19901 – 3	Petroleum and natural gas industries – Specific requirements for offshore structures. Topsides structure
ISO 19901 – 4	Petroleum and natural gas industries – Specific requirements for offshore structures. Geotechnical and foundation design considerations
ISO 19901 – 7	Petroleum and natural gas industries – Specific requirements for offshore structures. Stationkeeping systems for floating offshore structures and mobile offshore units
ISO 19904 – 1	Petroleum and natural gas industries – Floating offshore structures. Part 1 : Monohulls, semi-submersibles and spars
IMO Resolution A.1023(26)	Code for construction and equipment of Mobile Offshore Drilling Units, 2009 (2009 MODU Code)
IEC 61892 – 1	Mobile and fixed offshore units – Electrical installations. Part 1: General requirements and conditions
IEC 61892 – 2	Mobile and fixed offshore units – Electrical installations. Part 2: System Design
IEC 61892 – 3	Mobile and fixed offshore units – Electrical installations. Part 3: Equipment
IEC 61892 – 4	Mobile and fixed offshore units – Electrical installations. Part 4: Cables
IEC 61892 – 5	Mobile and fixed offshore units – Electrical installations. Part 5: Mobile Units
IEC 61892 – 6	Mobile and fixed offshore units – Electrical installations. Part 6: Installations
IEC 61892 – 7	Mobile and fixed offshore units – Electrical installations. Part 7: Hazardous Areas
IMO FTP Code	International Code for Application of Fire Test Procedures
IMO FSS Code	Fire Safety Systems Code
IP Code 15	Hazardous Areas
NFPA 10	Standard for Portable Fire Extinguishers
NFPA 15	Standard for Water Spray Fixed Systems for Fire Protection

End of Chapter

Chapter 2

Surveys

Contents

Section 1

Surveys – General

1.1 General

1.1.1 The scope and schedules of surveys for hull, machinery and mooring systems are to be in accordance with the requirements provided in Sections 2, 3 and 4.

1.1.2 Arrangements for access to the FOU's hull structure is to be in accordance with requirements as given in IRS Rules for Bulk Carriers and Oil Tankers Volume 1, Part 3, Chapter 1, Section 1 [5].

1.2 Application of Risk based techniques

1.2.1 IRS shall specially consider Surveys scheduled based on Risk based techniques. For this purpose, all reports and supporting documentation justifying the Survey programme (scope and schedule through the FOU life) are to be submitted to IRS. The assumptions utilized in the analyses within the reports shall be clearly mentioned.

1.2.2 The following details must be clearly specified within the report

- Identification of hazards
- HAZOP studies
- Frequency analysis
- Consequence analysis
- Risk acceptance criteria
- Frequency of surveys and inspections based upon the above factors.

Section 2

Surveys – Hull

2.1 Surveys during New Construction

2.1.1 For new construction surveys of FOUs, the requirements of IRS Rules for Bulk Carriers and Oil Tankers Volume 1, Part 3, Chapter 2 are applicable. For FOU hulls constructed from existing ships, reference is made to sub-section 2.3.

2.2 Periodic Survey of FOU hull

2.2.1 The survey requirements including applicable In-water survey requirements for FOU hulls are to be in accordance with requirements in IRS Rules for Bulk Carriers and Oil Tankers Volume 1, Part 1, Chapter 2 & Chapter 3, Sections 2 & 3 as applicable to Oil Tankers.

2.2.2 The requirements in this section will prevail in case of any conflict with those in the references in 2.2.1.

2.2.3 A survey programme is to be submitted to IRS for review and approval. The survey programme must consist of but not limited to:

- Tanks to be surveyed, close-up areas etc.
- Critical areas
- Surveys of outer hull (docking surveys or in-water surveys)
- Inspection methods, procedures and Maintenance schemes
- Monitoring systems and Reporting schedules for the FOU hull
- Testing procedures
- Locations and methods of NDT
- Any other items as may be necessary to maintain the structural and functional integrity of the hull.

2.2.4 IRS may increase the frequency and extent of surveys if indications suggest deterioration rate of FOU hull is above tolerable limits.

2.2.5 IRS will specially consider In-water surveys for FOUs more than 15 years of age. This will be subject to the assessments of IRS, based upon the previous surveys, inspections and necessary analyses performed. In addition to the In-water survey requirements in 2.2.1, additional requirements are to be complied with as provided in sub-section 2.5.

2.2.6 Considering the operational requirements/constraints of the FOU, IRS may also impose conditions for increased frequency of in-water surveys of the FOU hull. In case of high deterioration rate of FOU hull, increased frequency of in-water surveys for the hull may also be required. However, consideration will be made to the operational requirements / constraints of the FOU.

2.3 New construction surveys for FOU hulls converted from existing ships

2.3.1 A comprehensive pre-conversion survey of the vessel hull to be converted is to be performed. The purpose of the survey is to estimate the structural health of the existing hull (e.g. dimensions, scantlings, corrosion diminutions, fatigue cracks etc.).

2.3.2 The survey methods (visual inspection, MPI, NDT etc.), their extent and locations shall be agreed upon with IRS. Survey history of the existing vessel is also to be considered when planning the pre-conversion survey of 2.3.1.

2.3.3 The results of the survey performed in 2.3.1 should be considered during structural reassessment of the FOU hull in respect of design, steel renewal and structural modifications for strengthening.

2.3.4 The surveys during the conversion stages will be in accordance with the requirements described in sub-section 2.1 for new construction.

2.4 Periodic Surveys of Major Structures and Structural Foundations

2.4.1 All Major structures and Structural foundations are to be included within the scope of annual surveys (refer Chapter 5 for the definitions of Major Structures and Structural foundations). These are to be examined to the extent practicable and their general condition is to be verified.

2.4.2 All Major Structures and Structural foundations are to be included within the scope of Special Surveys. Close-up survey to the extent possible is recommended.

2.5 Additional Requirements for In-water surveys for FOUs

2.5.1 In lieu of dry docking, in-water survey of outer bottom is acceptable for FOUs which comply with the INWATER SURVEY class notation (Refer Chapter 1, Section 6.1) provided that not less than two in-water surveys have been carried out in any five year periods verifying the satisfactory condition of the FOU hull. The interval between such in-water surveys in any case is not to exceed 36 months.

2.5.2 Extent and Scope of In-water surveys is to be in accordance with plans approved by IRS at the design stage of construction/conversion of the FOU. The submitted survey programme (See also 2.2.3 and 2.5.4) is to clearly indicate the maximum duration upto which the FOU is designed to undergo in-water surveys in lieu of drydocking.

2.5.3 Safety management system on board is to specify and implement the procedures for regular monitoring and reporting of the condition of the hull and underwater fittings/equipment of the FOU. IRS will also verify the compliance of the Survey programme submitted in accordance with requirements in 2.5.2. In case of any adverse findings by IRS during the In-water survey which reveals damage or deterioration requiring immediate attention, IRS may require the FOU to be dry docked for detailed investigations for necessary rectifications.

2.5.4 The submitted survey programme (see 2.5.2) is to cover the following aspects as applicable, but not limited to:

.1 Environmental and visibility conditions under which the survey will be carried out

.2 Markings on the underwater hull to identify location of bulkheads, watertight doors, tanks and sea suctions/discharges

.3 Details and arrangements for inspecting and servicing sea-chests, sea inlet/discharge valves, other appendages and the underwater hull.

.4 Details for servicing the maintenance programme for essential equipment and underwater fittings such as the echo sounder, ICCP systems, speed log, sea water temperature gauges, electronic draught gauges, shaft seals, controllable pitch propeller blade seals, sea chests, sea inlet discharge valves etc.

.5 Corrosion protection scheme: Details of increased scantlings, cathodic protection, protective coating etc. to account for the longer period of service without dry docking.

.6 Details of protective coatings applied to double bottom, wing tanks, ballast tanks, void spaces and spaces adjacent to shell and the maintenance scheme to keep these coatings in "Good" conditions.

.7 Details of hull protection system adequate for the extended period (cathodic protection or other arrangements) and procedure for maintenance/renewal in afloat condition.

.8 Arrangements for underwater inspections and maintenance of propellers, thrusters and rudders; provision of efficient sealing/glands for stern tube and rudder including their renewal where required; arrangements for the measurement of wear in the stern tube bearings and rudder bush/bearings

.9 Provisions for surveys and maintenance of thrusters/stabilizers.

2.5.5 The In-water survey findings will be reviewed by IRS in relation with previous findings to identify areas of concern which may need further investigation and rectification.

Section 3

Surveys – Machinery and Systems

3.1 Survey of FOU Machinery & Systems

3.1.1 The survey requirements of FOU Machinery and Systems are to be in accordance with Rules and Regulations for Construction and Classification of Steel Ships, Part 1, Chapter 2, Sections 8 – 17.

Section 4

Surveys – Mooring Systems

4.1 General

4.1.1 Requirements for the surveys of position Mooring systems and Thruster assisted mooring arrangements are given in this section.

4.1.2 Position mooring systems consist of the following two variants:

- Spread mooring systems
- Single Point mooring systems

4.1.3 A survey programme for mooring systems is to be submitted to IRS for approval. The programme should consider inspection of at least the following :

- Mooring chains/ropes
- Winches/Windlasses
- Fairleads & Stoppers
- Anchors/Foundations
- Miscellaneous fittings/components
- Swivel Stacks (if applicable)
- Swivel bearings (if applicable)
- Turret bearings & seals (if applicable)
- Buoys (if applicable)

4.1.4 IRS may consider increasing the frequency and extent of surveys based upon the indications obtained as a result of inspections.

4.1.5 IRS may consider a survey programme developed using risk based approaches based upon the philosophy specified in Section 1.2.

4.2 Annual Surveys of mooring system

4.2.1 Annual Surveys are to be conducted at approximately twelve month intervals, with the vessel at operational draft, with the position mooring system in use.

4.2.2 The purpose of the Annual Survey is to confirm that the mooring system will continue to carry out its intended purpose until the next annual survey. No disruption of the unit's operation is intended unless absolutely essential for the purpose of survey.

4.2.3 The scope of the annual survey is the visual examination of the accessible mooring system components for verification of their condition. Particularly, the following items are to be inspected

- Anchor chains, stoppers, fairleads and other mooring components etc. as visible and accessible.
- Winches/windlasses
- Chain catenary angles or tensions within the chains
- Disconnect mechanism (if applicable)
- Monitoring system/equipment for the mooring systems (e.g tensions within the chains, excursions of the FOU etc.)
- Other items as considered necessary by the Surveyor.

4.2.4 The surveyor is to determine if any problems have been experienced in the previous 12 months period with the mooring system, e.g. breaks, mechanical damage, loose joining shackles, chain or wire jumping. Review of records of the onboard logs for the mooring system is to be carried out by the surveyor.

4.2.5 For single point mooring systems the following components are to be subjected to visual examination as accessible

- Turret bearings
- Turret seals
- Swivel stack Structure
- Swivel stack bearings
- Disconnect mechanism (if applicable)
- Buoys
- Other structures which are critical to the functioning of the single point mooring system

The components must be visually observed for evidences of damage, deterioration, corrosion and other degradations

4.2.6 Requirements relating to inspection of the different mooring system components such as chains, ropes, fairleads, stoppers etc. are provided in 4.4.

4.3 Special Surveys of mooring systems

4.3.1 Special surveys are to be carried out at five year intervals. Special surveys require extensive inspections and are recommended to be performed in sheltered waters or drydocks. The intervals between Special surveys may be reduced by IRS if considered necessary.

4.3.2 The following items are to be inspected closely as accessible but not limited to:

- All Chains, ropes, fairleads, stoppers and other miscellaneous components. The regions of the chains or ropes in contact with the fairleads, stoppers or the seabed are to be subject to a thorough examination. The above items may need to be thoroughly cleaned for an effective examination of their condition. Requirements for their examination are provided in 4.4.
- The condition of all the anchors or piles and scouring around anchors/piles is to be checked.
- NDT sampling for critical components
- Condition of corrosion protection systems
- Components of the single point mooring system as listed in 4.2.5 are to be subject to a thorough examination.

4.3.3 For areas which may be inaccessible /not readily accessible, owner is to submit to IRS a plan highlighting procedures for surveys and verification of conditions for such areas.

4.3.4 Tensions within the mooring lines are to be checked. The condition of the monitoring systems for mooring including alarms and safety systems is to be affirmed. Records of logs of the monitoring systems are to be examined.

4.4 Requirements for surveys of mooring chains, ropes and components

4.4.1 Annual Surveys

4.4.1.1 The scope of the Annual Survey is limited to the mooring components adjacent to the winch or windlass, fairleads and stoppers. Depending on the mooring component visible from the unit, particular attention should be given to:

Chain

- Wear on the chain shoulders in way of the fairleads, chain stopper and windlass pockets
- Support of chain links in the windlass pockets

Wire Ropes

- Flattened ropes
- Broken wires
- Worn out or corroded ropes

4.4.1.2 If the annual survey reveals severe damage or neglect to the visible parts of chain or cable, more extensive surveys should be carried out.

4.4.1.3 Typical damages warranting additional extensive surveys as required in 4.4.1.2 are as follows but not limited to:

Chain

- Reduction in diameter exceeding 4%;
- Missing studs;
- Loose studs in Grade 4 chain;
- Worn out cable lifters (i.e. gypsies) causing damage to the chain.

Wire rope

- Obvious flattening or reduction in area;
- Worn cable lifters causing damage to the wire rope;
- Severe wear or corrosion;
- Broken wires.

4.4.2 Special Surveys

4.4.2.1 Purpose of special surveys is to ascertain that each chain/wire rope is capable of fulfilling its intended purpose till the next special survey subject to appropriate care and maintenance of the mooring system.

4.4.2.2 The scope of a special survey is as follows but not limited to:

- Close visual examination of all links of mooring chains, with cleaning as required
- Enhanced representative NDT sampling
    - Atleast 5% on general chains
    - Atleast 20% on chain which has been in way of fairleads over last five (5) years
    - All connecting links
- Dimension checks, including length over five (5) links

4.4.2.3 In particular, attention is to be given to:

- Lengths of chain (or wire rope) which have frequently been in contact with the windlass, fairleads, stoppers, seabed etc. during the unit's operation since the last survey. The Surveyor is to ensure that these lengths are rated for use in the way of the windlass and fairlead.
- The looseness and pin securing arrangements of the joining-shackles
- All windlass and fairlead chain pockets for:
    - Unusual wear or damage to pockets
    - Rate of wear on pockets, including relative rate of wear between links and pockets
    - Mis-match between links and pockets, and improper support of the links in the pockets.
- Condition of corrosion protection systems
- Marine growth
- Damages (if any)

4.4.2.4 All joining-shackles of the Kenter type and bolted type which have been in service for more than four (4) years are to be dismantled and an MPI performed on all machined surfaces as per 4.4.9.2 & 4.4.9.3.

4.4.2.5 The thickness (diameter) of approximately 1% of all chain links should be measured. The selected links should be approximately uniformly distributed through the working length of the chain. The extent of measurement may be increased if the visual examination indicates excessive deterioration.

4.4.2.6 A functional test of the mooring system during anchor-handling operation is to be carried out keeping in focus:

- Smooth passage of chain links and/or wire rope and joining-shackles over the windlass and fairleads pockets
- The absence of chain jumping or other irregularities

4.4.3 Continuous Surveys

4.4.3.1 IRS may consider requests from owners for continuous survey programme in lieu of special survey if extra mooring line(s) is (are) provided on the unit. This would enable the exchange with another line(s) installed on the unit while the removed line could be inspected on shore. Such exchange may take place on an annual basis or an appropriate interval agreed by IRS.

4.4.4 Inspection of mooring system components - Anchors

4.4.4.1 The anchor head, flukes and shank are to be examined for damage, including cracks or bending. The anchor shackle pin and crown pin are to be examined and renewed if excessively worn or bent. Moveable flukes are to be free to rotate between stops on the anchor head.

4.4.4.2 Bent flukes or shanks should be heated and jacked back in place according to an approved procedure, followed by Magnetic Particle Inspection.

4.4.5 Inspection of mooring system components – Anchor Swivels

4.4.5.1 For anchor swivels in use, the threads engaging the swivel nut are to be carefully examined for evidences of corrosion and, if significant corrosion is found, the swivel is to be removed or replaced.

4.4.6 Chain Inspection Criteria

4.4.6.1 The present section is applicable for "Offshore" or "Rig Quality" chains with studs secured by one of the following means:

- Mechanically locked adjacent to the link's Flash-butt-weld and fillet welded on the other end (R3 chain for example)
- Studs mechanically locked in place on both ends (R4 chain for example)

4.4.6.2 Other types of chains will be specially considered by IRS.

4.4.6.3 Diameter measurements are to be taken in the curved or bend region of the link and at any area with excessive wear or gouging. Particular attention is to be given to the 'shoulder' areas which normally contact the windlass or fairlead pockets.

4.4.6.4 Links with minimum cross-sectional area less than 90% of the original nominal area are to be rejected. If repair is permitted, it should be done by qualified personnel using an approved procedure.

4.4.6.5 The repair in 4.4.6.4 is not permitted for R4, R4S and R5 chains (as defined in Rules and Regulations for Construction and Classification of Steel Ships, Part 2, Chapter 10, Section 5) (see also 4.4.6.8). Two diameter measurements should be taken 90 degrees apart and the average compared with original diameter considering with allowable diminution.

4.4.6.6 Links with missing studs are to be removed or the studs are to be refitted using an approved procedure.

4.4.6.7 For studs secured by fillet welds on one end, axial or lateral movement is unacceptable and the link is to be repaired or replaced. Links with studs fillet welded on the flash-butt-weld end of the stud are unacceptable.

4.4.6.8 Field repair of cracked welds is to be avoided. Welding is to be performed by qualified personnel using approved procedures. Weld repairs are not permitted for R4, R4S and R5 chains. Chains with studs mechanically locked in place on both ends may only be repaired by an approved mechanical 'squeezing' procedure to reseat the stud.

4.4.6.9 Fillet welding of studs on both ends and any welding on the stud end adjacent to the link's flash-butt-weld are not acceptable.

4.4.6.10 Existing studs with fillet welds on both ends are to be subjected to special consideration and special crack detection efforts. A reduction in mechanical properties in way of the flash-butt-weld is normally required. The approval of the coastal Administration may also be required.

4.4.6.11 For chain studs secured by press fitting and mechanical locking; the decision to reject or accept a link with a loose stud will be subject to the surveyor's judgment of the overall condition of the chain complement.

4.4.6.12 Axial movement of studs less than 1 mm is acceptable. Links with axial movement greater than 2 mm are to be repaired by 'squeezing' or removed. Acceptance of chain links with axial movements between 1 to 2 mm is to be evaluated based on the environmental conditions of the unit's location and expected period of time before the chain is again available for inspection.

4.4.6.13 Lateral movement of studs up to 4 mm is acceptable.

4.4.6.14 For the repair of links, cracks, gouges and other surface defects (excluding weld cracks) may be removed by grinding provided the resulting reduction in link diameter does not exceed 5% and the cross-sectional area due to abrasion, wear, and grinding is at least 90% of the original nominal area. Cross-sectional area is to be calculated for the lowest average of two diameters taken 90 degrees apart.

4.4.6.15 Links with surface defects which cannot be removed by grinding are to be replaced.

4.4.6.16 Defective links are to be removed and replaced with joining-shackles, i.e. connecting links, guided by the following good marine practice:

- The replacement joining-shackle is to comply with requirements in Rules and Regulations for Construction and Classification of Steel Ships, Part 2, Chapter 10, Section 5 or API 2F.
- Joining-shackle is to pass through fairleads and windlasses in the horizontal plane

4.4.6.17 The number of joining shackles to be used is to be kept as low as possible. For cases of large number of links distributed through the length of the chain and required be discarded; it is recommended to replace the entire chain.

4.4.7 Fairleads and Windlass – Chain systems

4.4.7.1 It is to be verified by inspection that all fairleads move freely about their respective pivot axes, to the full range of motion required for their proper operation. All bolts, nuts and other hardware used to secure the fairlead shafts are to be inspected and replaced if required.

4.4.7.2 The structural condition and integrity of the fairlead attachment to hull is to be verified. NDT may also be conducted for the verification. It is recommended to check the securing bolts on the closing plates to ensure that the bolt material does not corrode preferentially on failure of the sacrificial anode system.

4.4.7.3 Special attention is to be given to verify by inspection the holding ability of the windlass. The chain stopper and the resultant load path to the unit's structure are to be inspected to verify the structural integrity.

4.4.7.4 It is to be checked that a link resting in a chain pocket makes contact with the fairlead at only the four shoulder areas of the link to avoid critical bending stresses in the link. Satisfactory chain support is to be verified, and excessive wear in the pockets should be repaired as required, to prevent future damage to the chain.

4.4.7.5 Chain pockets may be repaired by welding in accordance with the standard procedures supplied by the fairlead/windlass manufacturer. Normally, the hardness of the pockets should be slightly softer than the hardness of the chain link, and procedures must be specific for the chain quality used.

4.4.8 Fairleads and Winches – Wire rope systems

4.4.8.1 For requirements for fairleads, refer relevant requirements provided within 4.4.7.1. and 4.4.7.2.

4.4.8.2 Special attention is to be given to the holding ability of the winch and the satisfactory operation of the pawls, ratchets and braking equipment. The soundness of the resultant load path to the unit's structure is to be verified.

4.4.8.3 Proper laying down of the wire on the winch drum is to be verified to the satisfaction of the Surveyor, and drums and spooling gear adjustments made, if required.

4.4.9 Accessories and Miscellaneous fittings

4.4.9.1 Anchor shackles, large open links, swivels and connecting links are to be visually inspected. Representative areas are to be examined by MPI. Areas to be examined should be clearly marked on each item. Links and fittings should be dismantled, as required. Damaged items should be replaced as required by the attending surveyor.

Illustrations showing the areas of concern may be found in API RP 2I, Figure 7.

4.4.9.2 At least the following representative areas are to be selected for MPI :

- Large open links: the interior contact surfaces of large open links
- Bolted shackles: the inside contact areas and the pins
- Swivels: the swivel pin and threads and mating surface.

4.4.9.3 Joining-shackles used for higher strength chains, such as ORQ and above, which do not have certificates of equivalent quality should receive special attention. All joining-shackles of Kenter or similar design which have been in service for more than four (4) years should be dismantled and MPI carried out. The areas for which MPI can be carried out are listed as below but not limited to:

- Joining shackle links: all machined and ground surfaces of the link and the sides of the curved portions of the link.
- Joining shackle stud: machined surfaces only.
- Joining shackle pin: 100%.

4.4.9.4 Fatigue is considered to be the critical criteria in way of the machined surfaces. On the remaining surface, the profile is to be ground smooth and MPI must be carried out upon completion of grinding. In general, the radius of the completed grinding operation should produce a recess with a minimum radius of 20 mm and a length along the link bar greater or equal to six times its depth. Sandblasting prior to MPI is to be avoided as far as practicable by use of alternative methods of cleaning. The maximum permissible depth of grinding is 5% of the nominal diameter. The minimum acceptable cross-sectional area in way of the grinding repair, due to the combined effect of local grinding and general corrosion/abrasion is 90% of the nominal cross-sectional area. The minimum acceptable diameter in way of the grind repair, due to the combined effect of local grinding and general corrosion/abrasion, is 95% of the nominal diameter.

4.4.9.5 The minimum acceptable cross-sectional area due to generally uniform corrosion/abrasion is 90% of the nominal cross-sectional area (equivalent to a uniform 5% reduction in diameter).

4.4.9.6 Tapered pins holding the covers of connecting links together are to make good contact at both ends and the recess of counterbore at the large end of the pin holder are to be solidly plugged with a peened lead slug to prevent the pin from working out.

4.4.9.7 Any joining-shackles of Kenter or similar designs which are loose upon re-assembly are to be rejected.

4.4.9.8 In case of defective links, the requirements provided in 4.4.6.16 are applicable.

4.4.10 Wire ropes

4.4.10.1 Acceptance criteria may be guided by ISO 4309. Further insight may be gained from the 'discard' guidance provided by API RP 2I, Figures 18 and 19.

4.4.10.2 In general, the age or time in service of the wire may not necessarily have a bearing on the acceptance or rejection of the wire.

4.4.10.3 100% visual examination and diameter measurements should be performed for each wire rope anchor line. The visual examination is to identify and record the following items but not limited to:
- The nature and number of wire breaks
- Wire breaks at the termination
- External wear and corrosion
- Localized grouping of wire breaks
- Deformation
- Fracture of strands
- Termination area
- Reduction of rope diameter, including breaking or extrusion of the core

4.4.10.4 Diameter measurements are to be taken at approximately 100 m intervals as far as practicable, at the discretion of the attending Surveyor. If areas of special interest are found, the survey may be concentrated on these areas and diameter measurements are to be taken at much smaller intervals.

4.4.10.5 An internal examination of the wire rope is to be undertaken as far as practicable if indications of severe internal corrosion or possible breakage of the core or wire breaks in underlaying areas. The requirements for internal inspection of the wire rope are to be in accordance with API RP 2I

Section 5

Surveys – Installation and Commissioning

5.1 Scope

5.1.1 This section provides guidance on the requirements for surveys during installation and commissioning of the FOU at its intended site of operation.

5.1.2 The objective of the survey is to verify and confirm that the FOU has been installed at the site of operation in accordance with the conditions as documented in the design and operations.

5.2 Scope

5.2.1 The installation and testing of the following items is to be witnessed at operation site as applicable but not limited to:

- Mooring system
    - Chains/Ropes
    - Anchors/Piles
    - Swivel Stacks operations (as applicable)
    - Turret operations (as applicable)
    - Operation of alarms and safety systems pertaining to mooring
    - Disconnect mechanisms (as applicable)
- Riser system (if classed)
- Offloading system
- Topside Production Facilities (if classed)

5.2.2 Prior to installation, survey is to be carried out to detect any damages/deterioration which may have occurred during the transit voyage to site.

5.2.3 Prior to installation, survey is to be carried out at the site to ascertain the readiness of the site for installation of FOU.

5.3 Installation & Testing Procedures at Site

5.3.1 Installation and testing procedures are to be submitted to IRS for review. Such procedures for installation & testing may include but are not limited to the following components as applicable:

- Anchors (piles, drag, embedment anchors, suction piles, plate anchors, gravity anchors etc.)
- Mooring lines, winches and stoppers.
- Thrusters (if provided for thruster assisted mooring)
- Safety systems (alarms & monitoring devices for mooring systems)
- Disconnect systems (if provided)
- Piping systems integration, mechanical equipments integration, electrical equipment integration etc. as may be applicable.
- Riser systems (if classed)
- Topsides facilities equipment (if classed)
- Other equipment/systems as may be applicable.

5.3.2 The installation and testing at site is to be as per the procedures in 5.3.1 which will be agreed upon between IRS and the Owner.

End of Chapter

Chapter 3

Materials

Contents

Section 1

General Requirements

1.1 General

1.1.1 The requirements in the Rules and Regulations for Construction and Classification of Steel Ships, Part 2, Chapter 1 are to be complied with.

Section 2

Mechanical Testing Procedures

2.1 General

2.1.1 The requirements in the Rules and Regulations for Construction and Classification of Steel Ships, Part 2, Chapter 2 are to be complied with.

Section 3

Rolled Steel Plates, Sections and Bars

3.1 General

3.1.1 The requirements in the Rules and Regulations for Construction and Classification of Steel Ships, Part 2, Chapter 3 are to be complied with.

Section 4

Steel Castings

4.1 General

4.1.1 The requirements in the Rules and Regulations for Construction and Classification of Steel Ships, Part 2, Chapter 4 are to be complied with.

Section 5

Steel Forgings

5.1 General

5.1.1 The requirements in the Rules and Regulations for Construction and Classification of Steel Ships, Part 2, Chapter 5 are to be complied with.

Section 6

Steel Pipes and Tubes

6.1 General

6.1.1 The requirements in the Rules and Regulations for Construction and Classification of Steel Ships, Part 2, Chapter 6 are to be complied with.

Section 7

Iron Castings

7.1 General

7.1.1 The requirements in the Rules and Regulations for Construction and Classification of Steel Ships, Part 2, Chapter 7 are to be complied with.

Section 8

Copper Alloys

8.1 General

8.1.1 The requirements in the Rules and Regulations for Construction and Classification of Steel Ships, Part 2, Chapter 8 are to be complied with.

Section 9

Aluminum Alloys

9.1 General

9.1.1 The requirements in the Rules and Regulations for Construction and Classification of Steel Ships, Part 2, Chapter 9 are to be complied with.

Section 10

Equipment

10.1 General

10.1.1 The requirements in the Rules and Regulations for Construction and Classification of Steel Ships, Part 2, Chapter 10 are to be complied with in general.

10.2 Mooring chains

10.2.1 The offshore mooring chain is to be manufactured in accordance with API SPEC 2F – Specification of mooring chain.

10.3 Fiber Ropes

10.3.1 For fiber ropes used for mooring systems, requirements as provided in API RP 2SM – Recommended practice for Design, Manufacturing and Maintenance of Synthetic Fiber Ropes for Offshore mooring are to be complied with.

Section 11

Approval of Welding Consumables for use in FOU Construction

11.1 General

11.1.1 The requirements in the Rules and Regulations for Construction and Classification of Steel Ships, Part 2, Chapter 11 are to be complied with.

End of Chapter

Chapter 4

Hull Structure

Contents

Section 1
General Principles

1.1 Definitions & Symbols

k : Material factor as defined in IRS Rules for Bulk Carriers and Oil Tankers, Volume 2, Part 1, Chapter 3, Section 1 [2.2].

k_{ij} : Material factor for plate *ij* as defined in IRS Rules for Bulk Carriers and Oil Tankers, Volume 2, Part 1, Chapter 3, Section 1 [2.2].

l_{bdg} : See Section 4.6.

s : Stiffener spacing

x ,y, z : X, Y and Z coordinates [m] of the considered point with respect to the coordinate system, as shown in Figure 1

L : Rule length [m], see definition in Rules and Regulations for Construction and Classification of Steel Ships, Part 3 Chapter 1, Section 2

B : Moulded breadth [m], see definition in Rules and Regulations for Construction and Classification of Steel Ships, Part 3 Chapter 1, Section 2

C_b : Block coefficient, see definition in Rules and Regulations for Construction and Classification of Steel Ships, Part 3 Chapter 1, Section 2

D : Moulded depth [m], see definition in Rules and Regulations for Construction and Classification of Steel Ships, Part 3 Chapter 1, Section 2

S : Primary support member spacing [m] as defined in IRS Rules for Bulk Carriers and Oil Tankers, Volume 2, Part 1, Chapter 3, Section 7 [1.2]

T : Moulded draught [m], see definition in Rules and Regulations for Construction and Classification of Steel Ships, Part 3 Chapter 1, Section 2

T_{LC} : Draught [m] in the loading condition being considered

T_{Bal} : Light draught [m] is the minimum ballast draught on which scantling evaluations are based

T_{SC} : Deep draught [m] is the maximum draught on which scantling evaluations are based

V : Maximum service speed [knots], see definition in Rules and Regulations for Construction and Classification of Steel Ships, Part 3 Chapter 1, Section 2

g : Acceleration due to gravity, 9.81 [m/s^2].

1.2 Application

1.2.1 The provisions within the present chapter are applicable to FOUs of conventional forms, proportions and speeds (if self propelled).

1.2.2 The FOU hull is to be of welded steel construction.

1.2.3 For FOUs with unconventional hull forms and proportions, IRS will provide special considerations subject to demonstration of structural integrity by submission of advanced calculations and/or model tests results.

1.2.4 Requirements for the hull items not covered by the present chapter are to be generally in accordance with the applicable requirements as provided within Rules and Regulations for Construction and Classification of Steel Ships.

1.3 Sign Convention

1.3.1 The coordinate system used within the Rules is defined in Figure 1. Motions and displacements are considered positive in the directions of the axes as indicated in Figure 1. Angular motions are considered positive in the clockwise direction about the x, y or z axes.

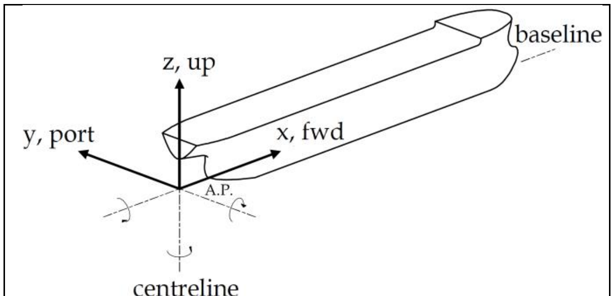


Figure 1: Origin and co-ordinate system

1.4 Equivalence

1.4.1 Alternative arrangements and scantlings may be accepted provided it is demonstrated to the satisfaction of IRS that such arrangements and scantlings provide a level of safety which under no condition is less than that provided by the Rules. Direct calculations may also be accepted by IRS to demonstrate the integrity of the FOU's hull structure.

1.5 Documentation

1.5.1 The plans, documentation and calculations to be submitted for review and approval are described in Chapter 1, Section 7.

Section 2

Materials of Construction

2.1 General

2.1.1 The materials used for the construction of the FOU are to be manufactured and tested in accordance with requirements in Chapter 3. Materials for which provisions are not made in Chapter 3 will be specially considered by IRS based upon their compliance with an approved specification and the tests carried out therein to demonstrate the conformance of the material to such specification.

2.2 Use of Steel grades

2.2.1 The steel grade selection for the FOU hull is to be in compliance with requirements in Rules and Regulations for Construction and Classification of Steel Ships, Part 3, Chapter 2.

2.2.2 For FOU operating in lower

below -20 degrees Celsius), the limitations on steel thicknesses as provided within Rules and Regulations for Construction and Classification of Mobile Offshore Drilling units, Chapter 3, Section 2 are also to be complied with. For this purpose Class III in the Steel Vessel rules is to be read as "Special" category in the MODU rules; Class II is to be read as "Primary" and Class I is to be read as "Secondary". However, in any case, the steel grade requirements are not to be less stringent than those in the Rules and Regulations for Construction and Classification of Steel Ships.

2.2.3 The support stools on the deck supporting the Topside Production facilities or other equipment are to be of the same or compatible grade as the deck structure they are attached to. The stiffening arrangements in way of the support stools with provided brackets or other attachments are to be of the same grade as that of the deck plates.

2.2.4 The grades of steel for the structural members in the Topsides production facilities are to be in accordance with an acceptable standard. (e.g. API RP 2A).

2.2.5 IRS may upon special request consider application of steel grades/thicknesses different from those mentioned within the present section.

Section 3

General Arrangement

3.1 Intact & Damage Stability

3.1.1 Arrangements provided on the FOU are to be in accordance with IRS Rules for Bulk Carriers and Oil Tankers, Volume 1, Part 3, Chapter 1, Section 1 subject to compliance with 3.1.2.

3.1.2 Requirements of Annex 1 of MARPOL 1973/78 are applicable to FOUs as specified in MEPC.139(53) (as amended by MEPC.142(54)) subject to adoption by the Administration. Applicable National regulations are also to be complied with. The set of requirements in 3.1.2 are to take precedence over the corresponding set in 3.1.1

3.2 Loadlines

3.2.1 All self propelled FOUs are to comply with the applicable requirements of the International Convention on Loadlines (ICLL).

3.2.2 All FOUs are to have load line marks in accordance with ICLL which indicate the maximum permissible draft for the unit. This is also to be applicable to FOUs which are not engaged on international voyages. National regulations may also be additionally applicable.

3.3 General arrangement design

3.3.1 Bulkhead arrangements are to be in accordance with IRS Rules for Bulk Carriers and Oil Tankers, Volume 2, Part 1, Chapter 2, Section 2.

3.3.2 Bulkheads are to be spaced at reasonably uniform intervals. Where the spacing of the bulkheads in not uniform and unavoidable, the transverse strength is to be maintained by providing additional web frames, increased scantlings etc.

3.3.3 Cofferdams are to be provided in accordance with IRS Rules for Bulk Carriers and Oil Tankers, Volume 2, Part 1, Chapter 2, Section 3.

3.3.4 Control Stations are to be located such that in the event of damage in the FOU hull, their operation is not hindered. For this purpose the damage could be the applicable damage as per the damage stability regulations as required by Section 3.1.

3.3.5 Openings in watertight bulkheads and closing appliances are to be in accordance with applicable requirements provided in Rules and Regulations for Steel Ships, Part 3, Chapter 10, Section 2.5.

3.3.6 Doors in watertight bulkheads are to comply with applicable requirements provided in Rules and Regulations for Construction and Classification of Steel Ships, Part 3, Chapter 10, Section 2.6.

3.3.7 Ventilators, Air pipes, Scuppers and sanitary discharges are to be in compliance with applicable requirements Rules and Regulations for Steel Ships, Part 3, Chapter 13.

3.3.8 Access arrangements are to be in accordance with IRS Rules for Bulk Carriers and Oil Tankers, Volume 1, Part 3, Chapter 1, Section 1 [5] and IRS Rules for Bulk Carriers and Oil Tankers, Volume 2, Part 1, Chapter 2, Section 4.

3.3.9 Deckhouses and Superstructure arrangements are to comply with requirements in Chapter 7, Section 3. Scantlings for Deckhouses and Superstructure can be determined in accordance with requirements provided in Rules and Regulations for Construction and Classification of Steel Ships, Part 3, Chapter 11.

3.3.10 Rudders (for self propelled units) are to be in compliance with requirements in Rules and Regulations for Construction and Classification of Steel Ships, Part 3, Chapter 14.

3.3.11 Any item not covered by the present chapter is to be in compliance with requirements in Rules and Regulations for Construction and Classification of Steel Ships, Part 3.

3.4 Emergency Towing arrangements

3.4.1 Emergency towing arrangements are to be provided in accordance with requirements of IRS Rules for Bulk Carriers and Oil Tankers, Volume 1, Part 3, Chapter 1, Section 1 [7].

Section 4

Structural Design Principles

4.1 Loads

4.1.1 The following loading conditions as a minimum are typically considered for FOU hull scantlings:

.1 On-site operation conditions
.2 Transit conditions
.3 Harbour & Docking condition
.4 Inspection & Test conditions (considering the FOU's inspection & maintenance while stationed on site)

4.1.2 The following loads are considered on the hull structure components as may be applicable. These are further categorized in Local and Global Loads.

.1 Local Loads
- .1 Inertial loads due to FOU Motions & Accelerations
- .2 Self & Imposed Weights (as applicable)
- .3 External Hydrostatic Pressure
- .4 External Hydrodynamic Pressure
- .5 Internal Hydrostatic pressure
- .6 Cargo pressures
- .7 Sloshing pressures
- .8 Slamming pressures
- .9 Tank Test pressure loads
- .10 Loads from mooring systems, riser systems or topside modules or other equipment.
- .11 Thermal loads
- .12 Vibratory loads
- .13 Other loads as applicable

.2 Global Loads
- .1 Still water bending moments and shear forces in horizontal and vertical directions
- .2 Still water bending moments and shear forces in horizontal and vertical directions.

4.1.3 Design Load combinations are to be developed considering combination of global and local load components as described in 4.1.2 such that these combinations encompass all possible scenarios which FOU may encounter during its service life.

4.1.4 Design load combinations are to consider the most unfavourable combinations of loads so as to maintain a consistent safety level for all combinations.

4.1.5 The design load combinations are to be categorized as follows:

.1 Static (S)
To cover application of all static loads typically covering load scenarios encountered by FOU in Docking, Testing or similar operational conditions where dynamic loads are not significant to be considered.

.2 Static +Dynamic (S+D)
To cover realistic combinations of static and dynamic loads. These combinations would typically include on-site operations of the FOU, transit conditions etc. Such loads combinations would also consider impact loads, sloshing etc.

.3 Accidental (A)
To consider accidental loads where these loads are not considered as occurring during normal operations

4.1.6 Characteristic values applied within this chapter are dependent upon the load combination being considered.

.1 For static loads, the expected value or the value specified in the design basis is considered.

.2 For environmental loads, characteristic value is chosen as the value which has a low probability of occurrence.

4.2 Net Scantlings

4.2.1 The Rules are based on a "net scantling approach". The net scantling approach is applicable in accordance with requirements in IRS Rules for Bulk Carriers & Oil Tankers, Volume 2, Part 1, Chapter 3, Section 2.

4.2.2 Scantling compliance is to be in accordance with requirements provided in IRS Rules for Bulk Carriers & Oil Tankers, Volume 2, Part 1, Chapter 3, Section 2, [1.3].

4.2.3 Corrosion additions are to be in accordance with IRS Rules for Bulk Carriers & Oil Tankers, Volume 2, Part 1, Chapter 3, Section 3.

4.2.4 Corrosion additions different from those in 4.2.3 may be specially considered by IRS based upon evidence and documentation submitted by Owner or Builder.

4.2.5 Owners' extras (if provided) are not to be considered as contributing towards the net scantlings used for evaluating the integrity of the hull and its components.

4.2.6 Corrosion protection systems are to be provided to maintain the integrity of the hull against corrosion. Such protection could be in the form of Cathodic protection systems, coatings or a combination of both.

4.2.7 Cathodic protection system in form of sacrificial anodes and impressed current systems is to be provided in accordance with requirements in EN 12495.

4.2.8 Coatings in dedicated seawater ballast tanks are to conform to performance standards as adopted by IMO Resolution MSC.215 (82), as amended.

4.2.9 Coatings in cargo oil tanks are to conform to performance standards as adopted by IMO Resolution MSC.288(87), as amended.

4.3 Structural Capacity Evaluation

4.3.1 Hull Scantlings are to be evaluated for the following:

.1 Prescriptive requirements: Minimum thickness requirements – Thickness under no condition is to be less than the values as prescribed in this chapter for the respective locations within the hull.

.2 Load effects based requirements:
  - .1 Local Scantlings check – Ability to withstand the local loads.
  - .2 Longitudinal strength check for hull girder
  - .3 Ultimate Strength check for hull girder
  - .4 Direct analysis based verification of scantlings.
  - .5 Fatigue strength verification for welded connections.

4.3.2 Working stress design (WSD) method to a significant extent has been used in the Rules. However, for checking the ultimate hull girder capacity, LRFD method is used.

4.3.3 Other methods of design such as Load Resistance Factor Design (LRFD) may be considered by IRS at its discretion for approval of the hull scantlings. Detailed analysis and calculations are to be submitted for such methods to IRS clearly outlining the assumptions used and the factors considered.

4.3.4 IRS at its discretion may consider direct calculation methods for the approval of the hull provided such methods are able to demonstrate the integrity of the FOU hull under all loading conditions and scenarios that the FOU may encounter during its service life. The assumptions, loading conditions, hydrodynamic and structural model files used for computations are to be submitted to IRS for its consideration.

4.3.5 Though structural verification of scantlings with analyses in 4.3.3 or 4.3.4 may be permitted by IRS at its discretion; these are not to be utilized for reducing scantlings below the minimum requirements as prescribed in this chapter.

4.4 Acceptance Criteria

4.4.1 Working stress design philosophy is used for checking the adequacy of the scantlings for the developed load combinations. For this purpose, three sets of acceptance criteria are utilized – AC1, AC2 and AC3. These are further described in this section.

4.4.2 The acceptance criteria set AC1 is applied when the combined characteristic loads are frequently occurring, typically for the static (S) design load combinations.

4.4.3 The acceptance criteria set AC2 is typically applied when the combined characteristic loads are extreme values, e.g. typically for the S+D design load combinations. Since such combinations do not occur seldom in the lifetime of the FOU; the permissible stresses are higher than those within the criteria set AC1.

4.4.4 The acceptance criteria set AC3 is typically applied for capacity formulations based on the plastic collapse models such as those that are applied to address bottom slamming and bow impact loads.

4.5 Structural Construction and Inspections

4.5.1 The structural requirements in the present chapter are applicable with the understanding that the hull will be well maintained through the service life. This is accomplished through an in-service inspection & survey programme. The developed programme is to be robust enough so as to timely detect and enable rectification of deterioration through the FOU's service life.

4.6 Structural Idealization

4.6.1 Structural idealization is to be in accordance with requirements provided in IRS Rules for Bulk Carriers and Oil Tankers, Volume 2, Part 1, Chapter 3, Section 7.

Section 5

Environmental Loads Principles

5.1 Definitions

k_r : Roll radius of gyration [m] as defined in Section 7

GM : Metacentric height [m] as defined in Section 7

f_{prob} : Adjustment factor for return period different from the return period specified in the Rules for same wave environments.

DLCF : Dynamic Load Combination Factor as defined in Section 5.7

5.2 Introduction

5.2.1 General

5.2.1.1 This Section describes philosophy of evaluation of for design loads applicable to FOUs of conventional hull form and proportions. FOUs of unconventional forms and proportions will be specially considered by IRS. For this purpose separate FOU motion analyses and direct load calculations may require to be submitted. The methods used for the calculations are to be agreed by IRS.

5.3 Definitions

5.3.1 Coordinate System

5.3.1.1 The applied coordinate system used in these rules is defined with respect to the right-hand coordinate system. The applied coordinate system *x*, *y*, *z* is defined in Section 1.3.

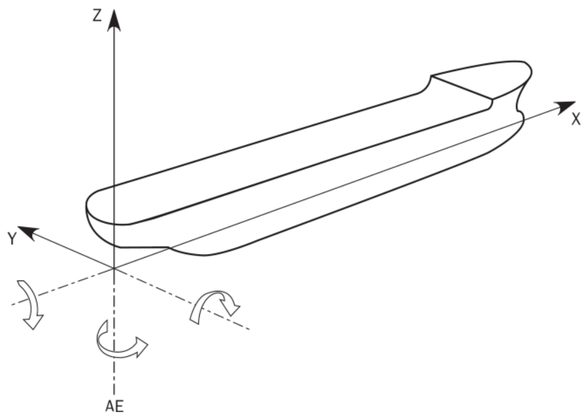


Figure 2: Reference co-ordinate system

5.3.2 Sign Conventions for FOU motion

5.3.2.1 Sign conventions for positive directions of FOU motions are indicated in figure 3.

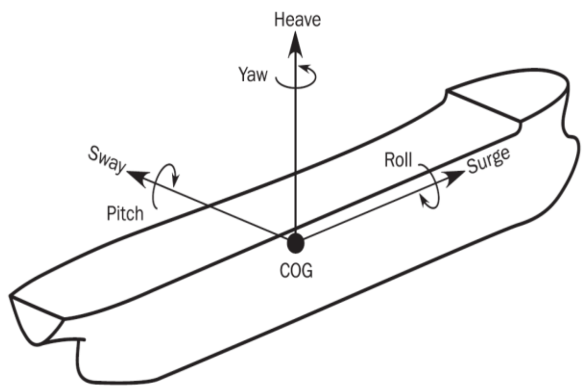


Figure 3: Definition of positive FOU motions

5.3.3 Sign Conventions for Bending moments and Shear forces

5.3.3.1 Positive directions for the hull girder bending moments and shear forces are shown in Figures 4 - 6.

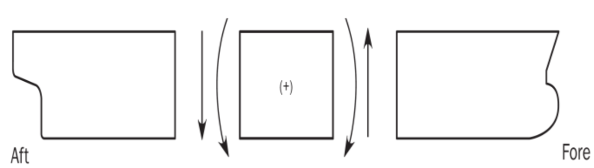


Figure 4: Positive VBM and VSF

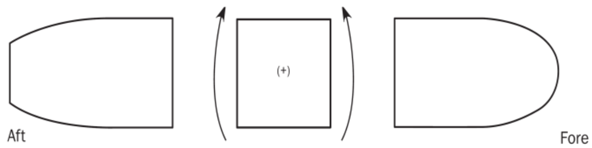


Figure 5: Positive HBM

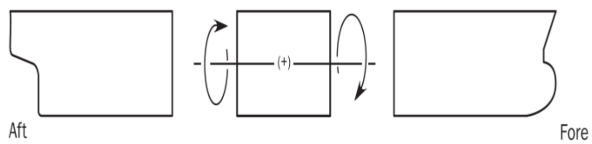


Figure 6: Positive TM

5.4 Envelope Load Values

5.4.1 The formulations for wave loads in the present chapter are based upon envelope values calculated in accordance with the following principles and rationalized based upon feedback from service and judicious engineering judgment:

.1 Application of load values is to be consistent for all load scenarios

.2 Characteristic load value is selected so as to be adequate for the intended purpose. e.g. for strength assessment, the expected lifetime maximum load is considered.

.3 Evaluations are based upon 3-D linear hydrodynamic computational tools considering speed effects.

.4 Derivation of characteristic wave loads based upon long term statistical approach which includes representation of the wave environment, probability of FOU headings and probability of load value exceedance based upon available data.

.5 In the present chapter, the wave scatter diagram for North Atlantic Ocean has been considered to derive the wave loads. For units operating at sites different from the North Atlantic, the envelope load values are rationalized considering Environmental Factors as described in Section 5.5.

5.5 Environmental Factors

5.5.1 Environmental factors are used to determine the dynamic load components for the intended operational conditions (including inspection & maintenance conditions) at site and for transit conditions.

5.5.2 The environmental factors are to be evaluated in accordance with the guidance provided in Appendix 1. The environmental factors so derived considering operation at the intended site data are to be submitted to IRS. Return periods along with the respective probability factors are to be in accordance with requirements of Section 5.6.

5.6 Return Period and Probability Factor, f_{prob}

5.6.1 For each load condition, the environmental loads for strength assessment and scantling requirements are to be determined considering return periods not less than those specified in Table 1.

5.6.2. In no case are the environmental loads used for the assessment of hull structure for on-site operation, inspection/maintenance, restricted service area transit, installation voyage and flooding to be less than 50% of the 25 year return period dynamic loads defined for unrestricted worldwide transit service.

5.6.3 For environmental loads computed at return periods as provided in Table 1 the factor f_{prob} is to be taken as 1.

5.6.4 At the request of the Owner and when consistent with the operational philosophy of the unit, seasonal environmental data may be used to derive the environmental loads for the inspection or maintenance condition. Alternatively, the all-year loads derived for the on-site operation condition may be used for the inspection/maintenance assessment, in conjunction with the probability factor derived to account for the difference between all-year loads and seasonal loads.

5.6.5 Loads computed for operation at sites with environment more severe than that considered in 5.4.1.5 are in any case not to be less than those obtained using present rules.

5.7 Dynamic Load Combination Factors (DLCF)

5.7.1 Dynamic Load Combination Factors are utilized in the present chapter to combine simultaneously occurring loads using the envelope values prescribed in the present chapter.

5.7.2 DLCFs are specified in Section 11 considering unrestricted worldwide navigation. These may be used for the scantling evaluation for units to be operated at a specific site(s) provided the environment conditions at the site are not more severe than the considerations for unrestricted navigation. DLCFs computed for site-specific conditions at which the FOU is to carry out its intended operations will be specially considered by IRS. For this purpose, the considered site specific DLCFs and the calculation methods used are to be submitted to IRS.

Table 1 : Return period for scantling requirements and strength assessment

Operational condition	**Transit**			**On-site operation**	**Inspection/ Maintenance**	**Accidental**
	Installation voyage [1]	**Restricted Service Area**	**Unrestricted World-wide**			
Return Period	1 year with all year data or 10 year with seasonal data	25 years	25 years	100 year	1 year with all year data or 10 year with seasonal data	1 year
Environment	World-wide or Specific Transit route	Restricted service area	World-wide	Site specific	Site specific	Site specific

Note: Alternative return period will be specially considered based on the duration of the inspection/ maintenance period and site specific environment

[1] Evaluation for installation voyage is not required if FOU is classed for unrestricted world wide transit

Section 6
Hull Girder Loads

6.1 Symbols

$f_{env\text{-}Qwv}$: Environmental Factor for vertical wave shear force, as described in 5.5.

$f_{env\text{-}Mwv\text{-}v}$: Environmental Factor for vertical wave bending moment, as defined in 5.5

$f_{env\text{-}Mwv\text{-}h}$: Environmental Factor for horizontal wave bending moment, as defined in 5.5

C_b : Block co-efficient as defined in 1.1

C_{wv} : Wave coefficient [m] is to be taken as:

$0.0856L$ $L < 90$

$10.75 - \left(\frac{300 - L}{100}\right)^{1.5}$ $90 \leq L \leq 300$

10.75 $300 < L \leq 350$

$10.75 - \left(\frac{L - 350}{150}\right)^{1.5}$ $350 < L \leq 500$

$f_{wv\text{-}v}$: Distribution factor for vertical wave bending moment as described in 6.3

$f_{wv\text{-}h}$:Distribution factor for horizontal wave bending moment as described in 6.3

$f_{qwv\text{-}v\text{-}pos}$:Distribution factor for Positive Vertical wave Shear force as described in 6.3

$f_{qwv\text{-}v\text{-}neg}$:Distribution factor for Negative Vertical wave Shear force as described in 6.3

$M_{sw\text{-}perm\text{-}flood}$: Permissible still water bending moment [kNm] envelopes for flooded condition as defined in 6.2

$M_{sw\text{-}perm\text{-}sea}$: Permissible still water bending moment [kNm] envelopes for transit condition, as defined in 6.2

$M_{sw\text{-}perm\text{-}opr}$: Permissible still water bending moment [kN-m] envelopes for operational condition as defined in 6.2

$M_{sw\text{-}perm\text{-}maint}$: Permissible still water bending moment [kN-m] envelopes for inspection/ maintenance condition as defined in 6.2

$M_{wv\text{-}h}$: Envelope wave hogging moment as defined in 6.3

$M_{wv\text{-}s}$: Envelope wave sagging moment as defined in 6.3

$Q_{sw\text{-}perm\text{-}flood}$: Permissible still water positive/ negative ($Q_{wv\text{-}pos}$ and $Q_{wv\text{-}neg}$) wave shear force [kN] envelope for flooded condition as defined in 6.2

$Q_{sw\text{-}perm\text{-}sea}$: Permissible still water positive/ negative ($Q_{wv\text{-}pos}$ and $Q_{wv\text{-}neg}$) wave shear force [kN] for transit condition as defined in 6.2

$Q_{sw\text{-}perm\text{-}opr}$: Permissible still water positive/ negative ($Q_{wv\text{-}pos}$ and $Q_{wv\text{-}neg}$) wave shear force [kN] for transit condition as defined in 6.2

$Q_{sw\text{-}perm\text{-}maint}$: Permissible still water positive/ negative ($Q_{wv\text{-}pos}$ and $Q_{wv\text{-}neg}$) wave shear force [kN] for transit condition as defined in 6.2

T_{LC} : Draft for loading condition being considered as defined in 1.1

6.2 Static Hull Girder Loads

6.2.1 Permissible Still Water Bending Moment and Shear Force

6.2.1.1 All loading patterns which represent the loading conditions of the FOU for its intended transit, on-site operations, inspection & maintenance, docking etc. are to be considered.

6.2.1.2 Permissible hull girder hogging and sagging still water bending moments limits in transit $M_{sw\text{-}perm\text{-}sea}$, on-site operations $M_{sw\text{-}perm\text{-}opr}$, inspection/ maintenance $M_{sw\text{-}perm\text{-}maint}$ and flooded condition, $M_{sw\text{-}perm\text{-}flood}$, are to be provided by the designer.

6.2.1.3 Permissible hull girder positive and negative shear force limits in transit $Q_{sw\text{-}perm\text{-}sea}$, operation $Q_{sw\text{-}perm\text{-}opr}$, inspection/ maintenance $Q_{sw\text{-}perm\text{-}maint}$ and flooded condition, $Q_{sw\text{-}perm\text{-}flood}$, are to be provided by the designer.

6.2.1.4 The permissible hull girder still water bending moment and shear force limits are to be provided at each transverse bulkhead in the cargo area, at the middle of each cargo tank and at significant structural discontinuities within the hull.

6.2.1.5 The permissible hull girder still water bending moment and shear force envelopes are to be included in loading manual.

6.2.1.6 Still water bending moments and shear forces are to take into consideration the effects of loads due to mooring systems & risers installed.

6.3 Dynamic Hull Girder Loads
6.3.1 Wave-Induced Loads
6.3.1.1 General
6.3.1.1.1 For loads computed using direct calculations, the total bending moments and shear force envelopes are to be provided in accordance with requirements in 6.2.1.

6.3.1.2 Vertical Wave Bending Moments and Shear Force
6.3.1.2.1 The vertical bending moments (hogging $M_{wv\text{-}h}$, and sagging $M_{wv\text{-}s}$) at any longitudinal section are to be taken as:

$$M_{wv-h} = f_{env-Mwv-v}\, f_{prob} 0.19 f_{wv-v} C_{wv} L^2 B C_b \quad \text{[kNm]}$$

$$M_{wv-s} = -f_{env-Mwv-v}\, f_{prob} 0.11 f_{wv-v} C_{wv} L^2 B\, (C_b + 0.7) \quad \text{[kNm]}$$

$f_{wv\text{-}v}$: Distribution factor for vertical wave bending moment along the vessel length as shown in Figure 7.

6.3.1.2.2 The vertical shear forces ($Q_{wv\text{-}pos}$, $Q_{wv\text{-}neg}$) at any longitudinal section are to be taken as:

$$Q_{wv-pos} = 0.3 f_{env-Qwv}\, f_{prob} f_{qwv-pos} C_{wv} LB (C_b + 0.7) \quad \text{[kN]}$$

$$Q_{wv-neg} = -0.3 f_{env-Qwv}\, f_{prob} f_{qwv-neg} C_{wv} LB (C_b + 0.7) \quad \text{[kNm]}$$

$f_{qwv\text{-}pos}$: Distribution factor for positive vertical wave shear force along the vessel length as shown in Figure 8

$f_{qwv\text{-}neg}$: Distribution factor for positive vertical wave shear force along the vessel length as shown in Figure 9

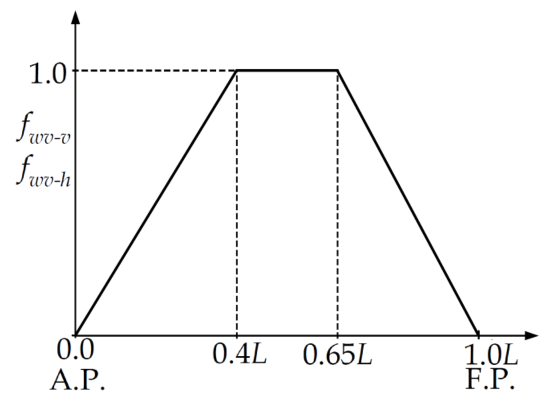


Figure 7: Vertical and Horizontal wave bending moment distribution

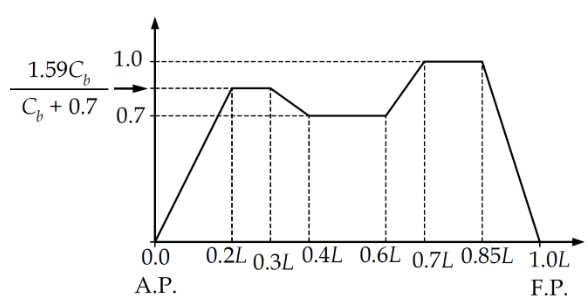


Figure 8: Positive vertical wave shear force distribution

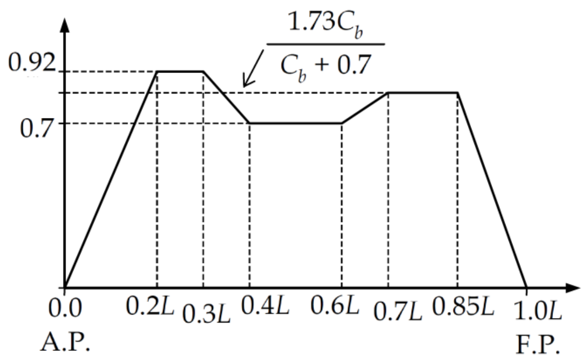


Figure 9: Negative vertical wave shear force distribution

6.3.1.3 Horizontal Wave Bending Moment

6.3.1.3.1 The horizontal wave bending moment (M_{wv-h}) at any longitudinal position is to be evaluated as:

$$M_{wv-h} = -f_{env-Mwv-h}\, f_{prob} f_{wv-h} C_{wv} L^2 T_{LC} C_b \left(0.31 + \frac{L}{2000}\right)$$

[kN-m]

where f_{wv-h} is to be taken as shown in **Figure 7**.

Section 7

FOU Motions and Accelerations

7.1 Definitions & Symbols

GM : Metacentric height [m] as defined in 7.2

R : Vertical coordinate [m], of the FOU center, as defined in 7.5.3

T_θ : Roll period [s], as defined in 7.3.1

T_φ : Pitch period [s], as defined in 7.3.2

T_{LC} : Draught [m] in loading condition being considered as defined in 1.1

a_0 : Common acceleration parameter, as defined in 7.4.1

a_{roll-z} : Vertical acceleration [m/s^2] due to roll, as defined in 7.5.2

$a_{pitch-z}$: Vertical acceleration [m/s^2] due to pitch, as defined in 7.5.2

a_{roll-y} : Transverse [m/s^2] acceleration due to roll, as defined in 7.5.3

$a_{pitch-x}$: Longitudinal acceleration [m/s^2] due to pitch, as defined in 7.5.4

f_T : Ratio between draught at loading condition and scantling draught, to be taken as:

$$f_T = \frac{T_{LC}}{T_{SC}}$$

k_r : Roll radius of gyration [m] as defined in 7.2

x, *y*, *z* : As defined in Section 1

θ : Roll angle [deg] as defined in 7.3.1

φ : Pitch angle [deg] as defined in 7.3.2

7.2 Metacentric Height and Roll Radius of Gyration

7.2.1 The metacentric height *GM* and the roll radius of gyration k_r are to be computed for loading conditions prescribed in Section 6 with their associated return periods and probability (f_{prob}). For initial design, values provided in Table 2 may be used. For the flooded conditions, values of metacentric height and radius of gyration may be taken as those obtained for the full load condition.

Table 2: Value of *GM* and k_r

Conditions	T_{LC}	GM	k_r
Loaded at deep draught/full draught conditions	≥0.9T_{sc}	0.12*B*	0.35*B*
Loaded on reduced draught (part load and part conditions)	0.6T_{sc}	0.24*B*	0.40*B*
Light draught condition usually ballast condition	T_{Bal}	0.33*B*	0.45*B*
Note: Values for intermediate draughts may be calculated by linear interpolation			

7.3 FOU Motions

7.3.1 Roll motion

7.3.1.1 The envelope value for natural roll period, T_θ, is to be taken as:

$$T_\theta = (2.3k_r)/\sqrt{GM} \quad \text{[s]}$$

GM : Metacentric height as defined in 7.2

k_r : roll radius of gyration as defined in 7.2

7.3.1.2 The envelope value for roll angle, θ, is to be taken as:

$$\theta = \frac{9000}{\pi(B+75)}(1.25 - 0.025T_\theta)f_{bk} \quad \text{[deg]}$$

Where: f_{bk} : 1.2 for FOU without bilge keels

1.0 for FOU with bilge keels

7.3.2 Pitch Motion

7.3.2.1 The characteristic pitch period, T_φ, is to be taken as:

$$T_\varphi = f_V\sqrt{\frac{2\pi\lambda_\varphi}{g}} \quad \text{[s]}$$

$$\lambda_\varphi = 0.6(1+f_T)L$$

$$f_V = 1 + \frac{V_0}{V}\left(\frac{L}{525} - 0.67\right)$$

Where:

V_0 : Vessel speed [knots] is to be taken as:

0 for scantling requirements and strength assessment

0.75V_0 for fatigue assessment (in transit)

7.3.2.2 The pitch angle, φ, is to be taken as:

$$\varphi = 960\left(\frac{V_1}{C_b}\right)^{0.25}\frac{1}{L} \quad \text{[deg]}$$

Where:

V_1 : Vessel speed [knots] is to be taken as *V*, (during transit) but not to be taken as less than 10 and to be taken as zero during on-site operations

7.4 FOU Accelerations at the center of gravity

7.4.1 Common Acceleration Parameter

7.4.1.1 The common acceleration parameter, a_0, is to be taken as:

$$a_0 = (1.58 - 0.47C_b)\left(\frac{2.4}{L} + \frac{34}{L} - \frac{600}{L^2}\right)$$

7.4.2 Surge Acceleration

7.4.2.1 Longitudinal acceleration due to surge is to be taken as:

$$a_{surge} = 0.2ga_0 \quad \text{[m/s}^2\text{]}$$

7.4.3 Sway Acceleration

7.4.3.1 Transverse acceleration due to sway is to be taken as:

$$a_{sway} = 0.3a_0g \quad \text{[m/s}^2\text{]}$$

7.4.4 Heave Acceleration

7.4.4.1 The vertical acceleration due to heave is to be taken as:

$$a_{heave} = f_Va_0g \quad \text{[m/s}^2\text{]}$$

7.4.5 Pitch Acceleration
7.4.5.1 The pitch acceleration, a_{pitch}, is to be taken as:

$$a_{pitch} = \varphi \frac{\pi}{180}\left(\frac{2\pi}{T_\varphi}\right)^2 \quad \text{[rad/s}^2\text{]}$$

7.4.6 Roll Acceleration
7.4.6.1 The roll acceleration, a_{roll}, is to be taken as:

$$a_{roll} = \theta \frac{\pi}{180}\left(\frac{2\pi}{T_\theta}\right)^2 \quad \text{[rad/s}^2\text{]}$$

7.5 Envelope Accelerations
7.5.1 General
7.5.1.1 The envelope values for combined translatory accelerations due to motion in six degrees of freedom are computed within the present sub-section. The transverse and longitudinal components of acceleration include the component of gravity due to roll and pitch.

7.5.2 Vertical Acceleration
7.5.2.1 The envelope vertical acceleration, a_v, at any position, is to be taken as:

$$a_v = f_{prob}\sqrt{(a_{heave})^2 + \left(a_{pitch-z}\right)^2 + (a_{roll-z})^2}$$

[m/s²]

Where:

$a_{pitch-z}$: Vertical acceleration due to pitch is to be taken as:

$$a_{pitch-z} = \left(0.3 + \frac{L}{325}\right) a_{pitch}|x - 0.45L| \quad \text{[m/s}^2\text{]}$$

a_{roll-z} : Vertical acceleration due to roll, is to be taken as:

$$a_{roll-z} = 1.2 a_{roll}|y| \quad \text{[m/s}^2\text{]}$$

7.5.3 Transverse Acceleration
7.5.3.1 The envelope transverse acceleration, at any position, is to be taken as:

$$a_t = f_{prob}\sqrt{\left(a_{sway}\right)^2 + \left(g\sin\theta + a_{roll-y}\right)^2}$$

[m/s²]

Where:

a_{roll-y} : Transverse acceleration due to roll is to be taken as:

$$a_{roll-y} = a_{roll}(z - R) \quad \text{[m/s}^2\text{]}$$

$$R = min\left(\frac{D}{4} + \frac{T_{LC}}{2}, \frac{D}{2}\right) \quad \text{[m]}$$

7.5.4 Longitudinal Acceleration
7.5.4.1 The envelope longitudinal acceleration, a_{lng}, at any position is to be taken as:

$$a_{lng} = 0.7 f_{prob}\sqrt{\left(a_{surge}\right)^2 + \frac{L}{325}\left(g\sin\theta + a_{pitch-x}\right)^2}$$

[m/s²]

Where:

$a_{pitch-x}$: longitudinal acceleration due to pitch is to be taken as:

$$a_{pitch-x} = f_V a_{pitch}(z - R) \quad \text{[m/s}^2\text{]}$$

Where:

R : as defined in 7.5.3

f_v : as defined in 7.3.2

Section 8
External Loads

8.1 Symbols

ρ_{sw} : Density of sea water, 1.025 [t/m^3]

θ : roll angle, as defined in 7.1.

$f_{env\text{-}Pex\text{-}dyn}$: Environmental factor due to dynamic wave pressure, as defined in 5

f_β : Heading correction factor as defined in 11.4.1.2

g : Acceleration parameter, 9.81 [m/s^2]

x ,y, z : X, Y and Z coordinates [m] as defined in Section 1

B_{local} : Local breadth at the waterline, for considered draught, not to be taken less than 0.5B [m]

L : Rule length [m], as defined in Section 1

T_{LC} : Draught [m] in the loading as defined in Section 1

T_{Bal} : Light draught as defined in Section 1 [m]

T_{sc} : Scantling draught as defined in Section 1 [m]

V : Service speed [knots] as defined in Section 1

8.2 External Pressures

8.2.1 The external pressure at any point of hull for static (*S*) design load scenarios is to be taken as:

$P_{ex} = P_{hys}$ but not to be taken less than zero

8.2.2 The total pressure at any point of hull for static and dynamic (*S*+*D*) load scenarios is to be taken as:

$P_{ex} = P_{hys} + P_{ex\text{-}dyn}$ but not to be taken less than zero

Where:

P_{hys} : Hydrostatic pressure [kN/m^2] is to be taken as given in 8.3.

$P_{ex\text{-}dyn}$: Wave pressure [kN/m^2] is to be taken as given in 8.4

8.3 External Hydrostatic Pressure

8.3.1 The hydrostatic pressure at any load point is to be taken as:

$$P_{hys} = \rho g (T_{LC} - z) \qquad z \le T_{LC}$$

$$P_{hys} = 0 \qquad z > T_{LC}$$

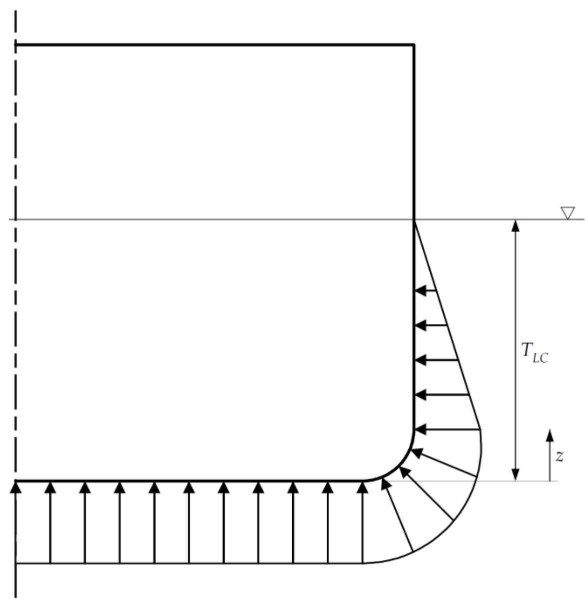


Figure 10: Hydrostatic pressure, P_s

8.4 External Dynamic Pressure

8.4.1 The envelope dynamic pressure $P_{ex\text{-}dyn}$ is to be taken as:

$$P_{ex-dyn} = \max[P_1, P_2]$$

Where:

$P_1 = 2f_{env-Pex-dyn}f_{prob}f_{nl-P1}\left[\left(\left(P_{11} + \frac{135B_{local}}{4(B+75)} - 1.2(T_{LC} - z)\right)f_1 + \frac{135B_{local}}{4(B+75)}f_2\right]$ [kN/m^2]

$P_2 = 26f_{env-Pex-dyn}f_{prob}f_{nl-P2}\left[\left(\frac{B_{local}}{8}\left(\theta\frac{\pi}{180}\right) + f_T C_b\ \frac{0.25B_{local}+0.8C_w}{14}\left(0.7 + \frac{2z}{T_{LC}}\right)\right)f_1 + \left(\frac{B_{local}}{8}\left(\theta\frac{\pi}{180}\right) + f_T C_b\ \frac{0.25B_{local}}{14}\left(0.7 + \frac{2z}{T_{LC}}\right)\right)f_2\right]$ [kN/m^2]

Where:

$P_{11} = (3f_s + 0.8)C_{wv}$

C_{wv} : Defined in Section 6.1.

$f_1 = f_{lng} - \frac{f_{lng}}{f_V}f_2 + f_2$

$f_2 = 0.25f_V\left(\frac{(4|y|)}{B_{local}} - 1\right)$ $|y| < 0.25B_{local}$

$= f_V\left(\frac{(4|y|)}{B_{local}} - 1\right)$ $|y| \geq 0.25B_{local}$

$f_T = \frac{T_{LC}}{T_{SC}}$

$f_s = C_b + \left(\frac{1.33}{\sqrt{C_b}}\right)$ at, and aft of AP

$= C_b$ between 0.2*L* to 0.7*L* from AP

$= C_b + \frac{1.33}{C_b}$ at, and forward of FP

intermediate values to be obtained by linear interpolation

f_{lng} = 1.0 at, and aft of AP
= 0.7 for 0.2*L* to 0.7*L* from AP
= 1.0 at, and forward of FP
intermediate values to be obtained by linear interpolation

f_{nl-P1}, f_{nl-P2}, f_{prob}, and f_V are defined in 8.4.2 for application to scantling requirements and strength assessment.

8.4.2 For scantling requirements and strength assessment, the envelope maximum dynamic wave pressure, P_{ex-max}, [kN/m^2] see Figure 11, and minimum dynamic wave pressure, P_{ex-min}, [kN/m^2], see Figure 12, are to be taken as:

P_{ex-max} $= P_{ex-dyn}$ below still water line

$= P_{WL} - 10(z - T_{LC})$ for $T_{LC} < z \leq T_{LC} + \frac{P_{WL}}{10}$

= 0 for $z > T_{LC} + \frac{P_{WL}}{10}$

P_{ex-min} $= -P_{ex-dyn}$ below still water line

= 0 above still water line

P_{ex-min} is not to be taken as less than $-\rho_{SW}g(T_{LC} - z)$

Where:

P_{ex-dyn} : Envelope dynamic pressure defined in 8.4.1 with

$f_{nl-P1} = 1 - 0.2(f_{prob} - 0.5)$

$f_{nl-P2} = f_\beta\left(1 - 0.375(f_{prob} - 0.5)\right)$

Where:

For scantling requirements and strength assessment f_v and f_{prob} taken as:

f_V = 1.0

f_{prob}, to be taken as defined in 5.6

P_{WL} : Pressure at waterline, to be taken as P_{ex-dyn} at still waterline [kN/m^2]

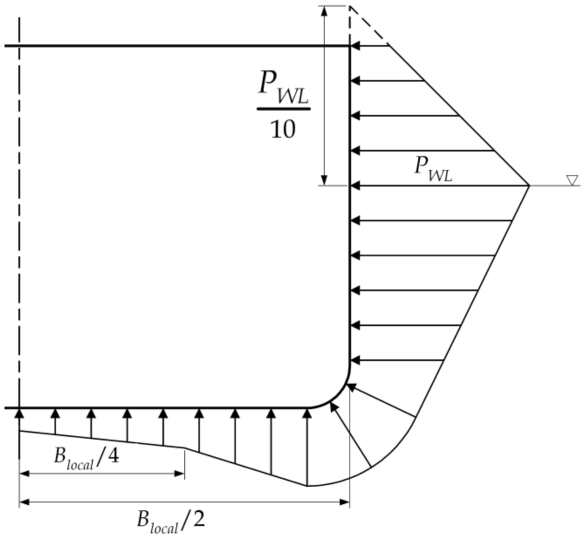


Figure 11: Transverse distribution of maximum dynamic wave pressure for scantling requirement and strength assessment

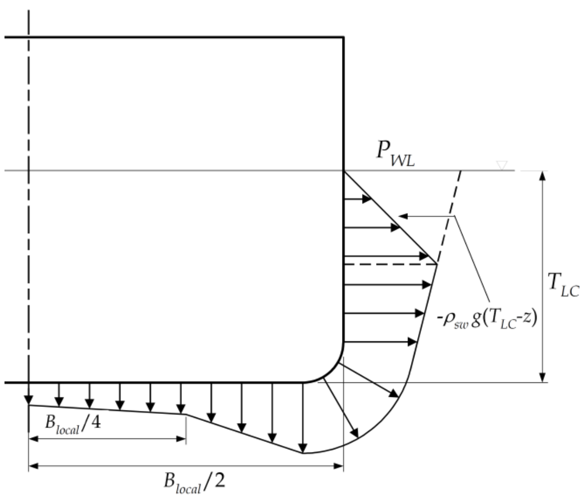


Figure 12: Transverse distribution of minimum dynamic wave pressure for scantling requirement and strength assessment

8.5 Green Sea Loads

8.5.1 Green sea loads are to be calculated as shown within Section 11.4.6.

8.6 External Impact on Bow Area

8.6.1 Application and Limitations

8.6.1.1 The bottom slamming loads in this section apply to Units with $C_b \geq 0.7$ and bottom slamming draught ≥ 0.01*L* and ≤ 0.045*L*. For operation at deeper draughts, the slamming loads will be specially considered by IRS. Direct calculations will be specially considered by IRS.

8.6.1.2 For units with unconventional bow shapes or for wave environments more severe than those listed in Section 5.4, the slamming loads, green sea loads and bow impact loads are to be determined by site-specific analysis. IRS may also require model tests to be performed.

8.6.2 Slamming Pressure

8.6.2.1 The bottom slamming pressure, P_{slm}, is to be taken as the greater of following cases:

Case 1: for empty tanks

$$P_{slm-mt} = f_{env-pex-dyn} f_{slm} 130 g c_{slm-mt} e^{c1}$$

[kN/m²]

Case 2: for full tanks

$$P_{slm-full} = f_{env-pex-dyn} f_{slm} 130 g c_{slm-full} e^{c1} - c_{av} \rho g z_{ball}$$

[kN/m²]

Where:

f_{slam} : Longitudinal slamming distribution factor, see Figure 13, is to be taken as:

0 at 0.5*L*

1 at $[0.175 - 0.5(C_{bl} - 0.7)]L$ from FP

1 at $[0.1 - 0.5(C_{bl} - 0.7)]L$ from FP

0.5 at, and forward of FP

Intermediate values to be obtained by linear interpolation.

C_{bl} : Block coefficient, C_b, as define in Section 1 but not to be take less than 0.7 or greater than 0.8.

c_{slm-mt} : Slamming coefficient for empty tanks is to be taken as:

$$= 5.95 - 10.5 \left(\frac{T_{Fp-mt}}{L}\right)^{0.2}$$

$c_{slm\text{-}full}$: Slamming coefficient for full tanks is to be taken as:

$$= 5.95 - 10.5\left(\frac{T_{Fp-full}}{L}\right)^{0.2}$$

c_1 : to be taken as

= 0 for L≤180 m
= $-0.0125(L-180)^{0.705}$ for L>180 m

$T_{FP\text{-}mt}$: Design slamming light draught at FP with tanks within the bottom slamming region empty as defined in 8.6.2.3 [m]

$T_{FP\text{-}full}$: Design slamming light draught at FP with tanks within the bottom slamming region full as defined in 8.6.2.4 [m]

c_{av} : dynamic load coefficient, to be taken as 1.25

z_{ball} : Vertical distance from tank top to load point [m]

8.6.2.2 The designer is to provide the design slamming draughts $T_{FP\text{-}mt}$ and $T_{Fp\text{-}full}$.

8.6.2.3 The design slamming draught at FP, $T_{FP\text{-}mt}$, is not to be greater than the minimum draught at the FP indicated in loading manual for all transit conditions wherein the tanks within the bottom slamming region are empty.

8.6.2.4 The design slamming draught at the FP, $T_{FP\text{–}full}$, is not to be greater than the minimum draught at the FP indicated in the loading manual for any transit conditions wherein the tanks within the bottom slamming region are full.

8.6.2.5 The loading guidance information is to indicate clearly the design slamming draught.

8.6.3 Bow Impact Loads

8.6.3.1 Application and Limitations

8.6.3.1.1 The bow impact pressure applies to side structure of the area forward of 0.1L aft of FP and between waterline at draught T_{Bal}, and the highest deck at side. Direct calculations will be specially considered by IRS.

8.6.3.2 Bow Impact Pressure

8.6.3.2.1 For scantling evaluation, the bow impact pressure, P_{im}, is to be taken as:

$$P_{im} = 1.025 f_{env-pex-dyn} f_{im} c_{im} V_{im}^2 sin\gamma_{wl}$$ [kN/m²]

Where:

f_{im} : 0.5 at 0.1L aft of FP

0.9 at 0.0125L aft of FP

1.0, at, and forward of FP

Intermediate values to be obtained by linear interpolation

V_{im} : Impact speed [m/s],

$= 0.514 V_{fwd} sin\alpha_{wl} + \sqrt{L}$ for transit

$= 4.63 sin\alpha_{wl} + \sqrt{L}$ for On-Site Operations

V_{fwd} : Forward speed [knots]

= 0.75V but is not to be taken as less than 10

α_{wl} : Local waterline angle at the position considered, but not to be taken less than 35 degrees, see Figure 14.

γ_{wl} : local bow impact angle measured normal to the shell from the horizontal to the tangent line at the position considered bit is not to be less than 50 degree, see Figure 14.

c_{im} : 1.0 for position between draughts T_{Bal} and T_{sc}

$= \sqrt{1 + \cos^2\left[90\frac{(h_{fb}-2h_o)}{h_{fb}}\right]}$ for position above draught T_{sc}

h_{fb} : Vertical distance from the waterline [m] at draught T_{sc} to the highest deck at side, see Figure 14.

h_o : Vertical distance from the waterline at draught T_{sc} to the position considered, see Figure 14.

WL_j : Waterline at position considered, see Figure 14.

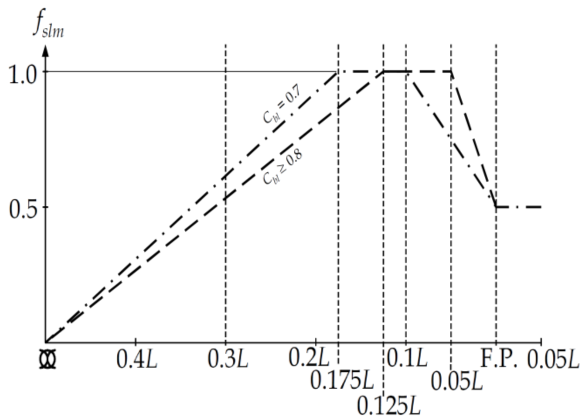


Figure 13: Longitudinal Distribution of Slamming Pressure

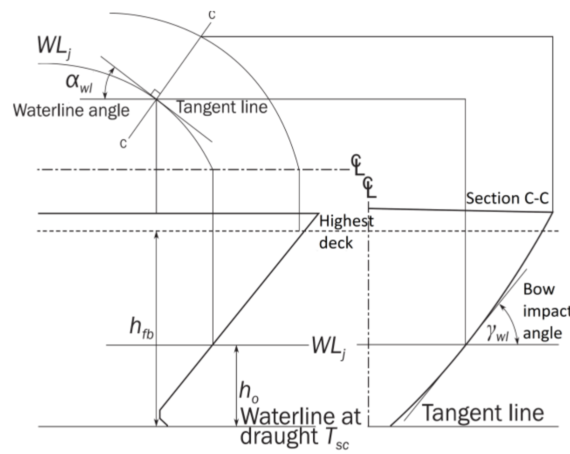


Figure 14: Definition of bow geometry

Section 9
Internal Loads

9.1 Symbols

ρ : Density of liquid [t/m^3] in the tank, and not to be taken less than 1.025 for scantling and strength evaluation.

ρ_{sw} : Density of sea water, 1.025 [t/m^3]

L : Rule length [m] as defined in Section 1.

a_{lng} : envelope longitudinal acceleration, [m/s^2] as defined in 7.5.4, and is to be taken at tank centre of gravity

a_t : Envelope transverse acceleration, [m/s^2] as 7.5.3, and is to be taken at tank centre of gravity

a_v : Envelope vertical acceleration, [m/s^2] as defined 7.5.2, and is to be taken at tank centre of gravity

g : acceleration due to gravity = 9.81 [m/s^2]

h_{air} : height of air pipe [m] is not be taken less than 0.76 m above highest point of tank, excluding small hatchways. For tank with top below weather deck the height of air pipe or overflow is not to be taken below 0.76 m above deck at side unless a lesser height is approved by the flag Administration. See also Figure 15.

x : Longitudinal co-ordinate of load point [m]

x_0 : Longitudinal coordinate of reference point, see 11.4.7 for scantling requirements and strength assessment.

y : Transverse coordinate of load point [m]

y_0 : Transverse coordinate of reference point, see 11.4.7 for scantling requirements and strength assessment.

z : Vertical coordinate of load point [m]

z_0 : Vertical co-ordinate of reference point, see 11.4.7 for scantling requirements and strength assessment.

z_{tk} : vertical distance from highest point of tank [m], excluding small hatchways, to load point, see Figure 15.

9.2 Static Tank Pressure

9.2.1 The static tank pressure, P_{in-tk}, is to be taken as:

$$P_{in-tk} = \rho g z_{tk} \quad \text{[kN/m}^2\text{]}$$

9.2.2 Static tank pressure, P_{in-air}, in case of overfilling or filling during flow through water ballast exchange, is to be taken as:

$$P_{in-air} = \rho_{sw} g Z_{air} + P_{drop} \quad \text{[kN/m}^2\text{]}$$

Where:

Z_{air} : Vertical distance of air pipe or overflow pipe to the load point [m], whichever is lesser, see Figure 15

$= z_{tk} + h_{air}$

P_{drop} : Added overpressure due to sustained liquid flow through air pipe or overflow pipe in case of overfilling or filling through water ballast exchange, is to be taken as 25 kN/m^2. Additional calculation may be required where piping arrangement may lead to a higher pressure drop for example long pipes or arrangements such as bends and valves.

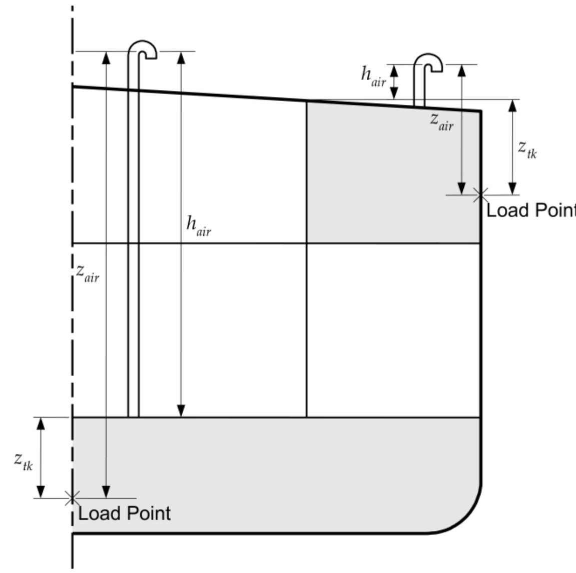


Figure 15: Pressure-heads and distance used for calculation of static tank pressure

9.2.3 The pressure, $P_{in-flood}$, in compartments and tanks in a flooded and damaged condition is to be taken as:

$$P_{in-flood} = \rho_{sw} g z_{flood} \quad \text{[kN/m}^2\text{]}$$

Where:

z_{flood} : Vertical distance [m] from the load point to the deepest equilibrium waterline in damaged condition obtained from applicable damage stability calculations or to freeboard deck if the damage waterline is not given.

9.2.4 The tank testing pressure, $P_{in-test}$, is to be taken as the greater of the following, see also the design pressure for tank testing in Section 24:

$$P_{in-test} = \rho_{sw} g z_{test} \quad \text{[kN/m}^2\text{]}$$

$$P_{in-test} = \rho_{sw} g z_{tk} + P_{valve} \quad \text{[kN/m}^2\text{]}$$

Where:

z_{test} : Vertical distance to the load point, is to be taken as the greater of the following, in m:

a. top of overflow
b. 2.4 m above top of tank

P_{valve} : setting of pressure relief valve [kN/m^2], if fitted, is not to be taken less than 25 kN/m^2.

9.3 Static Pressure on decks from distributed loading
9.3.1 The pressure on decks and inner bottom, P_{stat}, is to be taken as:

$P_{stat} = P_{deck}$ [kN/m^2]

Where:

P_{deck} :Uniformly distributed pressure on lower decks and decks within superstructures, including platform decks in the main engine room and for other spaces with heavy machinery components [kN/m^2]. P_{deck} is not to be taken less than 16 kN/m^2.

9.4 Static Deck Loads from Heavy Units
9.4.1 The scantlings of structure in way of heavy units of cargo and equipment are to consider gravity forces acting where the mass is 20 tonnes or greater. The load acting on supporting structures and securing systems for heavy units of cargo, equipment or structural components, F_{stat}, is to be taken as:

$F_{stat} = m_{un} g$ [kN]

Where:

m_{un} : mass of unit [t]

9.5 Dynamic Tank Pressure
9.5.1 The envelope dynamic tank pressure, P_{in-v}, due to vertical tank acceleration is to be taken as:

$P_{in-v} = \rho a_v (z_0 - z)$ [kN/m^2] for strength assessment and scantling requirement

9.5.2 The envelope dynamic tank pressure, P_{in-t}, due to transverse acceleration is to be taken as:

$P_{in-t} = f_{ull-t} \rho a_t (y_0 - y)$ [kN/m^2] for strength assessment and scantling requirement

Where:

f_{ull-t} : Factor to account for ullage in cargo tanks, and is to be taken as:

= 0.67 for cargo tanks, including cargo tanks designed for filling with water ballast

= 1.0 for ballast and other tanks

9.5.3 The envelope dynamic tank pressure, P_{in-lng}, due to longitudinal acceleration is to be taken as:

$P_{in-lng} = f_{ull-lng} \rho a_{lng} (x_0 - x)$ [kN/m^2] for strength assessment and scantling requirement

Where:

$f_{ull-lng}$: factor to account for ullage in cargo tanks, and is to be taken as:

= 0.62 for cargo tanks, including cargo tanks designed for filling with water ballast

= 1.0 for ballast and other tanks

9.5.4 For scantling and strength assessment the simultaneous acting dynamic tank pressure, P_{in-dyn}, is to be taken as the summation of the components for considered dynamic load case, see 11.4.7.

9.6 Dynamic Tank Pressure from Distributed Loading
9.6.1 The envelope dynamic tank pressure, $P_{deck-dyn}$, on deck, inner bottom, and hatch cover is to be taken as:

$$P_{deck-dyn} = P_{deck}\frac{a_v}{g} \quad [kN/m^2]$$

Where:

P_{deck} : uniformly distributed pressure on lower deck and decks within superstructures as defined in Section 9.3.

9.7 Dynamic Load from Heavy Units

9.7.1 The envelope dynamic deck loads, F_v, F_t, F_{lng} acting vertically, transversely and longitudinally on supporting structures and securing system for heavy units of cargo, equipments or structural components are to be taken as:

$$F_v = m_{un}a_v \quad [kN]$$

$$F_t = m_{un}a_t \quad [kN]$$

$$F_{lng} = m_{un}a_{lng} \quad [kN]$$

9.8 Sloshing Pressure in tanks

9.8.1 Application and Limitations

9.8.1.1 This sub section is applicable to all liquid cargo, ballast tanks and other tanks with volume exceeding 100 m^3.

9.8.1.2 The sloshing pressures are to be taken as per the IRS Rules for Bulk Carriers and Oil Tankers, Volume 2, Chapter 4, Section 6 [6].

9.8.1.3 Applicable Impact pressures as required by IRS Rules for Bulk Carriers and Oil Tankers, Volume 2, Chapter 4, Section 6 [6.1.2] are to be evaluated and submitted to IRS.

9.8.1.4 Sloshing impact pressures are to be evaluated for partial filling conditions of tanks using techniques to be agreed with by IRS.

Section 10

Accidental Loads

10.1 Flooded Condition

10.1.1 Local Pressure

10.1.1.1 The pressure in compartments and tanks in flooded condition or damaged condition is to be taken as $P_{in\text{-}flood}$, refer Section 9.2.

10.1.2 Global Loads

10.1.2.1 The still water bending moments and the still water shear forces in flooded condition are to be determined for each flooding scenario, considering the damaged compartments flooded up to the equilibrium waterline.

10.1.3 Assessment

10.1.3.1 Flooding strength calculations are to be carried out to determine the effect of accidental flooding on the hull strength.

10.1.3.2 Flooding calculations are to be undertaken for all flooding scenarios required by National Regulations.

10.2 Blast Condition

10.2.1 Pressure

10.2.1.1 For FOUs subject to risks of explosion and blasts (see chapter 7, 3.3.2), design blast pressures are to be defined by the owners/designers. Recognized standards such as API RP 2FB may be utilized for evaluating blast & explosion loads. Compliance is also required with National regulations as applicable.

10.2.1.2 Design calculations are to be submitted which may be based on elastic analysis or elasto-plastic design methods.

10.2.2 Load Combinations

10.2.2.1 For Scantling evaluation the blast condition is to be considered for the following load combinations of blast pressure and global loads. These considerations are to be based upon the risk of blasts (refer Chapter 7, Section 3.3.2)

a. Blast pressure + Permissible still water hogging bending moment for the operational condition.
b. Blast pressure + Permissible still water sagging bending moment for operational condition.

10.2.2.2 Actual Environmental loads are to be considered when evaluating the blast conditions. These are to be submitted by the designer to IRS.

10.2.3 Evaluations

10.2.3.1 The evaluations for the load combinations are to be submitted to IRS for approval. The evaluations are to demonstrate adequate mitigation of the risks to the applicable structural elements from blast load hazards.

10.3 Collision Loads

10.3.1 General

10.3.1.1 Collision loads are to be considered in the design of the unit as applicable to the function of the unit. Magnitudes, extent and application and structural analysis techniques of collision loads are to be submitted to IRS.

Section 11

Load Combinations

11.1 Symbols

B_{local} : Local breadth at waterline for considered draught [m]

L : Rule length as defined in Section 1 [m]

$F_{dk\text{-}dyn}$: Dynamic load acting on supporting structures and securing systems for heavy units of cargo, equipment or structural components [kN], see 11.4.8

F_{stat} : Load acting on supporting structures and securing system for heavy units of cargo, equipment or structural components [kN], as defined in 9.4

F_v : Envelope vertical dynamic load from heavy units [kN], as defined in 9.7

M_{hz} : Horizontal wave bending moment [kNm] for a considered dynamic load case, see 11.4.3

$M_{h\text{-}total}$: Design horizontal bending moment [kNm]

$M_{sw\text{-}perm\text{-}maint}$: Permissible still water bending moment [kNm] envelopes for inspection/maintenance condition as defined in Section 6

$M_{sw\text{-}perm\text{-}opr}$: Permissible still water bending moment [kNm] envelopes for operational condition as defined in Section 6

$M_{sw\text{-}perm\text{-}sea}$: Permissible still water bending moment [kNm] envelopes for transit condition as defined in Section 6

$M_{v\text{-}total}$: Design vertical bending moment [kNm]

M_{wv} : Vertical wave bending moment [kNm] for a considered dynamic load case, see 11.4.2.

Q : Design vertical shear force [kN]

$Q_{sw\text{-}perm\text{-}flood}$: Permissible still water positive/ negative wave shear force [kN] for flooded conditions as defined in Section 6

$Q_{sw\text{-}perm\text{-}maint}$: Permissible still water positive/ negative wave shear force [kN] for inspection/ maintenance conditions as defined in Section 6

$Q_{sw\text{-}perm\text{-}opr}$: Permissible still water positive/ negative wave shear force [kN] for operational conditions as defined in Section 6

$Q_{sw-perm-sea}$: Permissible still water positive/ negative wave shear force [kN] for transit conditions as defined in Section 6

Q_{wv} : Vertical wave shear force [kN] for a considered dynamic load case, see 11.4.4

P_{1-WL} : P_1 pressure [kN/m^2] at still waterline for considered draught, see 8.4

P_{2-WL} : P_2 pressure [kN/m^2] at still waterline for considered draught, see 8.4

P_{ex} : Design sea pressure [kN/m^2]

P_{hys} : Static sea pressure [kN/m^2], at considered draught see 8.3.

P_{wv-dyn} : Dynamic wave pressure [kN/m^2] for a considered dynamic load case, see 11.4.5.

$P_{wdk-dyn}$: Green sea load [kN/m^2] for a considered dynamic load case, see 11.4.6.

P_{in} : Design tank pressure [kN/m^2]

$P_{in-test}$: Tank testing pressure [kN/m^2], see 9.2

P_{in-air} : Static tank pressure [kN/m^2] in the case of overfilling or filling during flow through ballast water exchange, see 9.2

P_{drop} : Added overpressure [kN/m^2] due to liquid flow through air pipe or overflow pipe, see 9.2

P_{valve} : Setting of pressure relief valve [kN/m^2], see 9.2

P_{in-tk} : Static tank pressure [kN/m^2], see 9.2

P_{in-dyn} : Dynamic tank pressure [kN/m^2] for a considered dynamic load case, see 11.4.7.

$P_{in-flood}$: Pressure in compartments and tanks in flooded or damaged condition [kN/m^2], see 9.2

P_{stat} : Static pressure on decks and inner bottom [kN/m^2], see 9.3

P_{dk} : Design deck pressure [kN/m^2]

$P_{deck-dyn}$: Envelope dynamic deck pressure [kN/m^2], inner bottom and hatch covers, as defined in 9.6

$P_{dk\text{-dyn}}$: Dynamic deck pressure [kN/m^2] on decks, inner bottom and hatch covers for a considered dynamic load case, see 11.4.8.

T_{LC} : Draught in the loading condition being considered [m], Section 1.1

f_β : Heading correction factor as defined in 11.4.1.2.

f_{lng} : Dynamic load combination factor for longitudinal acceleration for considered dynamic load case. f_{lng} is to be taken as appropriate dependent on the tank location, see 11.5.

f_t : Dynamic load combination factor for transverse acceleration for considered dynamic load case, see 11.5.

f_v : Dynamic load combination factor for vertical acceleration for considered dynamic load case. f_v is to be taken as appropriate to the tank location, see 11.5.

f_{v-mid} : dynamic load combination factor for vertical acceleration for considered dynamic load case, see 11.5

f_{WL} : Dynamic load combination factor for dynamic wave pressure at still waterline for considered dynamic load case, see dynamic load combination factors 11.5.

x : Vertical co-ordinate [m]

x_0 : Longitudinal coordinate of reference point [m]

y : Transverse coordinate [m]

y_0 : Transverse co-ordinate of reference point [m]

z : Vertical coordinate [m]

z_0 : Vertical co-ordinate of reference point [m]

z_{dk-T} : Distance from deck to the still waterline at the applicable draught for the loading condition being considered [m].

ρ_{sw} : Density of sea water, 1.025 [t/m^3]

g : acceleration due to gravity, 9.81 [m/s^2]

11.2 General

11.2.1 Application

11.2.1.1 The design load combinations corresponding to applicable load scenarios like static *S* or *S+D* (static + dynamic) are to be used for scantling calculations for the scantling requirements and strength assessment (by FEM). Design load combinations are to taken as given in 11.3.

11.2.1.2 For each dynamic load case, the applicable envelope load values as given in Section 6 to section 10 are multiplied with dynamic load combination factors to give simultaneously acting dynamic loads.

11.2.1.3 The procedures for calculating the simultaneously acting dynamic loads are given in the present section.

11.3 Design Load Combination

11.3.1 General

11.3.1.1 The design load combinations are given in Table 3.

11.4 Application of Dynamic Loads

11.4.1 Dynamic Load Combination Factors

11.4.1.1 For scantling assessment and strength assessment by FEM, the dynamic load combination factors used for evaluation of the simultaneously acting dynamic loads are to be taken as specified in Section 11.5.

11.4.1.2 The heading correction factor, f_β, is to be taken as follows:

For transit conditions:

$f_\beta = 0.8$, for beam sea dynamic load cases

$f_\beta = 1.0$, for all other dynamic load cases

For all conditions other than transit

$f_\beta = 1.0$

11.4.2 Vertical Wave Bending Moment for a considered Dynamic Load Case

11.4.2.1 The simultaneous acting vertical wave bending moment, M_{wv}, is to be taken as follows:

$M_{wv} = f_\beta f_{mv} M_{wv-h}$ for $f_{mv} \geq 0$

$M_{wv} = -f_\beta f_{mv} M_{wv-s}$ for $f_{mv} < 0$

Where:

M_{wv-h} : Hogging vertical wave bending moment [kN-m], as defined in Section 6.

M_{wv-s} : Sagging vertical wave bending moment [kN-m], as defined in Section 6

f_{mv} : Dynamic load combination factor for vertical wave bending moment for considered dynamic load case, see 11.5

Table 3: Design Load Combinations

		Transit		On-Site Operations		Inspection/ maintenance		Flooded	
	Design load combination	**S**	**S + D**	**S**	**S + D**	**S**	**S + D**	**S**	**S + D**
Hull Girder	VBM $M_{v-total}$	M_{sw-sea}	$M_{sw-sea} + M_{wv}$	M_{sw-op}	$M_{sw-op} + M_{wv}$	$M_{sw-maint}$	$M_{sw-maint} + M_{wv}$	$M_{sw-flood}$	$M_{sw-flood} + M_{wv}$
	HBM $M_{h-total}$	-	M_{hz}	-	M_{hz}	-	M_{hz}	-	M_{hz}
	VSF Q	Q_{sw-sea}	$Q_{sw-sea} + Q_{wv}$	Q_{sw-op}	$Q_{sw-op} + Q_{wv}$	Q_{sw-sea}	$Q_{sw-maint} + Q_{wv}$	$Q_{sw-flood}$	$Q_{sw-flood} + Q_{wv}$
	TM								
P_{ex}	Exposed Deck	-	$P_{wdk-dyn}$	-	$P_{wdk-dyn}$	-	$P_{wdk-dyn}$	-	Max $(P_{hys} + P_{ex-dyn}, P_{wdk-dyn})$
	Hull envelope	P_{hys}	$P_{hys} + P_{wv-dyn}$	P_{hys}	$P_{hys} + P_{wv-dyn}$	P_{hys}	$P_{hys} + P_{wv-dyn}$	P_{hys}	$P_{hys} + P_{wv-dyn}$
P_{in}	Ballast tanks	P_{in-air}	$P_{in-tk} + P_{in-dyn}$	$P_{in-air} + P_{drop}$	$P_{in-tk} + P_{in-dyn}$	$P_{in-test}$	$P_{in-test} + P_{in-dyn}$	$P_{in-flood}$	$\max(P_{in-tk}, P_{in-flood}) + P_{in-dyn}$
	Cargo tanks / other tanks designed for filling with liquid	$P_{in-tk} + P_{valve}$	$P_{in-tk} + P_{in-dyn}$	$P_{in-tk} + P_{valve}$	$P_{in-tk} + P_{in-dyn}$	$\max(P_{in-tk} + P_{valve}, P_{in-test})$	$P_{in-test} + P_{in-dyn}$	$P_{in-flood}$	$\max(P_{in-tk}, P_{in-flood}) + P_{in-dyn}$
	Fresh water/lube oil/fuel oil	P_{in-air}	$P_{in-tk} + P_{in-dyn}$	P_{in-air}	$P_{in-tk} + P_{in-dyn}$	$P_{in-test}$	$P_{in-test} + P_{in-dyn}$	$P_{in-flood}$	$\max(P_{in-tk}, P_{in-flood}) + P_{in-dyn}$
	Watertight boundaries/void space	-	-	-	-	$P_{in-test}$	$P_{in-tk} + P_{in-dyn}$	$P_{in-flood}$	$\max(P_{in-tk}, P_{in-flood}) + P_{in-dyn}$
	Dry space	-	-	-	-	-	-	$P_{in-flood}$	$P_{in-flood} + P_{in-dyn}$
P_{dk}	Deck loads for heavy units	P_{stat}	$P_{stat} + P_{dk-dyn}$	P_{stat}	$P_{stat} + P_{dk-dyn}$	P_{stat}	$P_{stat} + P_{dk-dyn}$	P_{stat}	$P_{stat} + P_{dk-dyn}$

11.4.3 Horizontal Bending Moment for a considered Dynamic Load Case

11.4.3.1 The simultaneously acting horizontal wave bending moment, M_h, is to be taken as:

$$M_{hz} = f_\beta f_{mh} M_{wv-hz} \quad \text{[kNm]}$$

Where:

M_{wv-hz} : Horizontal wave bending moment [kNm] as defined in Section 6

f_{mh} : Dynamic load combination factor for horizontal wave bending moment for considered dynamic load case, see 11.5.

11.4.4 Vertical Wave Shear Force for a considered Dynamic Load Case

11.4.4.1 The simultaneously acting vertical wave shear force, Q_{wv}, is to be taken as:

$$Q_{wv} = f_\beta \, f_{qv} Q_{wv-pos} \quad \text{[kN] for } f_{qv} \geq 0$$

$$Q_{wv} = -f_\beta \, f_{qv} Q_{wv-neg} \quad \text{[kN] for } f_{qv} < 0$$

Where:

Q_{wv-pos} : Envelope positive vertical wave shear force [kN], as defined in Section 6

Q_{wv-neg} : Envelope negative vertical wave shear force [kN], as defined in Section 6

f_{qv} : Dynamic load combination factor for vertical wave shear force for considered dynamic load case, see 11.5.

11.4.5 Dynamic wave pressure distribution for a considered dynamic load case

11.4.5.1 The simultaneously acting dynamic wave pressure, P_{wv-dyn} [kN/m²], is to be taken as follows, but not to be less than $-\rho_{sw} g (T_{LC} - z)$ below still waterline or less than 0 above still waterline:

11.4.5.2 For port and starboard side within the cargo tank region as below:

$$P_{wv-dyn} = P_{ctr} + \frac{|y|}{0.5 B_{local}} \left(P_{bilge} - P_{ctr} \right)$$

between centerline and start of bilge

$$P_{wv-dyn} = P_{bilge} + \frac{z}{T_{LC}} \left(P_{WL} - P_{bilge} \right)$$

between end of bilge and still waterline

$$P_{wv-dyn} = P_{WL} - 10(z - T_{LC})$$

for side shell above still waterline

Intermediate values of P_{wv-dyn} around the bilge are to be obtained by linear interpolation along the vertical distance.

11.4.5.3 For port and starboard side outside the cargo tank region as below:

$$P_{wv-dyn} = P_{ctr} + \frac{z}{T_{LC}} \left(P_{WL} - P_{ctr} \right)$$

between bottom centerline and still waterline

$$P_{wv-dyn} = P_{WL} - 10(z - T_{LC})$$

above still waterline

Where:

P_{ctr} : Dynamic wave pressure at bottom centerline, to be taken as:

$$f_{ctr} P_{ex-max} \quad \text{[kN/m}^2\text{]}$$

P_{bilge} : Dynamic wave pressure at $z = 0$ and $y = B_{local}/2$, to be taken as:

$$f_{bilge} P_{ex-max} \quad \text{[kN/m}^2\text{]}$$

P_{WL} : Dynamic wave pressure at waterline, to be taken as:

$$f_{WL} P_{ex-max} \quad \text{[kN/m}^2\text{]}$$

P_{ex-max} : Envelope maximum dynamic wave pressure [kN/m²] as defined in 8.4.

f_{bilge} : Dynamic load combination factor for dynamic wave pressure at bilge for considered dynamic load case, see 11.5.

f_{ctr} : Dynamic load combination factor for dynamic wave pressure at centerline for considered dynamic load case, see 11.5.

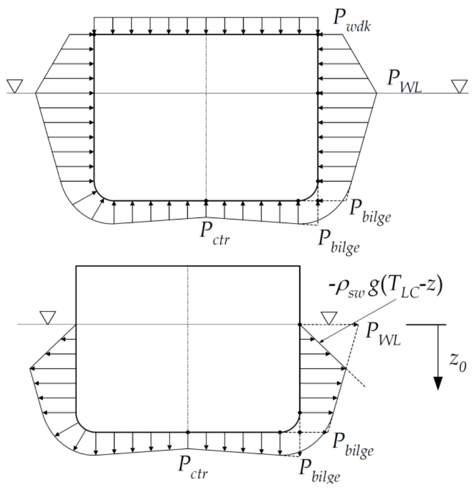


Figure 16: Dynamic wave pressure for head sea dynamic load case

11.4.5.4 Figure 16 to Figure 18 illustrate simultaneously acting dynamic wave pressures.

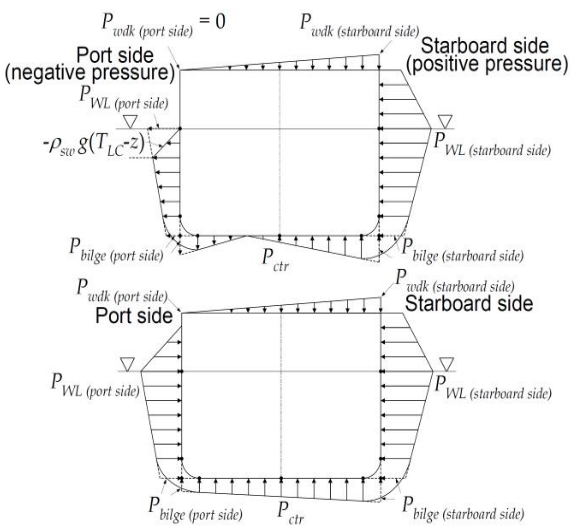


Figure 17: Dynamic wave pressure for beam and oblique sea dynamic load case

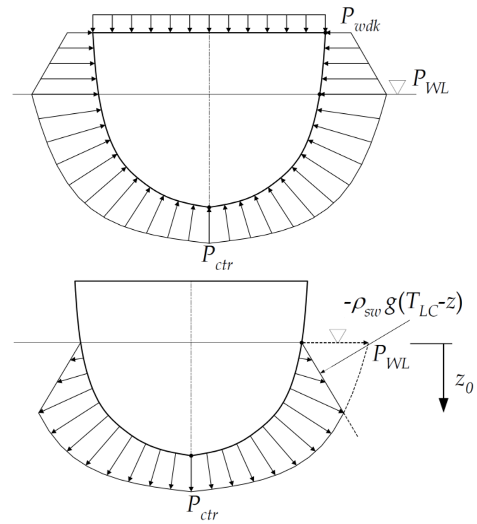


Figure 18: Pressure distribution for wave crest and wave trough for forward and aft

11.4.6 Green Sea Loads for a considered Dynamic Load Case

11.4.6.1 The simultaneously acting green sea load on the weather deck, $P_{wdk\text{-}dyn}$, for strength assessment is to be obtained by linear interpolation between $P_{wdk\text{-}pt}$ and $P_{wdk\text{-}stb}$.

11.4.6.2 The green sea load at the port side, $P_{wdk\text{-}pt}$, is to be taken as the greater of:

$$P_{wdk-pt} = f_{1-dk}\left(f_{WL}f_{op}P_{1-WL} - 10z_{dk-T}\right)$$
[kN/m²]

$$P_{wdk-pt} = 0.8(f_{WL}P_{2-WL} - 10z_{dk-T})$$
[kN/m²]

11.4.6.3 The green sea load at the starboard side, $P_{wdk\text{-}stb}$, is to be taken as the greater of:

$$P_{wdk-stb} = f_{1-dk}\left(f_{WL}f_{op}P_{1-WL} - 10z_{dk-T}\right)$$
[kN/m²]

$$P_{wdk-stb} = 0.8(f_{WL}P_{2-WL} - 10z_{dk-T})$$
[kN/m²]

$P_{wdk\text{-}pt}$ and $P_{wdk\text{-}stb}$ are not to be taken less than 34.3 kN/m^2 when f_{WL} = 1.0 and the FOU's draught used in design load case is greater or equal to $0.9T_{sc}$.

Where:

$f_{1\text{-}dk}$: $0.8 + L/750$

f_{op} : 1.0 at and forward of $0.2L$ from AP

: 0.8 at and aft of AP

: Intermediate values to be obtained by linear interpolation

11.4.6.4 The simultaneously acting green sea load on the weather deck, $P_{wdk\text{-}dyn}$, for scantling requirements is to be taken as greater of:

$$P_{wdk-dyn} = f_{1-dk}\left(f_{WL} f_{op} P_{1-WL} - 10 z_{dk-T}\right)$$

[kN/m^2]

but is not to be taken less than 34.3 when f_{WL} = 1.0 and $T_{LC} \geq 0.9T_{sc}$

$$P_{wdk-dyn} = 0.8 f_{2-dk}\left(f_{WL} P_{2-WL} - 10 z_{dk-T}\right)$$

[kN/m^2]

but is not to be taken less than 34.3 when f_{WL} = 1.0, $f_{2\text{-}dk}$ = 1.0 and $T_{LC} \geq 0.9T_{sc}$

$P_{wdk\text{-}dyn}$ is not to be taken less than zero in any case.

$f_{1\text{-}dk}$: $0.8 + L/750$

$f_{2\text{-}dk}$: $0.5 + |y|/B_{wdk}$

f_{op} : 1.0 at and forward of $0.2L$ from AP

: 0.8 at and aft of AP

: Intermediate values to be obtained by linear interpolation

11.4.7 Dynamic Tank Pressure for considered Dynamic Load Case

11.4.7.1 The simultaneous acting dynamic tank pressure, $P_{in\text{-}dyn}$ [kN/m^2], is to be taken as per 11.4.7.2 – 11.4.7.4.

11.4.7.2 For tanks in the cargo region

$$P_{in-dyn} = f_\beta\left(f_v P_{in-v} + f_t P_{in-t} + f_{lng} P_{in-lng}\right)$$

[kN/m^2]

11.4.7.3 For tanks outside the cargo region

$$P_{in-dyn} = f_\beta\left(f_{v-mid} P_{in-v} + |f_t P_{in-t}| + |f_{lng} P_{in-lng}|\right)$$

[kN/m^2]

Where:

$P_{in\text{-}v}$: Envelope dynamic tank pressure [kN/m^2] due to vertical acceleration as defined in 9.5.1 with reference point z_0 taken as:

a. Tank top
b. Top of air pipe/overflow for ballast tanks design for BWE by flow-through method

see, Figure 19

$P_{in\text{-}t}$: Envelope dynamic tank pressure [kN/m^2] due to transverse acceleration as defined in 9.5.2 with reference point y_0 taken as:

a. Tank top towards port side for $f_t > 0$
b. Tank top towards starboard side for $f_t < 0$

see, Figure 20

$P_{in\text{-}lng}$: Envelope dynamic tank pressure [kN/m^2] due to longitudinal acceleration as defined in 9.5.3 with reference point x_0 taken as:

a. Forward bulkhead for $f_{lng} > 0$
b. Aft bulkhead of the tank for $f_{lng} < 0$

see, Figure 21

11.4.7.4 For a non-parallel tank, y_0 should be selected from either forward or aft bulkhead corresponding to the reference point x_0. If the longitudinal load combination factor f_{lng} = 0, y_0 should be selected from the bulkhead with the greater breadth.

The vertical, transverse and longitudinal acceleration is to be taken at the centre of gravity of the tank under consideration.

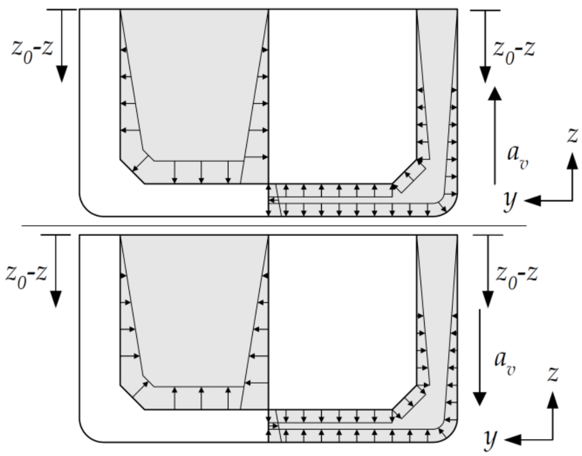


Figure 19: Dynamic tank pressure in cargo tank (left) and ballast tank (right) due to positive and negative vertical tank acceleration

11.4.8 Dynamic Deck Loads for a considered Dynamic Load Case

11.4.8.1 The simultaneously acting dynamic deck load for uniformly distributed load, $P_{dk\text{-}dyn}$, on the enclosed upper deck, where a forecastle or poop is fitted and also on all lower decks, is to be taken as:

$$P_{dk-dyn} = f_{\beta} f_{V-mid} P_{deck-dyn} \qquad \text{[kN/m}^2\text{]}$$

11.4.8.2 The simultaneous acting dynamic vertical force for heavy units, $F_{dk\text{-}dyn}$, acting on supporting structures and securing systems for heavy units of cargo, equipment or structural components, is to be taken as:

$$F_{dk-dyn} = f_{\beta} f_{v-mid} F_V \qquad \text{[kN]}$$

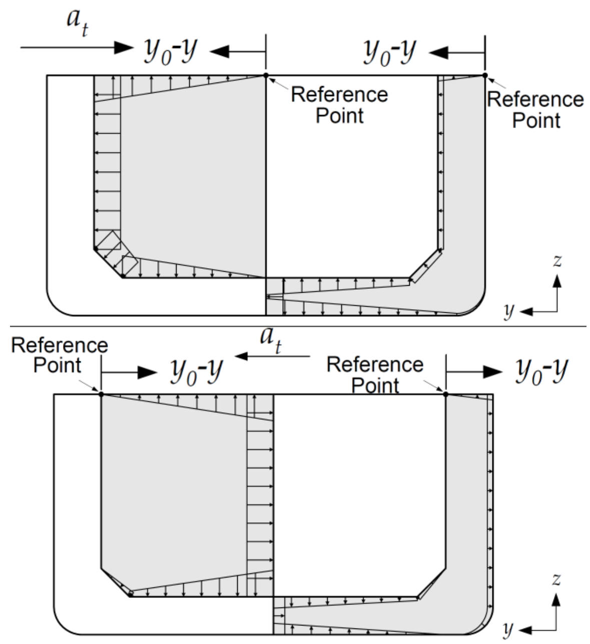


Figure 20: Dynamic tank pressure in cargo tank (left) and ballast tank (right) due to negative and positive transverse tank acceleration

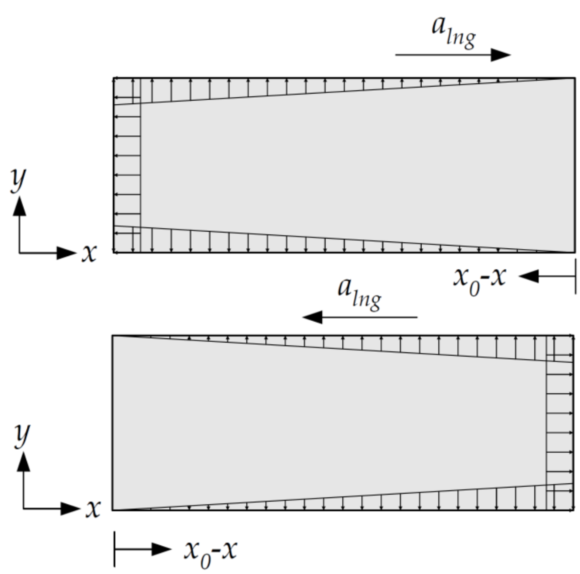


Figure 21: Dynamic tank pressure in tanks due to positive and negative longitudinal acceleration

11.5 Dynamic Load Cases and Dynamic Load Combination Factor for Scantling and Strength Assessment

11.5.1 General

11.5.1.1 For the scantling requirement and dynamic load cases are to be applied in accordance with the design load set for the design load combination *S+D*. The simultaneously acting dynamic load cases are to be derived using the dynamic combination factors given in Table 4 to Table 9.

11.5.1.2 The Dynamic Load Combination Factor (DLCF) to be used depends on the longitudinal location within the Unit as shown in **Figure 22**.

11.5.1.3 For strength assessment by direct calculations, the dynamic load combinations are discussed in Section 21.

11.5.1.4 DLCF for intended site(s) of operation as well as transit conditions will be specially considered by IRS in lieu of those in Tables 4 – 9. Such DLCFs if utilized for strength assessment are to be suitably justified to IRS and proven adequate for their utility for the site and transits.

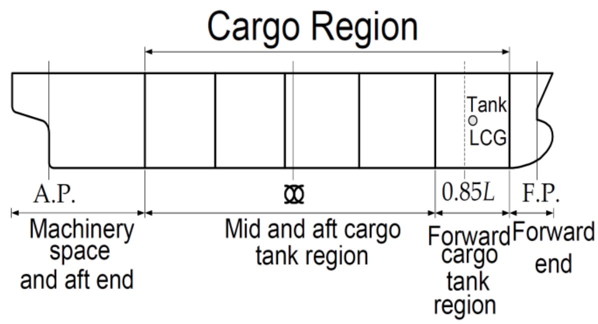


Figure 22: Illustration of structural region for DLCF

Table 4: Dynamic load cases for outside the cargo tank region for deep draught condition (≥0.9T_{sc})

Location			**Machinery Space and Aft End**							**Forward End**			
Wave direction			**Following Sea**	**Oblique sea**		**Beam sea**				**Beam sea**			
Max response			P_{ctr}	P_{WL}		a_v		a_t		a_v		a_t	
Dynamic load case			**1**	**2a**	**2b**	**3a**	**3b**	**4a**	**4b**	**5a**	**5b**	**6a**	**6b**
Global Loads	M_{wv}	f_{mv}	-1.0	-0.7	-0.7	-0.4	-0.4	-0.1	-0.1	-	-	-	-
Accelerations	$a_{v\text{-}mid}$	$f_{v\text{-}mid}$	0.6	0.9	0.9	1.0	1.0	0.3	0.3	1.0	1.0	0.3	0.3
	$a_{v\text{-}pt}$	$f_{v\text{-}pt}$	0.6	-	0.9	-	1.0	-	0.4	-	1.0	-	0.3
	$a_{v\text{-}stb}$	$f_{v\text{-}stb}$	0.6	0.9	-	1.0	-	0.4	-	1.0	-	0.3	-
	a_t	f_t	0.0	0.2	-0.2	0.5	-0.5	1.0	-1.0	0.7	-0.7	1.0	-1.0
	a_{lng}	f_{lng}	0.8	0.7	0.7	0.6	0.6	-0.1	-0.1	-0.7	-0.7	-0.1	-0.1
Dynamic wave pressure on starboard side	P_{ctr}	f_{ctr}	1.0	0.8	0.8	0.7	0.7	0.2	0.2	1.0	1.0	0.2	0.2
	P_{WL}	f_{WL}	0.5	1.0	0.2	0.8	0.3	0.5	-0.3	1.0	0.8	0.2	0.0
Dynamic wave pressure on port side	P_{ctr}	f_{ctr}	1.0	0.8	0.8	0.7	0.7	0.2	0.2	1.0	1.0	0.2	0.2
	P_{WL}	f_{WL}	0.5	0.2	1.0	0.3	0.8	-0.3	0.5	0.8	1.0	0.0	0.2

Where:

$a_{v\text{-}pt}$: Vertical acceleration for port tank [m/s^2]
$a_{v\text{-}stb}$: Vertical acceleration for starboard tank [m/s^2]
$a_{lng\text{-}mid}$: Longitudinal acceleration for centre tank [m/s^2]
$a_{lng\text{-}pt}$: Longitudinal acceleration for port tank [m/s^2]
$a_{lng\text{-}stb}$: Longitudinal acceleration for starboard tank [m/s^2]
$a_{lng\text{-}ctr}$: Longitudinal acceleration for centre double bottom ballast tank [m/s^2]

Table 5: Dynamic load cases for Mid tank and aft cargo tank region for deep draught condition (≥0.9T_{sc})

Wave direction			Head Sea			Oblique sea				Beam sea			
Max response			M_{wv}	a_v	a_{lng}	M_{hz}		a_t		P_{ctr}		P_{WL}	
Dynamic load case			**1**	**2**	**3**	**4a**	**4b**	**5a**	**5b**	**6a**	**6b**	**7a**	**7b**
Global Loads	M_{wv}	f_{mv}	1.0	-1.0	0.5	-0.2	-0.2	-0.1	-0.1	-0.2	-0.2	-0.3	-0.3
	M_{wv-hz}	f_{mh}	0.0	0.0	0.0	1.0	-1.0	-0.1	0.1	0.0	0.0	0.0	0.0
Accelerations	a_{v-mid}	f_{v-mid}	-0.2	0.5	-0.4	-0.1	-0.1	0.5	0.5	1.0	1.0	1.0	1.0
	a_{v-pt}	f_{v-pt}	-0.2	0.5	-0.4	-0.1	-0.1	0.2	0.6	0.8	1.0	0.8	1.0
	a_{v-stb}	f_{v-stb}	-0.2	0.5	-0.4	-0.1	-0.1	0.6	0.2	1.0	0.8	1.0	0.8
	a_t	f_t	0.0	0.0	0.0	0.0	0.0	1.0	-1.0	0.5	-0.5	0.6	-0.6
	$a_{lng-mid}$	$f_{lng-mid}$	0.3	-0.6	1.0	-0.3	-0.3	-0.1	-0.1	-0.5	-0.5	-0.6	-0.6
	a_{lng-pt}	f_{lng-pt}	0.3	-0.6	1.0	-0.4	-0.2	-0.1	-0.1	-0.5	-0.5	-0.6	-0.6
	$a_{lng-stb}$	$f_{lng-stb}$	0.3	-0.6	1.0	-0.2	-0.4	-0.1	-0.1	-0.5	-0.5	-0.6	-0.6
	$a_{lng-ctr}$	$f_{lng-ctr}$	0.3	-0.6	1.0	-0.3	-0.3	-0.1	-0.1	-0.5	-0.5	-0.6	-0.6
Dynamic wave pressure on starboard side	P_{ctr}	f_{ctr}	0.7	-0.6	0.2	-0.3	-0.3	0.5	0.5	1.0	1.0	0.9	0.9
	P_{bilge}	f_{bilge}	0.3	-0.2	0.1	-0.4	-0.1	0.8	-0.3	0.9	0.4	1.0	0.4
	P_{WL}	f_{WL}	0.3	-0.3	0.1	-0.6	-0.1	0.5	-0.2	0.8	0.4	1.0	0.4
Dynamic wave pressure on port side	P_{ctr}	f_{ctr}	0.7	-0.6	0.2	-0.3	-0.3	0.5	0.5	1.0	1.0	0.9	0.9
	P_{bilge}	f_{bilge}	0.3	-0.2	0.1	-0.1	-0.4	-0.3	0.8	0.4	0.9	0.4	1.0
	P_{WL}	f_{WL}	0.3	-0.3	0.1	-0.1	-0.6	-0.2	0.5	0.4	0.8	0.4	1.0

Where:

f_{lng-pt} : Dynamic load combination factor associated with the longitudinal acceleration of a port side cargo or ballast tank

$f_{lng-stb}$: Dynamic load combination factor associated with the longitudinal acceleration of a starboard side cargo or ballast tank

$f_{lng-ctr}$: Dynamic load combination factor associated with the longitudinal acceleration of a centre double bottom ballast tank

$f_{lng-mid}$: Dynamic load combination factor associated with the longitudinal acceleration of a centre tank

Table 6: Dynamic load cases for forward cargo tank region for deep draught condition (≥0.9T_{sc})

Wave direction			**Head Sea**		**Oblique sea**										**Beam sea**			
Max response			a_v	a_{lng}	a_{lng}		P_{ctr}		P_{bilge}		P_{WL}				a_v		a_t	
Dynamic load case			**1**	**2**	**3a**	**3b**	**4a**	**4b**	**5a**	**5b**	**6a**	**6b**			**7a**	**7b**	**8a**	**8b**
Global Loads	M_{wv}	f_{mv}	-0.7	0.9	0.3	0.3	-0.6	-0.6	-0.3	-0.3	-0.4	-0.4			-0.4	-0.4	-0.1	-0.1
	M_{wv-hz}	f_{mh}	0.0	0.0	-0.2	0.2	0.2	-0.2	-0.1	0.1	0.2	-0.2			-0.1	0.1	-0.5	0.5
Accelerations	a_{v-mid}	f_{v-mid}	0.7	-0.6	-0.6	-0.6	0.7	0.7	0.9	0.9	0.7	0.7			1.0	1	0.4	0.4
	a_{v-pt}	f_{v-pt}	0.7	-0.6	-0.6	-0.6	0.7	0.7	0.9	1.0	0.7	0.7			0.9	1	0.3	0.6
	a_{v-stb}	f_{v-stb}	0.7	-0.6	-0.6	-0.6	0.7	0.7	1.0	0.9	0.7	0.7			1.0	0.9	0.6	0.3
	a_t	f_t	0.0	0.0	-0.4	0.4	0.1	-0.1	0.7	-0.7	0.5	-0.5			0.6	-0.6	1	-1
	$a_{lng-mid}$	$f_{lng-mid}$	-0.8	1.0	0.8	0.8	-1.0	-1.0	-0.5	-0.5	-1.0	-1.0			-0.5	-0.5	-0.1	-0.1
	a_{lng-pt}	f_{lng-pt}	-0.8	1.0	1.0	0.6	-1.0	-0.9	-0.5	-0.5	-1.0	-0.7			-0.5	-0.5	-0.1	-0.1
	$a_{lng-stb}$	$f_{lng-stb}$	-0.8	1.0	0.6	1.0	-0.9	-1.0	-0.5	-0.5	-0.7	-1.0			-0.5	-0.5	-0.1	-0.1
	$a_{lng-ctr}$	$f_{lng-ctr}$	-0.8	1.0	0.8	0.8	-1.0	-1.0	-0.5	-0.5	-1.0	-1.0			-0.5	-0.5	-0.1	-0.1
Dynamic wave pressure on starboard side	P_{ctr}	f_{ctr}	1.0	-0.9	-0.4	-0.4	1.0	1.0	0.8	0.8	0.5	0.5			0.8	0.8	0.4	0.4
	P_{bilge}	f_{bilge}	0.6	-0.7	-0.6	-0.2	0.9	0.6	1.0	0.5	0.7	0.3			1.0	0.5	0.8	-0.1
	P_{WL}	f_{WL}	0.3	-0.5	-0.9	-0.2	0.8	0.4	0.9	0.4	1.0	0.2			0.9	0.4	0.6	-0.2
Dynamic wave pressure on port side	P_{ctr}	f_{ctr}	1.0	-0.9	-0.4	-0.4	1.0	1.0	0.8	0.8	0.5	0.5			0.8	0.8	0.4	0.4
	P_{bilge}	f_{bilge}	0.6	-0.7	-0.2	-0.6	0.6	0.9	0.5	1.0	0.3	0.7			0.5	1	-0.1	0.8
	P_{WL}	f_{WL}	0.3	-0.5	-0.2	-0.9	0.4	0.8	0.4	0.9	0.2	1.0			0.4	0.9	-0.2	0.6

Table 7: Dynamic load cases for outside the cargo tank region for light draught condition (T_{bal})

Location			Machinery Space and Aft End							Forward End			
Wave direction			Following Sea	Oblique sea		Beam sea				Beam sea			
Max response			P_{ctr}	P_{WL}		a_v		a_t		a_v		a_t	
Dynamic load case			1	2a	2b	3a	3b	4a	4b	5a	5b	6a	6b
Global Loads	M_{wv}	f_{mv}	-1.0	-0.3	-0.3	0.2	0.2	0.1	0.1	-	-	-	-
Accelerations	$a_{v\text{-}mid}$	$f_{v\text{-}mid}$	0.6	0.9	0.9	1.0	1.0	0.3	0.3	1.0	1.0	0.3	0.3
	$a_{v\text{-}pt}$	$f_{v\text{-}pt}$	0.6	-	0.9	-	1.0	-	0.5	-	1.0	-	0.5
	$a_{v\text{-}stb}$	$f_{v\text{-}stb}$	0.6	0.9	-	1.0	-	0.5	-	1.0	-	0.5	-
	a_t	f_t	0.0	0.1	-0.1	0.6	-0.6	1.0	-1.0	0.7	-0.7	1.0	-1.0
	a_{lng}	f_{lng}	0.7	0.8	0.8	0.2	0.2	0.0	0.0	-0.3	-0.3	0.0	0.0
Dynamic wave pressure on starboard side	P_{ctr}	f_{ctr}	1.0	0.7	0.7	0.5	0.5	0.1	0.1	0.6	0.6	0.1	0.1
	P_{WL}	f_{WL}	0.8	1.0	0.3	0.6	0.1	0.4	-0.3	0.7	0.3	0.3	-0.1
Dynamic wave pressure on port side	P_{ctr}	f_{ctr}	1.0	0.7	0.7	0.5	0.5	0.1	0.1	0.6	0.6	0.1	0.1
	P_{WL}	f_{WL}	0.8	0.3	1.0	0.1	0.6	-0.3	0.4	0.3	0.7	-0.1	0.3

Table 8: Dynamic load cases for Mid tank and aft tank cargo tank region for light draught condition (T_{bal})													
Wave direction			**Head Sea**			**Oblique sea**		**Beam sea**					
Max response			M_{wv}	a_v	a_{lng}	M_{Wv-hz}		a_t		P_{ctr}		P_{WL}	
Dynamic load case			**1**	**2**	**3**	**4a**	**4b**	**5a**	**5b**	**6a**	**6b**	**7a**	**7b**
Global Loads	M_{wv}	f_{mv}	1.0	-1.0	0.4	-0.4	-0.4	-0.1	-0.1	-0.2	-0.2	-0.2	-0.2
	M_{wv-hz}	f_{mh}	0.0	0.0	0.0	1.0	-1.0	0.1	-0.1	-0.1	0.1	-0.2	0.2
Accelerations	a_{v-mid}	f_{v-mid}	-0.1	0.4	-0.2	0.1	0.1	0.5	0.5	1.0	1.0	1.0	1.0
	a_{v-pt}	f_{v-pt}	-0.1	0.4	-0.2	0.1	0.1	0.1	0.8	0.7	1.0	0.6	1.0
	a_{v-stb}	f_{v-stb}	-0.1	0.4	-0.2	0.1	0.1	0.8	0.1	1.0	0.7	1.0	0.6
	a_t	f_t	0.0	0.0	0.0	0.0	0.0	1.0	-1.0	0.8	-0.8	0.6	-0.6
	$a_{lng-mid}$	$f_{lng-mid}$	0.2	-0.1	1.0	-0.6	-0.6	0.0	0.0	-0.2	-0.2	-0.1	-0.1
	a_{lng-pt}	f_{lng-pt}	0.2	-0.1	1.0	-0.6	-0.4	0.0	0.0	-0.2	-0.2	-0.1	-0.1
	$a_{lng-stb}$	$f_{lng-stb}$	0.2	-0.1	1.0	-0.4	-0.6	0.0	0.0	-0.2	-0.2	-0.1	-0.1
	$a_{lng-ctr}$	$f_{lng-ctr}$	0.2	-0.1	1.0	-0.4	-0.4	0.0	0.0	-0.2	-0.2	-0.1	-0.1
Dynamic wave pressure on starboard side	P_{ctr}	f_{ctr}	1.0	-0.8	0.3	-0.5	-0.5	0.3	0.3	0.8	0.8	0.4	0.4
	P_{bilge}	f_{bilge}	0.3	-0.2	0.1	-0.4	0.0	0.9	-0.4	0.9	0.3	0.9	0.2
	P_{WL}	f_{WL}	0.3	-0.2	0.1	-0.6	0.0	0.7	-0.4	0.9	0.2	1.0	0.2
Dynamic wave pressure on port side	P_{ctr}	f_{ctr}	1.0	-0.8	0.3	-0.5	-0.5	0.3	0.3	0.8	0.8	0.4	0.4
	P_{bilge}	f_{bilge}	0.3	-0.2	0.1	0.0	-0.4	-0.4	0.9	0.3	0.9	0.2	0.9
	P_{WL}	f_{WL}	0.3	-0.2	0.1	0.0	-0.6	-0.4	0.7	0.2	0.9	0.2	1.0

Table 9: Dynamic load cases for forward cargo tank region for light draught condition (T_{bal})																
Wave direction			**Head Sea**		**Oblique sea**								**Beam sea**			
Max response			a_v	a_{lng}	a_{lng}		P_{ctr}		P_{bilge}		P_{WL}		a_v		a_t	
Dynamic load case			**1**	**2**	**3a**	**3b**	**4a**	**4b**	**5a**	**5b**	**6a**	**6b**	**7a**	**7b**	**8a**	**8b**
Global Loads	M_{wv}	f_{mv}	-0.8	0.9	0.7	0.7	-1.0	-1.0	-0.2	-0.2	-0.3	-0.3	-0.1	-0.1	-0.1	-0.1
	M_{wv-hz}	f_{mh}	0.0	0.0	-0.4	0.4	0.0	0.0	-0.5	0.5	0.3	-0.3	-0.4	0.4	-0.4	0.4
Accelerations	a_{v-mid}	f_{v-mid}	0.7	-0.6	-0.7	-0.7	0.4	0.4	0.6	0.6	0.9	0.9	1.0	1.0	0.4	0.4
	a_{v-pt}	f_{v-pt}	0.7	-0.6	-0.7	-0.7	0.4	0.4	0.3	0.8	0.7	0.7	0.5	1.0	0.0	0.7
	a_{v-stb}	f_{v-stb}	0.7	-0.6	-0.7	-0.7	0.4	0.4	0.8	0.3	0.7	0.7	1.0	0.5	0.7	0.0
	a_t	f_t	0.0	0.0	0.0	0.0	0.0	0.0	0.9	-0.9	0.2	-0.2	0.7	-0.7	1.0	-1.0
	$a_{lng-mid}$	$f_{lng-mid}$	-0.9	1.0	1.0	1.0	-0.6	-0.6	-0.3	-0.3	-0.9	-0.9	0.0	0.0	0.0	0.0
	a_{lng-pt}	f_{lng-pt}	-0.9	1.0	1.0	1.0	-0.6	-0.6	-0.5	0.2	-0.9	-0.6	0.0	0.0	0.0	0.0
	$a_{lng-stb}$	$f_{lng-stb}$	-0.9	1.0	1.0	1.0	-0.6	-0.6	0.2	-0.5	-0.6	-0.9	0.0	0.0	0.0	0.0
	$a_{lng-ctr}$	$f_{lng-ctr}$	-0.9	1.0	1.0	1.0	-0.6	-0.6	-0.3	-0.3	-0.9	-0.9	0.0	0.0	0.0	0.0
Dynamic wave pressure on starboard side	P_{ctr}	f_{ctr}	1.0	-0.7	-0.9	-0.9	1.0	1.0	0.6	0.6	0.6	0.6	0.4	0.4	0.2	0.2
	P_{bilge}	f_{bilge}	0.5	-0.4	-0.7	-0.3	0.6	0.6	1.0	-0.3	0.9	0.2	0.8	0.2	0.7	-0.3
	P_{WL}	f_{WL}	0.3	-0.2	-0.6	-0.1	0.4	0.4	0.9	-0.3	1.0	0.1	0.8	0.2	0.7	-0.4
Dynamic wave pressure on port side	P_{ctr}	f_{ctr}	1.0	-0.7	-0.9	-0.9	1.0	1.0	0.6	0.6	0.6	0.6	0.4	0.4	0.2	0.2
	P_{bilge}	f_{bilge}	0.5	-0.4	-0.3	-0.7	0.6	0.6	-0.3	1.0	0.2	0.9	0.2	0.8	-0.3	0.7
	P_{WL}	f_{WL}	0.3	-0.2	-0.1	-0.6	0.4	0.4	-0.3	0.9	0.1	1.0	0.2	0.8	-0.4	0.7

Section 12
Longitudinal Strength

12.1 Symbols

σ_{perm} : Permissible hull girder bending stress [N/mm^2]

f_i : Shear force distribution factor for the main longitudinal hull girder shear carrying members being considered. For standard structural configurations f_i is as defined in Table 14.

k : Higher strength steel factor as defined in Section 1

k_{ij} : Higher strength steel factor, k, for plate *ij* as defined in 1.1

t_{corr} : Corrosion addition [mm] as defined in Section 4

$t_{f\text{-}grs}$: Gross thickness of corrugation flange [mm]

t_{grs} : Gross plate thickness [mm]. The gross plate thickness for corrugated bulkhead is to be taken as minimum of $t_{w\text{-}grs}$ and $t_{f\text{-}grs}$ [mm]

$t_{ij\text{-}net50}$: Equivalent net thickness [mm], $t_{net\text{-}50}$, for plate *ij*. For longitudinal bulkheads between cargo tanks, $t_{net\text{-}50}$ is to be taken as $t_{sfc\text{-}net50}$ and $t_{str\text{-}k}$ as appropriate, see 12.4.3.1 and 12.4.4.1.

t_{net50} : Net thickness of plate [mm]

$$= t_{grs} - 0.5t_{corr}$$

$t_{w\text{-}grs}$: Gross thickness of the corrugation web [mm]

C_b : Block coefficient, as defined in Section 1, but not be taken less than 0.70

C_{wv} : Wave coefficient defined in Section 6

$I_{v\text{-}net50}$: Net vertical hull girder section moment of inertia [m^4], at longitudinal position being considered (calculation is based on the t_{grs} - $0.5t_{corr}$ of all effective structural members comprising the hull girder section, where t_{corr} is defined in Section 4)

$I_{h\text{-}net50}$: Net horizontal hull girder moment of inertia [m^4], at the longitudinal position being considered (calculation is based on the t_{grs} - $0.5t_{corr}$ of all effective structural members comprising the hull girder section, where t_{corr} is as defined in Section 4)

$M_{sw\text{-}perm}$: Permissible hull girder hogging or sagging still water bending moments [kNm] corresponding to transit, on-site operation, inspection & maintenance, harbour, flooded conditions, see Section 6.2

$M_{wv\text{-}v}$: Hogging or sagging vertical wave bending moment is to be taken as:

: $M_{wv\text{-}hog}$ - for assessment with respect to hogging vertical wave bending moment [kNm]

: $M_{wv\text{-}sag}$ - for assessment with respect to sagging vertical wave bending moment [kNm]

Plate ij : For each plate *i*, index donates the structural member *j* of which the plate forms a component

$Q_{sw\text{-}perm}$: Permissible hull girder positive or negative shear force [kN] for static (S) or static and dynamic (*S* + *D*) design load combination, corresponding to transit, on-site operation, inspection &

maintenance, harbour, flooded conditions, see also Section 6

Q_{wv} : Positive or negative vertical wave shear force [kN] as defined in Section 6

$Q_{wv\text{-}pos}$: for assessment with respect to maximum positive permissible still water shear force

$Q_{wv\text{-}neg}$: for assessment with respect to maximum negative permissible still water shear force

12.2 Loading Guidance Information

12.2.1 All units are to be provided with loading guidance information containing sufficient information to enable loading, unloading and ballasting operations and inspection/ maintenance of the unit within the stipulated operational limitations. Loading Manual, Loading Computer System and loading instruments are to be provided in accordance with the requirements in the Rules and Regulation for Construction and Classification of Steel Ships Part 3, Chapter 5, Section 6.

12.2.2 All relevant loading conditions and limitations are to be clearly stated in the loading manual. An approved loading computer system is to be installed to monitor still water bending moments and shear forces and ensure they are maintained within the approved permissible limits.

12.3 Hull Girder Bending

12.3.1 General

12.3.1.1 The net vertical hull girder section modulus, $Z_{v\text{-}net50}$, is not to be less than the requirements in Section 12.3.2. The net vertical hull girder moment of inertia, $I_{v\text{-}net50}$, is to be equal to or greater than the requirements given in Section 12.3.2, $I_{v\text{-}net50}$, is to be calculated in accordance with IRS Rules for Bulk Carriers and Oil Tankers, Volume 2, Part 1, Chapter 5, Section 1 [1.5].

12.3.1.2 Scantling of all continuous longitudinal members of hull girder based on moment of inertia and section modulus requirements in 12.3.2 are to be maintained within an extent of atleast 0.4*L* mid-ship.

12.3.1.3 Hull girder section modulus requirements in 12.3.3 are applicable for the full length of the hull girder, from AP to FP.

12.3.1.4 Structural members included in the hull girder section modulus are to satisfy the buckling strength requirements in 12.5.

12.3.2 Minimum Requirements for Moment of Inertia and Section Modulus

12.3.2.1 At the mid-ship the net vertical hull girder moment of inertia about the horizontal neutral axis, $I_{v\text{-}net50}$, is not to be less than the rule minimum vertical hull girder bending moment of inertia, $I_{v\text{-}min}$, defined as:

$$I_{v-min} = 2.7C_{wv}L^3B(C_b + 0.7)10^{-8} \quad [m^4]$$

12.3.2.2 At the mid-ship cross section the net vertical hull girder section modulus, $Z_{v\text{-}min}$, at the deck and keel is not to be less than the rule minimum hull girder section modulus, $Z_{v\text{-}min}$, defined as:

$$Z_{v-min} = 0.9kC_{wv}L^2B(C_b + 0.7)10^{-6} \quad [m^3]$$

12.3.2.3 The net hull girder section modulus at keel and deck, $Z_{v\text{-}net50\text{-}kl}$, $Z_{v\text{-}net50\text{-}dk}$ is to be calculated in accordance with IRS Rules for Bulk Carriers and Oil Tankers, Volume 2, Part 1, Chapter 5, Section 1 [1.4.2 – 1.4.3].

12.3.3 Section Modulus Requirements based on Design Bending Moments

12.3.3.1 The net vertical hull girder section modulus is to be assessed considering both hogging and sagging conditions.

12.3.3.2 The net hull girder section modulus about the horizontal neutral axis, $Z_{v\text{-}net50}$, is not be less than the section modulus, $Z_{v\text{-}req}$, based on the permissible still-water bending moment and design wave bending moment defined as:

$$Z_{v-req} = \frac{|M_{sw-perm} + M_{wv-v}|}{\sigma_{perm}} 10^{-3} \quad [m]$$

Where, $M_{sw-perm}$ and M_{wv-v} are to be considered as per Table 10.

Table 10: Loads and corresponding acceptance criteria for hull girder bending assessment

Design load combination	Still water bending moment ($M_{sw-perm}$)	Wave bending moment (M_{wv-v})	Permissible hull girder bending stress σ_{perm}	
(S)	$M_{sw-perm}$	0	143/*k*	Within 0.4L amidships
			105/*k*	at and forward of 0.9L from AP and at and aft of 0.1L from AP
(S + D)	$M_{sw-perm}$	M_{wv-v}	190/*k*	within 0.4L amidships
			140/*k*	at and forward of 0.9L from AP and at and aft of 0.1L from AP

12.4 Hull Girder Shear Strength

12.4.1 General

12.4.1.1 The hull girder shear strength requirements are applicable to the full length of the hull girder, from AP to FP.

12.4.1.2 The requirements in 12.4 are applicable to Units with standard structural configurations. IRS will specially consider other alternative arrangements if provided.

12.4.1.3 Calculations using direct calculation of shear flow (IRS Rules for Bulk Carriers and Oil Tankers, Volume 2, Part 1, Chapter 5, Appendix 1) are considered acceptable by IRS if they demonstrate that the shear stresses for the considered load cases are less than the limits prescribed in Table 11.

12.4.2 Assessment of Hull Girder Shear Strength

12.4.2.1 The net hull girder shear strength capacity, $Q_{v-net50}$, as defined in 12.4.2.2 is not be less than the required vertical shear force, Q_{v-req}, as indicated in following:

$$Q_{v-req} = Q_{sw-perm} + Q_{wv} \quad [kN]$$

12.4.2.2 The permissible positive and negative still water shear force, $Q_{sw-perm}$, are to satisfy the following for each loading condition considering transit, on-site operations, inspection & maintenance, harbour, flooded conditions etc.

$$Q_{sw-perm} \le Q_{v-net50} - Q_{wv-pos} \quad [kN]$$

for maximum permissible positive shear force

$$Q_{sw-perm} \ge Q_{v-net50} - Q_{wv-neg} \quad [kN]$$

for minimum permissible negative shear force

Where:

$Q_{sw-perm}$: Permissible hull girder still water shear force as given in Table 11.

Q_{v-net} : Net hull girder vertical shear strength to be taken as the minimum for all plate elements that contributed to hull girder shear capacity

$$= \frac{\tau_{ij-perm} t_{ij-net50}}{1000 q_v} \quad [kN]$$

$\tau_{ij-perm}$: Permissible hull girder shear stress [N/mm^2] , for plate *ij* , see **Table** Table 11

Q_{wv-pos} : Positive vertical wave shear [kN] as given in Table 11.

Q_{wv-pos} : Positive vertical wave shear [kN] as given in Table 11.

q_v : Unit shear flow per mm for the plate being considered and based on the net scantling. Where direct calculation of the unit shear flow is not available, the unit shear flow may be taken equal to:

$$f_i\left(\frac{q_{i-net50}}{I_{v-net50}}\right)10^{-9} \qquad [mm^{-1}]$$

f_i : Shear force distribution factor for the main longitudinal hull girder shear carrying members being considered. For standard configurations, f_i is as defined in Table 14.

$q_{1-net50}$: first moment of area [cm^3] about the horizontal neutral axis of the effective longitudinal members between the vertical level at which the shear stress is being determined and the vertical extremity, taken at the section being considered. The first moment of area is to be based on the net thickness, t_{net50}

Table 11: Loads and corresponding acceptance criteria for hull girder shear assessment

Design load combination	Still water shear force $Q_{sw-perm}$	Vertical wave shear forces, Q_{wv}	Permissible shear stress, τ_{perm}
S	$Q_{sw-perm}$	0	*105/k* for plate *ij*
S + D	$Q_{sw-perm}$	Q_{wv}	*120/k* for plate *ij*

For flooded condition the permissible hull girder shear stress is to be taken as $0.58\sigma_y$.

12.4.3 Shear Force Correction for Longitudinal Bulkheads between Cargo Tanks

12.4.3.1 For longitudinal bulkheads between cargo tanks, the effective net plating thickness of the plating above the inner bottom, $t_{sfc-net50}$ for plate *ij*, used for calculation of hull girder shear strength, $Q_{v-net50}$, may be corrected for local shear distribution and is given by:

$$t_{sfc-net50} = t_{grs} - 0.5t_{corr} - t_{\Delta} \qquad [mm]$$

Where:

t_{Δ} : Thickness deduction for plate *ij* [mm] as defined in 12.4.3.2.

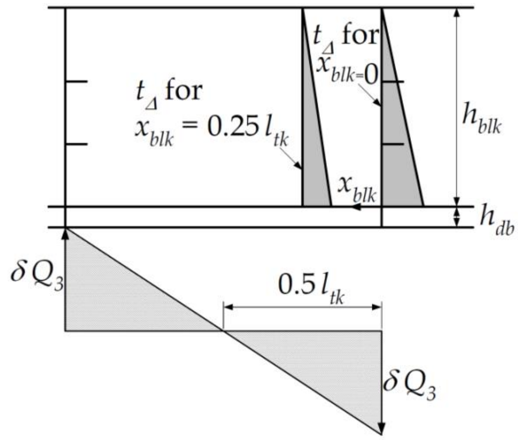


Figure 23: Shear force correction for longitudinal bulkhead

12.4.3.2 The vertical distribution of thickness reduction for shear force correction is assumed to be triangular as indicated in Figure 23. The thickness deduction t_{Δ},[mm] to account for shear force correction is to be taken as:

$$t_{\Delta} = \frac{\delta Q_3}{h_{blk}\tau_{ij-perm}}\left(1-\frac{x_{blk}}{0.5l_{tk}}\right)\left(2 - \frac{2(z_p - h_{db})}{h_{blk}}\right)$$

Where:

δQ_3 : Shear force correction for longitudinal bulkhead as defined in 12.4.3.3 and 12.4.3.5 for Units with one or two longitudinal bulkheads respectively [kN]

l_{tk} : Length of cargo tank [m]

h_{blk} : Height of longitudinal bulkhead [m] defined as the distance from inner bottom to the deck at the top of the bulkhead, as shown in Figure 23

x_{blk} : The minimum longitudinal distance from section considered to the nearest cargo tank transverse bulkhead [m]. To be taken positive and not greater than $0.5l_{tk}$

z_p : The vertical distance from the lower edge of plate *ij* to the baseline [m]. Not to be taken as less than h_{db}

h_{db} : Height of double bottom [m] as shown in Figure 23

$\tau_{ij\text{-}perm}$: Permissible hull girder shear stress [N/mm²] for Plate $ij = 120/k_{ij}$

12.4.3.3 For Units with a centerline bulkhead between the cargo tanks, the shear force correction in way of transverse bulkhead, δQ_3, is to be taken as:

$$\delta Q_3 = 0.5 K_3 F_{db} \quad \text{[kN]}$$

Where:

K_3 : Correction factor as defined in 12.4.3.4

F_{db} : Maximum resulting force on the double bottom in a tank [kN] as defined in 12.4.3.7

12.4.3.4 For Units with a centerline bulkhead between the cargo tanks, the correction factor, K_3, in way of transverse bulkheads is to be taken as:

$$K_3 = \left[0.4\left(1 - \frac{1}{1+n}\right) - f_3\right]$$

Where:

n : Number of floors between transverse bulkheads

f_3 : Shear force distribution factor, see Table 14

12.4.3.5 For Units with two longitudinal bulkheads between the cargo tanks, the shear force correction, δQ_3, is to be taken as:

$$\delta Q_3 = 0.5 K_3 F_{db}$$

Where:

K_3 : Correction factor, as defined in 12.4.3.6

F_{db} : Maximum resulting force on the double bottom in a tank, [kN] as defined in 12.4.3.7

12.4.3.6 For Units with two longitudinal bulkheads between the cargo tanks, the correction factor, K_3, in way of transverse bulkhead is to be taken as:

$$K_3 = \left[0.5\left(1 - \frac{1}{1+n}\right)\left(\frac{1}{r+1}\right) - f_3\right]$$

Where:

n : Number of floors between transverse bulkheads

r : Ratio of the part load carried by the wash bulkheads and floors from longitudinal bulkhead to the double side and is given by:

$$r = \frac{1}{\left[\frac{A_{3-net50}}{A_{1-net50}+A_{2-net50}} + \frac{2\times10^4 b_{80}(n_S+1)A_{3-net50}}{l_{tk}(n_S A_{T-net50}+R)}\right]}$$

For preliminary calculations, r may be taken as 0.5

l_{tk} : Length of cargo tank, between transverse bulkheads in the side cargo tank [m]

b_{80} : 80% of the distance from longitudinal bulkhead to the inner hull longitudinal bulkhead [m] at tank mid length

$A_{T\text{-}net50}$: Net shear area [cm²] of the transverse wash bulkhead, including the double bottom floor directly below, in the side cargo tank taken as the smallest area in a vertical section. $A_{T\text{-}net50}$ is to be calculated with net thickness given by $t_{grs} - 0.5t_{corr}$

$A_{1\text{-}net50}$: Net area, as shown in Table 14 [m²]

$A_{2\text{-}net50}$: Net area, as shown in Table 14 [m²]

$A_{3\text{-}net50}$: Net area, as shown in Table 14 [m²]

f_3 : Shear force distribution factor, as shown in Table 14.

n_S : Number of wash bulkheads in the side cargo tank

R : Total efficiency of the transverse primary support members in the side tank

$$R = \left(\frac{n - n_s}{2} - 1\right)\frac{A_{Q-net50}}{\gamma} \quad [\text{cm}^2]$$

$$\gamma = 1 + \frac{300{b_{80}}^2 A_{Q-net50}}{I_{psm-net50}}$$

$A_{Q\text{-}net50}$: Net shear area [cm²] of a transverse primary support member in the wing cargo tank, taken as the sum of the net shear areas of floor, cross ties and deck transverse webs. $A_{Q\text{-}net50}$ is to be calculated using the net thickness given by t_{grs} - $0.5t_{corr}$. The net shear area is to be calculated at the mid span of the members.

$I_{psm\text{-}net50}$: Net moment of inertia for primary support members [cm⁴] of a transverse primary support member in the wing cargo tank, taken as the sum of the moments of inertia of transverses and cross ties. It is to be calculated using the net thickness given by t_{grs} - $0.5t_{corr}$. The net moment of inertia is to be calculated at the mid span of the member including an attached plate width equal to the primary support member spacing

12.4.3.7 The maximum resulting force on the double bottom in a tank, F_{db}, is to be taken as:

$$F_{db} = g\left|W_{CT} + W_{CWBT} - \rho_{sw} b_2 l_{tk} T_{mean}\right| \quad [\text{kN}]$$

Where:

W_{CT} : Weight of cargo [t] as defined in Table 12

W_{CWBT} : Weight of ballast [t] as defined in Table 12

b_2 : Breadth [m] as defined in Table 12

l_{tk} : Length of cargo tank between watertight transverse bulkheads in wing cargo tank [m]

T_{mean} : Draught at the mid length of the tank for the loading condition considered [m]

12.4.3.8 The maximum resulting force on the double bottom in a tank, F_{db}, is in no case to be less than that given by rule minimum conditions given in Table 13.

12.4.4 Shear Force Correction due to Loads from Transverse Bulkhead Stringers

12.4.4.1 In way of transverse bulkhead stringer connections, within areas as specified in Figure 25, the equivalent net thickness of plate used for calculation of hull girder shear strength, $t_{sk\text{-}k}$, where the index k refers to the identification number of the stinger, is not to be taken greater than:

$$t_{str-k} = t_{sfc-net50}\left(1 - \frac{\tau_{str}}{\tau_{ij-perm}}\right) \quad [\text{mm}]$$

Where:

$t_{sfc\text{-}net50}$: Equivalent net plating thickness [mm] as defined in 12.4.3.1 and calculated at the transverse bulkhead for the height corresponding to the level of stringer

$\tau_{ij\text{-}perm}$: Permissible hull girder shear stress, τ_{perm}, [N/mm²] for plate ij

= $120/k_{ij}$

$$\tau_{str} = \frac{Q_{str-k}}{l_{str} t_{sfc-net50}} \quad [\text{kN}]$$

l_{str} : connection length of stringer [m], see Figure 24

$Q_{str\text{-}k}$: Shear force on the longitudinal bulkhead from the stringer in loaded condition with tank abreast full

$$= 0.8F_{str-k}\left(1 - \frac{Z_{str} - h_{db}}{h_{blk}}\right) \quad [\text{kN}]$$

$F_{str\text{-}k}$: Total stringer supporting force [kN], as defined in 12.4.4.2

h_{db} : Double bottom height [m] as shown in Figure 25

h_{blk} : Height of bulkhead [m], defined in as the distance from inner bottom to deck at top of the bulkhead as shown Figure 25

z_{str} : the vertical distance from baseline to the considered stringer [m]

12.4.4.2 The total stringer supporting force, F_{str-k}, in way of a longitudinal bulkhead is to be taken as:

$$F_{str-k} = \frac{P_{str} b_{str} (h_k + h_{k-1})}{2} \quad \text{[kN]}$$

Where:

P_{str} : Pressure on stringer [kN/m^2] to be taken = $10h_{tt}$

h_{tt} : Height from the top of the tank to the midpoint of the load area between $h_k/2$ below the stringer and $h_{k-1}/2$ above the stringer [m]

h_k : Vertical distance from the considered stringer to the stringer below. For the lowermost stringer, it is to be taken as 80 % of the average vertical distance to the inner bottom [m]

h_{k-1} : Vertical distance from the considered stringer to the stringer above. For the uppermost stringer, it is to be taken as the 80% of the average vertical distance to the upper deck [m]

b_{str} : Load breadth acting on the stringer [m] see Figure 27 and Figure 28

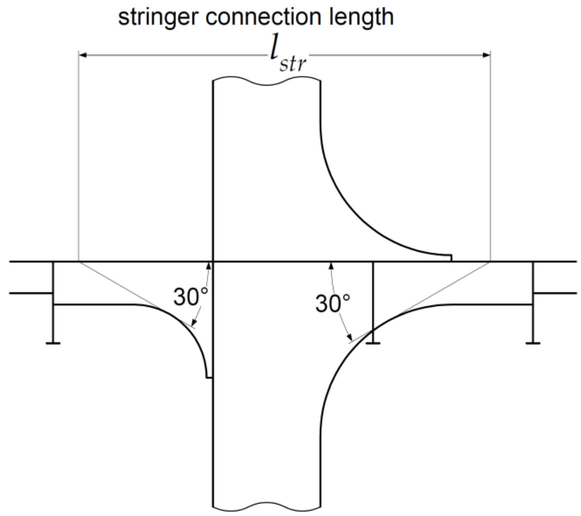


Figure 24: Effective connection length of stringer

12.4.4.3 Where reinforcement is provided to meet the above requirement, the reinforced area based on t_{str-k} is to extend longitudinally for the full length of the stringer connection and a minimum of one frame spacing forward and aft of the bulkhead. The reinforced area is to extend vertically from above the stringer level and down to $0.5h_k$ below the stringer, where h_k is the vertical distance from the considered stringer to the stringer below is as defined in 12.4.4.2. For the lowermost stringer the plate thickness requirement t_{str-k} is to extend down to the inner bottom, see Figure 25.

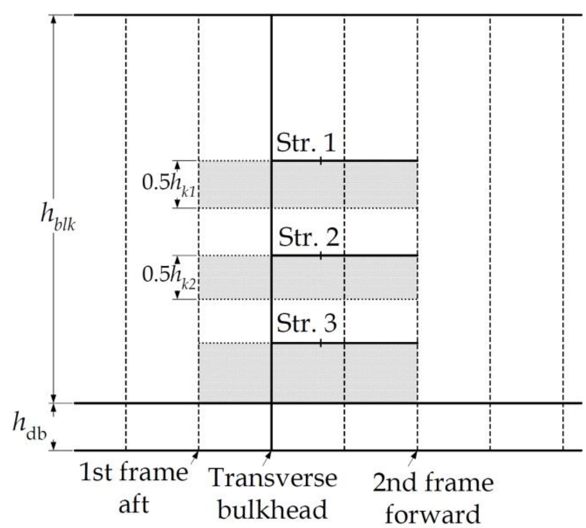
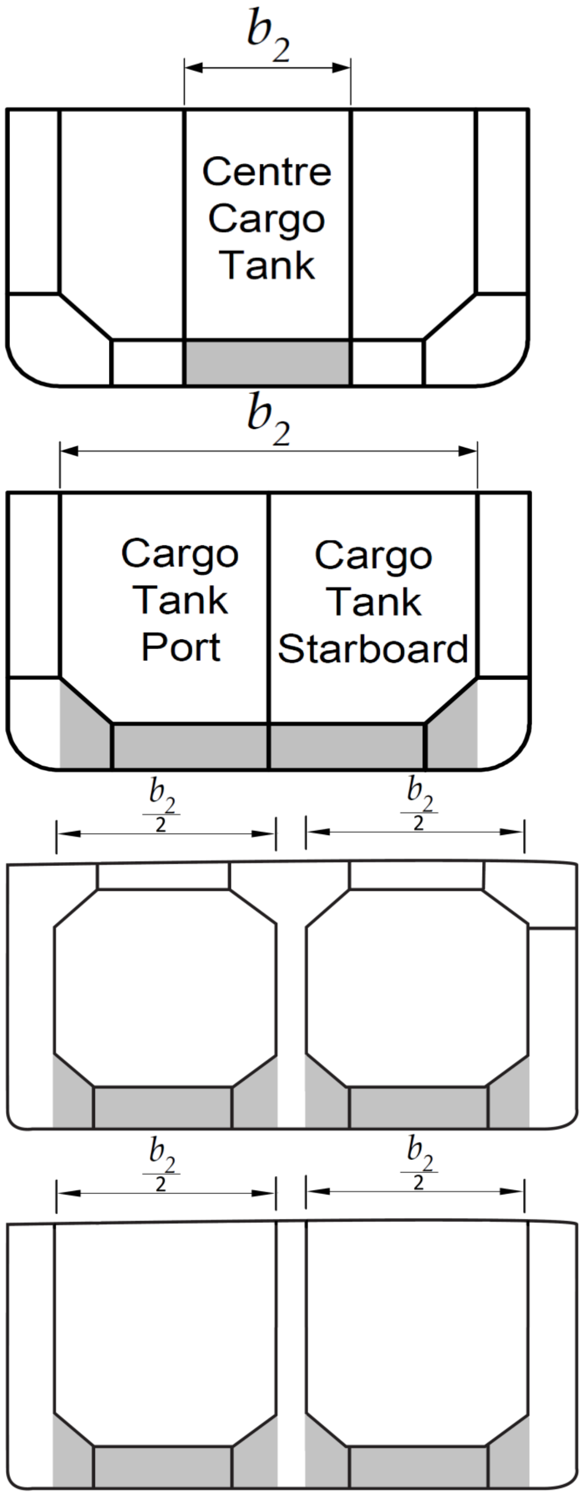


Figure 25: Region for Stringer Correction, t_{ij} for a Tanker with Three Stringers



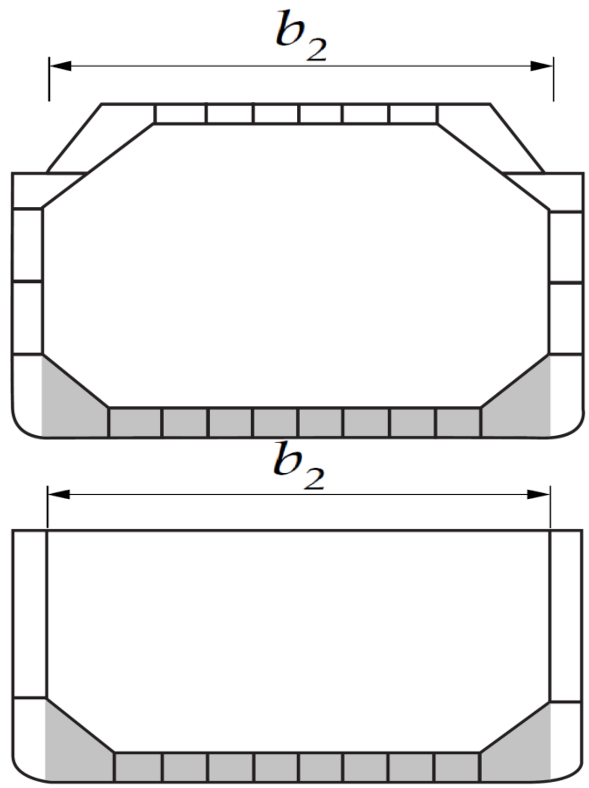


Figure 26: Tank breadth to be included for standard tank configuration

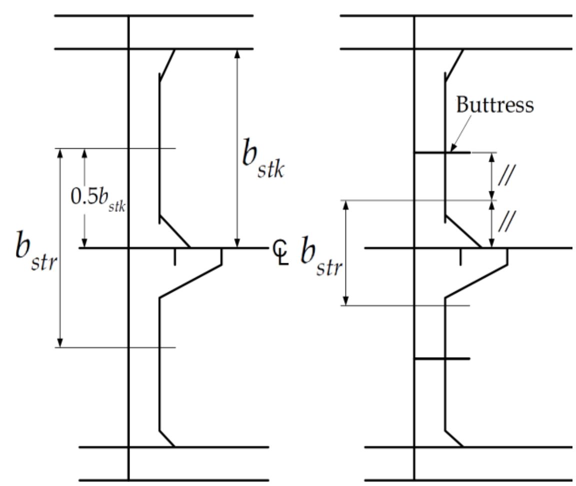


Figure 27: Load Breadth of Stringers for Units with a Centerline Bulkhead

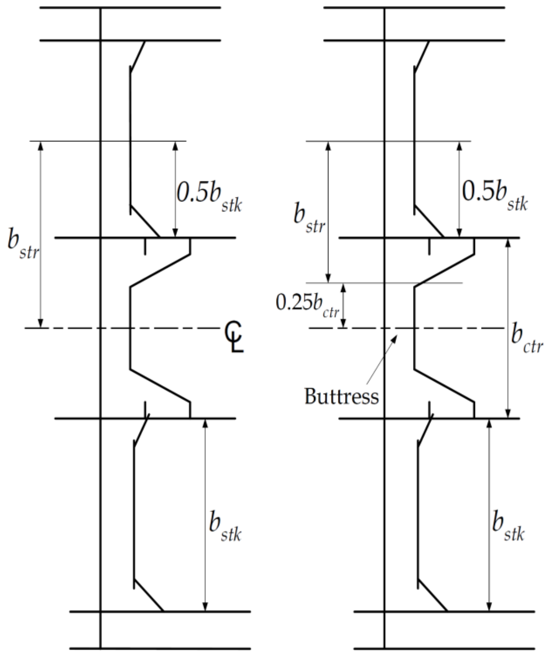
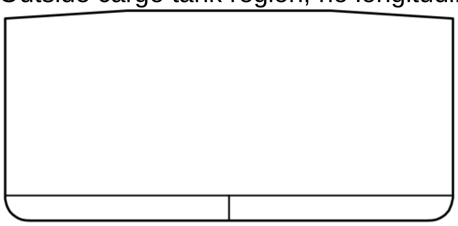
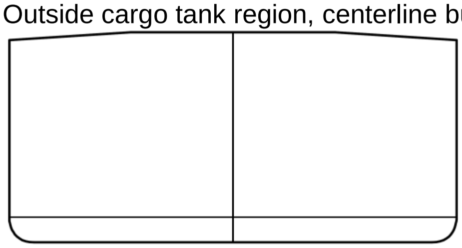
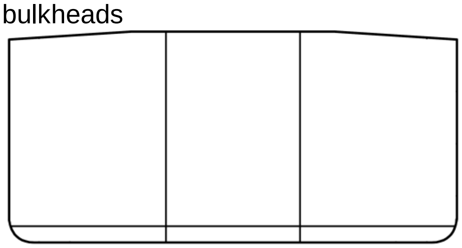
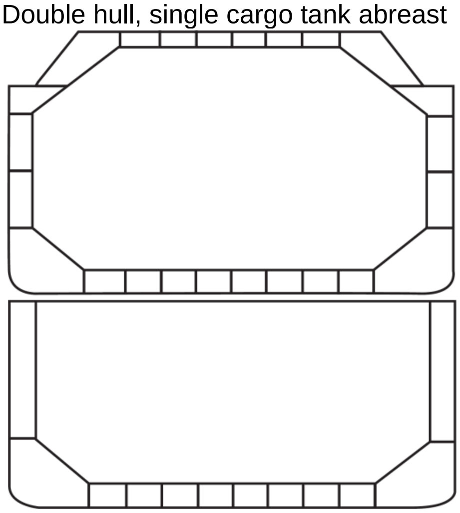


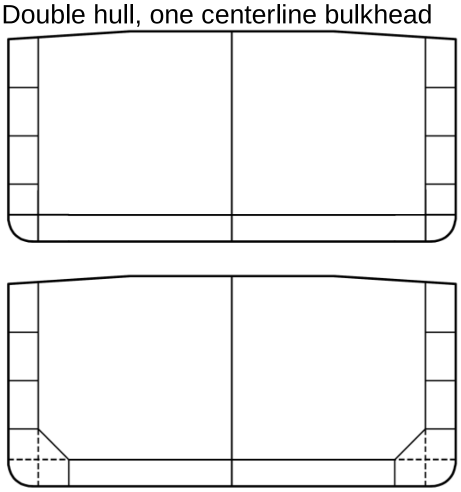
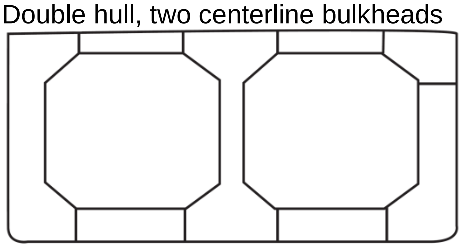
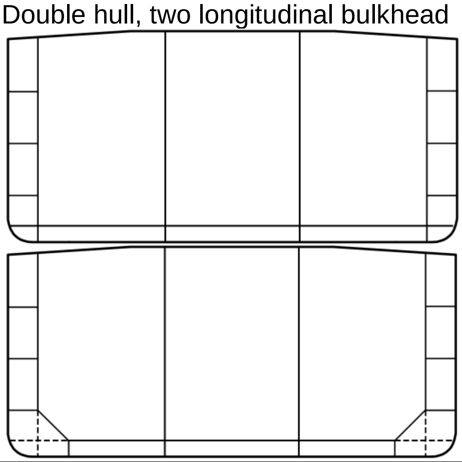
Figure 28: Load Breadth of Stringers for Units with Two Inner Longitudinal Bulkheads

Table 12: Design Conditions for Double Bottom			
Structural configuration	W_{CT}	W_{CWBT}	b_2
Units with one longitudinal bulkhead	Weight of cargo in cargo tanks [t] using a minimum specific gravity of 1.025 [t/m³]	Weight of ballast between port and starboard inner sides [t]	Maximum breadth between port and starboard inner sides at mid length of tank [m] as shown in Figure 26
Units with two longitudinal bulkheads	Weight of cargo in the center tank [t] using a minimum specific gravity of 1.025 [t/m³]	Weight of ballast below the center cargo tank [t]	Maximum breadth of the centre cargo tank at mid length of tank [m] as shown in Figure 26

Table 13: Rule minimum Conditions for Double Bottom		
Structural configuration	**Positive/negative force, F_{db}**	**Minimum conditions**
Unit with one longitudinal bulkhead	Max positive net vertical force, F_{db}+	0.9T_{sc} and empty cargo and ballast tanks
	Max negative net vertical force, F_{db}-	0.6T_{sc} full cargo tanks and empty ballast tanks
Unit with two longitudinal bulkheads	Max positive net vertical force, F_{db}+	0.9T_{sc} and empty cargo and ballast tanks
	Max negative net vertical force, F_{db}-	0.6T_{sc} and full centre cargo tank and empty ballast tanks

Table 14: Shear Force Distribution Factors

Hull Configuration	f_i factors
Outside cargo tank region, no longitudinal bulkhead 	Side shell $f_1 = 0.5$
Outside cargo tank region, centerline bulkhead 	Side shell $f_1 = 0.231 + 0.076\frac{A_{1-net50}}{A_{3-net50}}$ Longitudinal Bulkhead $f_3 = 0.538 + 0.152\frac{A_{1-net50}}{A_{3-net50}}$
Outside cargo tank region, two longitudinal bulkheads 	Side shell $f_1 = 0.135 + 0.088\frac{A_{1-net50}}{A_{3-net50}}$ Longitudinal Bulkhead $f_3 = 0.365 - 0.088\frac{A_{1-net50}}{A_{3-net50}}$
Double hull, single cargo tank abreast 	Side shell $f_1 = 0.128 + 0.105\frac{A_{1-net50}}{A_{2-net50}}$ Inner Hull $f_2 = 0.372 - 0.105\frac{A_{1-net50}}{A_{2-net50}}$

Double hull, one centerline bulkhead 	Side shell $f_1 = 0.055 + 0.097\frac{A_{1-net50}}{A_{2-net50}} + 0.020\frac{A_{2-net50}}{A_{3-net50}}$ Inner Hull $f_2 = 0.193 - 0.059\frac{A_{1-net50}}{A_{2-net50}} + 0.058\frac{A_{2-net50}}{A_{3-net50}}$ Longitudinal bulkhead $f_3 = 0.504 - 0.076\frac{A_{1-net50}}{A_{2-net50}} - 0.156\frac{A_{2-net50}}{A_{3-net50}}$
Double hull, two centerline bulkheads 	Side shell $f_1 = 0.011 + 0.103\frac{A_{1-net50}}{A_{2-net50}} + 0.046\frac{A_{2-net50}}{A_{3-net50}}$ Inner Hull $f_2 = 0.159 - 0.052\frac{A_{1-net50}}{A_{2-net50}} + 0.054\frac{A_{2-net50}}{A_{3-net50}}$ Longitudinal bulkhead $f_3 = 0.330 - 0.051\frac{A_{1-net50}}{A_{2-net50}} - 0.100\frac{A_{2-net50}}{A_{3-net50}}$
Double hull, two longitudinal bulkhead 	Side shell $f_1 = 0.028 + 0.087\frac{A_{1-net50}}{A_{2-net50}} + 0.023\frac{A_{2-net50}}{A_{3-net50}}$ Inner Hull $f_2 = 0.119 - 0.038\frac{A_{1-net50}}{A_{2-net50}} + 0.072\frac{A_{2-net50}}{A_{3-net50}}$ Longitudinal bulkhead $f_3 = 0.353 - 0.049\frac{A_{1-net50}}{A_{2-net50}} - 0.095\frac{A_{2-net50}}{A_{3-net50}}$

Where:

i : index for the structural member under consideration:
: 1, for the side shell
: 2, for the inner hull
: 3, for the longitudinal bulkhead

$A_{i-net50}$: Net area as defined in section and based on the deduction of $0.5t_{corr}$, of the structural member, *i*, at one side of the section under consideration. The area $A_{3-net50}$ for the centerline bulkhead is not to be reduced for symmetry around the centerline.

12.5 Hull Girder Buckling Strength

12.5.1 General

12.5.1.1 These requirements apply to plate panels and longitudinals subject to hull girder compression and shear stresses. These stresses are to be based on the permissible values for Hull girder loads as provided in Section 6.

12.5.1.2 The hull girder buckling strength requirements apply along the full length of the Unit, from AP to FP.

12.5.1.3 For the purposes of assessing the hull girder buckling strength in this sub-section, the following are to be considered separately:

i. Axial hull girder compressive stress to satisfy requirements in 12.5.2.6 and 12.5.2.8
ii. Hull girder shear stress to satisfy requirements in 12.5.2.7

12.5.2 Buckling Assessment

12.5.2.1 The buckling evaluation of plate panels and longitudinals is to be performed according to Section 20 with hull girder stresses calculated on net hull girder sectional properties.

12.5.2.2 The buckling strength for the buckling assessment is to be derived using local net scantlings, t_{net}, as follows:

$$t_{net} = t_{grs} - 1.0t_{corr} \quad \text{[mm]}$$

12.5.2.3 The hull girder compressive stress due to bending, $\sigma_{hg-net50}$, for the buckling assessment is to be calculated using net hull girder sectional properties and is to be taken as the greater of the following:

$$\sigma_{hg-net50} = \left|\frac{(z - z_{NA-net50})(M_{sw-perm} + M_{wv-v})}{I_{v-net50}}\right| 10^3$$

$$\sigma_{hg-net50} = \frac{30}{k} \quad \text{[N/mm}^2\text{]}$$

Where:

$z_{NA-net50}$: Distance from the baseline to the horizontal neutral axis[m]

Where:

$M_{sw-perm}$ and M_{wv} are defined in Section 12.1

12.5.2.4 The sagging bending moment values of $M_{sw-perm}$ and M_{wv-v} are to be taken for members above the neutral axis. The hogging bending moment values are to be taken for members below the neutral axis.

12.5.2.5 The design hull girder shear stress for the buckling assessment, $\tau_{hg-net50}$, is to be calculated based on the net hull girder sectional properties and is to be taken as:

$$\tau_{hg-net50} = \left|(Q_{sw-perm} + Q_{wv})\left(\frac{1000q_v}{t_{ij-net50}}\right)\right|$$

Where:

$$t_{ij-net50} = t_{ij-grs} - 0.5t_{corr}$$

t_{ij-grs} : Gross plate thickness of plate *ij* [mm]. The gross plate thickness for corrugated bulkheads is to be taken as the minimum of t_{w-grs} and t_{f-grs}

t_{w-grs} : Gross thickness of the corrugation web [mm]

t_{f-grs} : Gross thickness of the corrugation flange [mm]

q_v : Unit shear per mm for the plate being considered as defined in 12.4.2.2

Note

1. Maximum of the positive shear (still water + wave) and negative shear (still water + wave) is to be used as the basis for calculation of design shear stress.

2. All plate elements *ij* that contribute to the hull girder shear capacity are to be assessed. See also Table and

3. The gross rule required thicknesses is to be calculated considering shear force correction.

12.5.2.6 The compressive buckling strength of plate panels is to satisfy the following criteria:

$$\eta \leq \eta_{allow}$$

Where:

$$\eta = \frac{\sigma_{hg-net50}}{\sigma_{cr}}$$

$\sigma_{hg\text{-}net50}$: Hull Girder compressive stress based on net hull girder sectional properties [N/mm^2] as defined in 12.5.2.3

σ_{cr} : Critical compressive buckling stress, σ_{xcr} or σ_{ycr} as appropriate [N/mm^2] as specified in Section 20. The critical compressive buckling stress is to be calculated for the effects of hull girder compressive stress only. The effects of other membrane stresses and lateral pressure are to be ignored. The net thickness given as $t_{grs} - t_{corr}$ is to be used for the calculation of σ_{cr}.

η_{allow} : Allowable buckling utilization factor to be taken as:

= 1.0 for plate panels at or above 0.5*D*

= 0.90 for plate panels below 0.5*D*

12.5.2.7 The shear buckling strength, of plate panels, is to satisfy the following criteria:

$$\eta \leq \eta_{allow}$$

Where:

$$\eta = \frac{\tau_{hg-net50}}{\tau_{cr}}$$

$\tau_{hg\text{-}net50}$: Design hull girder shear stress [N/mm^2] as defined in 4.2.5

τ_{cr} : Critical shear buckling stress [N/mm^2] as specified in Section 20. The critical shear buckling stress is to be calculated for the effects of the hull girder shear stress only. The effect of other membrane stresses and lateral pressure are to be ignored. The net thickness given as $t_{grs} - t_{corr}$ is to be used for the calculation of τ_{cr}.

η_{allow} : Allowable buckling utilization factor

= 0.95

12.5.2.8 The compressive buckling strength of the longitudinal stiffeners is to satisfy the following criteria:

$$\eta \leq \eta_{allow}$$

η : Buckling utilization factor as provided in Section 20. The buckling utilization factor is to be calculated for the effects of hull girder compressive stress only. The effects of other membrane stresses and lateral pressure are to be ignored.

η_{allow} : Allowable buckling utilization factor to be taken as:

= 1.0 for stiffeners at or above 0.5*D*

= 0.90 for stiffeners below 0.5*D*

12.6 Tapering and Structural Continuity of Hull Girder Elements

12.6.1 Tapering based on Minimum Hull Girder Section Property Requirements

12.6.1.1 Scantlings of all continuous longitudinal members of the hull girder based on the moment of inertia and section modulus requirements given in 12.3.2 are to be maintained within an extent of atleast 0.4*L* of amidships of the Unit.

12.6.1.2 Scantlings outside of 0.4*L* amidships as required by the rule minimum moment of inertia and section modulus as given in 12.3.2 may be gradually reduced to the local requirements at the ends provided the hull girder bending and buckling requirements, along the full length of the Unit, as given in 12.3.3 and 12.4 are complied with. For tapering of higher strength steel, see 12.6.2 and 12.6.3.

12.6.2 Longitudinal Extent of Higher Strength Steel

12.6.2.1 Where used, the application of higher strength steel is to be continuous over the length of the Unit up to locations where the longitudinal stress levels are within the allowable range for mild steel structure, see Figure 29.

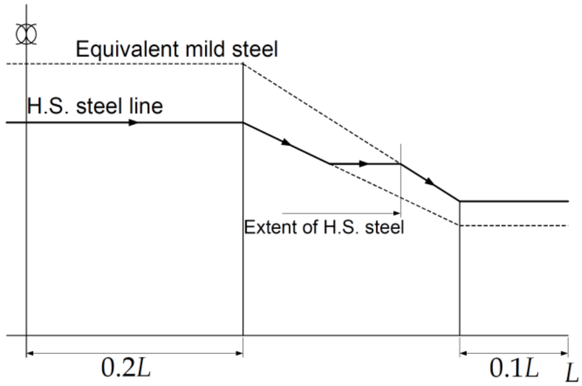


Figure 29: Longitudinal Extent of Higher Strength Steel

12.6.3 Vertical Extent of Higher Strength Steel

12.6.3.1 The vertical extent of higher strength steel, z_{hts}, used in the deck or bottom and measured from the moulded deck line at side or keel is not to be taken less than the following, see also Figure 30.

$$z_{hts} = z_1\left(1 - \frac{\sigma_{perm}}{\sigma_1}\right) \quad [m]$$

Where:

z_1 : Distance from horizontal neutral axis to moulded deck line or keel respectively [m]

σ_1 : Taken as σ_{dk} or σ_{kl} for the hull girder deck and keel respectively [N/mm²]

σ_{dk} : Hull girder bending stress at moulded deck line given by:

$$= \frac{\left|M_{sw-perm} + M_{wv-v}\right|}{I_{v-net50}}(z_{dk-side} - z_{NA-net50})10^{-3} \quad [N/mm^2]$$

σ_{kl} : Hull girder bending stress at keel given by:

$$= \frac{\left|M_{sw-perm} + M_{wv-v}\right|}{I_{v-net50}}(z_{NA-net50} - z_{kl})10^{-3} \quad [N/mm^2]$$

σ_{perm} : Permissible hull girder bending stress as given in Table 10 for design load combination *S* + *D*, [N/mm²]

12.6.4 Tapering of Plate Thickness due to Hull Girder Shear Requirement.

12.6.4.1 Longitudinal tapering of shear reinforcement is permitted, provided that for any longitudinal position the requirements given in 12.4.2 are complied with. Control of the shear strength at intermediate positions is to be carried out by linear interpolation of permissible shear limits at the bulkhead and in the middle of the tank.

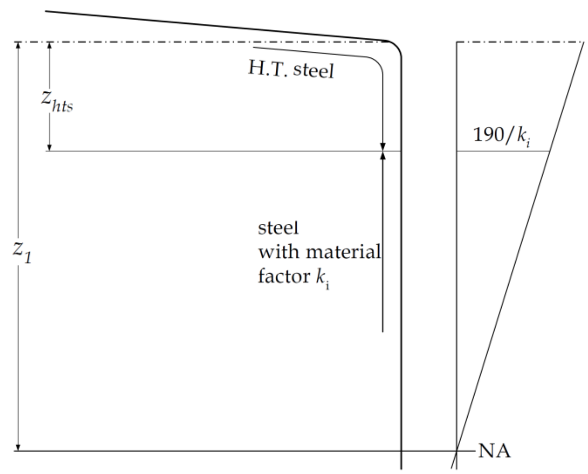


Figure 30: Vertical Extent of Higher Strength Steel

12.6.5 Structural Continuity of Longitudinal Bulkheads

12.6.5.1 Suitable scarphing arrangements are to be made to ensure continuity of strength and the avoidance of abrupt structural changes. In particular longitudinal bulkheads are to be terminated at an effective transverse bulkhead and large transition brackets are to be fitted in line with the longitudinal bulkhead.

12.6.6 Structural Continuity of Longitudinal Stiffeners

12.6.6.1 Where longitudinal stiffeners terminate, and are replaced by a transverse system, adequate arrangements are to be made to avoid an abrupt changeover.

12.6.6.2 Where a deck longitudinal stiffener is cut, in way of an opening, compensation is to be arranged to ensure structural continuity of the area. The compensation area is to extend well beyond the forward and aft end of the opening and not be less than the area of the longitudinal that is cut. Stress concentration in way of the stiffener termination and the associated buckling strength of the plate and panel are to be considered.

Section 13

Cargo Tank Region

13.1 Definitions & Symbol

σ_{yd} : Specified minimum yield stress of the material [N/mm^2]

τ_{yd} : $\sigma_{yd}/\sqrt{3}$ [N/mm^2]

d_{cg} : Depth of corrugation [mm] see 13.6.7.4 and Figure 33

l_{cg} : Length of corrugation [m], which is defined as the distance between the lower stool and the upper stool or the upper end where no upper stool is fitted, also see Figure 33

l_{bdg} : Effective bending span [m] as defined in Section 1

s : Stiffener spacing [mm]

s_{cg} : Spacing of corrugation [mm] see Figure 33

x, y, z : Longitudinal, Transverse and vertical coordinate of load calculation point respectively [m]

$z_{NA\text{-}net50}$: Distance from the baseline to the horizontal neutral axis [m]

B : Moulded breadth [m] defined in Section 1

L_2 : Rule length, L, [m] as defined in Section 1.1 but need not to be taken greater than 300 m.

P : Design pressure for the design load set being considered and calculated at the load point [kN/m^2]

P_l : Design pressure for the design load set being considered, calculated at the lower end of the corrugation [kN/m^2]

P_u : Design pressures for the design load set being considered, calculated at the upper end of the corrugation [kN/m^2]

T_{sc} : Scantling draught [m] as defined in Section 1.1

13.2 General

13.2.1 Application

13.2.1.1 The requirements of this Sub-Section apply to the hull structure within the cargo tank region of the FOU (as illustrated in Figure 22).

13.2.2 Evaluation of Scantlings

13.2.2.1 The following scantling requirements are based on the assumption that all structural joints and welded details are designed and fabricated, such that they are adequate for the anticipated working stress levels at the locations considered. The loading patterns, stress concentrations and potential failure modes of structural joints and details during the design of highly stressed regions are to be considered. Structural design details are to comply with the requirements given in Section 23.

13.2.2.2 The scantlings are to be assessed to ensure that the applicable strength criteria are satisfied at all longitudinal positions.

13.2.2.3 Local scantling increases are to be applied where applicable to cover local variations, such as increased spacing, increased stiffener spans and local loads.

13.2.2.4 For dry docking of Units (as applicable), the bottom structure is to be adequately strengthened.

13.2.3 General Scantling Requirements

13.2.3.1 The Hull structure is to comply with the applicable requirements of:

- Hull girder longitudinal strength, Section 12
- Strength against sloshing and impact loads, Section 17
- Hull girder ultimate strength, see Section 19
- Strength assessment (FEM), see Section 21
- Fatigue strength, see Section 22
- Buckling and ultimate strength, see Section 20.

13.2.3.2 The net section modulus, shear areas and other sectional properties of the local and primary support members are to be determined in accordance with Section 4.6.

13.2.3.3 The section modulus, shear areas and other sectional properties of the local and primary support members apply to the areas clear of the end brackets.

13.2.3.4 The spans of the local and primary support members are to be taken in accordance with requirements in Section 4.6.

13.2.3.5 The moments of inertia for the primary support members are to be determined in association with the effective attached plating at the mid span in accordance with requirements in Section 4.6.

13.2.3.6 Limber, drain and air holes are to be cut in all parts of the structure, as required, to ensure the free flow to the suction pipes and escape of air to the vents. See also, Section 23.

13.2.3.7 All shell frames and tank boundary stiffeners are in general to be continuous, or are to be bracketed at their ends, except as permitted in Section 23.

13.2.3.8 Enlarged stiffeners (with or without web stiffening) used for Permanent Means of Access (PMA) are to comply with the following requirements:

i. Buckling strength including proportion (slenderness ratio) requirements for primary support members, see Section 20.
ii. Buckling strength of longitudinal PMA platforms without web stiffeners may also be ensured using the criteria for local support members, see Section 20.
iii. All other requirements for local support members as follows:
    - Corrosion additions: requirements for local support members
    - Minimum thickness: requirements for local support members
    - Fatigue: requirements for local support members

For primary support members (or part of them) used as a PMA platform the requirements for primary support members are to be applied.

13.2.4 Minimum Thickness for Plating and Local Support Members

13.2.4.1 The thickness of plating and stiffeners in the cargo tank region is to comply with the appropriate minimum thickness requirements given in Table 15.

13.2.5 Minimum Thickness for Primary Support Members

13.2.5.1 The thickness of web plating and face plating of primary support members in the cargo tank region is to comply with the appropriate minimum thickness requirement given in Table 16.

Table 15 : Minimum net thickness for plating and local support members in the cargo tank region

Scantling Location			Net Thickness
Plating	Shell	Keel plating	$6.5+0.03L_2$
		Bottom shell/ Bilge/ Side shell	$4.5+0.030L_2$
	Upper Deck		$4.5+0.020L_2$
	Other Structures	Hull internal tank boundaries	$4.5+0.020L_2$
		Non-tight bulkheads, bulkheads between dry spaces and other plates in general	$4.5+0.010L_2$
Local Support Members	Local support members on tight boundary		$3.5+0.015L_2$
	Local support members on other structures		$2.5+0.015L_2$
Tripping Brackets	Local support members on other structures		$5.0+0.015L_2$

Table 16 : Minimum net thickness for primary support members in cargo tank region

Scantling Location	Net Thickness (mm)
Double bottom centerline girder	$5.5+0.025L_2$
Other double bottom girders	$5.5+0.020L_2$
Double bottom floors, web plates of side transverses and stringers in double hull	$5.0+0.015L_2$
Web and flanges of vertical web frames on longitudinal bulkheads, horizontal stringers on transverse bulkhead, deck transverse (above and below upper deck) and cross ties	$5.5+0.015L_2$

13.3 Hull Envelope Plating

13.3.1 Keel Plating

13.3.1.1 The keel plating is to extend over the flat of bottom for the complete length of the Unit. The breadth, b_{kl}, is not to be less than:

$$b_{kl} = 800 + 5L_2 \quad \text{[mm]}$$

13.3.1.2 The thickness of plating is to comply with requirement given in 13.3.2.

13.3.2 Bottom Shell Plating

13.3.2.1 The thickness of the bottom shell plating is to comply with the requirements in Table 17.

13.3.3 Bilge Plating

13.3.3.1 The thickness of bilge plating is not to be less than that required for adjacent bottom shell, see 13.3.2.1, or adjacent side plating, see 13.3.4.1, whichever is the greater.

13.3.3.2 The net thickness of bilge plating, t_{net}, without longitudinal stiffening is not to be less than:

$$t_{net} = \frac{\sqrt[3]{r^2 S_t P_{ex}}}{100} \quad \text{[mm]}$$

Where:

P_{ex} : Design sea pressure for the design load set 1 calculated at the lower turn of bilge [kN/m^2]

r : Effective bilge radius [mm]

$$= r_0 + 0.5(a + b)$$

r_0 : Radius of curvature [mm], see Figure 31

S_t : Distance between transverse stiffeners, webs or bilge brackets [m]

a : Distance between the lower turn of bilge and outmost bottom longitudinal [mm], see Figure 31 and 13.4.1.2 where the outermost bottom longitudinal is within the curvature, this distance is to be taken as zero

b : Distance between the upper turn of bilge and lowest side longitudinal [mm], see Figure 31 and 13.4.1.2 where the lowest side longitudinal is within the curvature, this distance is to be taken as zero

Where plate seam is located in the straight plate just below the lowest stiffener on the side shell, any increased thickness required for the bilge plating does not have to extend to the adjacent plate above the bilge provided that the plate seam is not more than $S_b/4$ below the lowest side longitudinal. Similarly, for flat part of adjacent bottom plating, any increased thickness for the bilge plating does not have to be applied provided that the plate seam is not more than $S_a/4$ beyond the outboard bottom longitudinal. Regularly longitudinally stiffened bilge plating is to be assessed as a stiffened plate. The bilge keel is not considered as "longitudinal stiffening" for the application of this requirement.

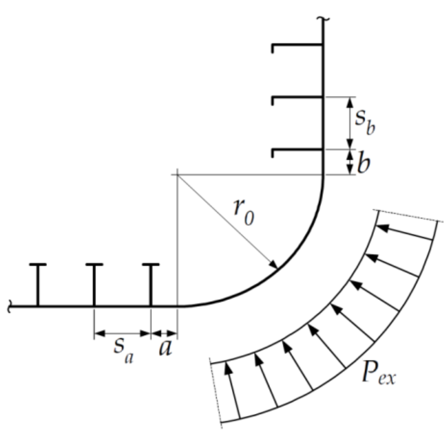


Figure 31: Unstiffened bilge plating

13.3.3.3 Where bilge longitudinals are omitted, the bilge plate thickness outside 0.4*L* amidships is to be considered in relation to the support derived from the hull form and internal stiffening arrangements. In general, outside of 0.4*L* amidships the bilge plate scantlings and arrangement are to comply with the requirements of ordinary side or bottom shell plating in the same region. Consideration is to be given where there is increased loading in the forward region.

13.3.4 Side Shell Plating
13.3.4.1 The thickness of the side shell plating is to comply with the requirements given in Table 17.

13.3.4.2 The net thickness, t_{net}, of the plating within the range as specified in 13.3.4.3 is not to be less than:

$$t_{net} = 26\left(\frac{s}{1000} + 0.7\right)\left(\frac{BT_{sc}}{{\sigma_{yd}}^2}\right)^{0.25} \quad \text{[mm]}$$

13.3.4.3 The thickness in 13.3.4.2 is to be applied to the following extent of the side shell plating, (also see Figure 32):

Longitudinal extent:

Between section aft of amidships where breadth at the waterline exceeds 0.9*B*, and a section forward of amidships where the breadth at the waterline exceeds 0.6*B*.

Vertical extent:

Between 300 mm below the minimum design waterline at the light load draught, T_{Bal}, amidships to $0.25T_{SC}$ or 2.2 m whichever is greater, above the draught T_{SC}.

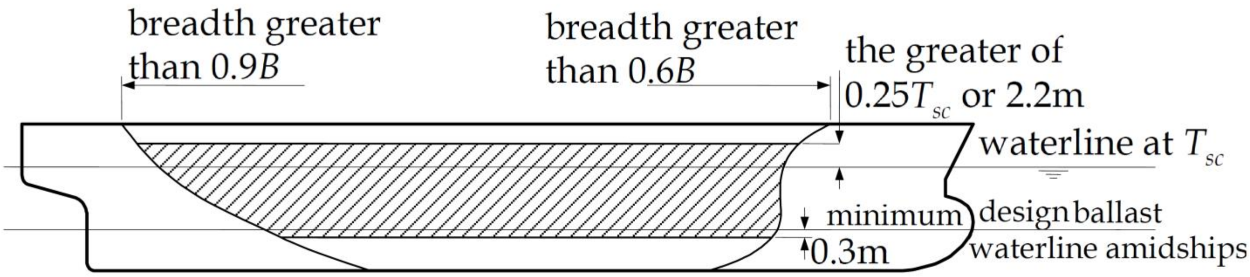


Figure 32: Extent of side shell plating

Table 17: Thickness requirement for plating

The minimum net thickness, t_{net}, is to be taken as the greatest value of all applicable design load sets, as given in Table 21, and given by

$$t_{net} = 0.0158\alpha_p s\sqrt{\frac{|P|}{C_a\sigma_{yd}}} \quad \text{[mm]}$$

Acceptance criteria set	Structural member		β_a	α_a	C_{a-max}
AC1	Longitudinal strength members	Longitudinally stiffened plating	0.90	0.50	0.80
		Transversely or vertically stiffened plating	0.90	1.00	0.80
	Other members		0.80	0.00	0.80
AC2	Longitudinal strength members	Longitudinally stiffened plating	1.05	0.50	0.95
		Transversely or vertically stiffened plating	1.05	1.00	0.95
	Other members, including watertight boundary plating		1.00	0.00	1.00
AC3	All members		1.00	0.00	1.00

Where:

α_p : Correction factor for the panel aspect ratio
$= 1.2 - \frac{s}{2100 l_p}$ but not to be taken as greater than 1.0

l_p : Length of plate panel, to be taken as the spacing of primary support members, *S*, unless carlings are fitted [m]

C_a : Permissible bending stress coefficient for the design load set being considered
$= \beta_a - \alpha_a \frac{|\sigma_{hg}|}{\sigma_{yd}}$ but not to be taken greater than C_{a-max}

σ_{hg} : Hull girder bending stress for the design load set being considered and calculated at the load calculation point [N/mm^2]

$$= \left(\frac{(z - z_{NA-net50})M_{v-total}}{I_{v-net50}} - \frac{yM_{h-total}}{I_{h-net50}}\right)10^{-3}$$

$I_{v-net50}$: Net vertical hull girder moment of inertia at the longitudinal position being considered [m^4]

$I_{h-net50}$: Net horizontal hull girder moment of inertia at the longitudinal position being considered [m^4]

$M_{h-total}$: Design horizontal bending moment at the longitudinal position under consideration for the design load set being considered [kNm]

$M_{v-total}$: design vertical bending moment at the longitudinal position under consideration for the design load set being considered [kNm]. The still water bending moment, $M_{sw-perm}$, is to be taken with the same sign as the simultaneously acting wave bending moment, M_{wv},

13.3.5 Sheerstrake
13.3.5.1 The sheer strake is to comply with the requirements in 13.3.4.

13.3.5.2 The welding of deck fitting to rounded sheer strake is to be avoided within 0.6*L* of amidships.

13.3.5.3 Where the sheer strake extends above the deck stringer plate, the top edge of the sheer strake is to be kept free from notches and isolated welded fittings, and is to be smooth with rounded edges. Grinding may be required if the cutting surface is not smooth. Drainage opening with a smooth transition in the longitudinal direction may be permitted.

13.3.6 Deck Plating
13.3.6.1 The thickness of the deck plating is to comply with the requirements given in Table 17.

13.4 Hull Envelope Framing
13.4.1 General
13.4.1.1 The bottom shell, inner bottom and deck are to be longitudinal framed in the cargo tank region. The side shell, inner hull bulkheads and longitudinal bulkheads are generally to be longitudinally framed. Suitable alternatives which take accounts of the resistance to buckling will be specially considered by IRS.

13.4.1.2 Where longitudinals are omitted in way of bilge, a longitudinal is to be fitted at the bottom and at the side close to the position where the curvature of the bilge part starts. The distance between lower turn of bilge and the outermost bottom longitudinal, *a*, is generally not to be greater than one-third of spacing between the two outermost bottom longitudinals, s_a. Similarly, the distance between upper turn of the bilge and lowest side longitudinal, *b*, is generally not to be greater than one-third of the spacing between the two side longitudinals, s_b, see Figure 31

13.4.1.3 The longitudinals are to comply with the requirements of continuity as provided in Section 23.

13.4.2 Scantling Criteria
13.4.2.1 The section modulus and thickness of the hull envelope is to comply with the requirements given in Table 17, Table 18 and Table 19.

13.4.2.2 Where the side shell longitudinal or the vertical stiffener is inclined to the longitudinal or vertical axis, respectively, the span is to be taken in accordance with requirements in Section 4.6.

13.4.2.3 For curved stiffeners, the span is to be taken in accordance with requirements in Section 4.6.

13.5 Inner Bottom
13.5.1 Inner Bottom Plating
13.5.1.1 The thickness of inner bottom plating is to comply with the requirements given in Table 17.

13.5.1.2 In way of welded hopper knuckle, the inner bottom is to be scarphed to ensure adequate load transfer to surrounding structure and reduce stress concentrations.

13.5.1.3 In way of corrugated stool, where fitted, particular attention is to be given to the through thickness properties and arrangement for continuity of strength, at the connection of bulkhead stool to the inner bottom. For requirements for plates with specified through-thickness properties, see applicable requirements in Chapter 3.

13.5.2 Inner Bottom Longitudinals
13.5.2.1 The section modulus and web plate thickness of the inner bottom longitudinal are to comply with the requirements given in Table 18 and Table 19.

Table 18: Section modulus requirement for stiffeners

The minimum net section modulus, Z_{net}, is to be taken as the greatest value of all applicable design load sets, as given in Table 21, and given by:

$$Z_{net} = \frac{|P| s l_{bdg}{}^2}{f_{bdg} C_s \sigma_{yd}} \quad [cm^3]$$

f_{bdg} : Bending moment factor:
for continuous stiffeners and where end connections are fitted consistent with idealization of the stiffener as having as fixed ends:
= 12 for horizontal stiffeners
= 10 for vertical stiffeners
for stiffeners with reduced end fixity, see Section 18

C_s : Permissible bending stress coefficient for the design load set being considered, to be taken as:

Sign of hull girder bending stress, σ_{hg}	Side pressure acting on	Acceptance criteria
Tension (+ve)	Stiffener side	$C_s = \beta_s - \alpha_s \frac{\lvert\sigma_{hg}\rvert}{\sigma_{yd}}$ but not to be greater than C_{s-max}
Compression (-ve)	Plate side	
Tension (+ve)	Plate side	$C_s = C_{s-max}$
Compression (-ve)	Stiffener side	

Acceptance criteria set	Structural member	β_s	α_s	C_{S-max}
AC1	Longitudinal strength members	0.85	1.00	0.75
	Transversely or vertical members	0.75	0.00	0.75
AC2	Longitudinally stiffened plating	1.00	1.00	0.90
	Transversely or vertically stiffened plating	0.90	0.00	0.90
	Watertight boundary stiffeners	0.90	0.00	0.90
AC3	All members	1.0	0	1.0

Where:

σ_{hg} : Hull girder bending stress for the design load set being considered and calculated at the load calculation point [N/mm²]

$$= \left(\frac{(z - z_{NA-net50}) M_{v-total}}{I_{v-net50}} - \frac{y M_{h-total}}{I_{h-net50}} \right) 10^{-3} \quad [N/mm^2]$$

$I_{v-net50}$: Net vertical hull girder moment of inertia at the longitudinal position being considered [m⁴]
$I_{h-net50}$: Net horizontal hull girder moment of inertia at the longitudinal position being considered [m⁴]
$M_{h-total}$: Design horizontal bending moment at the longitudinal position under consideration for the design load set being considered [kNm]
$M_{v-total}$: Design vertical bending moment at the longitudinal position under consideration for the design load set being considered [kNm].see also Table 3
$M_{v-total}$, is to be calculated accordance with Table 3 hogging and sagging still water bending moment, M_{sw}, to be taken as:

Stiffener location	M_{sw}	
	Pressure acting on plate side	Pressure acting on stiffener side
Above neutral axis	Sagging SWBM	Hogging SWBM
Below neutral axis	Hogging SWBM	Sagging SWBM

Table 19: Web thickness requirements for stiffeners
The minimum net web thickness, t_{w-net}, is to be taken as the greatest value calculated for all applicable design load sets, given in Table 21 and given by:
$t_{w-net} = \frac{f_{shr}\lvert P\rvert s l_{shr}}{d_{shr} C_t \tau_{yd}}$ [mm]
d_{shr} : Effective shear depth [mm] (see section 4.6) l_{shr} : Effective shear span [m] (see section 4.6) f_{shr} : Shear force distribution factor: for continuous stiffeners and where end connections are fitted consistent with idealization of stiffener as having as fixed ends: = 0.5 for horizontal stiffeners = 0.7 for vertical stiffeners For stiffeners with reduced end fixity, see Section 18 C_t : Permissible shear stress coefficient for the design load set being considered, to be taken as: = 0.75 for acceptance criteria set AC1 = 0.90 for acceptance criteria set AC2 = 1.00 for acceptance criteria set AC3

13.6 Bulkheads

13.6.1 General

13.6.1.1 The inner hull and longitudinal bulkheads are generally to be longitudinally framed and plane. Corrugated bulkheads are to comply with the requirements given in 13.6.6.

13.6.1.2 Where bulkheads are penetrated by cargo or ballast piping, the structural arrangements in way are to be adequate for the loads imparted to the bulkheads by the hydraulic forces in pipes.

13.6.2 Longitudinal Tank Boundary Bulkhead Plating

13.6.2.1 The thickness of the longitudinal tank boundary bulkhead plating is to comply with the requirements given in Table 17.

13.6.2.2 Inner hull and longitudinal bulkheads are to extend as far forward and aft as practicable and are to be effectively scarphed into the adjoining structure.

13.6.3 Hopper Side Structure

13.6.3.1 Knuckles in the hopper tank plating are to be supported by side girders and stringers, or by a deep longitudinal.

13.6.4 Transverse Tank Boundary Bulkhead Plating

13.6.4.1 The thickness of the transverse tank boundary bulkhead plating is to comply with the requirements given in Table 17.

13.6.5 Tank Boundary Bulkhead Stiffeners

13.6.5.1 The section modulus and web thickness of stiffeners, on longitudinal or transverse tank boundary bulkheads, are to comply with the requirements given in Table 18 and Table 19.

13.6.6 Corrugated Bulkheads

13.6.6.1 The scantling requirements relating to corrugated bulkheads defined in 13.6.6 and 13.6.7 are net requirements. The gross scantling requirements are obtained from the applicable requirements by adding the full corrosion additions specified in Section 4.2.

13.6.6.2 In general, corrugated bulkheads are to be designed with the corrugation angles, φ, between 55 and 90 degrees, see Figure 33.

13.6.6.3 The global strength of corrugated bulkheads, lower stools and upper stools, where fitted, and attachments to surrounding structures are to be verified with the cargo tank FEM model in the mid-ship region, see Section 21. The global strength of corrugated bulkheads outside of mid-ship region are to be considered based on results from the cargo tank FEM model and using the appropriate pressure for the bulkhead being considered. Additional FEM analysis of cargo tank bulkheads forward and aft of the mid-ship region may be necessary if the bulkhead geometry, structural details and support arrangement details differ significantly from bulkheads within the mid cargo tank region.

13.6.6.4 The net thicknesses, t_{net}, of the web and flange plates of corrugated bulkheads are to be taken as the greatest value calculated for all applicable design load sets, as given in Table 21 and given by:

$$t_{net} = 0.0158 b_p \sqrt{\frac{|P|}{C_a \sigma_{yd}}} \quad \text{[mm]}$$

Where:

b_p : Breadth of plate [mm], to be taken as:

= b_f for flange plating [mm]

= b_w for web plating [mm]

C_a : Permissible bending stress coefficient

= 0.75 for acceptance criteria set AC1

= 0.90 for acceptance criteria set AC2

= 1.00 for acceptance criteria set AC3

13.6.6.5 Where the corrugated bulkhead is built with flange and web plate of different thickness, the thicker net plating thickness, tm-net, is to be taken as the greatest value calculated for all applicable design load sets, as given in Table 21, and given by:

$$t_{m-net} = \sqrt{\frac{0.005 {b_p}^2 |P|}{C_a \sigma_{yd}} - {t_{n-net}}^2} \quad \text{[mm]}$$

Where:

t_{n-net} : Net thickness of thinner plating, either flange or web [mm]

b_p : Breadth of plate, either flange or web [mm]

C_a : Permissible bending stress coefficient

= 0.75 for acceptance criteria set AC1

= 0.90 for acceptance criteria set AC2

= 1.00 for acceptance criteria set AC3

13.6.7 Vertically Corrugated Bulkheads

13.6.7.1 In addition to the requirements of 13.6.6, vertically corrugated bulkheads are also to comply with the requirements of 13.6.7.

13.6.7.2 The net plate thicknesses as required by 13.6.7.5 and 13.6.7.6 are to be maintained for two thirds of the corrugation length, l_{cg}, from the lower end, where l_{cg} is as defined in 13.6.7.3. Above that, the net plate thickness may be reduced by 20%.

13.6.7.3 The net web plating thickness of the lower 15% of the corrugation, t_{w-net}, is to be taken as the greatest value calculated for all applicable design load sets, as given in Table 21, and given by the following. This requirement is not applicable to corrugated bulkheads without a lower stool, see 13.6.7.9.

$$t_{w-net} = \frac{1000|Q_{cg}|}{d_{cg} C_{t-cg} \tau_{yd}}$$ [mm]

Where:

Q_{cg} : Design shear force imposed on the web plating at the lower end of the corrugation [kN]

$$= \frac{s_{cg} l_{cg} |3P_l + P_u|}{8000}$$ [kN]

C_{t-cg} : Permissible shear stress coefficient

= 0.75 for acceptance criteria set AC1

= 0.90 for acceptance criteria set AC2

= 1.00 for acceptance criteria set AC3

$$\tau_{yd} = \frac{\sigma_{yd}}{\sqrt{3}}$$ [N/mm²]

13.6.7.4 The depth of corrugation, d_{cg}, is not to be less than:

$$d_{cg} = \frac{1000 l_{cg}}{15}$$ [mm]

13.6.7.5 The net thicknesses of the flanges of corrugated bulkheads, t_{f-net}, for two thirds of the corrugation length from the lower end are to be taken as the greatest value calculated for all applicable design load sets, as given in Table 21, and given by the following. This requirement is not applicable to corrugated bulkheads without a lower stool, see 13.6.7.9.

$$t_{f-net} = \frac{0.00657 b_f \sqrt{\sigma_{bdg-max}}}{C_f}$$ [mm]

Where:

$\sigma_{bdg-max}$: Maximum value of the vertical bending stresses in the flange. The bending stress is to be calculated at the lower end and at the mid span of the corrugation length

$$= \frac{1000 M_{cg}}{Z_{cg-act-net}}$$ [N/mm²]

M_{cg} : See 13.6.7.6

$Z_{cg-act-net}$: Actual net section modulus at the lower end and at the mid length of the corrugation [cm³]

b_f : Breadth of flange plating [mm] see Figure 33

b_w : Breadth of web plating [mm] see Figure 33

$$C_f = 7.65 - 0.26 \left(\frac{b_w}{b_f}\right)^2$$

13.6.7.6 The net section modulus at the lower and upper ends and at the mid length of the corrugation (l_{cg}/2) of a unit corrugation, Z_{cg-net}, are to be taken as the greatest value calculated for all applicable design load sets, as given in Table 21, and given by the following:

$$Z_{cg-net} = \frac{1000 M_{cg}}{C_{s-cg} \sigma_{yd}}$$ [cm³]

Where:

$$M_{cg} = \frac{C_i |P| s_{cg} l_o^2}{12000}$$ [cm³]

$$P = \frac{P_u + P_l}{2}$$ [kN/m²]

P_l, P_u : Design pressure [kN/m²] for the design load set being considered, calculated at the lower and upper ends of the corrugation, respectively:

- for transverse corrugated bulkheads, the pressures are to be calculated at a section located at b_{tk}/2 from the longitudinal bulkheads of each tank
- for longitudinal corrugated bulkheads, the pressures are to be calculated at the ends of the tank, i.e., the intersection of the forward and aft transverse bulkheads and the longitudinal bulkhead

b_{tk} : Maximum breadth of tank under consideration measured at the bulkhead [m]

l_o : Effective bending span of the corrugation, measured from the mid depth of the lower stool to the mid depth of the upper stool, or upper end where no upper stool is fitted, in m, see Figure 33

C_i : Relevant bending moment coefficients as given in Table 20

$C_{s\text{-}cg}$: Permissible bending stress coefficient at the mid length of the corrugation length, l_{cg}:

= c_e, but not to be taken as greater than 0.75 for acceptance criteria set AC1

= c_e, but not to be taken as greater than 0.90 for acceptance criteria set AC2

= c_e, but not to be taken as greater than 1.00 for acceptance criteria set AC3

at the lower and upper ends of corrugation length, lcg:

= 0.75 for acceptance criteria set AC1

= 0.90 for acceptance criteria set AC2

= 1.00 for acceptance criteria set AC3

c_e $= \frac{2.25}{\beta} - \frac{1.25}{\beta^2}$ for β ≥ 1.25

= 1.0 for β < 1.25

b_f : Breadth of flange plating [mm] see Figure 32

β $= \frac{b_f}{t_{f-net}}\sqrt{\frac{\sigma_{yd}}{E}}$

$t_{f\text{-}net}$: Net thickness of the corrugation flange [mm]

Table 20: Values of C_i

Bulkhead	At lower end of l_{cg}	At mid length of l_{cg}	At the upper end of l_{cg}
Transverse bulkhead	C_1	C_{m1}	$0.65C_{m1}$
Longitudinal bulkhead	C_3	C_{m3}	$0.65C_{m3}$
Where:			

C_1	$= a_1 + b_1\sqrt{\frac{A_{dt}}{b_{dk}}}$	but is not to be taken less than 0.60
	$= a_1 - b_1\sqrt{\frac{A_{dt}}{b_{dk}}}$	for transverse bulkhead with no lower stool, but is not to be taken less than 0.55
a_1	$= 0.95 - \frac{0.41}{R_{bt}}$	
	=1.0	for transverse bulkhead with no lower stool
b_1	$= -0.20 + \frac{0.078}{R_{bt}}$	
	= 0.13	for transverse bulkhead with no lower stool
C_{m1}	$= a_{m1} + b_{m1}\sqrt{\frac{A_{dt}}{b_{dk}}}$	but is not to be taken less than 0.55
	$= a_{m1} - b_{m1}\sqrt{\frac{A_{dt}}{b_{dk}}}$	for transverse bulkhead with no lower stool, but is not to be taken less than 0.60
a_{m1}	$= 0.63 + \frac{0.25}{R_{bt}}$	
	=0.85	for transverse bulkhead with no lower stool

b_{m1}	$= -0.25 - \dfrac{0.11}{R_{bt}}$ = 0.34	for transverse bulkhead with no lower stool
C_3	$= a_3 + b_3\sqrt{\dfrac{A_{dl}}{b_{dk}}}$	but is not to be taken less than 0.60
	$= a_3 - b_3\sqrt{\dfrac{A_{dl}}{b_{dk}}}$	for longitudinal bulkhead with no lower stool, but is not to be taken less than 0.55
a_3	$= 0.86 - \dfrac{0.35}{R_{bl}}$ =1.0	for longitudinal bulkhead with no lower stool
b_3	$= -0.17 + \dfrac{0.11}{R_{bl}}$ =0.13	for longitudinal bulkhead with no lower stool
C_{m3}	$= a_{m3} + b_{m3}\sqrt{\dfrac{A_{dl}}{l_{dk}}}$	for longitudinal bulkhead with no lower stool but not to be taken lower than 0.55
	$= a_{m3} - b_{m3}\sqrt{\dfrac{A_{dl}}{l_{dk}}}$	for longitudinal bulkhead with no lower stool but not to be taken lower than 0.60
a_{m3}	$= 0.32 + \dfrac{0.24}{R_{bl}}$ = 0.85	for longitudinal bulkhead with no lower stool
b_{m3}	$= -0.12 - \dfrac{0.10}{R_{bt}}$ =0.19	for longitudinal bulkhead with no lower stool
R_{bt}	$= \dfrac{A_{bt}}{b_{ib}}\left(1 + \dfrac{l_{ib}}{b_{ib}}\right)\left(1 + \dfrac{b_{av-t}}{h_{st}}\right)$	for transverse bulkheads
R_{bl}	$= \dfrac{A_{bl}}{l_{ib}}\left(1 + \dfrac{l_{ib}}{b_{ib}}\right)\left(1 + \dfrac{b_{av-l}}{h_{sl}}\right)$	for longitudinal bulkheads

A_{dt} : Cross sectional area enclosed by the moulded lines of the transverse bulkhead upper stool [m^2]
= 0 if no upper stool is fitted

A_{dl} : Cross sectional area enclosed by the moulded lines of the longitudinal bulkhead upper stool [m^2]
= 0 if no upper stool is fitted

A_{bt} : Cross sectional area enclosed by the moulded lines of the transverse bulkhead lower stool [m^2]

A_{bl} : Cross sectional area enclosed by the moulded lines of the longitudinal bulkhead lower stool [m^2]

b_{av-t} : Average width of transverse bulkhead lower stool [m], see Figure 33

b_{av-l} : Average width of longitudinal bulkhead lower stool [m], see Figure 33

h_{st} : Height of transverse bulkhead lower stool [m], see Figure 33

h_{sl} : Height of longitudinal bulkhead lower stool [m], see Figure 33

b_{ib} : Breadth of cargo tank at the inner bottom level between hopper tanks, or between the hopper tank and centerline lower stool [m], see Figure 33

b_{dk} : Breadth of cargo tank at the deck level between upper wing tanks, or between the upper wing tank and centerline deck box or between the corrugation flanges if no upper stool is fitted [m], see Figure 33

l_{ib}	: Length of cargo tank at the inner bottom level between transverse lower stools [m], see Figure 33
l_{dk}	: Length of cargo tank at the deck level between transverse upper stools or between the corrugation flanges if no upper stool is fitted [m], see Figure 33

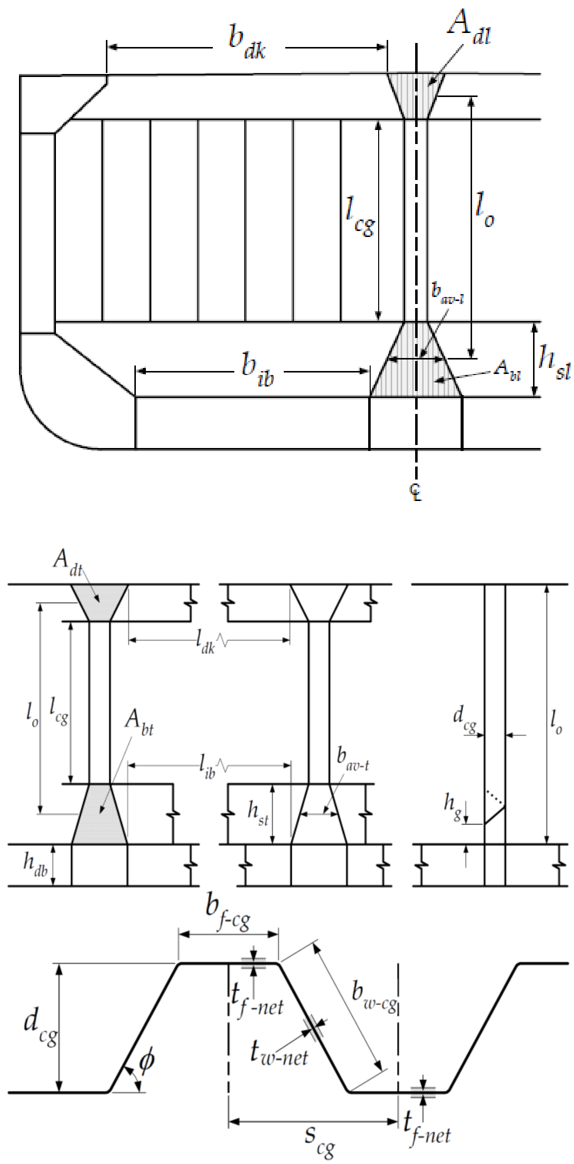


Figure 33: Definition of Parameters for Corrugated Bulkhead (Units with Longitudinal Bulkhead at Centerline)

13.6.7.7 For tanks with effective sloshing breadth, b_{slh}, greater than 0.56*B* or effective sloshing length l_{slh}, greater than 0.13L, additional sloshing analysis is to be carried out to assess the section modulus of the unit corrugation.

13.6.7.8 For Units with a moulded depth equal or greater than 16 m, a lower stool is to be fitted in compliance with the following requirements:

(i) General:

- The height and depth are not to be less than the depth of the corrugation
- The lower stool is to be fitted in line with the double bottom floors or girders
- The side stiffeners and vertical webs (diaphragms) within the stool structure are to align with the structure below, as far as is practicable, to provide appropriate load transmission to structures within the double bottom

(ii) Stool top plating:

- The net thickness of the stool top plate is not to be less than that required for the attached corrugated bulkhead and is to be of at least the same material yield strength as the attached corrugation
- The extension of the top plate beyond the corrugation is not to be less than the as-built flange thickness of the corrugation

(iii) Stool side plating and internal structure:

- Within the region of the corrugation depth from the stool top plate, the net thickness of the stool side plate is not to be less than 90 per cent of that required by 13.6.7.2 for the corrugated bulkhead flange at the lower end and is to be of at least the same material yield strength
- The net thickness of the stool side plating and the net section modulus of the stool side stiffeners is not to be less than that required by 13.6.2, 13.6.4 and 13.6.5 for transverse or longitudinal bulkhead plating and stiffeners

- The ends of stool side vertical stiffeners are to be attached to brackets at the upper and lower ends of the stool
- Continuity is to be maintained, as far as practicable, between the corrugation web and supporting brackets inside the stool. The bracket net thickness is not to be less than 80 per cent of the required thickness of the corrugation webs and is to be of at least the same material yield strength
- Scallops in the diaphragms in way of the connections of the stool sides to the inner bottom and to the stool top plate are not permitted.

13.6.7.9 For Units with a moulded depth less than 16 m, the lower stool may be eliminated, provided the following requirements are complied with:

(i) General:

- Double bottom floors or girders are to be fitted in line with the corrugation flanges for transverse or longitudinal bulkheads, respectively
- Brackets/carlings are to be fitted below the inner bottom and hopper tank in line with corrugation webs. Where this is not practicable, gusset plates with shedder plates are to be fitted, see item (iii) below and Figure 33.
- The corrugated bulkhead and its supporting structure are to be assessed by Finite Element (FE) analysis, in accordance with the Section 21. In addition, the local scantlings requirements of 13.6.6.4 and 13.6.6.5 and the minimum corrugation depth requirement of 13.6.7.4 are to be applied.

(ii) Inner bottom and hopper tank plating:

- The inner bottom and hopper tank in way of the corrugation are to be of at least the same material yield strength as the attached corrugation.

(iii) Supporting structure:

- Within the region of the corrugation depth below the inner bottom, the net thickness of the supporting double bottom floors or girders is not to be less than the net thickness of the corrugated bulkhead flange at the lower end, and is to be of at least the same material yield strength;
- The upper ends of vertical stiffeners on supporting double bottom floors or girders are to be bracketed to adjacent structure
- Brackets/carlings arranged in line with the corrugation web are to have a depth of not less than 0.5 times the corrugation depth and a net thickness not less than 80% of the net thickness of the corrugation webs and are to be of at least the same material yield strength
- Cut-outs for stiffeners in way of supporting double bottom floors and girders in line with corrugation flanges are to be fitted with full collar plates
- Where support is provided by gussets with shedder plates, the height of the gusset plate, see h_g in Figure 33, is to be at least equal to the corrugation depth, and gussets with shedder plates are to be arranged in every corrugation. The gusset plates are to be fitted in line with and between the corrugation flanges. The net thicknesses of the gusset and shedder plates are not to be less than 100% and 80%, respectively, of the net thickness of the corrugation flanges and are to be of at least the same material yield strength. See also 13.6.7.11.
- Scallops in brackets, gusset plates and shedder plates in way of the connections to the inner bottom or corrugation flange and web are not permitted.

13.6.7.10 In general, an upper stool is to be fitted in compliance with the following requirements:

(i) General:

- Where no upper stool is fitted, finite element analysis is to be carried out to demonstrate the adequacy of the details and arrangements of the bulkhead support structure to the upper deck structure
- Side stiffeners and vertical webs (diaphragms) within the stool structure are to align with adjoining structure to provide for appropriate load transmission
- Brackets are to be arranged in the intersections between the upper stool and the structure on deck.

(ii) Stool bottom plating:

- The net thickness of the stool bottom plate is not to be less than that required for the attached corrugated bulkhead, and is to be of at least the same material yield strength as the attached corrugation
- The extension of the bottom plate beyond the corrugation is not to be less than the attached as-built flange thickness of the corrugation.

(iii) Stool side plating and internal structure:

Within the region of the corrugation depth above the stool bottom plate, the net thickness of the stool side plate is to be not less than 80% of that required by 13.6.7.2 for the corrugated bulkhead flange at the upper end, where the same material is used. If material of different yield strength is used, the required thickness is to be adjusted by the ratio of the two material factors (*k*).

- The net thickness of the stool side plating and the net section modulus of the stool side stiffeners are not to be less than that required by 13.6.2, 13.6.4 and 13.6.5 for the transverse or longitudinal bulkhead plating and stiffeners
- The ends of stool side vertical stiffeners are to be attached to brackets at the upper and lower ends of the stool
- Scallops in the diaphragms in way of the connections of the stool sides to the deck and to the stool bottom plate are not permitted.

13.6.7.11 Where gussets with shedder plates, or shedder plates (slanting plates), are fitted at the end connection of the corrugation to the lower stool or the inner bottom, appropriate means are to be provided to prevent the possibility of gas pockets being formed by these plates.

13.6.7.12 Welding for all connections and joints is to be in accordance with requirements in Section 23.

13.6.8 Non-tight Bulkheads

13.6.8.1 Non-tight bulkheads (wash bulkheads), where fitted, are to be in line with transverse webs, bulkheads or similar structures. They are to be of plane construction, horizontally or vertically stiffened, and scantlings are to comply with the sloshing load requirements given in Section 17. In general, openings in the non-tight bulkheads are to have generous radii and their aggregate area is not to be less than 10% of the area of the bulkhead.

Table 21 : Design load sets for plating and local support members

Structural Member		Design Load set	Load Component	Draught	Remark
Keel, Bottom Shell, Bilge, Side Shell, Sheer Strake		1	P_{ex}	T_{sc}	Sea pressure only
		2	P_{ex}	T_{sc}	
		7	P_{in}-P_{ex}	T_{bal}	Net pressure difference between water ballast pressure and sea pressure
		8	P_{in}-P_{ex}	$0.25T_{sc}$	
Deck	**In way of cargo tanks**	1	P_{ex}	T_{sc}	Green sea pressure only for other loads on deck
		3	P_{in}	$0.6T_{sc}$	Cargo pressure only
		4	P_{in}	-	
		11	$P_{in\text{-}flood}$	-	
	In way of tanks other than cargo tanks	1	P_{ex}	T_{sc}	Green sea pressure only for other loads on deck
		5	P_{in}	T_{bal}	Water ballast or other liquid pressure only
		6	P_{in}	$0.25T_{sc}$	
		11	$P_{in\text{-}flood}$	-	
	Any location	9	P_{dk}	T_{bal}	Distributed or concentrated loads only. Simultaneously occurring green sea pressure may be ignored
		10	P_{dk}	-	
Inner bottom, Inner hull, Hopper side		3	P_{in}	$0.6T_{sc}$	Cargo pressure only
		4	P_{in}	-	
		5	P_{in}	T_{bal}	Water ballast or other liquid pressure only
		6	P_{in}	$0.25T_{sc}$	
		11	$P_{in\text{-}flood}$		
Longitudinal bulkhead, Centerline bulkhead		3	P_{in}	$0.6T_{sc}$	Pressure from one side only. Full cargo tank with adjacent cargo tank empty. Two cases are to be evaluated: 1. Inner empty, outer full 2. Inner full, outer empty
		4	P_{in}	-	
		11	$P_{in\text{-}flood}$	-	
Transverse Bulkhead	**In way of cargo tanks**	3	P_{in}	$0.6T_{sc}$	Pressure from one side only. Full cargo tank with adjacent fwd or aft cargo tank empty. Need to evaluate 2 cases 1) Fwd empty, aft full 2) Fwd full, aft empty
		4	P_{in}	-	
		11	$P_{in\text{-}flood}$	-	
	In way of tanks other than cargo tanks	5	P_{in}	T_{sc}	
		6	P_{in}	$0.25T_{sc}$	
		11	$P_{in\text{-}flood}$	-	
Other tank boundaries. e.g Girders, floors and stringers		5	P_{in}	T_{bal}	Pressure from one side only. Full tank with adjacent tank empty. Need to evaluate 2 cases, see above
		6	P_{in}	$0.25T_{sc}$	
		11	$P_{in\text{-}flood}$	-	

Note:
T_{sc}: Scantling draught
T_{bal}: minimum ballast draught

1. Description of design load set is provided in Table 22
2. The boundaries of void and dry space not forming part of the hull envelope are to be evaluated using Design Load Set 11.
3. The above load sets are to be checked considering on-site, transit and inspection/maintenance conditions. For transit and inspection maintenance conditions, if the draught of the unit does not correspond to draughts mentioned for the load sets mentioned above, then the consideration of draughts for the checks is to be decided by IRS.
4. For structural members/configurations not covered by above specifications, the applicable Design Load sets to determine the scantling requirements of structural boundaries are to be selected so as to specify a full tank on one side with the adjacent tank or space empty. The boundary is to be evaluated for loading from both sides. Design Load Sets are to be selected based on the tank or space contents and are to maximize the pressure on the structural boundary, the draught to use is to be taken in accordance with the Design Load Set and this table. Design Load Sets covering the *S* and *S+D* design load combinations are to be selected.

Table 22 : Design Load Set specification

Design Load set	Load Component	Design load combination	Acceptance criteria set	Parameters for dynamic load calculations		
				DLCF Table selection	*GM*	$R_{roll\text{-}gyr}$
Hull Envelope (primary and local support members)						
1	Sea Pressure	*S*	AC1	-		
2		*S+D*	AC2	Full Load	0.12*B*	0.35*B*
Cargo Tank Boundaries						
3	Cargo tank pressures	*S*	AC1	-		
4		*S+D*	AC2	Full Load	0.24*B*	0.40*B*
Boundaries of water ballast and other tanks						
5	Water ballast or other tank pressures	*S*	AC1	-		
6		*S+D*	AC2	Ballast	0.33*B*	0.45*B*
7	Net pressures (ballast – sea)	*S*	AC1	-		
8		*S+D*	AC2	Ballast	0.33*B*	0.45*B*
Decks (primary and local support members)						
9	Distributed pressures and concentrated loads	*S*	AC1	-		
10		*S+D*	AC2	Ballast	0.33*B*	0.45*B*
11	Flooded condition (Accidental)	*A*	AC2	-		
Hull Envelope (primary support members)						
12	Net pressure (Cargo – Sea)	*S*	AC1	-		
13		*S+D*	AC2	Loaded	0.24*B*	0.40*B*
14	Average pressure (cargo & sea)	*S*	AC1	-		
15		*S+D*	AC2	Loaded	0.12*B*	0.35*B*
16		*S+D*	AC2	Loaded	0.24*B*	0.40*B*

13.7 Primary Support Members

13.7.1 General

13.7.1.1 The scantlings of primary support members in the cargo tank region are to comply with the minimum requirements given in Section 13.2.5.

13.7.1.2 Section modulus and Shear area requirements are applicable to primary support members as defined in this present sub section.

13.7.1.3 Scantlings of primary support members are to be verified with direct calculations as described in Section 21.

13.7.1.4 In general, primary support members are to be arranged in one plane to form continuous transverse rings. Brackets forming connections between primary support members of the ring are to be in accordance with requirements in Section 23.

13.7.1.5 Webs of primary support members are to have a depth not less than specified in the relevant requirements of the present section. They are also to be suitably stiffened and proportioned in accordance with requirements in Section 20.

13.7.1.6 Scantlings of primary structural members determined on basis of direct calculations may be specially considered by IRS in lieu of 13.7.3 – 13.7.9 provided that the associated factor of safety is no less stringent than that as prescribed in Section 13.7. This however is not to reduce the minimum scantlings required by 13.2.5

13.7.1.7 Scantlings of primary structural members not covered in 13.7 may be determined based upon the requirements in 13.7.1.6

13.7.2 Design Load sets

13.7.2.1 The design load sets to be considered for primary supporting members are listed in Table 23. The acceptance criteria are listed in Table 24.

13.7.3 Floors and Girders in Double Bottom

13.7.3.1 Continuous double bottom girders are to be arranged at the centerline or duct keel, at the hopper side and in way of longitudinal bulkheads and bulkhead stools. Plate floors are to be arranged in way of transverse bulkheads and bulkhead stools.

13.7.3.2 The net shear area of the floors at any position in the floor is not to be less than

$$A_{shr-net50} = \frac{10Q}{C_{t-pr}\tau_{yd}} \quad [cm^2]$$

Where:

Q : Design Shear Force

$= f_{shr} P S l_{shr}$ [kN]

f_{shr} : Shear force distribution factor

$$f_{shr} = f_{shr-i}\left(1 - \frac{2y_i}{l_{shr}}\right)$$

f_{shr-i} : Shear force distribution factor at the end of the span l_{shr} as provided in Table 25.

l_{shr} : Effective span as shown in Figure 35. In way of bracket ends, the effective shear span is measured to the toes of the effective end bracket, as defined in Section 4.6. Where the floor ends on a girder at a hopper or stool structure, the effective shear span is measured to a point that is one-half of the distance from the girder to the adjacent bottom and inner-bottom longitudinal, as shown in Figure 35.

y_i : distance from the considered cross-section of the floor to the nearest end of the effective shear span, *lshr*,[m]

S : Primary Support member spacing as defined in Section 1.

P : Design pressure for the load set calculated at mid-point of effective shear span, l_{shr}, of a floor located midway between transverse bulkheads or transverse bulkhead and wash bulkhead, where fitted [kN/m²]

C_{t-pr} : permissible shear stress coefficient for primary support member as given in Table 24.

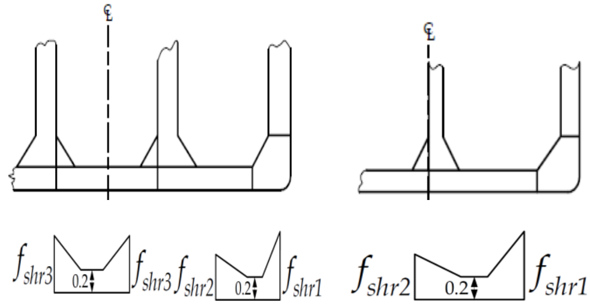


Figure 34: Floor shear force distribution factors

Table 23: Design load sets for Primary support members

Structural Member		Design Load set	Load Component	Draught	Remarks
Double Bottom Girders and Floors		1	P_{ex}	$0.9T_{sc}$	Sea Pressure only
		2	P_{ex}	T_{sc}	
		12	P_{in}-P_{ex}	$0.6T_{sc}$	*Net pressure difference(sea-cargo)*
		13	P_{in}-P_{ex}	#	
Side Transverses		1	P_{ex}	$0.9T_{sc}$	Sea Pressure only
		2	P_{ex}	T_{sc}	
		3	P_{in}	$0.6T_{sc}$	Cargo Pressure only
		4	P_{in}	-	
Deck Transverses		1	P_{ex}	T_{sc}	Green Sea Pressure only or other loads on deck
		3	P_{in}	$0.6T_{sc}$	Cargo Pressure only
		4	P_{in}	-	
Vertical webframes on longitudinal bulkheads		3	P_{in}	$0.6T_{sc}$	Pressure from one side only
		4	P_{in}	-	
		3	P_{in}	$0.6T_{sc}$	Pressure from one side only
		4	P_{in}	-	
Horizontal stringers on transverse bulkheads		3	P_{in}	$0.6T_{sc}$	Pressure from one side only.
		4	P_{in}	-	
		11	$P_{in-flood}$	-	
Cross ties	**Centre tanks**	3	$0.5(P_{in-pt}+P_{in-stb})$	$0.6T_{sc}$	Full wing cargo tanks, centre tank empty
		4	P_{in}	-	
	Wing tanks	14	$0.5(P_{in}+P_{ex})$	T_{sc}	Empty wing cargo tanks, centre tank full
		15	$0.5(P_{in}+P_{ex})$	$0.6T_{sc}$	
		16	$0.5(P_{in}+P_{ex})$	T_{sc}	

For tankers with two oil tight longitudinal bulkheads, the draught is to be taken as $0.25T_{sc}$, for tankers with one centerline bulkhead, draught is to be taken as $0.33T_{sc}$

1. Evaluations are to be made considering On-site Operations, Transit and Inspection / maintenance. In case of the specified draughts not applicable for a particular mode, choice of evaluation at an alternate draught to be decided by IRS

2. For structural members not covered by the above specifications, Design Load Sets are to be selected based on the tank or space contents and are to maximise the net pressure on the structural boundary, the draught to use is to be taken in accordance with the Design Load Set and this table. Design Load Sets covering the S and S+D design load combinations are to be selected. Design Load Set 11 may also need to be applied, depending on the particular structural configuration.

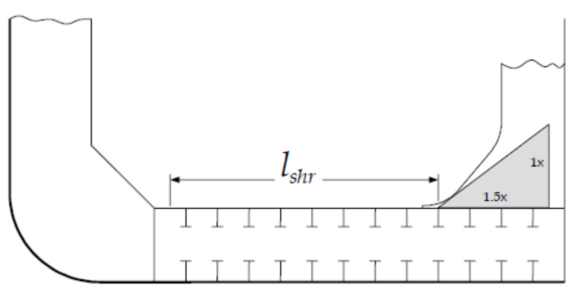
3. For a void or dry space, the pressure component from the void side is to be ignored, except where Design Load Set 11 needs to be applied.

Table 24 : Permissible Stress coefficients

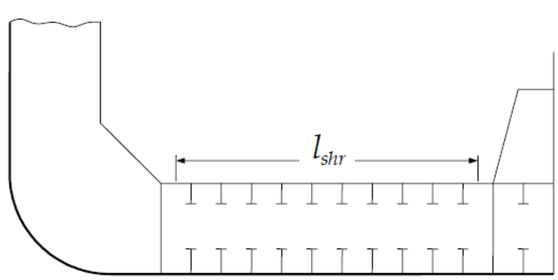
Acceptance Criteria Set	Permissible Bending stress coefficient c_{s-pr}	Permissible Shear stress coefficient c_{t-pr}
AC1	0.70	0.70
AC2	0.85	0.85

Table 25 : Shear force distribution factors

Structural Configuration	Centre tank [1]	Wing Tank	
		At inboard end[1]	At hopper knuckle end At inboard end[1]
Units with centerline longitudinal bulkhead	-	0.40	0.60
Units with tow longitudinal bulkhead	0.5	0.50	0.65
[1] Refer Figure 34			



Typical arrangement with hopper and end bracket



Typical arrangement with hopper and stool

Figure 35: Effective shear span of floors

13.7.3.3 For double bottom centre girders where no longitudinal bulkhead is fitted above, the net shear area of the double bottom centre girder in way of the first bay from each transverse bulkhead and wash bulkhead, where fitted, is not to be less than:

$$A_{shr-net50} = \frac{10Q}{C_{t-pr}\tau_{yd}} \quad [cm^2]$$

Where

Q : Design shear force as given below

$$Q = 0.21 n_1 n_2 P l_{shr}^2 \quad [kN]$$

C_{t-pr}, P and l_{shr} are defined in 13.7.3.2

n_1 and n_2 are as defined below

$$n_1 = 0.00935\left(\frac{l_{shr}}{S}\right)^2 - 0.163\left(\frac{l_{shr}}{S}\right) + 1.289$$

$$n_2 = 1.3 - \left(\frac{S}{12}\right)$$

S : Double bottom floor spacing [m]

13.7.3.4 For double bottom side girders where no longitudinal bulkhead is fitted above, the net shear area of the double bottom side girder in way of the first bay from each transverse bulkhead and wash bulkhead, where fitted, is not to be less than:

$$A_{shr-net50} = \frac{10Q}{C_{t-pr}\tau_{yd}} \quad [cm^2]$$

Q : Design shear force as given below

$$Q = 0.14 n_3 n_4 P l_{shr}^2 \quad [kN]$$

n_3 and n_4 are as defined below

C_{t-pr}, P and l_{shr} are defined in 13.7.3.2

$$n_3 = 1.072 - 0.0357\left(\frac{l_{shr}}{S}\right)$$

$$n_4 = 1.2 - \left(\frac{S}{18}\right)$$

S : Double bottom floor spacing [m]

13.7.4 Deck Transverses

13.7.4.1 The web depth of the deck transverses is not to be less than the following:

.1 $0.20 l_{bdg-dt}$: for deck transverses in the wing cargo tanks of Units with two longitudinal bulkheads

.2 $0.13 l_{bdg-dt}$: for deck transverses in the centre cargo tanks of Units with two longitudinal bulkheads. The web depth of deck transverses in centre cargo tank is not to be less than 90% of that of the deck transverses in the wing cargo tankl bulkheads

.3 $0.10 l_{bdg-dt}$: for deck transverses of Units with centreline bulkhead

Where:

l_{bdg-dt} : effective bending span of the deck transverse, in m, (refer section 4.6) and Figure 36, but is not to be taken as less than 60% of the breadth of the tank at the location being considered

13.7.4.2 The moment of inertia of the deck transverses, with associated deck plating, is to comply with slenderness and proportions requirements in Section 20 to control the overall deflection of the deck structure.

13.7.4.3 The net section modulus of deck transverses is not to be less than $Z_{in-net50}$ and $Z_{ex-net50}$ as given by the following. The net section modulus of the deck transverses in the wing cargo tanks is also not to be less than required for the deck transverses in the centre tanks.

$$Z_{in-net50} = \frac{1000 M_m}{C_{s-pr}\sigma_{yd}} \quad [\text{cm}^3]$$

$$Z_{ex-net50} = \frac{1000 M_{ex}}{C_{s-pr}\sigma_{yd}} \quad [\text{cm}^3]$$

Where:

M_{in} : Design bending moment due to cargo pressure in kNm to be taken as:

a)

$M_{in} = 0.042\varphi_t P_{in-dt} S l_{bdg-dt}{}^2 + M_{st}$:

for deck transverses in wing cargo tanks of Units with two longitudinal bulkheads, and for deck transverses in cargo tanks of Units with a centreline longitudinal bulkhead but is not to be taken less than M_o

b)

$M_{in} = 0.042\varphi_t P_{in-dt} S l_{bdg-dt}{}^2 + M_{vw}$:

for deck transverses in centre cargo tank of Units with two longitudinal bulkheads but is not to be taken less than M_o

M_{st} : Bending moment transferred from side transverse [kNm]

$$M_{st} = c_{st}\beta_{st} P_{in-st} S l_{bdg-st}{}^2$$

where a cross tie is fitted in a wing cargo tank and $l_{bdg-st-ct}$ is greater than $0.7 l_{bdg-st}$, then l_{bdg-st} in the above formula may be taken as $l_{bdg-st-ct}$

M_{vw} : Bending moment from vertical webframe on longitudinal bulkhead [kNm]

$$M_{vw} = c_{vw}\beta_{vw} P_{in-vw} S l_{bdg-vw}{}^2$$

where a cross tie is fitted in a wing cargo tank and $l_{bdg-vw-ct}$ is greater than $0.7 l_{bdg-st}$, then l_{bdg-st} in the above formula may be taken as $l_{bdg-vw-ct}$

M_o : Minimum Bending moment [kNm]

$M_o = 0.083 P_{in-dt} S l_{bdg-dt}{}^2$

M_{ex} : design bending moment due to green sea pressure [kNm]

$M_{ex} = 0.067 P_{ex-dt} S l_{bdg-dt}{}^2 + \sum M_{tp-dk}$

P_{in-dt} : design cargo pressure [kN/m^2] for the design load set being considered, calculated at mid point of effective bending span, l_{bdg-dt}, of the deck transverse located at mid tank.

P_{in-st} : corresponding design cargo pressure [kN/m^2] in wing cargo tank for the design load set being considered, calculated at mid point of effective bending span, l_{bdg-st}, of the side transverse located at mid tank.

P_{in-vw} : corresponding design cargo pressure [kN/m^2] on centre cargo tank of Units with two longitudinal bulkheads for the design load set being considered, calculated at mid point of effective bending span, l_{bdg-vw} of the vertical web frame on the longitudinal bulkhead located at mid tank.

P_{ex-dt} : design green sea pressure [kN/m^2] for the design load set being considered, calculated at mid point of effective bending span, l_{bdg-dt} of the deck transverse located at mid tank.

M_{tp-dk} : Reaction moments from topside module / equipment attachments on deck (see chapter 5)

φ_t : is defined as shown below

$$\varphi_t = 1 - 5\left(\frac{y_{toe}}{l_{bdg-dt}}\right)$$

But not to be taken less than 0.6

y_{toe} : distance from the end of effective bending span, l_{bdg-dt}, to the toe of the end bracket of the deck transverse, in m

β_{st} : as defined below

$$\beta_{st} = 0.9\left(\frac{l_{bdg-st}}{l_{bdg-dt}}\right)\left(\frac{I_{dt}}{I_{st}}\right)$$

But is not to be taken less than 0.1 or greater than 0.65

β_{vw} : as defined below

$$\beta_{vw} = 0.9\left(\frac{l_{bdg-vw}}{l_{bdg-dt}}\right)\left(\frac{I_{dt}}{I_{vw}}\right)$$

But is not to be taken less than 0.1 or greater than 0.50

S : Primary support member spacing as defined in Section 1

l_{bdg-dt} : effective bending span of the deck transverse [m] but not to be taken less than 60% of the breadth of the tank at the location being considered.

l_{bdg-st} : effective bending span of the side transverse [m] between deck transverse and bilge hopper.

$l_{bdg-st-ct}$: effective bending span of the side transverse [m] between deck transverse and mid-depth of the cross tie where fitted in the wing cargo tank.

l_{bdg-vw} : effective bending span of the vertical web frame on the longitudinal bulkhead [m] between deck transverse and bottom structure

$l_{bdg-vw-ct}$: effective bending span of the vertical web frame on the longitudinal bulkhead [m] between deck transverse and mid-depth of the cross tie

I_{dt} :net moment of inertia of the deck transverse with an effective breadth of attached plating specified in cm^4

I_{st} :net moment of inertia of the side transverse with an effective breadth of attached plating specified in cm^4

I_{vw} :net moment of inertia of the longitudinal bulkhead vertical webframe with an effective breadth of attached plating specified in cm^4

c_{st} : Defined in Table 26

c_{vw} : Defined in Table 26

C_{s-pr} : Defined in Table 24

Table 26: Values of c_{st} and c_{vw} for deck transverses				
Structural Configuration			c_{st}	c_{vw}
Units with centreline longitudinal bulkhead			0.056	-
Units with two longitudinal bulkheads	Cross tie in centre cargo tank	M_{vw} based on $l_{bdg-vw-ct}$	-	0.044
		M_{st} based on l_{bdg-st} or M_{vw} based on l_{bdg-vw}	0.044	0.016
	Cross tie in wing cargo tanks	M_{st} based on $l_{bdg-st-ct}$ or M_{vw} based on $l_{bdg-vw-ct}$	0.044	0.044
		M_{st} based on l_{bdg-st} or M_{vw} based on l_{bdg-vw}	0.041	0.015

13.7.4.4 The net shear area of deck transverses is not to be less than $A_{shr-in-net50}$ and $A_{shr-ex-net50}$ as shown below:

$$A_{shr-in-net50} = \frac{10Q_{in}}{c_{t-pr}\tau_{yd}} \quad [cm^2]$$

$$A_{shr-ex-net50} = \frac{10Q_{ex}}{c_{t-pr}\tau_{yd}} \quad [cm^2]$$

Where:

Q_{in} and Q_{ex} are as shown below:

$$Q_{in} = 0.65P_{in-dt}Sl_{shr} + c_1 D b_{ctr} S\rho g \quad [kN]$$

$$Q_{ex} = 0.65P_{ex-dt}Sl_{shr} + \sum P_{tp-dk} \quad [kN]$$

P_{in-dt} : Design cargo pressure [kN/m^2] for the design load set being considered, calculated at midpoint of effective bending span, l_{bdg-dt}, of the deck transverse located at mid tank

P_{ex-dt} : Design green sea pressure [kN/m^2] for the design load set being considered, calculated at midpoint of effective bending span, l_{bdg-dt}, of the deck transverse located at mid tank

P_{tp-dk} : Reaction forces from topside module / equipment attachments on deck (see Chapter 5)

S : Primary support member spacing [m]

l_{shr} : Effective shear span as defined in Section 4.6 [m]

l_{bdg-dt} : Effective bending span span of deck transverse (See Section 4.6 and Figure 36) but not to be taken less than 60% of the breadth of the tank at the location being considered, [m]

c_1 = 0.04 in way of wing cargo tanks of Units with two longitudinal bulkheads
= 0.00 in way of centre tank of Units with two longitudinal bulkheads
= 0.00 for Units with centerline bulkhead

D : Moulded depth as defined in Section 1

b_{ctr} : breadth of centre tank [m]

g : acceleration due to gravity; taken as 9.81 [m/s^2]

c_{t-pr} : Defined in Table 24

ρ : Density of liquid in the tank, not to be taken less than 1.025 [tonnes/m^3].

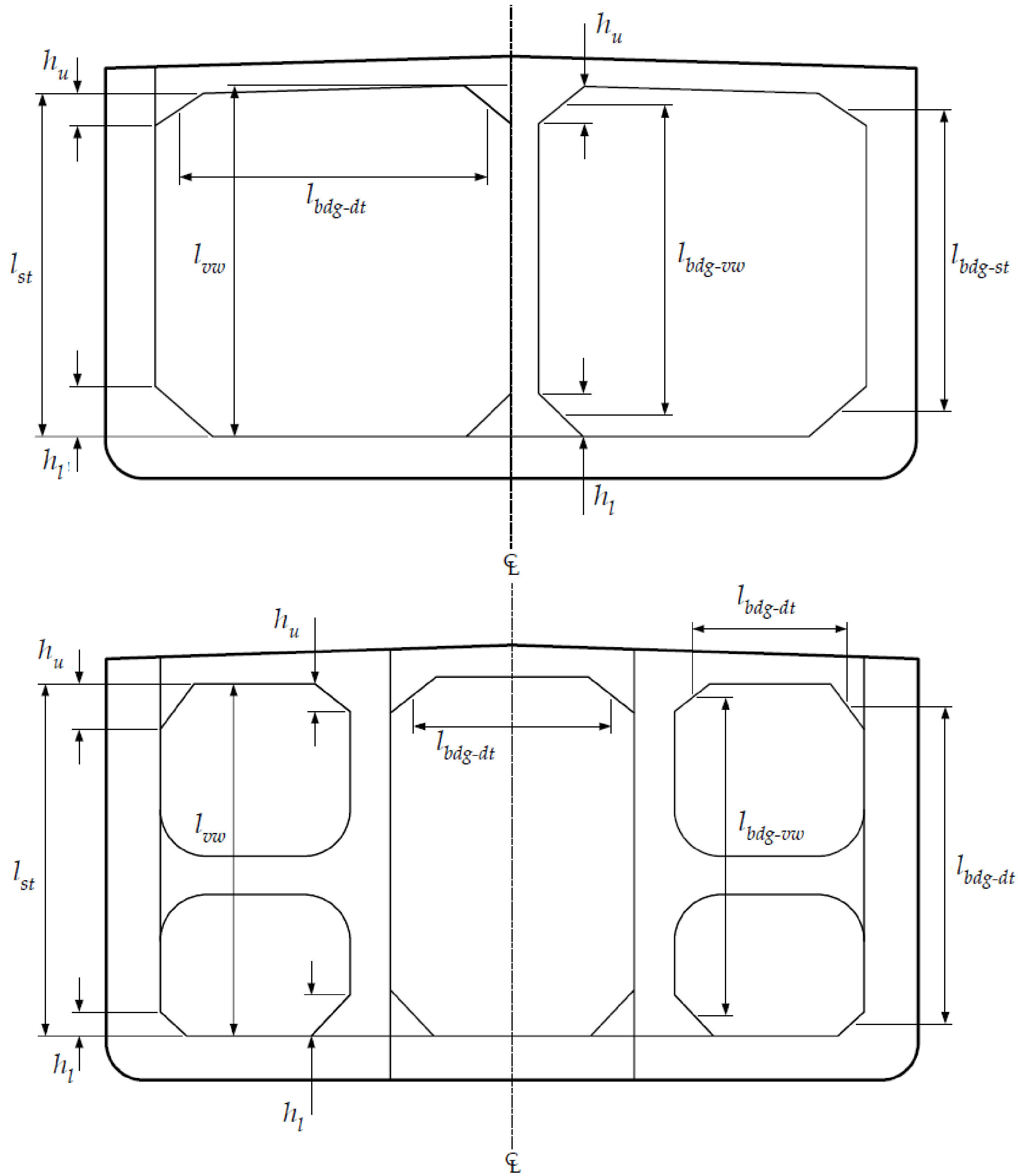
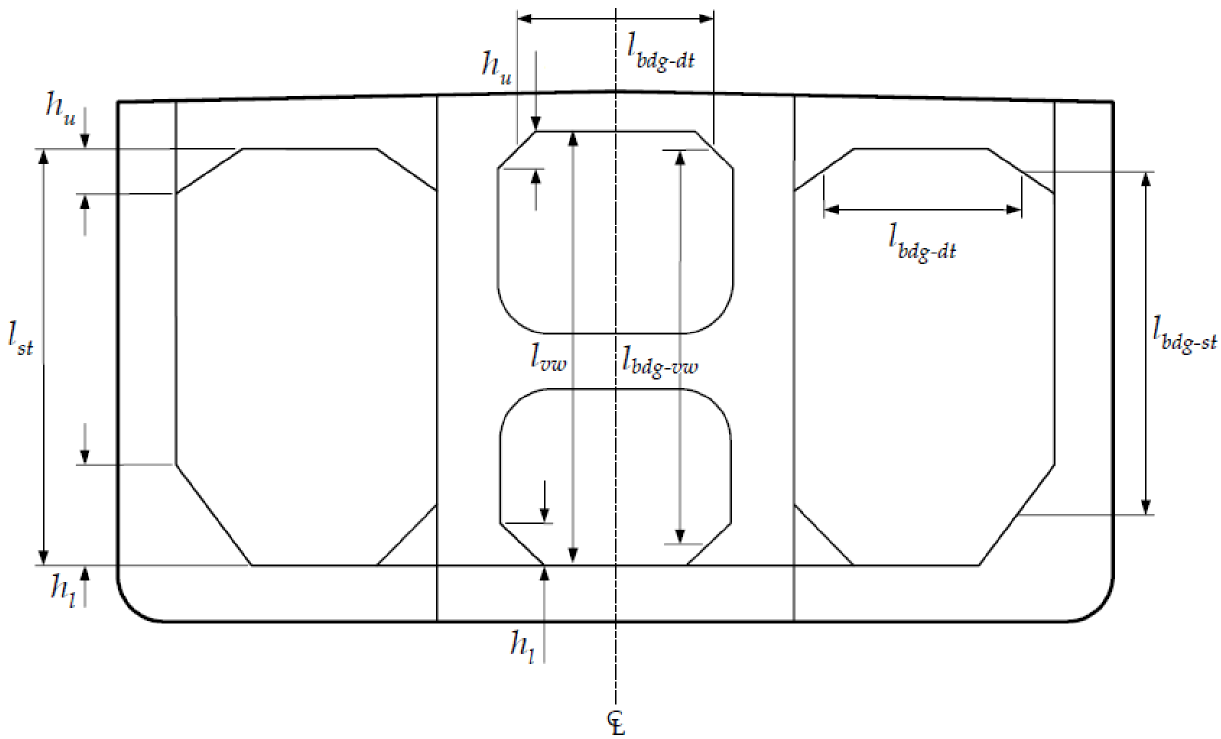


Figure 36 : Definition of spans of deck, side transverses, vertical webframes on longitudinal bulkheads and horizontal stringers on transverse bulkheads **(… continued on next page)**



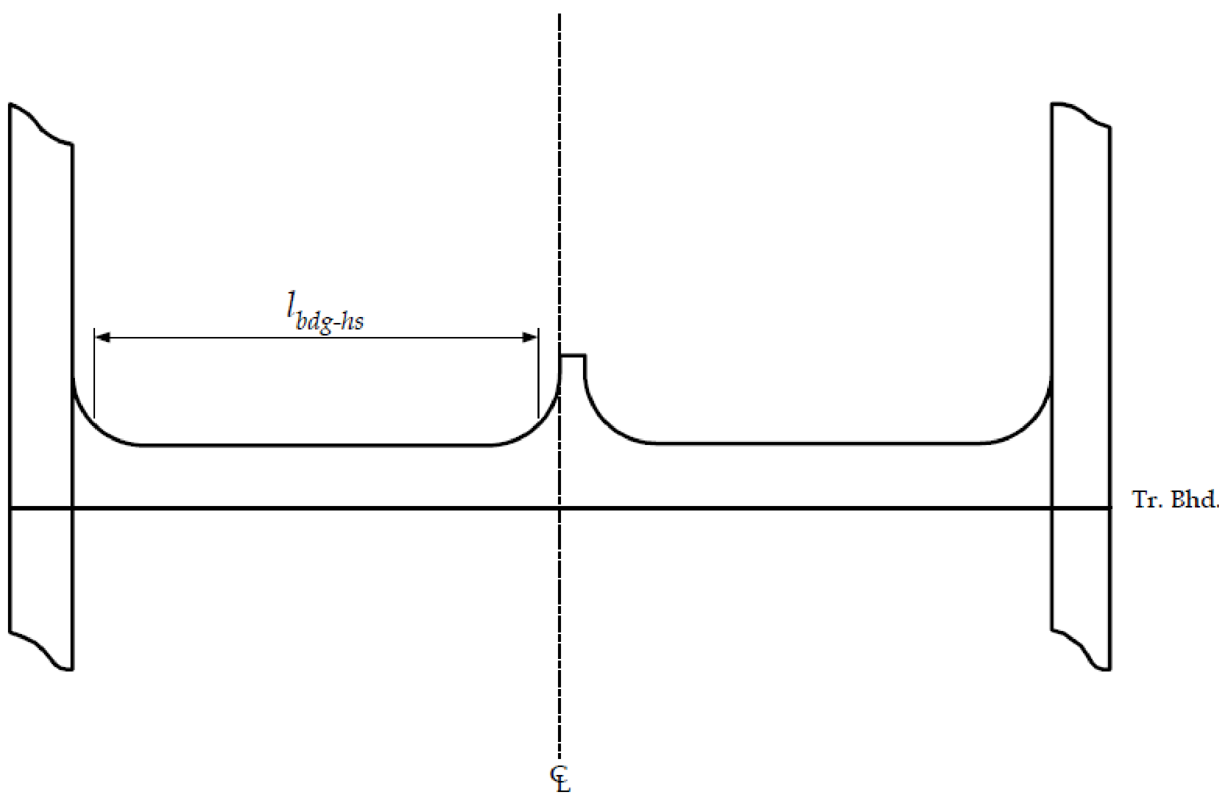


Figure 36 (continued): Definition of spans of deck, side transverses, vertical webframes on longitudinal bulkheads and horizontal stringers on transverse bulkheads

13.7.4.5 The scantlings of deck transverses in cargo tanks where one or more deck girders have been fitted will be specially considered by IRS. The requirements of 13.7.4 could be used to obtain trial values for the scantlings of deck transverses and girders followed by detailed evaluations as specified in 13.7.1.6.

13.7.5 Side Transverses

13.7.5.1 The net shear area $A_{shr-net50}$ of side transverses is not to be less than

$$A_{shr-net50} = \frac{10Q}{C_{t-pr}\tau_{yd}} \quad [cm^2]$$

Where:

Q : design shear force as shown below

Q $=Q_u$ for upper part of side transverse
$=Q_l$ for lower part of side transverse

$$Q_u = S[c_u l_{st}(P_u + P_l) - h_u P_u] \quad [kN]$$

Where a cross tie is fitted in a wing cargo tank and $l_{st-ct} > 0.7 l_{st}$, then l_{st} in the above formula is to be taken as l_{st-ct}

Q_l is to be taken as the greater of the following [kN]

a. $S[c_l l_{st}(P_u + P_l) - h_u P_l]$
b. $0.35 c_l S l_{st}(P_u + P_l)$
c. $1.2Q_u$

Where a cross tie is fitted in a wing cargo tank and $l_{st-ct} > 0.7 l_{st}$, then lst in the above formula is to be taken as l_{st-ct}

P_u : Design pressure for the load set being considered [kN/m^2], calculated at mid-tank as follows:

a. where deck transverses are fitted below deck, P_u is to be calculated at mid height of upper bracket of the side transverse, h_u
b. where deck transverses are fitted above deck, P_u is to be calculated at the elevation of the deck at side, except in cases where item (c) applies
c. where deck transverses are fitted above deck and the inner hull longitudinal bulkhead is arranged with a top wing structure as follows:
   - the breadth at top of the wing structure is greater than 1.5 times the breadth of the double side
   - the angle at a line between the point at the base of the slope plate at its intersection with the inner hull longitudinal bulkhead and the point of intersection of top wing structure and deck is 30 degrees or more to the vertical

P_u is to be calculated at mid depth of the top wing structure

P_l : corresponding design pressure for the design load set being considered [kN/m^2], calculated at mid height of bilge hopper hl located at mid tank [kN/m^2]

l_{st} : length of the side transverse, in m, and is to be taken as follows:

a. where deck transverses are fitted below deck, l_{st} is the length between the flange of the deck transverse and the inner bottom, see Figure 36
b. where deck transverses are fitted above deck, l_{st} is the length between the elevation of the deck at side and the inner bottom

l_{st-ct} : length of the side transverse, in m, and is to be taken as follows:

a. where deck transverses are fitted below deck, l_{st} is the length between the flange of the deck transverse and mid depth of cross tie, where fitted in wing cargo tank
b. where deck transverses are fitted above deck, l_{st} is the length between the elevation of the deck at side and mid depth of the cross tie, where fitted in wing cargo tank

S : Primary member spacing as defined in Section 1

h_u : effective length of upper bracket of the side transverse, in m, and is to be taken as follows:

a. where deck transverses are fitted below deck, h_u is as shown in Figure 36 (also refer Section 4.6).
b. where deck transverses are fitted above deck, h_u is to be taken as 0.0, except in cases where item (c) applies.
c. where deck transverses are fitted above deck and the inner hull longitudinal bulkhead is arranged with a top wing structure as follows:
   - the breadth at top of the wing structure is greater than 1.5 times the breadth of the double side, and
   - the angle along a line between the point at base of the slope plate at its intersection with the inner hull longitudinal bulkhead and the point at the intersection of top wing structure and the deck is 30 degrees or more to vertical

h_u is to be taken as the distance between the deck at side and the lower end of slope plate of the top wing structure.
h_l : height of bilge hopper, in m, as shown in Figure 36

c_l : as defined in Table 27
c_u : as defined in Table 27
c_{t-pr} : Permissible shear stress coefficient as given in Table 24

13.7.5.2 The shear area over the length of side transverse is to comply with the following:
a. the required shear area for the upper part is to be maintained over the upper 0.2 l_{shr}
b. the required shear area for the lower part is to be maintained over the lower 0.2 l_{shr}
c. where Q_u and Q_l are determined based on l_{st-ct}, the required shear area for the lower part is also to be maintained below the cross tie
d. for Units without cross ties in the wing cargo tanks, the required shear area between the upper and lower parts is to be reduced linearly towards 50% of the required shear area for the lower part at mid span
e. for Units with cross ties in the wing cargo tanks, the required shear area along the span is to be tapered linearly between the upper and lower parts.

Where:
l_{shr} is the effective shear span of the side transverse [m]
$= l_{st} - h_u - h_l$ Where Q_u and Q_l are determined based on l_{st}
$= l_{st-ct} - h_u - h_l$ Where Q_u and Q_l are determined based on l_{st-ct}
For materials of different yield stresses, appropriate adjustments are to be made to account for the differences.

Table 27: Values of c_u and c_l for side transverses

Structural Configuration			c_u		c_l	
Number of side stringers			<3	≥3	<3	≥3
Units with centerline longitudinal bulkhead			0.12	0.09	0.29	0.21
Units with two longitudinal bulkheads	Cross tie in centre cargo tank		0.12	0.09	0.29	0.21
	Cross tie in wing cargo tanks	Q_u or Q_l based on l_{st-ct}	0.12	0.09	0.29	0.21
		Q_u or Q_l based on l_{st}	0.08		0.20	

13.7.6 Vertical Webframes on longitudinal bulkhead

13.7.6.1 The web depth of the vertical web frame on the longitudinal bulkhead is not to be less than:

a. $0.14 l_{bdg-vw}$ for Units with a centerline longitudinal bulkhead
b. $0.09 l_{bdg-vw}$ for Units with two longitudinal bulkheads

Where:

l_{bdg-vw} : effective bending span of the vertical web frame on the longitudinal bulkhead. See also 13.7.6.2 and Figure 36

13.7.6.2 The net section modulus of the vertical webframe is not to be less than:

$$Z_{net50} = \frac{1000M}{C_{s-pr}\sigma_{yd}} \quad [\text{cm}^3]$$

Where:

M : Design bending moment [kNm] as shown below

$= c_u PS l_{bdg-vw}{}^2$ for upper part of the web frame

$= c_l PS l_{bdg-vw}{}^2$ for lower part of the web frame

P : Design pressure for the load set being considered, calculated at midpoint of the effective bending span l_{bdg-vw} of the vertical web frame at mid tank [kN/m^2]

l_{bdg-vw} : Effective bending span of the vertical web frame on the longitudinal bulkhead, between the deck transverse and the bottom structure, [m], Also refer Section 4.6 and Figure 36.

$l_{bdg-vw-ct}$: Effective bending span of the vertical web frame on the longitudinal bulkhead, between the deck transverse and deck transverse and mid depth of the cross tie on Units with two longitudinal bulkheads, [m], also refer Section 4.6

S : Primary member spacing as defined in Section 1

C_{s-pr} : permissible bending stress coefficient as defined in Table 24

c_l : as defined in Table 28

c_u : as defined in Table 28

Table 28 : Values of c_u and c_l for vertical web frame on longitudinal bulkheads

Structural Configuration			c_u	c_l
Units with centreline longitudinal bulkhead			0.057	0.071
Units with two longitudinal bulkheads	Cross tie in centre cargo tank	*M* based on $l_{bdg-vw-ct}$	0.057	0.071
		M based on l_{bdg-vw}	0.012	0.028
	Cross tie in wing cargo tanks	*M* based on $l_{bdg-vw-ct}$	0.057	0.071
		M based on l_{bdg-vw}	0.016	0.032

13.7.6.3 The section modulus over the length of the vertical web frame on the longitudinal bulkhead is to comply with the following:

a. the required section modulus for the upper part is to be maintained over the upper $0.2l_{bdg-vw}$ or $0.2l_{bdg-vw-ct}$, as applicable
b. the required section modulus for the lower part is to be maintained over the lower $0.2l_{bdg-vw}$ or $0.2l_{bdg-vw-ct}$, as applicable
c. where the required section modulus is determined based on $l_{bdg-vw-ct}$, the required section modulus for the lower part is also to be maintained below the cross tie
d. the required section modulus between the upper and lower parts is to be reduced linearly to 70% of the required section modulus for the lower part at mid span

Where l_{bdg-vw} or $l_{bdg-vw-ct}$ are defined in 13.7.6.2

13.7.6.4 The net shear area of the vertical web frame is not to be less than

$$A_{shr-net50} = \frac{10Q}{C_{t-pr}\tau_{yd}} \quad [\text{cm}^2]$$

Where:

Q : Design shear force [kN]; obtained as shown below:

= Q_u for upper part of the web frame

= Q_l for lower part of the web frame

$$Q_u = S[c_u l_{vw}(P_u + P_l) - h_u P_u]$$

where a cross tie is fitted in a centre or wing cargo tank and l_{vw-ct} is greater than $0.7l_{vw}$, then l_{vw} in the above formula is to be taken as l_{vw-ct}.

Q_l : To be taken as the lower of the following

a. $S[c_l l_{vw}(P_u + P_l) - h_l P_l]$

b. $c_w c_l S l_{vw}(P_u + P_l)$
c. $1.2Q_u$

where a cross tie is fitted in a centre or wing cargo tank and $l_{vw\text{-}ct}$ is greater than $0.7l_{vw}$, then l_{vw} in the above formula is to be taken as $l_{vw\text{-}ct}$.

P_u : Design pressure for the design load set being considered, calculated at mid height of upper bracket of the vertical web frame, h_u, located at mid tank [kN/m^2]

P_l : Design pressure for the design load set being considered, calculated at mid height of lower bracket of the vertical web frame, h_l, located at mid tank, [kN/m^2]

l_{vw} : Length of the vertical web frame, [m] between the flange of the deck transverse and the inner bottom, see Figure 36

$l_{vw\text{-}ct}$: Length of the vertical web frame, [m] between the flange of the deck transverse and mid depth of the cross tie, where fitted

S : Primary support member spacing as defined in Section 1.

h_u : Effective length of upper bracket of the vertical web frame, [m] as shown in Figure 36. Also refer Section 4.6.

h_l : Effective length of lower bracket of the vertical web frame, [m] as shown in Figure 36. Also refer Section 4.6

c_w = 0.57 for Units with centerline longitudinal bulkhead

= 0.50 for Units with two longitudinal bulkheads

c_l : as defined in Table 29

c_u : as defined in Table 29

$C_{t\text{-}pr}$: permissible shear stress coefficient as defined in Table 24

13.7.6.5 The shear area over the length of the vertical web frame on the longitudinal bulkhead is to comply with the following:

a. the required shear area for the upper part is to be maintained over the upper $0.2l_{shr}$
b. the required shear area for the lower part is to be maintained over the lower $0.2l_{shr}$
c. where Q_u and Q_l are determined based on $l_{vw\text{-}ct}$, the required shear area for the lower part is also to be maintained below the cross tie
d. for Units without cross ties in the wing or centre cargo tanks, the required shear area between the upper and lower parts is to be reduced linearly towards 50% of the required shear area for the lower part at mid span
e. for Units with cross ties in the wing or centre cargo tanks, the required shear area along the span is to be tapered linearly between the upper and lower parts

Where:

l_{shr} : effective span between the transverse

$= l_{vw} - h_u - h_l$ Where Q_u and Q_l are determined based on l_{vw}

$= l_{vw-ct} - h_u$ Where Q_u and Q_l are determined based on $l_{vw\text{-}ct}$

l_{vw}, $l_{vw\text{-}ct}$, h_u, h_l, Q_u and Q_l are defined in 13.7.6.4

Table 29 : Values of c_u and c_l for vertical web frame on longitudinal bulkhead

Structural Configuration			c_u	C_l
Units with centerline longitudinal bulkhead			0.17	0.28
Units with two longitudinal bulkheads	Cross tie in centre cargo tank			
	Cross tie in wing cargo tanks	Q_u or Q_l based on $l_{vw\text{-}ct}$		
		Q_u or Q_l based on l_{vw}	0.075	0.18

13.7.7 Horizontal Stringers on Transverse Bulkheads

13.7.7.1 The web depth of the horizontal stringers on transverse bulkhead is not to be less than:

a. $0.28l_{bdg-hs}$ for horizontal stringers in wing cargo tanks of Units two longitudinal bulkheads
b. $0.20l_{bdg-vw}$ for horizontal stringers in centre tanks of Units with two longitudinal bulkheads, but the web depth of horizontal stringers in centre tanks is not to be less than the required depth for a horizontal stringer in wing cargo tanks.
c. $0.20l_{bdg-vw}$ for horizontal stringers in Units with centreline bulkhead
d. See also Section 13.7.1

l_{bdg-hs} : effective bending span of the horizontal stringer on the transverse bulkhead [m], but not to be taken less than 50% of the breadth of the tank under consideration. Also refer Section 4.6 and Figure 36

13.7.7.2 The net section modulus of the horizontal stringer over the end $0.2l_{bdg-hs}$ is not to be less than:

$$Z_{net50} = \frac{1000M}{C_{s-pr}\sigma_{yd}} \quad [cm^3]$$

Where:

M : Design bending moment [kNm] as shown below
$= cPSl_{bdg-hs}{}^2$

P : Design pressure for the load set being considered, calculated at midpoint of the effective bending span l_{bdg-hs} and at midpoint of spacing S of the horizontal stringer [kN/m^2]

l_{bdg-hw} : Effective bending span of the horizontal stringer [m], but not less than 50% of the breadth of the tank at the location being considered. Also refer Section 4.6 and Figure 36

c = 0.073 for horizontal stringers in cargo tanks of Units with centerline bulkhead
=0.083 for horizontal stringers in wing cargo tanks of Units with two longitudinal bulkheads
=0.063 for horizontal stringers in the centre tanks of Units with two longitudinal bulkheads

S : sum of half spacing (distance between horizontal stringers) on each side of the horizontal stringer under consideration

C_{s-pr} : permissible bending stress coefficient as defined in Table 24

13.7.7.3 The required section modulus at mid effective bending span is to be taken as 70% of that required at the ends; intermediate values are to be obtained by linear interpolation. When materials of different yield stress are employed, appropriate adjustments are to be made to account for differences in material yield stress.

13.7.7.4 The net shear area of the vertical web frame is not to be less than

$$A_{shr-net50} = \frac{10Q}{C_{t-pr}\tau_{yd}} \quad [cm^2]$$

Where:

Q : Design shear force [kN]; obtained as shown below:
$= 0.5PSl_{shr}$

P : Design pressure for the load set being considered, calculated at midpoint of the effective bending span l_{bdg-hs} and at midpoint of spacing S of the horizontal stringer [kN/m^2]

S : Sum of half spacing (distance between horizontal stringers) on each side of the horizontal stringer under consideration

C_{t-pr} : Permissible shear stress coefficient as defined in Table 24

l_{shr} : Effective shear span of the stringer [m], also refer 4.6.

13.7.7.5 The required shear area at mid effective shear span is to be taken as 50% of that required in the ends, intermediate values are to be obtained by linear interpolation. When materials of different yield stress are employed, appropriate adjustments are to be made to account for differences in material yield stress.

13.7.8 Cross ties

13.7.8.1 The maximum applied design axial load on cross ties, W_{ct}, is to be less than or equal to the permissible load, $W_{ct\text{-}perm}$, as given by:

$$W_{ct} \leq W_{ct-perm}$$

Where:

W_{ct} : Applied axial load [kN] as given below

$$= Pb_{ct}S$$

$W_{ct\text{-}perm}$: Permissible axial load [kN] as given below

$$= 0.1A_{c-net50}\eta_{ct}\sigma_{cr}$$

P : Maximum design pressure for all the applicable design load sets being considered, calculated at centre of the area supported by the cross tie located at mid tank, [kN/m^2]

b_{ct} =0.5$l_{bdg\text{-}vw}$ where cross tie is fitted in centre cargo tank

=0.5$l_{bdg\text{-}vw}$ for design cargo pressure from cargo in centre tank where cross tie is fitted in wing cargo tank

=0.5$l_{bdg\text{-}st}$ for design sea pressure where cross tie is fitted in wing cargo tank

$l_{bdg\text{-}vw}$: Effective bending span of the vertical web frame on the longitudinal bulkhead (also see figure 36)

$l_{bdg\text{-}st}$: Effective bending span of the side transverse (also Refer Figure 36 and Section 4.6)

S : Primary member spacing as defined in Section 1

η_{ct} : Utilization factor

=0.65 for AC1 criteria

=0.75 for AC2 criteria

σ_{cr} : Critical buckling stress in compression of cross tie [N/mm^2] as calculated using section properties in accordance with Section 20. The effective length of the cross tie is to be taken as:

a. For Cross tie in Centre tank - distance between the flanges of longitudinal stiffeners on the starboard and port longitudinal bulkheads to which the cross tie's horizontal stiffeners are attached
b. For Cross tie in wing tank - distance between the flanges of longitudinal stiffeners on the longitudinal bulkhead to which the cross tie's horizontal stiffeners are attached, and the inner hull plating

$A_{c\text{-}net50}$: net cross sectional area of cross tie [cm^2]

13.7.8.2 Special attention is to be paid to the adequacy of the welded connections for the transmission of the forces, and also to the stiffening arrangements, in order to provide effective means for transmission of the compressive forces into the webs. Particular attention is to be paid to the welding at the toes of all end brackets of the cross ties.

13.7.8.3 Horizontal stiffeners are to be located in line with, and attached to, the longitudinals at the ends of the cross ties.

13.7.9 Primary Support members beyond 0.4*L* amidships

13.7.9.1 Net section modulus of primary support members located beyond 0.4*L* amidships is not to be less than

$$Z_{end-net50} = \frac{Z_{mid-net50}\sigma_{yd-mid}M_{end}}{\sigma_{yd-end}M_{mid}} \quad [\text{cm}^3]$$

Where:

M_{end} : Bending moment, in kNm, for the structural member under consideration located beyond 0.4*L* amidships, calculated in accordance with corresponding requirements of 13.7.2 –

13.7.8 and using the design pressure specified for the given location

M_{mid} : Bending moment, in kNm, for the corresponding structural member and location of cross section, amidships, obtained from the corresponding requirements of 13.7.2 – 13.7.8

$Z_{mid-net50}$: Net section modulus at the flange of the corresponding structural member and location of cross section amidships, [cm^3]

σ_{yd-end} : Specified minimum yield stress of the flange of the structural member under consideration located beyond 0.4*L* amidships [N/mm^2]

σ_{yd-mid} : Specified minimum yield stress [N/mm^2] of the flange of the structural member under consideration amidships

13.7.9.2 Net shear area of primary support members located beyond 0.4L amidships is not to be less than

$$A_{shr-end-net50} = \frac{A_{shr-mid-net50}\tau_{yd-mid}Q_{end}}{\tau_{yd-end}Q_{mid}}$$

[cm^2]

Where:

Q_{end} : Shear force [kN] for the structural member under consideration located beyond 0.4*L* amidships, calculated in accordance with corresponding requirements of 13.7.2 – 13.7.8 and using the design pressure specified for the given location

Q_{mid} : Shear force [kN] for the corresponding structural member and location of cross section, amidships, obtained from the corresponding requirements of 13.7.2 – 13.7.8

$A_{mid-net50}$: Shear area of the corresponding structural member and location of cross section amidships [cm^2]

τ_{yd-end} $= \sigma_{yd-end}/\sqrt{3}$

τ_{yd-mid} $= \sigma_{yd-mid}/\sqrt{3}$

Section 14
Forward Region

14.1 Symbols

L_2 : Rule length, *L* [m] as defined in Section 1 but need not be taken greater than 300m

σ_{yd} : Specified minimum yield stress of the material [N/mm^2]

s : Stiffener spacing [mm] as defined in Section 1

14.2 General

14.2.1 Application

14.2.1.1 The requirements of this sub-section apply to the structure forward of the forward end of the foremost cargo tank. Where the forward end of the foremost cargo tank is aft of 0.1*L* of the Unit's length, measured from FP, special consideration will be given by IRS to the applicability of these requirements and the requirements within Section 13.

14.2.1.2 Requirements in 13.2.2.4 are to be complied with as applicable.

14.2.2 General Scantling Requirements

14.2.2.1 The hull structure is to comply with the applicable requirements of:

a. Hull girder longitudinal strength, see Section 12
b. Strength against sloshing and impact loads, see Section 17
c. Buckling and ultimate strength, see Section 20

14.2.2.2 The deck plating thickness and supporting structure are to be suitably reinforced in way of topside units, deck machinery, and in way of cranes, masts, anchor windlass and derrick posts.

14.2.2.3 The net section modulus, shear area and other sectional properties of local and primary support members are to be determined in accordance with IRS Rules for Bulk Carrier and Oil Tankers, Volume 2, Part 1, Chapter 3, Section 7

14.2.2.4 The section modulus and web thickness of local support members apply to the areas clear of the end brackets. The section modulus and cross sectional shear areas of primary support members are to be applied as required in the notes to Table 39.

14.2.2.5 The scantling criteria are based on assumptions that all structural joints and welded details are designed and fabricated such that they are compatible with the anticipated working stress levels at the location considered. The loading patterns, stress concentration and potential failure modes of structural joints and details during the design of highly stressed regions are to be considered. Structural design details are to comply with requirements in IRS Rules for Bulk Carrier and Oil Tankers, Volume 2, Part 1, Chapter 3, Section 6.

14.2.2.6 Limber, drain and air holes are to be cut in all parts of the structure, as required, to ensure free flow to the suction pipes and the escape of air to the vents. Arrangements are to be made for draining the spaces above deep tanks. See also IRS Rules for Bulk Carrier and Oil Tankers, Volume 2, Part 1, Chapter 3, Section 6.

14.2.2.7 Web stiffeners are to fitted on primary support members at each longitudinal on the side and bottom shell. Alternative arrangements may be accepted by IRS where adequacy of stiffener end connections and strength of adjoining web and bulkhead plating is demonstrated.

14.2.3 Structural Continuity

14.2.3.1 Scantlings of the shell envelope, upper deck and inner bottom are to be tapered towards the forward end. See also Section 12.6.

14.2.3.2 In the transition zone aft of the fore peak into the forward cargo tank, due consideration is to be given to the arrangement of major longitudinal members in order to avoid abrupt changes in section. Structures within the fore peak, such as flats, decks, horizontal ring frames or side stringers, are to be scarphed effectively into the structure aft into the cargo tank. Where such structures are in line with longitudinal members aft of the forward cargo tank bulkhead fitting of tapered transition brackets may be used.

14.2.3.3 Where inner hull or longitudinal bulkhead structures terminate at the forward bulkhead of the forward cargo tank, adequate backing structure is to be provided together with tapering brackets to ensure continuity of strength.

14.2.3.4 Longitudinal framing of the strength deck is to be carried as far forward as practicable.

14.2.3.5 All shell frames and tank boundary stiffeners are to be continuous, or are to be bracketed at their ends, except as permitted in IRS Rules for Bulk Carrier and Oil Tankers, Volume 2, Part 1, Chapter 3, Section 6 [3.3-3.4].

14.2.4 Minimum Thickness

14.2.4.1 In addition to thickness, section modulus and stiffener web shear area requirements as given in this sub-section, the thickness of plating and stiffeners in forward region are to comply with appropriate minimum thickness requirements given in Tables 15 – 16, except for members as shown in Table 30.

Table 30: Minimum net thickness of structure forward of the forward cargo tank	
Scantling Location	**Net Thickness**
Pillar bulkheads	7.5
Breasthooks	6.5
Floor and bottom girders	$5.5 + 0.02L_2$
Web plating of primary supporting members	$6.5 + 0.015L_2$

14.3 Bottom Structure

14.3.1 Plate Keel

14.3.1.1 A flat keel is to be extended as far forward as practical and is to satisfy the scantling requirements given in Section 13.3.1.

14.3.2 Bottom Shell Plating

14.3.2.1 The thickness of the bottom shell plating is to comply with the requirements in Section 14.11.2.1.

14.3.3 Bottom Longitudinals

14.3.3.1 Bottom longitudinals are to be carried as far forward as practicable. Beyond this, suitably stiffened frames are to be fitted.

14.3.3.2 The section modulus and thickness of the bottom longitudinals are to comply with the requirements in Section 14.11.2.2 and Section 14.11.2.3.

14.3.4 Bottom Floors

14.3.4.1 Bottom floors are to be fitted at each web frame location. The minimum depth of the double floor at the centerline is to be not to be less than the required depth of the double bottom of the cargo tank region. Also refer Section 3 for the related arrangements.

14.3.5 Bottom Girders

14.3.5.1 A supporting structure is to be provided at the centerline either by extending the centerline girder to the stem or by providing a deep girder or centerline bulkhead.

14.3.5.2 Where a centerline girder is fitted, the minimum depth and thickness is not to be less than that required for the depth of the double bottom in the cargo tank region, and the upper edge is to be stiffened. Where a centerline wash bulkhead is fitted, the lowest strake is to have thickness not less than required for a centerline girder.

14.3.6 Plate Stems

14.3.6.1 Plate stems are to be supported by stringers and flats, and by intermediate breasthook diaphragms spaced not more than 1500mm apart, measured along the stem. Where the stem radius is large, a centerline support structure is to be fitted.

14.3.6.2 Between the minimum design light draught, T_{Bal}, at the stem and the deep loading draught, T_{sc}, the plate stem net thickness, $t_{stem-net}$, is not to be less than:

$$t_{stem-net} = \frac{L_2\sqrt{\frac{235}{\sigma_{yd}}}}{12}$$

[mm] but need not to be taken greater than 21 mm

Above the deep load draught the thickness of the stem plate may be tapered to the requirements for the shell plating at the upper deck.

Below the minimum design light load draught the thickness of the stem plate may be tapered to the requirements for the plate keel.

14.3.7 Floors and Girders in Space Aft of the Collision Bulkhead

14.3.7.1 Floors and girders which are aft of the collision bulkhead and forward of the forward cargo tank, are to comply with requirements in 14.3.4 and 14.3.5 and are to comply with the shear area requirements in 14.11.3.3.

14.4 Side Structures

14.4.1 Side Shell Plating

14.4.1.1 The thickness of the side shell plating is to comply with the requirements in 14.11.2. Where applicable, the thickness of the side shell plating is to comply with the requirements in 13.3.4.1.

14.4.1.2 Where a forecastle is fitted, the side shell plating requirements are to be applied to the plating extending to the forecastle deck elevation.

14.4.2 Side Shell Local Support Members
14.4.2.1 Longitudinal framing of the side shell is to be carried as far forward as practicable.

14.4.2.2 The section modulus and thickness of the hull envelope framing is to comply with the requirements in 14.11.2.2 and 14.11.2.3.

14.4.2.3 End connections of longitudinals at transverse bulkheads are to provide adequate fixity, lateral support, and where not continuous are to be provided with soft-nosed brackets. Brackets lapped onto the longitudinals are not to be used.

14.4.3 Side Shell Primary Support Structure
14.4.3.1 In general, the spacing of web frames, S, is to be taken as

$S = 2.6 + 0.005L_2$ [m], but not to be taken greater than 3.5 m

14.4.3.2 In general, the transverse framing forward of the collision bulkhead stringers are to be spaced approximately 3.5m apart. Stringers are to have an effective span not greater than 10m, and are to be adequately supported by web frame structures. Aft of the collision bulkhead, where transverse framing is adopted, the spacing of stringers may be increased.

14.4.3.3 Perforated flats are to be fitted to limit the effective span of web frames to not greater than 10m.

14.4.3.4 The scantlings of web frames supporting longitudinal frames, and stringers and/or web frames supporting transverse frames in the forward region are to be determined from 14.11.3, with the following additional requirements:

a. Where no cross ties are fitted:
   - The required section modulus of the web frame is to be maintained for 60% of the effective span for bending, measured from the lower end. The value of the bending moment used for calculation of the required section modulus of the remainder of the web frame may be appropriately reduced, but not greater than 20%
   - The required shear area of the lower part of the web frame is to be maintained for 60% of the shear span measured from the lower end.
b. Where one cross tie is fitted:
   - The effective spans for bending and shear of a web frame or stringer are to be taken ignoring the presence of the cross tie. The shear forces and bending moments may be reduced to 50% of the values that are calculated ignoring the presence of the cross ties. For a web frame, the required section modulus and shear area of the lower part of the web frame is to be maintained up to the cross tie, and the required section modulus and shear area of the upper part of the web frame is to be maintained for the section above the cross tie
   - Cross ties are to be designed using the applicable design loads specified in Table 23.
c. Configurations with multiple cross ties are to be specially considered, in accordance with 14.4.3.4d.
d. Where complex grillage structures are employed the suitability of the scantlings of the primary support members is to be determined by more advanced calculation methods.

14.4.3.5 The web depth of primary support members is not to be less than 14% of the bending span and is to be at least 2.5 times as deep as the slots for stiffeners if the slots are not closed.

14.5 Deck Structure

14.5.1 Deck Plating

14.5.1.1 The thickness of the deck plating is to comply with the requirements in 14.11.2.1 with the applicable lateral pressure, green sea and deck loads.

14.5.2 Deck Stiffeners

14.5.2.1 The section modulus and thickness of deck stiffeners are to comply with the requirements in 14.11.2.2 and 14.11.2.3, with the applicable lateral pressure, green sea and deck loads.

14.5.3 Deck Primary Support Structures

14.5.3.1 The section modulus and shear area of primary support members are to comply with the requirements in 14.11.3.

14.5.3.2 The web depth of primary support members is not to be less than 10% and 7% of the unsupported span in bending in tanks and in dry spaces, respectively, and is not to be less than 2.5 times the depth of the slots if the slots are not closed. In case of a grillage structure, the distance between connections to other primary support members.

14.5.3.3 In way of concentrated loads from heavy equipment and topside modules, the scantlings of the deck structure are to be determined based on the actual loading. See Section 18.

14.5.4 Pillars

14.5.4.1 Pillars are to be fitted in the same vertical line wherever possible and effective arrangements are to be made to distribute the load at the heads and heels of all pillars. Where pillars support eccentric loads, they are to be strengthened for the additional bending moment imposed upon them.

14.5.4.2 Tubular and hollow square pillars are to be attached at their heads and heels by efficient brackets or doublers/insert plates, where applicable, to transmit the load effectively. Pillars are to be attached at their heads and heels by continuous welding. At the heads and heels of pillars built of rolled sections, the load is to be distributed by brackets or other equivalent means.

14.5.4.3 Pillars in tanks are to be of solid section. Where the hydrostatic pressure may result in tensile stresses in the pillar, the tensile stress in the pillar and its end connections is not to exceed 45% of the specified minimum yield stress of the material.

14.5.4.4 The scantlings of pillars are to comply with the requirements in 14.11.5.

14.5.4.5 Where the loads from heavy equipment exceed the design load of 14.11.5, the pillar scantlings are to be determined based on the actual loading.

14.6 Bulkheads

14.6.1 General

14.6.1.1 Tanks may be required to have divisions or deep wash plates in order to minimize the dynamic stress on the structure.

14.6.2 Construction

16.6.2.1 In no case are the scantlings of tank boundary bulkheads to be less than the requirements for watertight bulkheads.

14.6.3 Scantling of Tank Boundary Bulkheads

14.6.3.1 The thickness of tank boundary plating is to comply with the requirements in 14.11.2.1.

14.6.3.2 The section modulus and thickness of stiffeners are to comply with the requirements in 14.11.2.2 and 14.11.2.3.

14.6.3.3 The section modulus and shear area of primary support members are to comply with the requirements in 14.11.3.

14.6.3.4 Web plating of primary support members is to have a depth of not less than 14% of the unsupported span in bending, and is not to be less than 2.5 times the depth of the slots if the slots are not closed.

14.6.3.5 Scantlings of corrugated bulkheads are to comply with the requirements in 14.11.4.

14.7 Watertight Boundaries

14.7.1 General

14.7.1.1 Watertight boundaries are to be fitted in accordance with Section 3.

14.7.2 Collision Bulkhead

14.7.2.1 The scantlings of structural components of the collision bulkheads are to comply with the requirements given in 14.7.3, as applicable. Additionally, the collision bulkhead is to comply with the requirements in 14.7.2.2 to 14.7.2.4.

14.7.2.2 The position of the collision bulkhead is to be in accordance with Section 3.

14.7.2.3 Doors, manholes, permanent access openings or ventilation ducts are not to be cut in the collision bulkhead below the freeboard deck. Where the collision bulkhead is extended above the freeboard deck, the number of openings in the extension is to be kept to a minimum compatible with the design and proper working of the Unit. The openings are to be fitted with weathertight closing appliances. The collision bulkhead may be pierced by pipes necessary for dealing with the contents of tanks forward of the bulkhead, provided the pipes are fitted with valves capable of being operated from above the freeboard deck. The valves are generally to be fitted on the collision bulkhead inside the fore peak and are not to be fitted inside the cargo tank.

14.7.2.4 Compartments forward of the collision bulkhead may not be arranged for the carriage of flammable liquids.

14.7.3 Scantling of Watertight Boundaries

14.7.3.1 The thickness of boundary plating is to comply with the requirements given in 14.11.2.1.

14.7.3.2 The section modulus and thickness of stiffeners are to comply with the requirements in 14.11.2.2 and 14.11.2.3.

14.7.3.3 The section modulus and shear area of primary support members are to comply with the requirements in 14.11.3.

14.7.3.4 Web plating of primary support members is to have a depth of not less than 10% of the unsupported span in bending, and is not to be less than 2.5 times the depth of the slots if the slots are not closed.

14.7.3.5 Scantlings of corrugated bulkheads are to comply with the requirements in 14.11.4.

14.8 Superstructure

14.8.1 Forecastle structures

14.8.1.1 Forecastle structures are to be supported by girders with deep beams and web frames, and in general, arranged in complete transverse belts and supported by lines of pillars extending down into the structure below. Deep beams and girders are to be arranged, where practicable, to limit the spacing between deep beams, web frames, and/or girders to about 3.5m. Pillars are to be provided as required by 14.5.4 in this section. Main structural intersections are to be carefully developed with special attention given to pillar head and heel connections, and to the avoidance of stress concentrations.

14.9 Mooring & Riser Systems Support Structures

14.9.1. Applicable Requirements in Chapter 5 are to be complied.

14.10 Miscellaneous Structures

14.10.1 Pillar Bulkheads

14.10.1.1 Bulkheads that support girders, or pillars and longitudinal bulkheads which are fitted in lieu of girders are to be stiffened to provide supports not less effective than required for stanchions or pillars. The acting load and the required net cross sectional area of the pillar section are to be determined using the requirements of 14.5.4. The net moment of inertia of the stiffener is to be calculated with a width of $40t_{net}$, where t_{net} is the net thickness of plating [mm].

14.10.1.2 Pillar bulkheads are to comply with the following requirements:

a. The distance between bulkhead stiffeners is not to exceed 1500mm

b. Where corrugated, the depth of the corrugation is not to be less than 100mm.

14.11 Scantling Requirements

14.11.1 General

14.11.1.1 The applicable design load sets are to considered for the plating, local support and primary support members as given in Tables 21 & 23. The static and dynamic load components are to be combined in accordance DLCFs provided in Section 11.

14.11.2 Plating and Local Support Members

14.11.2.1 For plating subjected to lateral pressure, the net plating thickness, t_{net}, is to be calculated using the formulae as provided in Table 17, however the permissible bending stress coefficient, C_a is to be taken as shown in Table 31.

Table 31: Permissible bending stress coefficient for plating		
Acceptance criteria set	Structural member	C_a
AC1	All plating	0.80
AC2	Hull envelope plating	0.95
	Internal boundary plating	1.00
AC3	All plating	1.00

14.11.2.2 For stiffeners subjected to lateral pressure, the net section modulus, Z_{net}, is to be calculated using the formulae in Table 18, however the permissible bending stress coefficient, C_s is to be taken as shown in Table 32.

Table 32: Permissible bending stress coefficient for stiffeners		
Acceptance criteria set	Structural member	C_s
AC1	All Stiffeners	0.75
AC2	All Stiffeners	0.90
AC3	All Stiffeners	1.00

14.11.2.3 The stiffeners subjected to lateral pressure, the net web thickness based on shear area requirements, $t_{w\text{-}net}$, is to be calculated using the formulae in Table 19 with shear stress coefficient C_t as shown in Table 33.

Table 33: Permissible shear stress coefficient for stiffeners		
Acceptance criteria set	Structural member	C_t
AC1	All Stiffeners	0.75
AC2	All Stiffeners	0.90
AC3	All Stiffeners	1.00

14.11.3 Primary Support Members

14.11.3.1 For primary support members intersecting with or in way of curved hull sections, the effectiveness of end brackets is to include allowance for the curvature of the hull. For side transverse frames, the requirements may be reduced due to the presence of cross ties, see 14.4.3.4.

14.11.3.2 For primary support members subjected to lateral pressure, the net section modulus, Z_{net50}, is to be evaluated using formulae provided in 18.3.3.4 for applicable design load sets in Table 23.

14.11.3.3 For primary support members subjected to lateral pressure, the effective net shear area, $A_{\text{shr-net50}}$, is to be evaluated with formulae provided in 18.3.3.5 for applicable design load sets in Table 23.

14.11.3.4 Primary support members are to generally be analyzed with the specific methods as described for the particular structure type. IRS may require advanced calculations to be submitted if deemed necessary.

14.11.4 Corrugated Bulkheads

14.11.4.1 Special consideration will be given to the approval of corrugated bulkheads where fitted. Scantling requirements of corrugated bulkheads in the cargo tank region may be used as a basis, (see 13.6.6 and 13.6.7).

14.11.5 Pillars

14.11.5.1 The maximum load on a pillar, W_{pill}, is to be taken as the greatest value calculated for applicable design load sets, as given in Table 21 or 23 and is to be less than or equal to the permissible pillar load as given by the following equation, where $W_{pill\text{-}perm}$ is based on the net properties of the pillar.

$$W_{pill} \leq W_{pill-perm}$$

Where:

W_{pill} : Applied axial load on pillar

$$= Pb_{a-sup}l_{a-sup} + W_{pill-upr} \quad \text{[kN]}$$

$W_{pill\text{-}perm}$: Permissible load on a pillar

$$= 0.1A_{pill-net50}\eta_{pill} + \sigma_{crb} \quad \text{[kN]}$$

P : Design pressure for the design load set being considered, calculated at centre of the deck area supported by the pillar being considered [kN/m^2]

$b_{a\text{-}sup}$: Mean breadth of area supported [m]

$l_{a\text{-}sup}$: Mean length of area supported [m]

$W_{pill\text{-}upr}$: Axial load from pillar or pillars above [kN]

$A_{pill\text{-}net50}$: Net cross section area of the pillar [cm^2]

h_{pill} : Utilization factor for the design load set being considered:

= 0.5 for acceptance criteria set AC1

= 0.6 for acceptance criteria set AC2

= 0.65 for acceptance criteria set AC3

σ_{crb} : Critical buckling stress in compression of pillar based on the net sectional properties calculated in accordance with Section 20 [N/mm^2]

Section 15

Machinery Space

15.1 Symbols

σ_{yd} : Specified minimum yield stress of the material [N/mm^2]

$I_{v\text{-}net50}$: Net vertical hull girder moment of inertia [m^4], at the longitudinal position being considered, as defined in 4.6.1

l_{bdg} : Effective bending span [m] as defined in Section 1

s : Stiffener spacing as defined in Section 1 [mm]

z : Vertical coordinate of the load calculation point under consideration [m]

$z_{NA\text{-}net50}$: Distance from the baseline to the horizontal neutral axis

15.2 General

15.2.1 Application

15.2.1.1 This section prescribes scantling requirements for a machinery space /spaces located at any longitudinal frame location. The requirements of this section apply to all machinery spaces, regardless of location. For conventional self-propelled FOUs, the requirements of Rules and Regulations for Construction and Classification of Steel Ships, Part 4 may be used for guidance.

15.2.1.2 Where machinery space is permitted to overlap either of the regions defined in Section 14 and Section 16, the most onerous requirements for machinery space and overlapping region are to take precedence.

15.2.1.3 For machinery space located in forward or aft region susceptible to local impact and slamming loads, scantlings are also to be checked for local slamming and impact loads in addition to requirements in this section.

15.2.1.4 Requirements in 13.2.2.4 are to be complied as applicable.

15.2.2 General Scantling Requirements
15.2.2.1 The hull structure is to also comply with the applicable requirements of:

a. Hull girder longitudinal strength, see Section 12
b. Strength against sloshing and impact loads, see Section 17
c. Buckling and ultimate strength, see Section 20

15.2.2.2 The net section modulus, shear area and other sectional properties of local and primary support members are to be calculated in accordance with considerations in Section 4.6

15.2.2.3 The section modulus and web thickness of local support members apply to the area clear of the end brackets. The section modulus and cross sectional shear areas of primary support members are to be utilized in accordance with instructions in the notes to Table 39.

15.2.2.4 The scantling criteria are based on assumptions that all structural joints and welded details are designed and fabricated such that they are compatible with the anticipated working stress levels at the location considered. The loading patterns, stress concentration and potential failure modes of structural joints and details during the design of highly stressed regions are to be considered. Detail design is to be in accordance with requirements in Section 23.

15.2.2.5 Limber, drain and air holes are to be cut in all parts of the structure, as required, to ensure free flow to the suction pipes and the escape of air to the vents. Arrangements are to be made for draining the spaces above deep tanks. See also Section 23.

15.2.3 Structural Continuity
15.2.3.1 Scantlings of the shell envelope, upper deck and inner bottom are to be tapered towards the aft end. See also Section 12.6.

15.2.3.2 Suitable arrangements are to be made to ensure continuity of strength and the avoidance of abrupt discontinuities when structure that contributes to the main longitudinal strength of the Unit is omitted in way of the machinery space.

15.2.3.3 Where inner hull or longitudinal bulkhead structures terminate at the forward bulkhead of the forward cargo tank, adequate backing structure is to be provided together with tapering brackets to ensure continuity of strength.

15.2.3.4 All shell frames and tank boundary stiffeners are to be continuous, or are to be bracketed at their ends, except as permitted in Section 23.

15.2.3.5 Longitudinal primary support members, lower decks and bulkhead arranged in the engine room are to be aligned with similar structures in the cargo tank region as far as practicable, where direct alignment is not possible, suitable scarphing arrangements such as taper brackets are to be provided.

15.2.4 Arrangements
15.2.4.1 Wherever openings are provided in machinery space, the arrangements are to ensure support for deck, side and bottom structures.

15.2.4.2 All parts of machinery, shafting, system etc. are to be supported to distribute the loads into structure of unit. The adjacent structure is to be suitably stiffened.

15.2.4.3 The primary support members are to be positioned giving consideration to the provision of through stiffeners and in-line pillar supports to achieve an efficient structural design.

15.2.4.4 Based on the propulsion and other machinery, it may require additions to the scantling of the structure and the area of attachments, which are proportional to the weight, power and proportions of the machinery especially where the engines are positioned relatively high in proportion to the width of the bed plate.

15.2.4.5 The foundation for main machinery and where fitted, propulsion system, reduction gear, shaft, thrust bearing and the structure supporting those foundations are to maintain the required alignment and rigidity under all anticipated conditions of loading.

15.2.4.6 A cofferdam is to be provided to separate the cargo tanks from the machinery space. Pump room, ballast tanks, or fuel oil tanks may be considered as cofferdams for this purpose.

15.2.5 Minimum Thickness
15.2.5.1 In addition to the requirements for thickness, section modulus and shear area, as given in 15.3 to 15.9, the thickness of plating and stiffeners in the machinery space is to comply with applicable minimum thickness requirements given in Tables 15 - 16 except as shown in Table 34.

Table 34: Minimum net thickness of structure in the machinery space

Scantling Location		Net Thickness (mm)
Plating (other structure)	Lower decks & flats	$3.3 + 0.0067s$
	Inner bottom	$0.5 + 0.020L_2$
Floors and bottom longitudinal girders off centerline		$5.5 + 0.020L_2$
Web plating of primary support members		$5.5 + 0.015L_2$

15.3 Bottom Structures
15.3.1 General
15.3.1.1 In general, a double bottom is to be fitted in the machinery space. The depth of the double bottom is to be at least the same as required in the cargo tank region. Where the depth of the double bottom in the machinery space differs from that in the adjacent spaces, continuity of the longitudinal material is to be maintained by sloping the inner bottom over a suitable longitudinal extent. Lesser double bottom height may be accepted in local areas provided that the overall strength of the double bottom structure is not thereby impaired.

15.3.2 Bottom Shell Plating
15.3.2.1 The keel plate breadth is to comply with the requirements given in 13.3.1.1.

15.3.2.2 The thickness of the bottom shell plating (including keel plating) is to comply with the requirements in 15.9.1.1.

15.3.3 Bottom Shell Stiffeners
15.3.3.1 The section modulus and thickness of bottom shell stiffeners are to comply with the requirements in 15.9.1.2 – 15.9.1.3.

15.3.4 Girder and Floors
15.3.4.1 The double bottom is to be arranged with a centerline girder.

15.3.4.2 Full depth bottom girders are to be arranged in way of the main machinery to effectively distribute its weight, and to ensure rigidity of the structure. The girders are to be carried as far forward and aft as practicable, and suitably supported at their ends to provide distribution of loads from the machinery. The girders are to be tapered beyond their required extent.

15.3.4.3 Where fitted, side girders are to align with the bottom side girders in the adjacent space.

15.3.4.4 Where the double bottom is transversely framed, plate floors are to be fitted at every frame.

15.3.4.5 Where the double bottom is longitudinally framed, plate floors are to be fitted at every frame under the main engine and thrust bearing. Outboard of the engine and bearing seatings, the floors may be fitted at alternate frames.

15.3.4.6 Where heavy equipment is mounted directly on the inner bottom, the thickness of the floors and girders is to be suitably increased.

15.3.5 Inner Bottom plating
15.3.5.1 Where main engines or thrust bearings are bolted directly to the inner bottom, the net thickness of the inner bottom plating is to be at least 19mm. Hold-down bolts are to be arranged as close as possible to floors and longitudinal girders. Plating thickness and the arrangements of hold-down bolts are also to consider the manufacturer’s recommendations.

15.3.6 Sea Chests
15.3.6.1 Where the inner bottom or double bottom structure forms part of a sea chest, the thickness of the plating is not to be less than that required for the shell at the same location, taking into account the maximum unsupported width of the plating.

15.4 Side Structures
15.4.1 General
15.4.1.1 The scantlings of the side shell plating and longitudinals are to be properly tapered from the mid-ship region towards the aft end.

15.4.1.2 A suitable scarphing arrangement of the longitudinal framing is to be arranged where the longitudinal framing terminates and is replaced by transverse framing.

15.4.1.3 Stiffeners and primary support members are to be supported at their ends.

15.4.2 Side Shell Plating
15.4.2.1 The thickness of the side shell plating is to comply with the requirements in 15.9.1.1. Where applicable, the thickness of the side shell plating is to comply with the requirements in 13.3.4.1.

15.4.3 Side Shell Local Support Members
15.4.3.1 The section modulus and thickness of side longitudinal and vertical stiffeners are to comply with the requirements in 15.9.1.2 and 15.9.1.3.

15.4.3.2 End connections of longitudinals at transverse bulkheads are to provide fixity, lateral support, and when not continuous are to be provided with soft-nosed brackets. Brackets lapped onto the longitudinals are not to be fitted.

15.4.4 Side Shell Primary Support Members
15.4.4.1 Web frames are to be connected at the top and bottom to members of suitable stiffness, and supported by deck transverses.

15.4.4.2 The spacing of web frames in way of transversely framed machinery spaces is generally not to exceed five transverse frame spaces.

15.4.4.3 The section modulus and shear area of primary support members are to comply with the requirements in 15.9.2.

15.4.4.4 The web depth is to be not less than 2.5 times the web depth of the adjacent frames if the slots are not closed.

15.4.4.5 Web plating of primary support members is to have a depth of not less than 14% of the unsupported span in bending.

15.5 Deck Structures
15.5.1 General
15.5.1.1 All openings are to be framed. Attention is to be paid to structural continuity. Abrupt changes of shape, section or plate thickness are to be avoided.

15.5.1.2 The corners of the machinery space openings are to be of suitable shape and design to minimize stress concentrations.

15.5.1.3 In way of machinery openings, deck or flats are to have sufficient strength where they are intended as effective supports for side transverse frames or web frames.

15.5.1.4 Where a transverse framing system is adopted, deck stiffeners are to be supported by a suitable arrangement of longitudinal girders in association with pillars or pillar bulkheads. Where fitted, deck transverses are to be arranged in line with web frames to provide end fixity and transverse continuity of strength.

15.5.1.5 Where a longitudinal framing system is adopted, deck longitudinals are to be supported by deck transverses in line with web frames in association with pillars or pillar bulkheads.

15.5.1.6 Machinery casings are to be supported by a suitable arrangement of deck transverses and longitudinal girders in association with pillars or pillar bulkheads. In way of particularly large machinery casing openings, cross ties may be required. These are to be arranged in line with deck transverses.

15.5.1.7 The structural scantlings are to be not less than the requirement for tank boundaries if the deck forms the boundary of a tank.

15.5.1.8 The structural scantlings are to be not less than the requirement for watertight bulkheads if the deck forms the boundary of a watertight space.

15.5.2 Deck Scantling
15.5.2.1 The plate thickness of deck plating is to comply with the requirements in 15.9.1.1.

15.5.2.2 The section modulus and thickness of deck stiffeners are to comply with the requirements in 15.9.1.2 and 15.9.1.3.

15.5.2.3 The web depth of deck stiffeners is to be not less than 60mm.

15.5.2.4 The section modulus and shear area of primary support members are to comply with the requirements in 15.9.2.

15.5.2.5 The web depth of primary support members is not to be less than 10% and 7% of the unsupported span in bending in tanks and in dry spaces, respectively, and is not to be less than 2.5 times the depth of the slots if the slots are not closed. Unsupported span in bending is bending span in accordance with requirements in Section 4.6 or in case of a grillage structure the distance between connections to other primary support members.

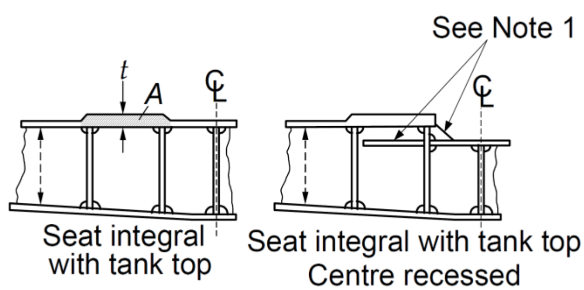
15.5.2.6 In way of concentrated loads from heavy equipment, the scantlings of the deck structure are to be determined based on the actual loading.

15.5.3 Pillars
15.5.3.1 Pillars are to comply with the requirements given in 14.5.4.

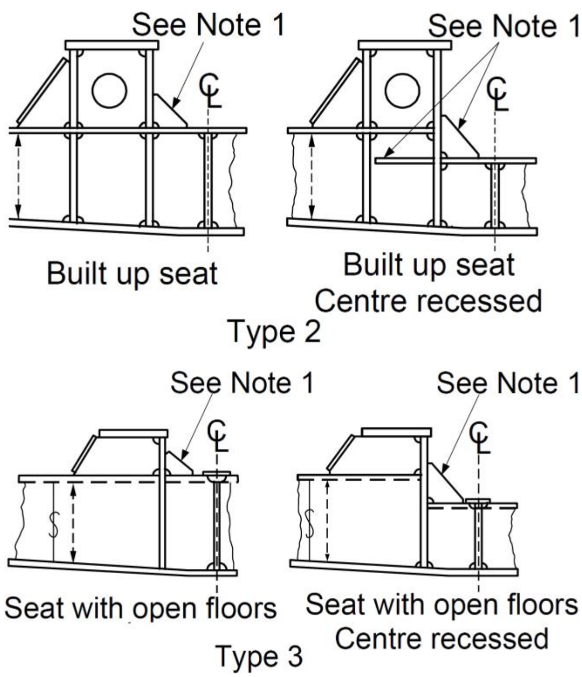
15.5.3.2 In double bottoms under widely spaced pillars, the connections of the floors to the girders, and of the floors and girders to the inner bottom, are to be suitably increased. Where pillars are not directly above the intersection of plate floors and girders, partial floors and intercostals are to be fitted as necessary to support the pillars. Manholes are not to be cut in the floors and girders below the heels of pillars.

15.6 Machinery Foundations
15.6.1 General
15.6.1.1 Main engines and thrust bearings are to be effectively secured to the hull structure by foundations of strength that is sufficient to resist the various gravitational, thrust, torque, dynamic, and vibratory forces which may be imposed on them.

15.6.1.2 In the case of higher power internal combustion engines or turbine installations, the foundations are generally to be integral with the double bottom structure. Consideration is to be given to substantially increase the inner bottom plating thickness in way of the engine foundation plate or the turbine gear case and the thrust bearing, see Figure 37, Type 1.



Type 1



Note: Brackets are to be as large as possible. Brackets may be omitted to avoid interference with the girders of the engine foundation, in accordance with recommendations of the engine manufacturer.

Figure 37: Machinery foundations

15.6.1.3 For main machinery supported on foundations of Type 2, as shown in Figure 37, the forces from the engine into the adjacent structure are to be distributed as uniformly as possible. Longitudinal members supporting the foundation are to be aligned with girders in the double bottom, and transverse stiffening is to be arranged in line with the floors, see Figure 37, Type 2.

15.6.1.4 For Units with open floors in the machinery space, the foundations are generally to be arranged above the level of the top of the floors and securely bracketed, see Figure 37, Type 3.

15.6.2 Foundation for IC Engines and Thrust Bearing
15.6.2.1 In determining the scantlings of foundations for internal combustion engines and thrust bearings, consideration is to be given to the general rigidity of the engine and to its design characteristics with regard to out of balance forces.

15.6.2.2 Generally two girders are to be fitted in way of the foundation for internal combustion engines and thrust bearings. In general, the gross thickness of foundation top plates is not to be less than 45mm, where the maximum continuous output of the propulsion machinery is 3500kw or greater.

15.6.3 Auxiliary Foundations
15.6.3.1 Auxiliary machinery is to be secured on foundations that are of suitable size and arrangement to distribute the loads from the machinery evenly into the supporting structure.

15.7 Tank Bulkheads
15.7.1 General
15.7.1.1 Tank Bulkheads are to comply with the requirements given in Section 14.6 with the scantlings determined using the bending stress coefficients for plating and stiffeners as provided in Tables 35 – 36.

15.8 Watertight Boundaries
15.8.1 General
15.8.1.1 Watertight boundaries are to comply with the requirements of Section 14.7.1.

15.8.2 Scantling of Watertight Boundaries
15.8.2 The scantlings of watertight boundaries are to comply with the requirements of 14.7.3.

15.9 Scantling Requirements
15.9.1 Plating and Local Support Members
15.9.1.1 For plating subjected to lateral pressure the net plating thickness is to comply with the requirements in 14.11.2.1, but using the permissible bending stress coefficient, C_a, defined in Table 35.

15.9.1.2 For stiffeners subjected to lateral pressure the net section modulus requirement is to comply with the requirements in 14.11.2.2, but using the permissible bending stress coefficient, C_s, defined in Table 36.

15.9.1.3 For stiffeners subjected to lateral pressure the net web thickness based on shear area requirements is to comply with the requirements in 14.11.2.3.

15.9.2 Primary Support Members

15.9.2.1 For primary support members intersecting with or in way of curved hull sections, the effectiveness of end brackets is to include allowance for the curvature of the hull.

15.9.2.2 For primary support members subjected to lateral pressure the net section modulus requirement is to comply with the requirements in 14.11.3.2.

15.9.2.3 For primary support members subjected to lateral pressure the net cross sectional area of the web is to comply with the requirements in 14.11.3.3.

15.9.2.4 Primary support members are to generally be analyzed with the specific methods as described for the particular structure type. More advanced calculation methods may be required to ensure that nominal stress level for all primary support members are less than permissible stresses and stress coefficients given in 14.11.3.2 and 14.11.3.3 when subjected to the applicable design load sets.

15.9.3 Corrugated Bulkheads

15.9.3.1 Special consideration will be given by IRS to the approval of corrugated bulkheads where fitted. Scantling requirements of corrugated bulkheads in the cargo tank region may be used as a design basis, see 13.6.6 and 13.6.7.

15.9.4 Pillars

15.9.4.1 The maximum load on a pillar is to be less than the permissible pillar load as given by the requirements in 14.11.5

Table 35: Permissible Bending stress coefficient for plating					
The permissible bending stress coefficient, C_a, for the design load set being considered is to be taken as: $C_a = \beta_a - \alpha_a \frac{\lvert\sigma_{hg}\rvert}{\sigma_{yd}}$ but not to be taken greater than C_{a-max}					
Acceptance criteria set	Structural member		β_a	α_a	C_{a-max}
AC1	Longitudinal strength members	Longitudinally stiffened plating	0.90	0.50	0.80
		Transversely or vertically stiffened plating	0.90	1.00	0.80
	Other members		0.80	0.00	0.80
AC2	Longitudinal strength members	Longitudinally stiffened plating	1.05	0.50	0.95
		Transversely or vertically stiffened plating	1.05	1.00	0.95
	Other members, including watertight boundary plating		1.00	0.00	1.00
AC3	All members		1.00	0.00	1.00

Where:

α_a, β_a, C_{a-max} as given above:

σ_{hg} : Hull girder bending stress [N/mm^2] for the design load set being considered and calculated at the load calculation point as defined in IRS Rules for Bulk Carrier and Oil Tanker Part 1, Chapter 3, Section 7, 3.1.

$$= \left(\frac{(z - z_{NA-net50})M_{v-total}}{I_{v-net50}}\right)10^{-3}$$

$M_{v-total}$: Design vertical bending moment at the longitudinal position under consideration for the design load set being considered [kNm]. The still water bending moment, $M_{sw-perm}$, is to be taken with the same sign as the simultaneously acting wave bending moment, M_{wv}, see Section 11

Table 36: Permissible Bending stress coefficient for stiffeners

C_s : Permissible bending stress coefficient for the design load set being considered, to be taken as:

Sign of hull girder bending stress, σ_{hg}	Side pressure acting on	Acceptance criteria
Tension (+ve)	Stiffener side	$C_s = \beta_s - \alpha_s \frac{\lvert\sigma_{hg}\rvert}{\sigma_{yd}}$ but not to be greater than C_{s-max}
Compression (-ve)	Plate side	
Tension (+ve)	Plate side	$C_s = C_{s-max}$
Compression (-ve)	Stiffener side	

Where α_s β_s C_{S-max} : Permissible bending stress factors and are to be taken as:

Acceptance criteria set	Structural member	β_s	α_s	C_{S-max}
AC1	Longitudinal effective Stiffeners	0.85	1.00	0.75
	Other stiffeners	0.75	0.00	0.75
AC2	Longitudinal effective Stiffeners	1.00	1.00	0.90
	Other stiffeners	0.90	0.00	0.90
	Watertight boundary stiffeners	0.90	0.00	0.90
AC3	All members	1.0	0	1.0

Where:

σ_{hg} : Hull girder bending stress [N/mm²] for the design load set being considered and calculated at the load calculation point as defined in IRS Rules for Bulk Carrier and Oil Tanker Part 1, Chapter 3, Section 7, 3.1.

$$= \left(\frac{(z - z_{NA-net50})M_{v-total}}{I_{v-net50}}\right)10^{-3} \quad \text{[N/mm}^2\text{]}$$

$M_{v-total}$: design vertical bending moment at the longitudinal position under consideration for the design load set being considered [kNm]. $M_{v-total}$, is to be calculated accordance with Table 3 hogging and sagging still water bending moment, M_{sw}, to be taken as:

Stiffener location	M_{sw}	
	Pressure acting on plate side	Pressure acting on stiffener side
Above neutral axis	Sagging SWBM	Hogging SWBM
Below neutral axis	Hogging SWBM	Sagging SWBM

Section 16
Aft Region

16.1 Symbols

l_{stf} : Length of stiffener as shown in Figure 38 [m]

l_{stn} : Length of stern frame [mm] see Figure 39 (a)

$t_{1\text{-}grs}$: Gross thickness of casting at end [mm] see Figure 39 (b)

$t_{2\text{-}grs}$: Gross thickness of casting at mid length [mm] see Figure 39 (b)

t_{grs} : Gross thickness of side plating [mm]

w_{stn} : Width of stern frame [mm] see Figure 39 (a)

L : Rule length, as defined in Section 1.1

L_2 : Rule length, L, as defined in Section 1, but need not be taken greater than 300m

s : Stiffener spacing [mm]

16.2 General

16.2.1 Application

16.2.1.1 The requirements of this sub-section apply to structure located between the aft peak bulkhead and the aft end of the Unit

16.2.1.2 The requirements of this sub-section do not apply to the following:

- Rudder horns
- Structures which are not integral with the hull, such as rudders, steering nozzles and propellers
- Other appendages permanently attached to hull

Where such items are fitted, the requirements of the Rules and Regulations for Construction and Classification of Steel Ships, Part 3 are to be complied with.

16.2.1.3 Requirements in 13.2.2.4 are to be complied with as applicable.

16.2.2 General Scantling Requirements

16.2.2.1 The hull structure is to also comply with the applicable requirements of:

a. Hull girder longitudinal strength, see Section 12.
b. Strength against sloshing and impact loads, see Section 17
c. Buckling and ultimate strength, see Section 20

16.2.2.2 The deck plating thickness and supporting structure are to be suitably reinforced for applicable machinery & equipment, see Section 18.

16.2.2.3 The net section modulus, shear area and other sectional properties of local and primary support members are to be determined in accordance with requirements in Section 4.6.

16.2.2.4 The section modulus and web thickness of local support members apply to the area clear of the end brackets. The section modulus and cross sectional shear areas of primary support members are to be applied as required in the notes to Table 39.

16.2.2.5 The scantling criteria are based on assumptions that all structural joints and welded details are designed and fabricated such that they are compatible with the anticipated working stress levels at the location considered. The loading patterns, stress concentration and potential failure modes of structural joints and details during the design of highly stressed regions are to be considered. Structural design details are to comply with requirements in Section 23.

16.2.2.6 Limber, drain and air holes are to be cut in all parts of the structure, as required, to ensure free flow to the suction pipes and the escape of air to the vents. Arrangements are to be made for draining the spaces above deep tanks. See also Section 23.

16.2.3 Structural Continuity
16.2.3.1 Scantlings of the shell envelope, upper deck and inner bottom are to be tapered towards the aft end. See also Section 12.6.

16.2.3.2 In transition zones forward of the aft peak into the machinery space, due consideration is to be given to the tapering of primary support members.

16.2.3.3 Longitudinal framing of the strength deck is to be carried aft to the stern.

16.2.3.4 All shell frames and tank boundary stiffeners are in general to be continuous, or are to be bracketed at their ends, except as permitted in Section 23.

16.2.4 Minimum Thickness
16.2.4.1 In addition to the scantling requirements given in 16.3 – 16.8, the thickness of plating and stiffeners in the aft end region is to comply with the appropriate minimum thickness requirements given in Section 13.2.4 & 13.2.5, except for members as shown in Table 37. For shell plating and stiffeners also see Section 16.4

Table 37 : Minimum net thickness of structure aft of the aft peak bulkhead

Scantling Location	Net Thickness (mm)
Pillar bulkhead plating	*7.5*
Bottom girder aft peak floor	$5.5 + 0.02L_2$
Web Plating of primary support members	$6.5 + 0.015L_2$

16.3 Bottom Structure
16.3.1 General
16.3.1.1 Floors are to be fitted at each frame space in the aft peak and carried to a height at least above the stern tube. Where floors do not extend to flats or decks they are to be stiffened by flanges at their upper end.

16.3.1.2 The centerline bottom girder is to extend as far aft as is practicable and is to be attached to the stern frame.

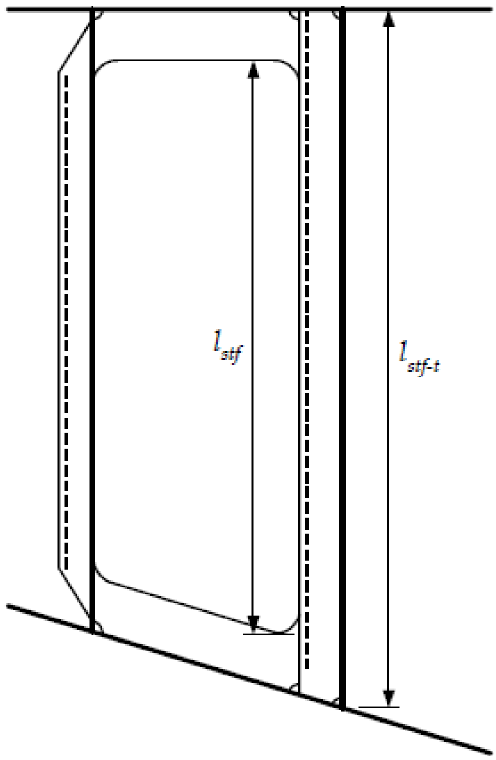
16.3.2 Aft Peak Floor and Girders
16.3.2.1 The height of stiffeners, h_{stf}, on the floors and girders are to be not less than:

$h_{stf} = 80.0 l_{stf}$	[mm] for flat bar stiffeners
$h_{stf} = 70.0 l_{stf}$	[mm] for bulb profiles and flanged stiffeners

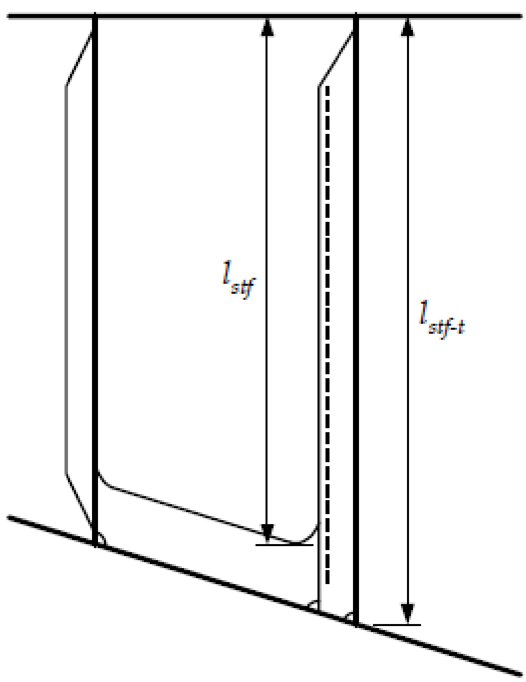
16.3.2.2 In conjunction with the requirements of 16.3.2.1, stiffeners are to be provided with end brackets as follows:

a. Brackets are to be fitted at the lower and upper ends when l_{stf-t} exceeds 4m
b. Brackets are to be fitted at the lower end when l_{stf-t} exceeds 2.5m.

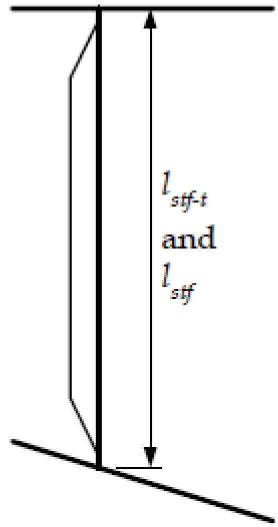
16.3.2.3 Heavy plate floors are to be fitted in way of the aft face of the horn and in line with the webs in the rudder horn. They may be required to be carried up to the first deck or flat. In this area, cut outs, scallops or other openings are to be kept to a minimum.



(a) $l_{stf} > 4$



(b) $l_{stf\text{-}t} > 2.5$



(c) $l_{stf\text{-}t} \leq 2.5$

Figure 38 : Stiffening of floors and girders in aft peak

16.3.3 Stern Frames

16.3.3.1 Stern frames may be fabricated from steel plates or made of cast steel. For applicable material specifications and steel grades see Section 2. Stern frames of other material or construction will be specially considered.

16.3.3.2 Scantlings below the propeller boss on stern frames for single screw vessels are to comply with the requirements in 16.3.3.3 or 16.3.3.4, as applicable.

16.3.3.3 Fabricated stern frames are to satisfy the following criteria:

a. $$t_{grs} \geq 2.25\sqrt{L} \quad \text{[mm]}$$

b. $$w_{stn} \geq 450 \quad \text{[mm]}$$

c. $$t_{grs} \geq \frac{C_f L^{1.5}}{{w_{stn}}^2 \sqrt{1 + \left(\frac{2 l_{stn}}{w_{stn}}\right)^2}} \quad \text{[mm]}$$

Where:

C_f : Coefficient = 9600

16.3.3.4 Cast stern frames are to satisfy the following criteria:

a. $t_{1-grs} \geq 3.0\sqrt{L}$ [mm]

but not less than 25 mm

b. $t_{2-grs} \geq 1.25 t_{1-grs}$ [mm]

c. $$\frac{(t_{1-grs} + t_{2-grs})}{2} \geq \frac{C_f L^{1.5}}{{w_{stn}}^2 \sqrt{1 + \left(\frac{2 l_{stn}}{w_{stn}}\right)^2}}$$ [mm]

Where,

C_f = 8400

The thickness of butt welding to shell plating may be tapered below t_1 with a length of taper that is at least three times the offset. The castings are to be cored out to avoid large masses of thick material likely to contain defects and are to maintain a relatively uniform section throughout. Suitable radii are to be provided in way of changes in section.

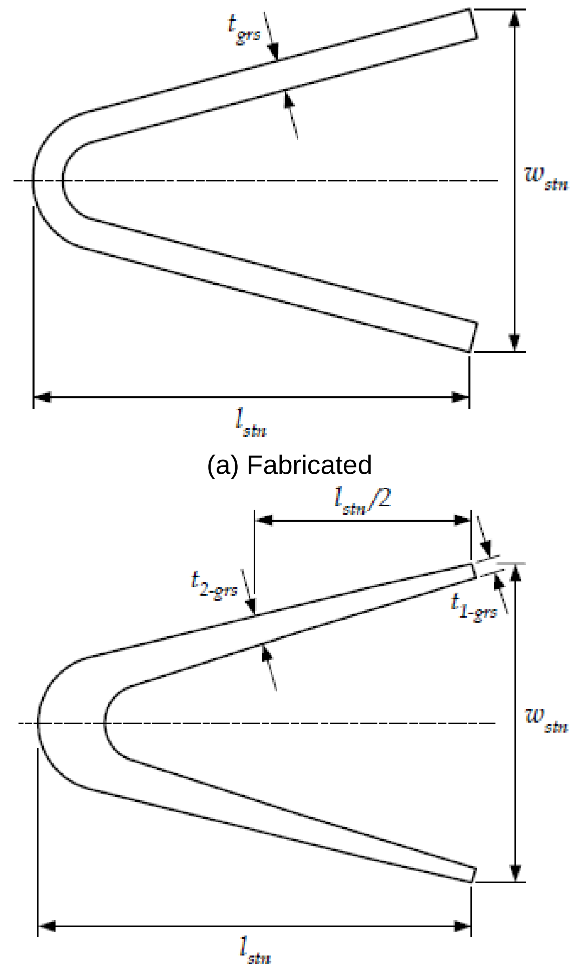
16.3.3.5 Above the propeller boss, the scantlings are to be in accordance with 16.3.3.2 to 16.3.3.4 except that in the upper part of the propeller aperture, where the hull form is full and centerline supports are provided, the thickness may be reduced to 80% of the applicable requirements in 16.3.3.2 to 16.3.3.4.

16.3.3.6 Where round bars are used at the aft edge of stern frames, their scantlings and connection details are to facilitate welding.

16.3.3.7 Ribs or horizontal brackets of thickness not less than $0.8t_{grs}$ or $0.8t_{1-grs}$ are to be provided at suitable intervals, where t_{grs} and t_{1-grs} are as defined in 16.3.3.3 and 16.3.3.4.

When t_{grs} or t_{1-grs} is reduced in accordance with 16.3.3.5, a proportionate reduction in the thickness of ribs or horizontal brackets may be made.

16.3.3.8 Rudder gudgeons are to be an integral part of the stern frame and are to meet the requirements of the relevant Sections of Rules for Steel Ships.



(a) Fabricated

(b) Cast

Figure 39: Stern Frame

16.4 Shell Structure

16.4.1 Shell Plating

16.4.1.1 The net thickness of the side shell and transom plating, t_{net}, is to comply with the requirements in 14.11.2.1 and is not to be less than:

$$t_{net} = 0.035(L_2 - 42) + 0.009s$$ [mm]

16.4.1.2 The net plating thickness of shell, t_{net}, attached to the stern frame is to comply with the requirements in 14.11.2.1 and is not to be less than:

$$t_{net} = 0.094(L_2 - 43) + 0.009s$$ [mm]

16.4.1.3 In way of the boss and heel plate, the shell net plating thickness, t_{net}, is not to be less than:

$$t_{net} = 0.105(L_2 - 47) + 0.011s \quad \text{[mm]}$$

16.4.1.4 Within the extents specified in 13.3.4.3, the thickness of the side shell plating is to comply with the requirements in 13.3.4.2.

16.4.1.5 Heavy shell plates are to be fitted locally in way of the heavy plate floors as required by 16.3.2.3. Outboard of the heavy floors, the heavy shell plates may be reduced in thickness in as gradual a manner as practicable. Where the horn plating is radiused into the shell plating, the radius at the shell connection, *r*, is not to be less than:

$$r = 150 + 0.8L_2 \quad \text{[mm]}$$

16.4.2 Shell Local Support Members
16.4.2.1 The section modulus and thickness of the hull envelope framing are to comply with the requirements in 14.11.2.2 and 14.11.2.3.

16.4.3 Shell Primary Support Members
16.4.3.1 The requirements of 16.4.3 apply to single side skin construction supported by system of vertical webs and/or horizontal stringers or flats.

16.4.3.2 Where a longitudinal framing system is adopted, longitudinals are to be supported by vertical primary support members extending from the floors to the upper deck. Deck transverses are to be fitted in line with the web frames.

16.4.3.3 Where a transverse framing system is adopted, frames are to be supported by horizontal primary support members spanning between the vertical primary support members.

16.4.3.4 The scantlings of web frames supporting; longitudinal framing, stringers and transverse framing are to be determined from 14.11.3.

16.4.3.5 The web depth of primary support members is not to be less than 14% of the bending span and is to be at least 2.5 times as deep as the slots for stiffeners if the slots are not closed.

16.5 Deck Structures
16.5.1 Deck Plating
16.5.1.1 The thickness of the deck plating is to comply with the requirements in 14.11.2.1.

16.5.2 Deck Stiffeners
16.5.2.1 The section modulus and thickness of deck stiffeners are to comply with the requirements in 14.11.2.2 and 14.11.2.3.

16.5.3 Deck Primary Support Members
16.5.3.1 The section modulus and shear area of primary support members are to comply with the requirements in 14.11.3.

16.5.3.2 The web depth of primary support members is not to be less than 10% and 7% of the unsupported span in bending in tanks and in dry spaces, respectively, and is not to be less than 2.5 times the depth of the slots if the slots are not closed. Unsupported span in bending is bending span as defined in Section 4.6 or in case of a grillage structure the distance between connections to other primary support members.

16.5.3.3 In way of concentrated loads from heavy equipment, the scantlings of the deck structure are to be determined based on the actual loading. See also Section 18.

16.5.4 Pillars
16.5.4.1 Pillars are to comply with the requirements of 14.5.4.

16.6 Tank Bulkheads
16.6.1 General
16.6.1.1 Tanks are to comply with the requirements of 14.6.

16.7 Watertight Boundaries
16.7.1 General
16.7.1.1 Watertight boundaries are to comply with the requirements of 14.7.

16.7.2 Aft Peak Bulkhead
16.7.2.1 An aft peak bulkhead in accordance with requirements in Section 3 is to be provided.

16.7.2.2 The scantlings of structural components of the aft peak bulkhead are to comply with the requirements in 16.6 and 16.7.1 as applicable.

16.8 Miscellaneous Structures
16.8.1 Pillar Bulkhead
16.8.1.1 Bulkheads that support girders, or pillars and longitudinal bulkheads which are fitted in lieu of girders, are to be stiffened to provide supports not less effective than required for stanchions or pillars. The acting load and the required net cross sectional area of the pillar section is to be determined using the requirements of 16.5.4. The net moment of inertia of the stiffener is to be calculated with a width of $40t_{net}$ of the plating, where t_{net} is net plating thickness [mm].

16.8.1.2 Pillar bulkheads are to meet the following requirements:

a. The distance between bulkhead stiffeners is not to exceed 1500mm
b. Where corrugated, the depth of the corrugation is not to be less than 100mm.

16.8.2 Rudder Trunk
16.8.2.1 The scantlings of the rudder trunk are to be in accordance with the shell plating and framing in 16.4.1 and 16.4.2. Where the rudder trunk is open to the sea, a seal or stuffing box is to be fitted above the deepest load waterline to prevent water from entering the steering gear compartment.

16.8.3 Stern Thruster Tunnels
16.8.3.1 The net thickness of the tunnel plating, $t_{tun-net}$, is not to be less than required for shell plating in the vicinity of the thruster. In addition $t_{tun-net}$ is not to be taken less than:

$$t_{tun-net} = 0.008 d_{tun} + 1.8 \quad \text{[mm]}$$

Where:

d_{tun} : Inside diameter of tunnel [mm] but not to be less than 970 mm

16.8.3.2 Where the outboard ends of the tunnel are provided with bars or grids, the bars or grids are to be effectively secured.

Section 17

Structural Evaluation for Sloshing and Other Impact loads

17.1 Symbols

T_{FP-mt} : Design slamming light load draught [m] at FP as defined in 8.6.2.1

$T_{FP-full}$: Design slamming light load draught [m] at FP as defined in 8.6.2.1

17.1.1 General
17.1.1.1 The requirements of this Sub-Section cover the strengthening requirements for localized sloshing loads that may occur in tanks carrying liquid and local impact loads that may occur in the forward structure. The sloshing and impact loads to be applied in 17.2 to 17.4 are described in 9.8 and 8.6 respectively.

17.1.2 General Scantling Requirements
17.1.2.1 The requirements of 17.2 to 17.4 are to be applied in addition to the applicable requirements in Sections 12-16.

17.1.2.2 Local scantling increases due to impact or sloshing loads are to be made with due consideration given to details and avoidance of hard spots, notches and other harmful stress concentrations.

17.2 Sloshing in Tanks
17.2.1 Scope and Limitation
17.2.1.1 The requirements of 17.2 specify the scantling requirements for boundary and internal structure of tanks subjected to sloshing loads, as given in 9.8, due to free movement of liquid in tanks.

17.2.1.2 The structure of cargo tanks, slop tanks, ballast tanks and large deep tanks, e.g. fuel oil bunkering tanks and main fresh water tanks, are to be assessed for sloshing. Small tanks do not need to be assessed for sloshing pressure.

17.2.1.3 All cargo and ballast tanks are to have scantling suitable for unrestricted filling heights.

17.2.1.4 The following structural members are to be assessed:

a. Plates and stiffeners forming boundaries of tanks
b. Plates and stiffeners on wash bulkheads
c. Web plates and web stiffeners of primary support members located in tanks
d. Tripping brackets supporting primary support members in tanks.

17.2.2 Sloshing Assessment for Scantlings
17.2.2.1 The strengthening requirements for applicable scantlings due to localized sloshing loads are to comply with the requirements in IRS Rules for Bulk Carriers & Oil Tankers, Volume 2, Part 1, Chapter 10, Section 4. Strengthening requirements are to also consider partial filling levels in tank as described in Section 9.8.

17.3 Bottom Slamming
17.3.1 Application
17.3.1.1 Where the minimum draughts forward, T_{FP-mt} or $T_{FP-full}$, as specified in 8.6.2.1, is less than 0.045L, the bottom forward is to be additionally strengthened to resist bottom slamming pressures (see Figure 40).

17.3.1.2 The draughts for which the bottom has been strengthened are to be indicated on the shell expansion plan and loading guidance information.

17.3.1.3 The strengthening requirements due to localized loads are to comply with the requirements given in IRS Rules for Bulk Carriers & Oil Tankers, Volume 2, Part 1, Chapter 10, Section 1 [3.2]. IRS may also require Direct calculations to be carried out.

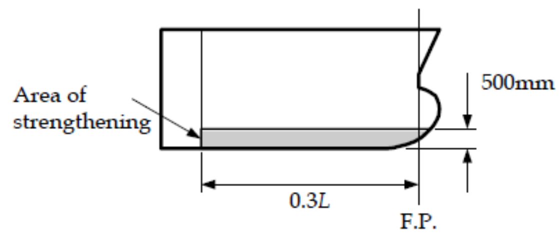


Figure 40: Extent of strengthening against bottom slamming

17.3.2 Connection of Longitudinal to Primary Support Members
17.3.2.1 Longitudinals are, in general, to be continuous. Where this not practicable end brackets complying with requirements in Section 23 are to be provided.

17.3.2.2 The scantlings in way of the end connections of each longitudinal are to comply with the applicable requirements of Section 23.

17.4 Bow Impact
17.4.1 Application
17.4.1.1 The side structure in the area forward of *0.1L* from the F.P. is to be strengthened against bow impact pressures (see figure 41).

17.4.1.2 The strengthening requirements due to localized loads are to comply with the requirements given in IRS Rules for Bulk Carriers & Oil Tankers, Volume 2, Part 1, Chapter 10, Section 1 [3.3].

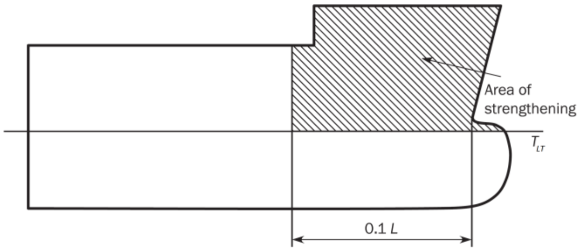


Figure 41: Extent of strengthening against bow impact

17.4.2 Connection of Stiffeners to Primary Support Members

17.4.2.1 Stiffeners are, in general, to be continuous. Where this not practicable end brackets complying with applicable requirements in Section 23 are to be provided.

17.4.2.2 The scantlings of the end connection of each stiffener are to comply with applicable requirements in Section 23.

Section 18

Miscellaneous Structures

18.1 Symbols

σ_{yd} : Specified minimum yield stress of the material [N/mm²]

τ_{yd} $= \frac{\sigma_{yd}}{\sqrt{3}}$ [N/mm²]

i : Indices for load component i

j : Indices for load component j

l : Effective span, l_{bdg} and l_{shr} as applicable

l_{bdg} : see Section 4.6

l_{shr} : see Section 4.6

l_p : Length of plate panel, to be taken as the spacing of primary support members, S, unless carlings are fitted [m]

s : Stiffener spacing, in mm,

F : Point load for the design load set being considered [kN]

S : Primary support member spacing [m] as defined in Section 1.1

18.2 General

18.2.1 Application

18.2.1.1 The requirements of this Sub-Section apply to plating, local and primary support members of the hull where the basic structural configurations or strength models covered in Sections 13 – 16 may not appropriate. These are general purpose strength requirements to cover various load assumptions and end support conditions. These requirements are however not to be used as an alternative to the requirements of Sections 13 – 16 where those sections can be applied.

18.2.1.2 The requirements for local and primary support members are to be specially considered when the member is:

a. Part of a grillage structure
b. Subject to large relative deflection between end supports
c. Where the load model or end support condition is not given in Table 39.

18.2.1.3 The application of alternative strength assessment will be specially considered by IRS.

18.3 Scantling Requirements

18.3.1 General

18.3.1.1 The design load sets to be applied to the structural requirements for the local and primary support members are to be taken from Tables 21 and 23, as applicable for the particular structure under consideration. The static and dynamic load components are to be combined in accordance with requirements in Section 11.

18.3.2 Plating and Local Support Members

18.3.2.1 For plating subjected to lateral pressure the net thickness, t_{net}, is to be taken as the greatest value for all applicable design load sets given in Table 21, and given by:

$$t_{net} = 0.0158\alpha_p s\sqrt{\frac{|P|}{C_a\sigma_{yd}}} \quad \text{[mm]}$$

Where:

α_p : Correction factor for the panel aspect ratio

$$= 1.2 - \frac{s}{2100 l_p}$$

P : Design pressure for the design load set being considered, calculated at the load calculation point (see Section 4.6). [kN/m^2]

C_a : Permissible bending stress coefficient for the design load set being considered, as given in Table 17, Table 31 or Table 35, as applicable for the individual member being considered

18.3.2.2 For stiffeners subjected to lateral pressure, point loads, or some combination thereof, the net section modulus requirement, Z_{net}, is to be taken as the greatest value for all applicable design load sets given in Table 21, and given by:

for lateral pressure loads

$$Z_{net} = \frac{|P| s {l_{bdg}}^2}{f_{bdg} C_s \sigma_{yd}} \quad \text{[cm}^3\text{]}$$

for point loads

$$Z_{net} = \frac{1000|F| l_{bdg}}{f_{bdg} C_s \sigma_{yd}} \quad \text{[cm}^3\text{]}$$

for combination of loads

$$Z_{net} = \frac{\left|\sum \frac{P_i s {l_{bdg}}^2}{f_{bdg-i}} + \sum \frac{1000 F_j l_{bdg}}{f_{bdg-j}}\right|}{C_s \sigma_{yd}} \quad \text{[cm}^3\text{]}$$

Where:

P : Design pressure [kN/m^2] for the design load set being considered, calculated at the load calculation point (see Section 4.6).

f_{bdg} : Bending moment factor for continuous stiffeners and where end connections are fitted consistent with idealization of the stiffener as having fixed ends:

= 12 for horizontal stiffeners

= 10 for vertical stiffeners

for other configurations the bending moment factor may be taken as in Table 39.

C_s : Permissible bending stress coefficient for the design load set being considered as given in Table 18, Table 32 or Table 36, as applicable for the individual member being considered

18.3.2.3 For stiffeners subjected to lateral pressure, point loads, or some combination thereof, the net web thickness, t_{w-net}, based on shear area requirements is to be taken as the greatest value for all applicable design load sets given in Table 21, and given by:

for lateral pressure loads

$$t_{w-net} = \frac{f_{shr}|P| s l_{shr}}{d_{shr} C_t \tau_{yd}} \quad \text{[mm]}$$

for point loads

$$t_{w-net} = \frac{1000|F| f_{shr}}{d_{shr} C_t \tau_{yd}} \quad \text{[mm]}$$

for combination of loads

$$t_{w-net} = \frac{\left|\sum f_{shr-i} P_i S l_{shr} + \sum 10^3 F_j f_{shr-j}\right|}{d_{shr} C_t \tau_{yd}}$$ [mm]

Where:

P : Design pressure [kN/m^2] for the design load set being considered, calculated at the load calculation point (see Section 4.6).

f_{shr} : Shear force factor

for continuous stiffeners and where end connections are fitted consistent with idealization of the stiffener as having fixed ends:

= 0.5 for horizontal stiffeners

= 0.7 for vertical stiffeners

for other configurations the shear force factor may be taken as in Table 39.

d_{shr} : see Section 4.6

C_t : Permissible shear stress coefficient for the design load set being considered as given in Table 19 or Table 33, as applicable for the individual member being considered

18.3.3 Primary Support Members

18.3.3.1 The requirements in 18.3.3 are applicable where the primary support member is idealized as a simple beam. More advanced calculation methods may be required to ensure that nominal stress level for all primary support members are less than the permissible stresses and stress coefficients given in 18.3.3.4 and 18.3.3.5 when subjected to the applicable design load sets. (See also 18.2.1.2).

18.3.3.2 The section modulus and web thickness of the local support members apply to the areas clear of the end brackets. The section modulus and cross sectional shear areas of the primary support member are to be applied as required in the notes of Table 39.

18.3.3.3 For primary support members intersecting with or in way of curved hull sections, the effectiveness of end brackets is to include an allowance for the curvature of the hull.

18.3.3.4 For primary support members the net section modulus requirement, Z_{net50}, is to be taken as the greatest value for all applicable design load sets given in Table 23, and given by:

for lateral pressure loads

$$Z_{net50} = \frac{1000|P| S {l_{bdg}}^2}{f_{bdg} C_s \sigma_{yd}}$$ [cm^3]

for point loads

$$Z_{net} = \frac{1000|F| l_{bdg}}{f_{bdg} C_s \sigma_{yd}}$$ [cm^3]

for combination of loads

$$Z_{net} = \frac{\left|\sum \frac{10^3 P_i S {l_{bdg}}^2}{f_{bdg-i}} + \sum \frac{10^3 F_j l_{bdg}}{f_{bdg-j}}\right|}{C_s \sigma_{yd}}$$ [cm^3]

Where:

P : Design pressure for the design load set being considered, calculated at the load calculation point (see Section 4.6). [kN/m^2]

f_{bdg} : Bending moment factor, as given in Table 39

C_s : Permissible bending stress coefficient for the design load set being considered as given in Table 38, as applicable for the individual member being considered

18.3.3.5 For primary support members the net shear area of the web, $A_{shr-net50}$, is to be taken as the greatest value for all applicable design load sets given in Table 23, and given by:

for lateral pressure loads

$$A_{shr-net50} = \frac{10 f_{shr} |P| S l_{shr}}{C_t \tau_{yd}}$$ [cm^2]

for point loads

$$A_{shr-net50} = \frac{10|F|f_{shr}}{C_t \tau_{yd}} \quad [\text{cm}^2]$$

for combination of loads

$$A_{shr-net50} = \frac{\left|\sum 10 f_{shr-i} P_i l_{shr} + \sum 10 F_j f_{shr-j}\right|}{C_t \tau_{yd}} \quad [\text{cm}^2]$$

Where:

P : Design pressure for the design load set being considered, calculated at the load calculation point (see Section 4.6). [kN/m²]

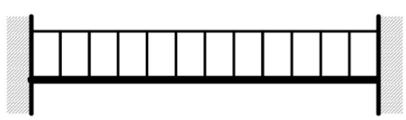
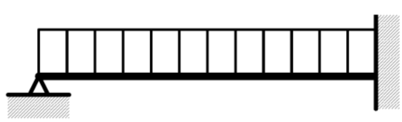
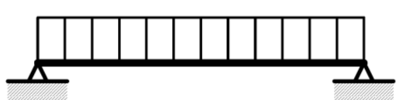
f_{shr} : Shear force factor, as given in Table 39

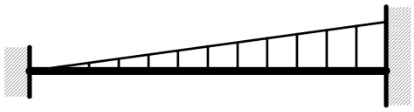
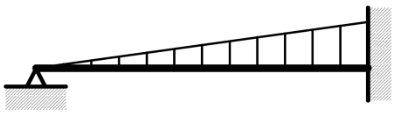
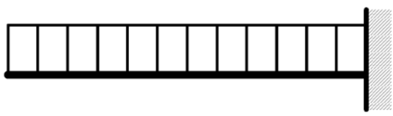
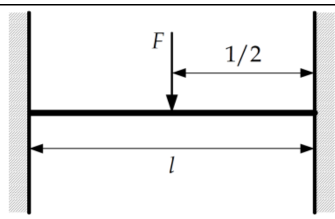
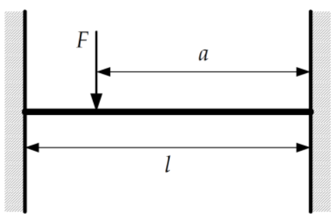
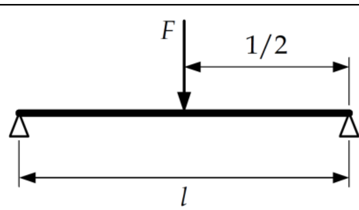
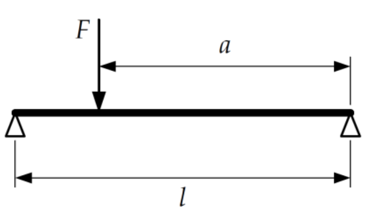
C_t : Permissible shear stress coefficient for the design load set being considered as given in Table 38, as applicable for the individual member being considered

Table 38: Permissible stress coefficient, C_s, C_t for primary support members

Acceptance criteria set	Permissible bending stress coefficient, C_s	Permissible shear stress coefficient,, C_t
AC1	0.70	0.70
AC2	0.85	0.85
AC3	0.90	0.90

Table 39: Values of, f_{bdg}, f_{shr}

Load and Boundary Conditions				Bending moment and shear force factor (based on load at mid span where load varies)			Application
Load model	Position (see Note 1)			1	2	3	
	1 Support	2 Field	3 Support	f_{bdg1} f_{shr1}	f_{bdg2} -	f_{bdg3} f_{shr3}	
A				12.0 0.50	24.0 -	12.0 0.50	Built in both ends. Uniform pressure distribution
B				- 0.38	14.2 -	8.0 0.63	Built in one end + simply supported at one ends Uniform pressure distribution
C				- 0.50	8.0 -	- 0.50	Simply supported (both ends are free to rotate) Uniform pressure distribution

D		15.0 0.30	23.3 -	10.0 0.70	Built in both end Linearly varying pressure distribution
E		- 0.20	16.8 -	7.5 0.80	Built in one end + simply supported one end. Linearly varying pressure distribution
F		- -	- -	2.0 1.0	Cantilever beam Uniform pressure distribution
G		8.0 0.5	8.0 -	8.0 0.5	Built in both ends. Single point load in the centre of the span
H		$\frac{l^3}{a^2(l-a)}$ $\frac{a^2(3l-2a)}{l^3}$	$\frac{l^4}{2a^2(l-a)^2}$ -	$\frac{l^3}{a(l-a)^2}$ $\frac{(l-a)^2(l+2a)}{l^3}$	Built in both end Single point load with load anywhere in the span
I		- 0.5	4 -	- 0.5	Simply supported Single point load in the centre of span
J		- $\frac{a}{l}$	$\frac{l^2}{a(l-a)}$ -	- $\frac{l-a}{l}$	Simply supported Single point load anywhere along the span

Note

- The bending moment factor f_{bdg} for the support positions are applicable for a distance of $0.2l_{bdg}$ from the end of the effective bending span for both local and primary support members.
- The shear force factor f_{shr} for the support positions are applicable for a distance of $0.2l_{shr}$ from the end of the effective shear span for both local and primary support members.
- Application of f_{bdg} and f_{shr} for local support members:
  a. The section modulus requirement of local support members is to be determined using the lowest value of f_{bdg1} , f_{bdg2} and f_{bdg3}
  b. The shear area requirement of local support members is to be determined using the greatest value of f_{shr1} and f_{shr3}.
- Application of f_{bdg} and f_{shr} for primary support members:
  a. The section modulus requirement within $0.2l_{bdg}$ from the end of the effective span is generally to be determined using the applicable f_{bdg1} and f_{bdg3}, however f_{bdg} is not to be taken greater than 12
  b. The section modulus of mid span area is to be determined using f_{bdg} =24, or f_{bdg2} from the table if lesser
  c. The shear area requirement of end connections within $0.2l_{shr}$ from the end of the effective span is to be determined using f_{shr} = 0.5 or the applicable f_{shr1} or f_{shr3}, whichever is greater
  d. For models A through F the value of fshr may be gradually reduced outside of $0.2l_{shr}$ towards $0.5f_{shr}$ at mid span where f_{shr} is the greater value of f_{shr1} and f_{shr3}.

Section 19

Hull Girder Ultimate Strength

19.1 Ultimate Strength Capacity

19.1.1 Hull girder ultimate strength is to be computed in accordance with requirements provided in IRS Rules for Bulk Carriers & Oil Tankers, Volume 2, Part 1, Chapter 5, Hull Girder Strength.

Section 20

Buckling Capacity

20.1 General

20.1.1 The present section specifies the criteria for buckling and ultimate strength of local support members, primary support members and other structures such as pillars, corrugated bulkheads and brackets.

20.1.2 All structural members are to comply with requirements for slenderness and proportions as specified in Section 20.2.

20.1.3 For each structural member, characteristic buckling ultimate strength is to be taken as the most unfavourable buckling failure mode.

20.1.4 Within the present section, direct compressive stresses and shear stresses are to be taken as positive; tension stresses are to be taken as negative.

20.2 Slenderness Requirements
20.2.1 Structural members are to comply with the slenderness requirements as provided in IRS Rules for Bulk Carriers & Oil Tankers, Volume 2, Part 1, Chapter 8, Section 2.

20.3 Buckling Checks
20.3.1 Buckling checks are to be performed for the load combinations as provided in Section 11.

20.3.2 Stress combinations to be checked are to be as per the requirements of IRS Rules for Bulk Carriers & Oil Tankers, Volume 2, Part 1, Chapter 8, Section 3 [2.2].

20.3.3 Buckling criteria are to be in accordance with IRS Rules for Bulk Carriers & Oil Tankers, Volume 2, Part 1, Chapter 8, Section 2 [3].

20.4 Buckling Capacity
20.4.1 Buckling Capacity is to be evaluated in accordance with requirements provided in

IRS Rules for Bulk Carriers & Oil Tankers, Volume 2, Part 1, Chapter 8, Section 5.

20.5 Advanced Buckling
20.5.1 Buckling capacities calculated considering elasto-plastic non-linear behavior of structural members may be accepted by IRS in lieu of the capacities calculated in 20.4.

20.5.2 The assumptions and methodology have to be submitted to IRS. Requirements in Section 21.3 are also to be complied with.

Section 21

Direct Calculations

21.1 Objective
21.1.1 The objective of direct calculations is to verify the scantlings of the primary structural members of the FOU which are computed using the prescriptive requirements in the present chapter. Such verification is performed using finite element method based evaluations

21.2 Scope
21.2.1 The verification of strength using direct calculations is mandatory for all FOU hulls with $L \geq 150$ m.

21.2.2 The scope of the direct calculations is the verification the following:

.1 Strength of longitudinal hull girder structural members, primary structural members and transverse bulkheads in the midship cargo region.
.2 Strength of longitudinal hull girder shear members in way of transverse bulkheads within the cargo tank area.

21.2.3 Verification of strength in accordance with 21.2.2 is to include the following:

.1 Check of stresses in the structural members considering yield failure
.2 Check of stresses in structural members considering buckling failures

21.2.4 Loads to be considered for the verification of strength are to consider combination of Static (S) and Dynamic (D) load scenarios. See Section 21.4 for further details.

21.3 Computer Programs
21.3.1 Computer program or software which is capable of accurately evaluating the deformations, strains and stresses in the hull structure is to be used for performing the verification as described in this Section.

21.3.2 Computer program or software suitable for accurately evaluating the buckling capacities as described in Section 20 is to be used for checking the buckling strength required for the verification.

21.3.3 The correctness and accuracy of the computer software and programs has to be demonstrated to IRS's satisfaction.

21.4 Requirements for mandatory strength assessments
21.4.1 Requirements for mandatory strength assessments are provided in Appendix 3.

21.5 Requirements for GSA Class notation
21.5.1 Requirements for analyses to be performed for GSA class notation are provided in Appendix 3.

Section 22

Fatigue

22.1 Symbols

D : Total fatigue damage

D_i : Total fatigue damage for the i^{th} loading condition

n_{ij} : number of stress cycles encountered by the Unit for the stress range corresponding to the j^{th} environment scenario in the i^{th} loading condition

N_{ij} : number of cycles to failure for the unit for the stress range corresponding to the the j^{th} environment scenario in the i^{th} loading condition

w_i : weightage factor corresponding to the relative period spent by the unit in the i^{th} loading condition

22.2 General
22.2.1 Fatigue life of structural details is mandated to be evaluated in accordance with requirements provided within the present section

22.3 Structural Details
22.3.1 Fatigue life evaluation is to be performed for all structural connections which include the following:

- Details as listed in IRS Rules for Bulk Carriers and Oil Tankers, Volume 2, Part 1, Chapter 9, Section2.
- Mooring line attachments with hull
- Topside module foundation connection with hull
- Riser connection points
- Turret supporting structure (as applicable)
- Terminations of structural members
- Large Openings in stressed areas
- Bracket landings
- Other areas where stress concentrations arise.

22.4 Methodology
22.4.1 Fatigue evaluations using Nominal stress approach or hotspot stress approach are considered acceptable by IRS. Details mandated for evaluation of the hotspot stress are provided in IRS Rules for Bulk Carriers and Oil Tankers, Volume 2, Part 1, Chapter 9, Section 2. IRS may impose requirements for hotspot stress evaluations for additional details as may be required.

22.4.2 Deterministic approach or Spectral methods based fatigue evaluations are considered acceptable by IRS.

22.4.3 The evaluation of stress ranges is to consider the environmental conditions to be experienced at the site where the FOU is to be operated. Loading conditions are to consider the unit at drafts $\geq 0.9T_{sc}$ minimum ballast draught and intermediate drafts. The total fatigue damage is obtained by summation of the damages corresponding to the considered loading conditions with appropriate weightage factors representing the relative times for which the unit is operating in the considered loading conditions. The weightage factors representing the relative times for loading conditions are to be consistent with the FOU operations.

$D = \sum w_i D_i \; \forall \; i = 1 \; to \; n$

Where:

n : number of loading conditions

$D_i = \sum \frac{n_{ij}}{N_{ij}}$

22.4.4 Consideration is also to be given to the fatigue damage during transit conditions.

22.4.5 Applicable SN curves are to be used which are suitable for the joint being evaluated and also the method used for evaluating the stress range (nominal or hotspot). In absence of actual data, guidelines for SN curves provided in Appendix 4 are to be used for fatigue evaluations.

22.4.6 The fatigue life is to be evaluated considering that the Unit will encounter 10^8 stress cycles in 25 years. The cumulative damage index *D* is not to exceed 1.0.

22.4.7 For the hotspot stress range approach, the finite element modeling is to be in accordance with requirements provided in IRS Rules for Bulk Carriers and Oil Tankers, Volume 2, Part 1, Chapter 9.

22.4.8 Detail design of structural connections is recommended to be in accordance with requirements provided in IRS Rules for Bulk Carriers and Oil Tankers, Volume 2, Part 1, Chapter 9, Section 6.

22.4.9 A detailed report for the fatigue assessment is to be submitted to IRS. The report is to consist of the following as a minimum

- Structural connections for which fatigue life evaluation is performed
- Assumptions and approach
- Loading conditions considered with supporting data
- Environmental loads considered with supporting data
- Method used for direct evaluation of environmental loads if applicable
- Fatigue life computations with details of SN curves utilized. Details of post weld treatments or weld improvement methods considered for the fatigue evaluation are also to be specified and the same must be marked upon the relevant structural drawings.
- For FOU conversions from existing tankers, an estimate of the accumulated fatigue damage is to be provided considering the operational records. This is to help evaluate the remaining fatigue life of the structural details.
- Probability level of the evaluated fatigue life.

22.5 Acceptance Criteria

22.5.1 For a Newbuild FOU, the evaluated fatigue life of a structural detail as listed in Section 22.3 is not to be less than 25 years. For structural details in Section 22.3 which are critical to the hull integrity and difficult to access & repair for inspections, additional factor of safety may be required by IRS.

22.5.2 For existing ships converted to FOUs, the remaining fatigue life of is not to be less than the period for which the FOU is intended to operate at the site. However, in any case remaining fatigue life of atleast 10 years has to be demonstrated.

Section 23

Welding and Structural Details

23.1 Symbols and Definitions

σ_{perm} : permissible direct stress [N/mm^2]
τ_{perm} : permissible shear stress [N/mm^2]
σ_{yd} : minimum specified yield stress [N/mm^2]
τ_{yd} : $\sigma_{yd}/\sqrt{3}$

23.2 Welding

23.2.1 Welding is to be in compliance with applicable requirements in IRS Rules for Bulk Carriers & Oil Tankers, Volume 2, Part 1, Chapter 12.

23.2.2 Welding requirements for locations which are not covered by present section shall be specially considered by IRS.

23.3 Structural Details

23.3.1 Standard Construction Details

23.3.1.1 A booklet of standard construction details is to be submitted for review. It is to include the following:

.1 the proportions of built-up members to demonstrate compliance with established standards for structural stability, see Section 20.
.2 the design of structural details which reduce the harmful effects of stress concentrations, notches and material fatigue such as
  - details of the ends, at the intersections of members and associated brackets
  - shape and location of air, drainage, and/or lightening holes
  - shape and reinforcement of slots or cut-outs for internals elimination or closing of weld scallops in way of butts, 'softening' of bracket
  - toes, reduction of abrupt changes of section or structural discontinuities
  - proportion and thickness of structural members to reduce fatigue response due to engine, propeller or wave induced cyclic stresses, particularly for higher strength steels.

23.3.2 Termination of Local Support Members

23.3.2.1 In general, structural members are to be effectively connected to adjacent structures to avoid hard spots, notches and stress concentrations.

23.3.2.2 Where a structural member is terminated, structural continuity is to be maintained by suitable back-up structure fitted in way of the end connection of frames, or the end connection is to be effectively extended with additional structure and integrated with an adjacent beam, stiffener, etc.

23.3.2.3 All types of stiffeners (longitudinals, beams, frames, bulkhead stiffeners) are to be connected at their ends. However, in special cases sniped ends may be permitted as described in this section.

Longitudinal Members

23.3.2.4 All longitudinals are to be kept continuous within the 0.4*L* amidships cargo tank region. In special cases, in way of large openings, foundations and partial girders, the longitudinals may be terminated, but end connection and welding is to be specially considered.

23.3.2.5 Where continuity of strength of longitudinal members is provided by brackets, the correct alignment of the brackets on each side of the primary support member is to be ensured, and the scantlings of the brackets are to be such that the combined stiffener/bracket section modulus and effective cross-sectional area are not less than those of the member.

Bracketed Connections

23.3.2.6 At bracketed end connections, continuity of strength is to be maintained at the stiffener connection to the bracket and at the connection of the bracket to the supporting member. The brackets are to have scantlings sufficient to compensate for the non-continuous stiffener flange or non- continuous stiffener.

23.3.2.7 The arrangement of the connection between the stiffener and the bracket is to be such that at no point in the connection, the section modulus is less than that required for the stiffener.

23.3.2.8 Minimum net bracket thickness, $t_{bkt\text{-}net}$, is to be taken as:

$$t_{bkt-net} = \left(2 + f_{bkt}\sqrt{Z_{rl-net}}\right)\left(\sqrt{\frac{\sigma_{yd-stf}}{\sigma_{yd-bkt}}}\right) \quad \text{[mm]}$$

$t_{bkt\text{-}net}$ is not be less than 6 mm and need not exceed 13.5 mm.

$f_{bkt\text{-}net}$ = 0.2 for brackets with flange or edge stiffener

= 0.3 for brackets without flange or edge stiffener

$Z_{rl\text{-}net}$:net rule section modulus for the stiffener in cm^3. In case of two stiffeners connected it need not be taken greater than that of the smallest connected stiffener.

$\sigma_{yd\text{-}stf}$: specified minimum yield stress of the material of the stiffener [MPa]

$\sigma_{yd\text{-}bkt}$: specified minimum yield stress of the material of the bracket [MPa]

23.3.2.9 Brackets to provide fixity of end rotation are to be fitted at the ends of discontinuous local support members, except as otherwise permitted by 23.3.2.12 to 23.3.2.14. The end brackets are to have arm lengths, l_{bkt}, not less than:

$$l_{bkt} = (c_{bkt})\left(\sqrt{\frac{Z_{rl-net}}{t_{bkt-net}}}\right) \quad \text{[mm]}$$

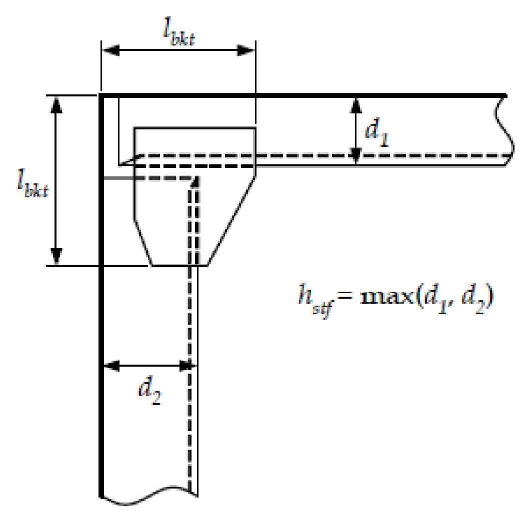
l_{bkt} is not to be less than:

- 1.8 times the depth of the stiffener web for connections where the end of the stiffener web is supported and the bracket is welded in line with the stiffener web or with offset necessary to enable welding, see Figure 42 (c)
- 2 times the depth of stiffener web for other cases (See Figure 42 (a), (b) and (d))

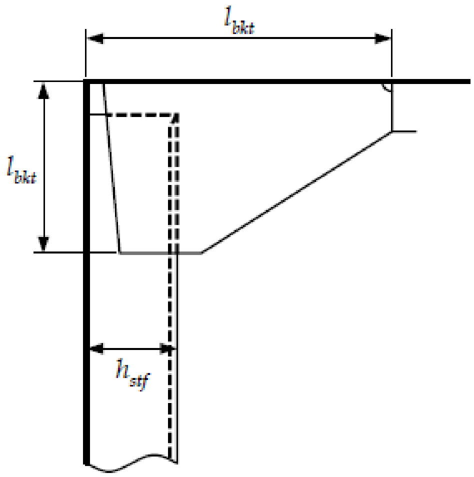
c_{bkt} = 65 for brackets with flange or edge stiffener

=70 for brackets without flange or edge stiffener

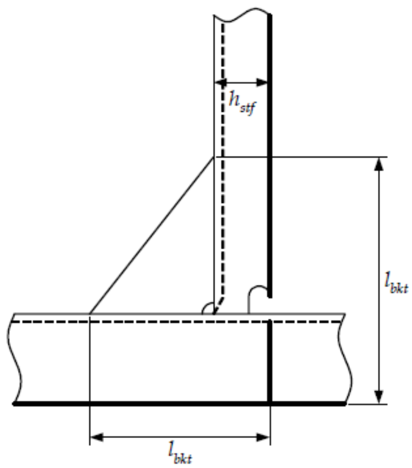
$Z_{rl\text{-}net}$: net rule section modulus for the stiffener in cm^3. In case of two stiffeners connected it need not be taken greater than that of the smallest connected stiffener.



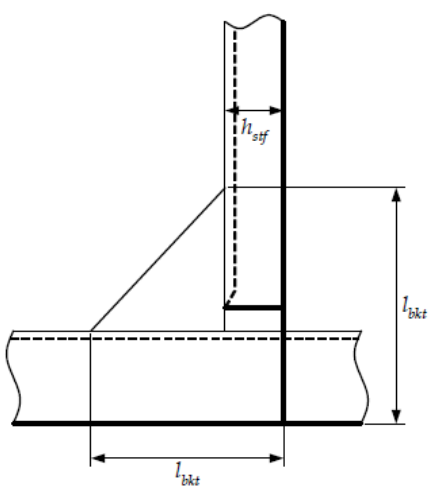
(a)



(b)



(c)



(d)

Figure 42: Bracket Arm Length

Note:

- For stiffeners of configuration (b) that are not lapped, the bracket arm length l_{bkt} is not to be less than the stiffener height h_{stf}.
- For stiffener arrangements similar to (c) and (d) where the smaller attached stiffener, labelled as h_{stf} , is connected to a primary support member or bulkhead, the height of the bracket is not to be less than the height of the attached stiffener, h_{stf}.

23.3.2.10 In case of different arm lengths the lengths of the arms, measured from the plating to the toe of the bracket, are to be such that the sum of them is greater than $2l_{bkt}$ and each arm not to be less than $0.8l_{bkt}$, where l_{bkt} is as defined in 23.3.2.9.

23.3.2.11 The proportions and edge stiffening of brackets are to be in accordance with the requirements of Section 20. Where an edge stiffener is required, the depth of stiffener web, d_w, is not to be less than:

$$d_w = Max\left(45\left(1+\frac{Z_{rl-net}}{2000}\right), 50\right) \text{ [mm]}$$

Z_{rl-net} : net rule section modulus for the stiffener [cm^3]. In case of two stiffeners connected it need not be taken greater than that of the smallest connected stiffener.

Bracketless Connections

23.3.2.12 Local support members, for example longitudinals, beams, frames and bulkhead stiffeners forming part of the hull structure, are generally to be connected at their ends, in accordance with the requirements of 23.3.2.4 – 23.3.2.11.

23.3.2.13 Where alternative connections are adopted, the proposed arrangements will be specially considered by IRS.

23.3.2.14 The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint.

Snipped End

23.3.2.15 Stiffeners with sniped ends may be used where dynamic loads are small and where the incidence of vibration is considered to be small, provided the net thickness of plating supported by the stiffener, $t_{p\text{-}net}$, is not less than:

$$t_{p-net} = c_1 \sqrt{\left(1000l - \frac{s}{2}\right)\frac{sPk}{10^6}} \quad \text{[mm]}$$

l : Stiffener span [m].

s : Stiffener spacing [mm]

P : Design pressure [kN/m^2] for the stiffener for the design load set being considered. The design load sets are to be considered based upon the location (e.g. cargo tank or aft region etc.)

k : Higher strength steel factor as defined in 1.1

c_1 : Coefficient for design load being considered to be taken as:

1.2 for Acceptance criteria set AC1 and sloshing loads

1.1 for Acceptance criteria set AC2

1.05 for Acceptance criteria set AC3

23.3.2.16 Bracket toes and sniped end members are, in general, to be kept within 25mm of the adjacent member. The maximum distance is not to exceed 40mm unless the bracket or member is supported by another member on the opposite side of the plating. Special attention is to be given to the end taper by using a sniped end of not more than 30 degrees. The depth of toe or sniped end is, generally, not to exceed the thickness of the bracket toe or sniped end member, but need not be less than 15mm.

23.3.2.17 The end attachments of non-load bearing members may be snipe ended. The sniped end is to be not more than 30 degrees and is generally to be kept within 50mm of the adjacent member unless it is supported by a member on the opposite side of the plating. The depth of the toe is generally not to exceed 15mm.

Air and Drain Holes and Scallops

23.3.2.18 Air and drain holes and scallops are to be kept at least 200mm clear of the toes of end brackets, end connections and other areas of high stress concentration measured along the length of the stiffener toward the mid-span and 50mm measured along the length in the opposite direction. See Figure 43 (b). Openings that have been fitted with closing plates, such as scallops, may be permitted in way of block fabrication butts. In areas where the shear stress is less than 60 percent of the allowable limit, alternative arrangements may be accepted. Openings are to be well-rounded. See Figure 43(a) shows some examples of air and drain holes and scallops. In general, the ratio of *a*/*b*, as defined in Figure 43 (a), is to be between 0.5 and 1.0. In fatigue sensitive areas further consideration may be required with respect to the details and arrangements of openings and scallops.

Special Requirements

23.3.2.19 Closely spaced scallops or drain holes, i.e. where the distance between scallops/drain holes is less than twice the width *b* as shown in Figure 43 (a), are not permitted in longitudinal strength members or within 20% of the stiffener span measured from the end of the stiffener. Widely spaced air or drain holes may be permitted provided that they are of elliptical shape or equivalent to minimise stress concentration and are, in general, cut clear of the weld connection.

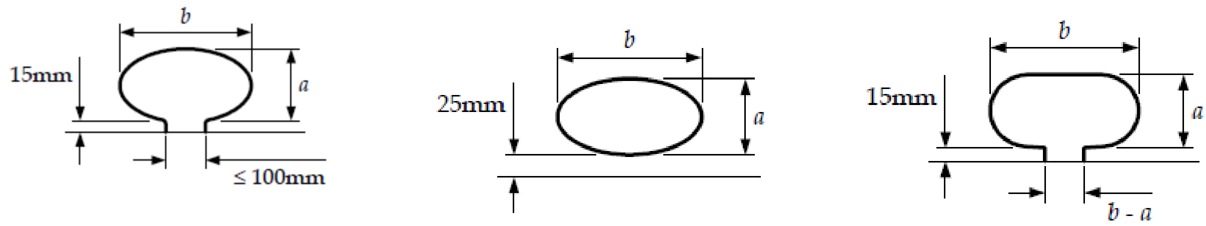


Figure 43 (a): Examples of Air and Drain holes and Scallops
Note: The details shown in the figure are only for illustration purpose

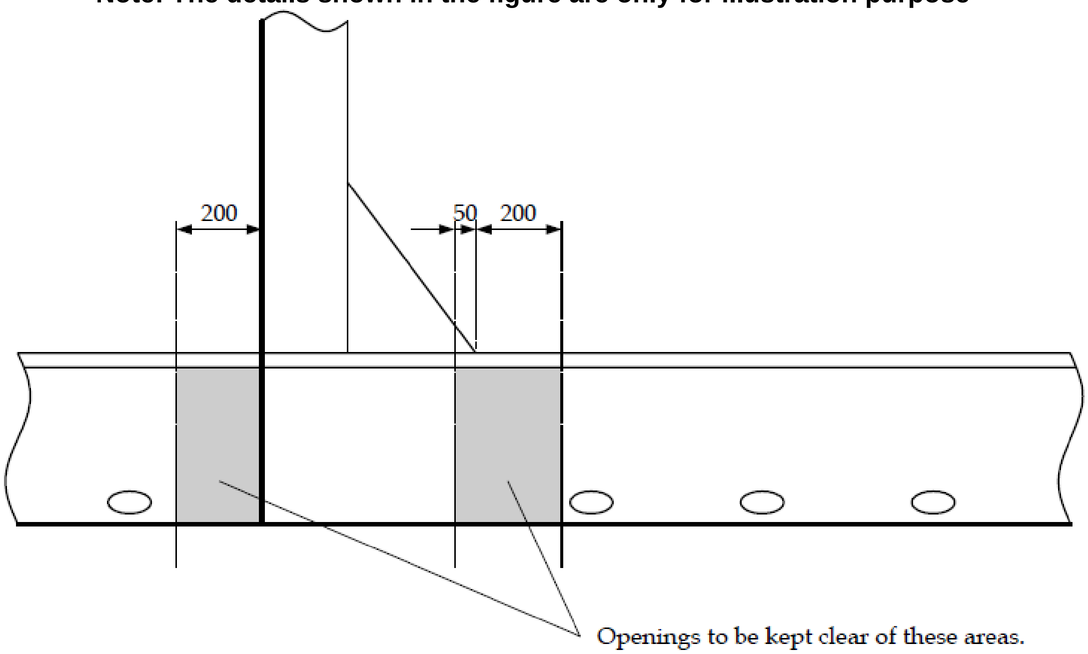


Figure 43 (b): Location of Air and Drain Holes

23.3.3 Termination of Primary Support Members

General

23.3.3.1 Primary support members are to be arranged to ensure effective continuity of strength. Abrupt changes of depth or section are to be avoided. Primary support members in tanks are to form a continuous line of support and wherever possible, a complete ring system.

23.3.3.2 The members are to have adequate lateral stability and web stiffening, and the structure is to be arranged to minimise hard spots and other sources of stress concentration. Openings are to have well-rounded corners and are to be located considering the stress distribution and buckling strength of the panel.

End Connections

23.3.3.3 Primary support members are to be provided with adequate end fixity by brackets or equivalent structure. The design of end connections and their supporting structure is to provide adequate resistance to rotation and displacement of the joint and effective distribution of the load from the member.

23.3.3.4 The ends of brackets are generally to be soft-toed. The free edges of the brackets are to be stiffened. Scantlings and details are given in 23.3.3.7 – 23.3.3.10.

23.3.3.5 Where primary support members are subject to concentrated loads additional strengthening may be required, particularly if these are out of line with the member web.

23.3.3.6 In general, ends of primary support members or connections between primary support members forming ring systems are to be provided with brackets. Bracketless connections may be applied provided that there is adequate support of the adjoining face plates.

Brackets

23.3.3.7 In general, the arm lengths of brackets connecting primary support members are not to be less than the web depth of the member, and need not be taken as greater than 1.5 times the web depth. The thickness of the bracket is, in general, not to be less than that of the girder web plate.

23.3.3.8 For a ring system where the end bracket is integral with the webs of the members and the face plate is carried continuously along the edges of the members and the bracket, the full area of the largest face plate is to be maintained close to the midpoint of the bracket and gradually tapered to the smaller face plates. Butts in face plates are to be kept well clear of the bracket toes.

23.3.3.9 Where a wide face plate abuts a narrower one, the taper is generally not to be greater than 1 in 4. Where a thick face plate abuts against a thinner one and the difference in thickness is greater than 4mm, the taper of the thickness is not to be greater than 1 in 3.

23.3.3.10 Face plates of brackets (typical brackets similar to those indicated in described in Section 4.6 are to have a net cross-sectional area, $A_{f\text{-}net}$, which is not to be less than:

$$A_{f-net} = l_{bkt-edge} t_{bkt-net} \quad [\text{cm}^2]$$

Where:

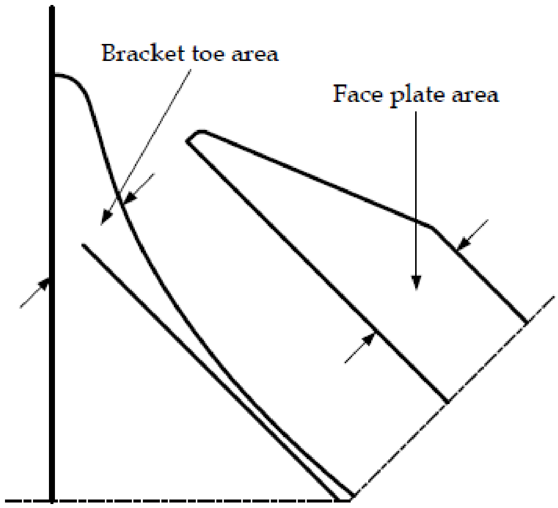
$l_{bkt\text{-}edge}$: Length [m] of free edge of bracket. For brackets that are curved the length of the free edge may be taken as the length of the tangent at the midpoint of the free edge. If $l_{bkt\text{-}edge}$ is greater than 1.5m, 40% of the face plate area is to be in a stiffener fitted parallel to the free edge and a maximum 0.15m from the edge.

$t_{bkt\text{-}net}$: minimum thickness [mm] of bracket as defined in 23.3.2.8.

Bracket Toes

23.3.3.11 The toes of brackets are not to land on unstiffened plating. Notch effects at the toes of brackets may be reduced by making the toe concave or otherwise tapering it off. In general, the toe height is not to be greater than the thickness of the bracket toe, but need not be less than 15mm. The end brackets of large primary support members are to be soft-toed. Where any end bracket has a face plate, it is to be sniped and tapered at an angle not greater than 30^{o}.

23.3.3.12 Where primary support members are constructed of higher strength steel, particular attention is to be paid to the design of the end bracket toes in order to minimise stress concentrations. Sniped face plates, which are welded onto the edge of primary support member brackets, are to be carried well around the radiused bracket toe and are to incorporate a taper not greater than 1 in 3. Where sniped face plates are welded adjacent to the edge of primary support member brackets, adequate cross-sectional area is to be provided through the bracket toe at the end of the snipe. In general, this area, measured perpendicular to the face plate is to be not less than 60% of the full cross-sectional area of the face plate, see Figure 44.



Note: The details shown in this figure are only used to illustrate items described in the text and are not intended to represent design guidance or recommendations.

Figure 43: Bracket Toe Construction

23.3.4 Intersection of Continuous Local Support members and Primary Support Members

General

23.3.4.1 Cut-outs for the passage of stiffeners through the web of primary support members, and the related collaring arrangements, are to be designed to minimize stress concentrations around the perimeter of the opening and on the attached web stiffeners.

23.3.4.2 Cut-outs in way of cross-tie ends and floors under bulkhead stools or in high stress areas are to be fitted with “full” collar plates, see Figure 45.

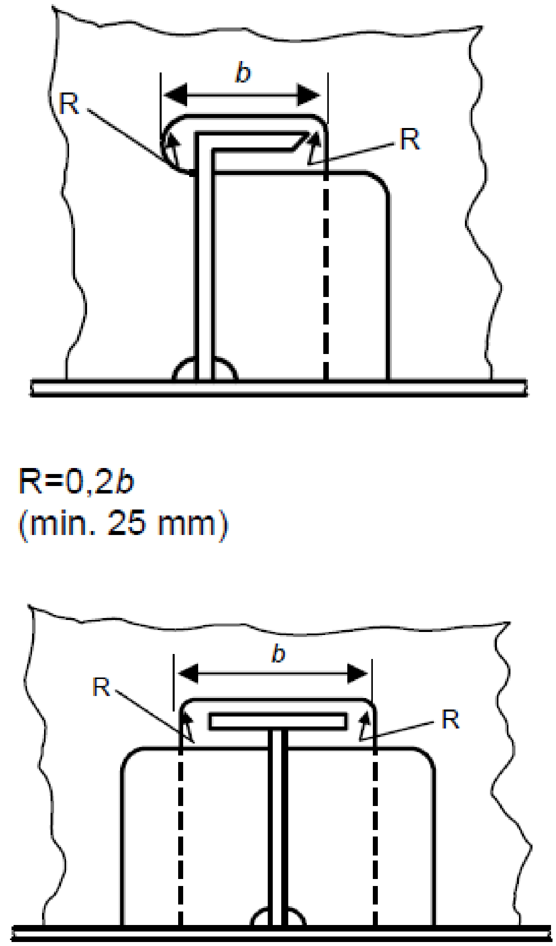


Figure 44: Collars for cut-outs in Areas of High Stress

23.3.4.3 Lug type collar plates are to be fitted in cut-outs where required for compliance with the requirements of 23.3.4.7 – 23.3.4.18 and in areas of significant stress concentrations, e.g., in way of primary support member toes. See Figure 46 for typical lug arrangements.

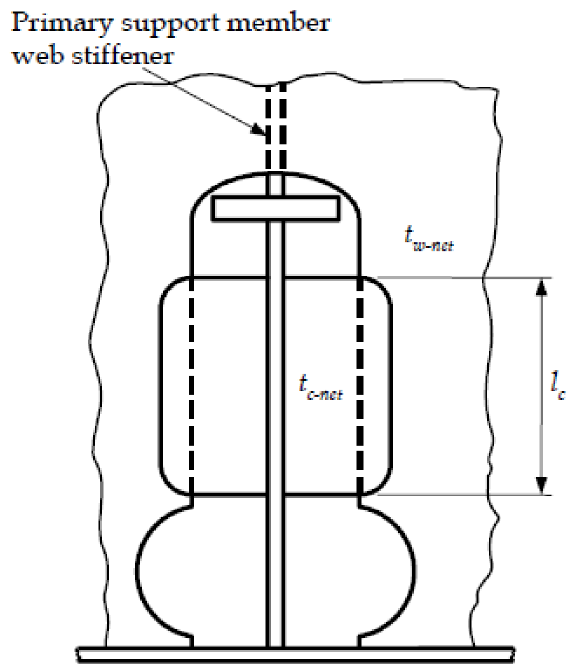
23.3.4.4 When, in the following locations, the calculated direct stress, σ_w, in the primary support member web stiffener according to 23.3.4.11 exceeds 80% of the permissible values a soft heel is to be provided in way of the heel of primary support member web stiffeners:

a. connection to shell envelope longitudinals below the scantling draught, T_{SC}
b. connection to inner bottom longitudinals.

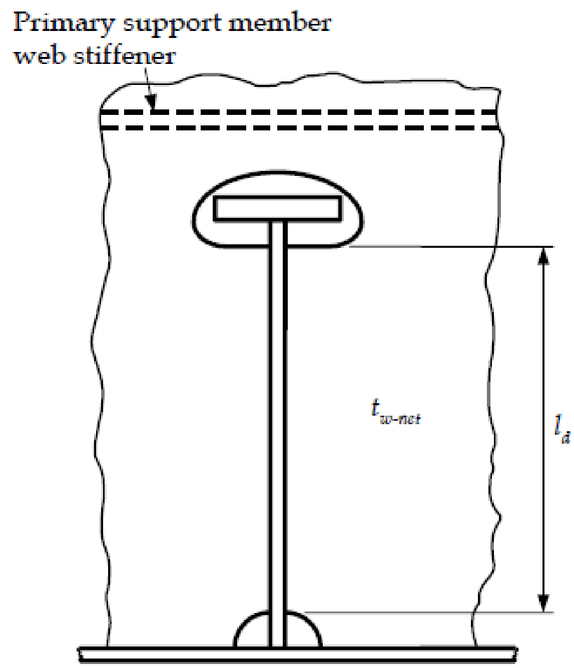
A soft heel is not required at the intersection with watertight bulkheads and primary support members, where a back bracket is fitted or where the primary support member web is welded to the stiffener face plate. The soft heel is to have a keyhole, similar to that shown in Figure 47(c).

Details of cut-outs

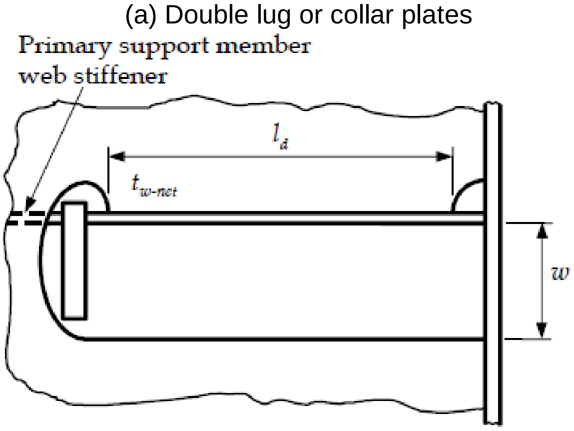
23.3.4.5 In general, cut-outs are to have rounded corners and the corner radii, *R*, are to be as large as practicable, with a minimum of 20% of the breadth, *b*, of the cutout or 25mm, whichever is greater, but need not be greater than 50mm, see Figure 45. Consideration will be given to other shapes on the basis of maintaining equivalent strength and minimizing stress concentration.



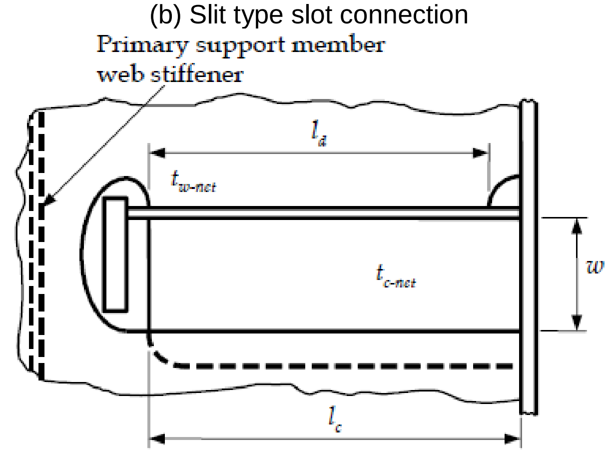
(a) Double lug or collar plates



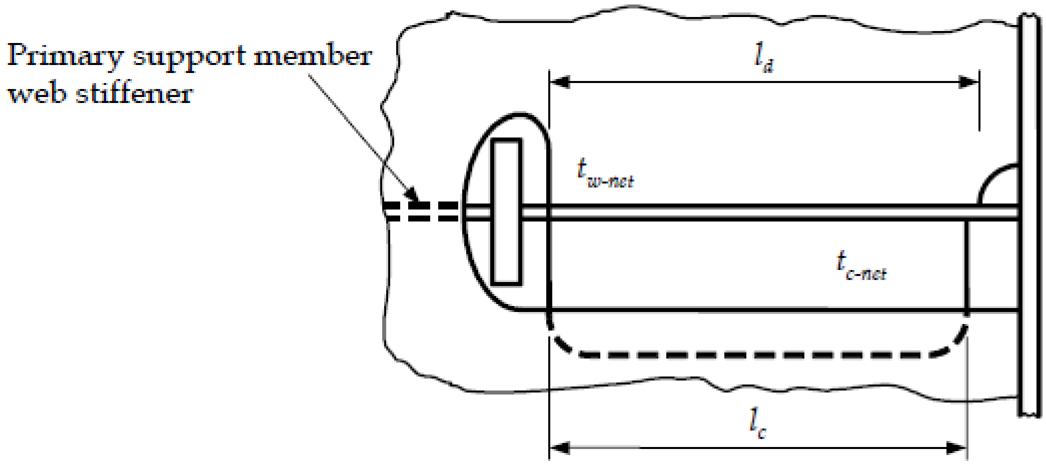
(b) Slit type slot connection



(c) direct connection without lug or collar plate



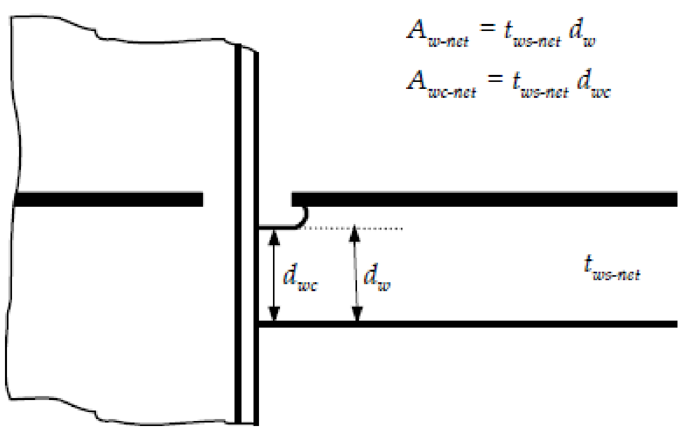
(d) lug or collar plate and direct connection



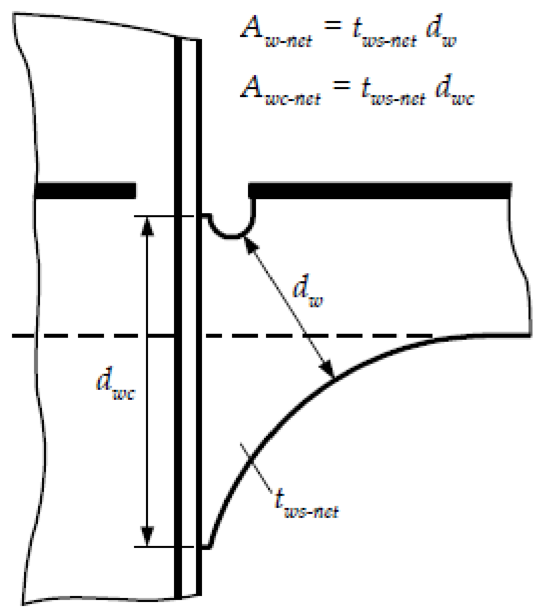
(e) Lug or collar plate and direct connection

Note: The figures (a) – (e) are only for illustration purposes and are not intended to represent guidance or recommendations

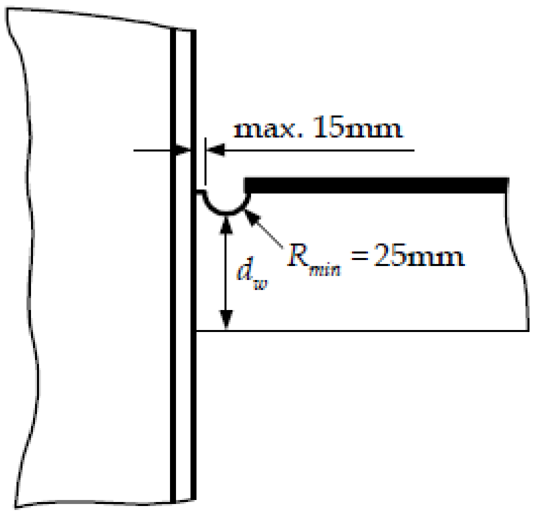
Figure 45: Symmetric and Asymmetric cutouts



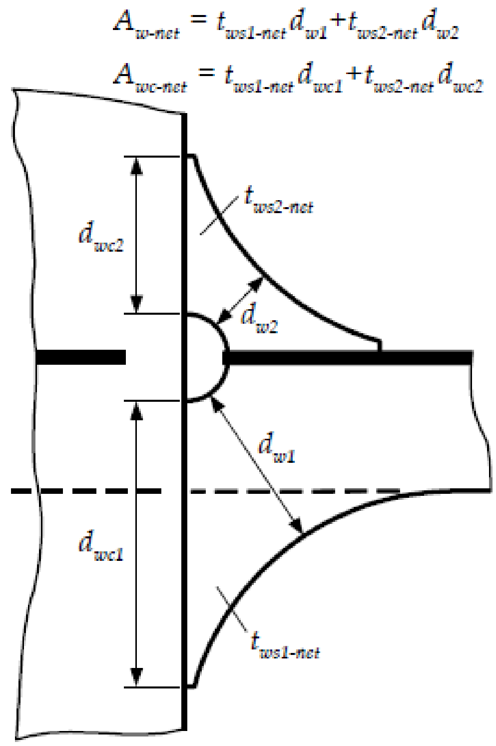
(a) Straight heel no bracket



(b) Soft toe and soft heel



(c) Key hole in way of heel



(d) Symmetrical soft toe brackets

Except where specific dimensions are noted for the details of the keyhole in way of the soft heel, see *3.4.1.4*, the details shown in this figure are only used to illustrate symbols and definitions and are not intended to represent design guidance or recommendations.

Figure 46: Primary Support Member Web Stiffener details

23.3.4.6 The requirements from 23.3.4.7 – 23.3.4.18 are applicable to connections between primary support members and intersecting stiffeners (local support members)

Connection between primary support members and intersecting stiffeners (local support members)

23.3.4.7 The cross-sectional areas of the connections are to be determined from the proportion of load transmitted through each component in association with its appropriate permissible stress.

23.3.4.8 The total load, *W*, transmitted through the connection to the primary support member is given by:

$$W = Ps\left(S - \frac{s}{2000}\right)10^{-3} \qquad \text{[kN]}$$

Where:

P : Design pressure [kN/m^2] for the stiffener for the design load set being considered. The design load sets are to be considered based upon the location (e.g. cargo tank or aft region etc.)

S : Primary support member spacing [m]

s : Stiffener spacing [mm]

For stiffeners having different primary support member spacing, *S*, and/or different pressure, *P*, at each side of the primary support member, the average load for the two sides is to be applied, e.g. vertical stiffeners at transverse bulkhead.

23.3.4.9 The load, W_1, transmitted through the shear connection is to be taken as follows. If the web stiffener is connected to the intersecting stiffener:

$$W_1 = W\left(\alpha_a + \frac{A_{1-net}}{4 f_c A_{w-net} + A_{1-net}}\right) \quad [kN]$$

If the web stiffener is not connected to the intersecting stiffener

$W_1 = W$

Where:

W : the total load [kN] as defined in 23.3.4.8

α_a : panel aspect ratio = $s/1000S$ but not to be taken greater than 0.25 *;* Where *s* and *S* are as defined in 23.3.4.8

A_{1-net} : Effective net shear area of connection to be taken as the sum of the components of connection:

$$A_{1-net} = A_{1d-net} + A_{1c-net} \quad [cm^2]$$

In case of a slit type slot connection area, A_{1-net} is given by:

$$A_{1-net} = 2 l_d t_{w-net} 10^{-2} \quad [cm^2]$$

In case of a typical double lug or collar plate connection area, A_{1-net}, is given by:

$$A_{1-net} = 2 f_1 l_c t_{c-net} 10^{-2} \quad [cm^2]$$

A_{1d-net} :net shear connection area excluding lug or collar plate, as given by the following and Figure 46:

$$A_{1d-net} = l_d t_{w-net} 10^{-2} \quad [cm^2]$$

l_d : length of direct connection between stiffener and primary support member web [mm]

t_{w-net} : Net web thickness [mm] of the primary support member

A_{1c-net} : Net shear connection area with lug or collar plate, as given by the following and Figure 46:

$$A_{1c-net} = f_1 l_c t_{c-net} 10^{-2} \quad [cm^2]$$

l_c : Length of connection between lug or collar plate and primary support member [mm]

t_{c-net} : Net thickness of lug or collar plate, not to be taken greater than the thickness of the primary support member web [mm]

f_1 : Shear stiffness coefficient

= 1.0 for stiffeners of symmetrical cross section

= 140/*w* for stiffeners of unsymmetrical cross section but not to be greater than 1.0

w : Width of the cut-out for an asymmetrical stiffener, measured from the cut-out side of the stiffener web [mm], as indicated in Figure 46

A_{w-net} : Effective net cross-sectional area of the primary support member web stiffener in way of the connection including backing bracket where fitted, as shown in Figure 47 [cm^2]. If the primary support member web stiffener incorporates a soft heel ending or soft heel and soft toe ending, A_{w-net}, is to be measured at the throat of the connection, as shown in Figure 47.

f_c : Collar load factor as shown below

For intersecting stiffeners of symmetrical cross section

= 1.85	$A_{w-net} \le 14$
= 1.85-0.0441(A_{w-net} – 14)	$14 < A_{w-net} \le 31$
= 1.1-0.013(A_{w-net} – 31)	$31 < A_{w-net} \le 58$
=0.75	$A_{w-net} > 58$

For intersecting stiffeners of unsymmetrical cross section

$$= 0.68 + 0.0172 \frac{l_s}{A_{w-net}}$$

Where

l_s = l_c for a single lug or a collar plate connection to the primary support member

= l_d for a single sided direct connection to the primary support member

= mean of the connection length on both sides, i.e. in the case of a lug or collar plus direct connection
$l_s = 0.5(l_c + l_d)$

23.3.4.10 The load, W_2, transmitted through the primary support member web stiffener is to be taken as follows.
If the web stiffener is connected to the intersecting stiffener

$$W_2 = W\left(1 - \alpha_a - \frac{A_{1-net}}{4f_c A_{w-net} + A_{1-net}}\right) \quad [kN]$$

If the web stiffener is not connected to the intersecting stiffener
$W_2 = 0$
Where:

W : Total load [kN] as defined in 23.3.4.8
α_a : Panel aspect ratio s/1000S
S : Primary support member spacing [m]
s : Stiffener spacing [mm]
A_{1-net} : As defined in 23.3.4.9
f_c : As defined in 23.3.4.9
A_{w-net} : As defined in 23.3.4.9

23.3.4.11 The values of A_{w-net}, A_{wc-net} and A_{1-net} are to be such that the calculated stresses satisfy the following criteria:
For the connection to the primary support member web stiffener away from the weld:
$\sigma_w \le \sigma_{perm}$

For the connection to the primary support member web stiffener in way of the weld:
$\sigma_{wc} \le \sigma_{perm}$

For the shear connection to the primary support member web:
$\tau_w \le \tau_{perm}$
Where:

σ_w : Direct stress in the primary support member web stiffener at the minimum bracket area away from the weld connection:

$$\sigma_w = \frac{10W_2}{A_{w-net}} \quad [N/mm^2]$$

σ_{wc} : Direct stress in the primary support member web stiffener in way of the weld connection:

$$\sigma_{wc} = \frac{10W_2}{A_{wc-net}} \quad [N/mm^2]$$

τ_w : Shear stress in the shear connection to the primary support member :

$$\tau_{wc} = \frac{10W_1}{A_{1-net}} \quad [N/mm^2]$$

A_{w-net} : As defined in 23.3.4.9

A_{wc-net} : Effective net area of the web stiffener in way of the weld as shown in Figure 47 in cm^2
A_{1-net} : Effective net shear area as defined in 23.3.4.9
W_1, W_2 : Loads as defined in 23.3.4.9
σ_{perm} : Permissible direct stress as given in Table 40
τ_{perm} : Permissible shear stress as given in Table 40

23.3.4.12 When total load, W, is bottom slamming or bow impact loads the following criteria apply in lieu of 23.3.4.9-23.3.4.11.

$$0.9W \le \frac{(A_{1-net}\tau_{perm} + A_{w-net}\sigma_{perm})}{10} \quad [kN]$$

Where A_{1-net}, A_{w-net}, σ_{perm} , τ_{perm} are defined in 23.3.4.9 and 23.3.4.11

23.3.4.13 Where a backing bracket is fitted in addition to the primary support member web stiffener, it is to be arranged on the opposite side to, and in alignment with the web stiffener. The arm length of the bracket is to be not less than the depth of the web stiffener and its net cross-sectional area through the throat of the bracket is to be included in the calculation of A_{w-net} as shown in Figure 47.

23.3.4.14 Lapped connections of primary support member web stiffeners or tripping brackets to local support members are not permitted in the cargo tank region, e.g., lapped connections between transverse and longitudinal local support members.

23.3.4.15 Where the web stiffener of the primary support member is parallel to the web of the intersecting stiffener, but not connected to it, the offset primary support member web stiffener may be located as shown in Figure 48. The offset primary support member web stiffener is to be located in close proximity to the slot edge. See also Figure 48. The ends of the offset web stiffeners are to be suitably tapered and softened.

23.3.4.16 Fabricated stiffeners having their face plate welded to the side of the web, leaving the edge of the web exposed, are not recommended for side shell and longitudinal bulkhead longitudinals. Where such sections are connected to the primary support member web stiffener, a symmetrical arrangement of connection to the transverse members is to be incorporated. This may be implemented by fitting backing brackets on the opposite side of the transverse web or bulkhead. In way of the cargo tank region, the primary support member web stiffener and backing brackets are to be butt welded to the intersecting stiffener web.

23.3.4.17 Alternative arrangements will be specially considered on the basis of their ability to transmit load with equivalent effectiveness. Details of calculations made and/or testing procedures and results are to be submitted.

23.3.4.18 The size of the fillet welds is to be calculated according to 23.2 based upon the weld factors in Table 41. For the welding in way of the shear connection the size is not to be less than that required for the primary support member web plate for the location under consideration.

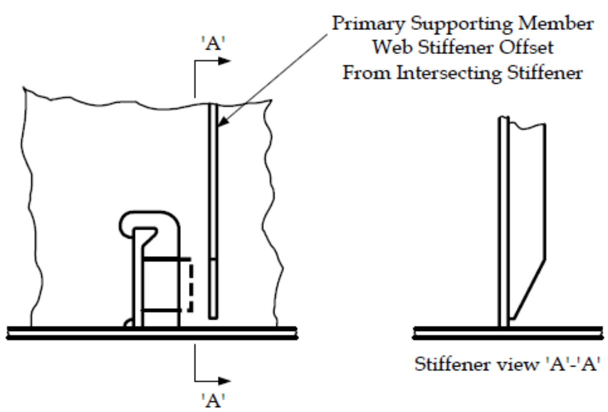


Figure 47: Offset Primary Support member web stiffeners

Table 40: Permissible Stresses for Connection between Stiffeners and Primary Members						
Item	Direct Stress σ_{perm} [N/mm^2]			Direct Shear τ_{perm} [N/mm^2]		
	Acceptance Criteria Set			Acceptance Criteria Set		
	AC1	AC2	AC3	AC1	AC2	AC3
Primary Support member web Stiffener	$0.83\sigma_{yd}$ (3)	σ_{yd}	σ_{yd}	-	-	-
Primary support member web stiffener to intersecting stiffener in				-	-	-

way of weld connection for:						
a) double continuous fillet	$0.58\sigma_{yd}$ (3)	$0.7\sigma_{yd}$(3)	σ_{yd}	-	-	-
b) partial penetration fillet	$0.83\sigma_{yd}$ (2) (3)	σ_{yd}(2)	σ_{yd}	-	-	-
Primary support member stiffener to intersecting stiffener in way of lapped welding	$0.50\sigma_{yd}$	$0.6\sigma_{yd}$	σ_{yd}	-	-	-
Shear connection including lugs or collar plates:						
a) single sided connection	-	-	-	$0.71\tau_{yd}$	$0.85\tau_{yd}$	τ_{yd}
b)double sided connection	-	-	-	$0.83\ \tau_{yd}$	τ_{yd}	τ_{yd}

Note:
1. The stress computation on plate type members is to be performed on the basis of net thicknesses, whereas gross values are to be used in weld strength assessments, see 23.3.4.18.
2. The root face is not to be greater than one third of the gross thickness of the primary support member stiffener.
3. Allowable stresses may be increased by 5 percent where a soft heel is provided in way of the heel of the primary support member web stiffener.

Table 41: Weld factors for connection between Stiffeners and Primary Support Members

Item	Weld Factor
Primary support member stiffener to intersecting stiffener	$0.6\sigma_{wc}/\sigma_{perm}$ not to be less than 0.38
Shear connection inclusive lug or collar plate	0.38
Shear connection inclusive lug or collar plate, where the web stiffener of the primary support member is not connected to the intersection stiffener	$0.6\tau_w/\tau_{perm}$ not to be less than 0.44

23.3.5 Openings

23.3.5.1 Openings are to have well rounded corners.

23.3.5.2 Manholes, lightening holes and other similar openings are to be avoided in way of concentrated loads and areas of high shear. In particular, manholes and similar openings are to be avoided in high stress areas unless the stresses in the plating and the panel buckling characteristics have been calculated and found satisfactory. Examples of high stress areas include:

- in vertical or horizontal diaphragm plates in narrow cofferdams/double plate bulkheads within one-sixth of their length from either end
- in floors or double bottom girders close to their span ends
- above the heads and below the heels of pillars.

Where larger openings than given by 23.4.5.3 or 23.4.5.4 are proposed, the arrangements and compensation required will be specially considered by IRS.

23.3.5.3 Openings cut in the web with depth of opening not exceeding 25 percent of the web depth and located so that the edges are not less than 40 percent of the web depth from the faceplate do not generally require reinforcement. The length of opening is not to be greater than the web depth or 60 percent of the local support member spacing, whichever is greater. The ends of the openings are to be equidistant from the corners of cut outs for local support members. This is applicable for only for manholes and lightening holes in single skin section not requiring reinforcement.

23.3.5.4 Where openings are cut in the web and are clear of high stress areas, reinforcement of these openings is not required provided that the depth of the opening does not exceed 50 percent of the web depth and is located so that the edges are well clear of cut outs for the passage of local support members. This is applicable for only manholes and lightening holes in double skin sections not requiring reinforcements.

23.3.5.5 Manholes and lightening holes which are required to be stiffened are to comply with requirements as provided in 23.3.5.6 and 23.3.5.7. Modifications to the mentioned requirements may be permitted on satisfactory demonstration of alternative arrangements with regards to stress and stability requirements (Sections 13,14,15,16 and 20 as applicable).

23.3.5.6 The web plate is to be stiffened at openings when the mean shear stress, as determined by application of the requirements of Sections 12 – 18 and Section 21, is greater than 50 N/mm² for acceptance criteria set *AC1* or greater than 60 N/mm² for acceptance criteria sets *AC2* and *AC3*. The stiffening arrangement is to ensure buckling strength as required by Section 20

23.3.5.7 On members contributing to longitudinal strength, stiffeners are to be fitted along the free edges of the openings parallel to the vertical and horizontal axis of the opening. Stiffeners may be omitted in one direction if the shortest axis is less than 400 mm, and in both directions if length of both axes is less than 300mm. Edge reinforcement may be used as an alternative to stiffeners. See Figure 49.

23.3.6 Local Reinforcement

23.3.6.1 Requirements as provided in 23.3.6.2 – 23.3.6.4 are applicable to reinforcements at knuckles.

23.3.6.2 Whenever a knuckle in a main member (shell, longitudinal bulkhead etc.) is arranged, adequate stiffening is to be fitted at the knuckle to transmit the transverse load. This stiffening, in the form of webs, brackets or profiles, is to be connected to the transverse members to which they are to transfer the load (in shear). See Figure 50.

23.3.6.3 In general, for longitudinal shallow knuckles, closely spaced carlings are to be fitted across the knuckle, between longitudinal members above and below the knuckle. Carlings or other types of reinforcement need not be fitted in way of shallow knuckles that are not subject to high lateral loads and/or high in-plane loads across the knuckle, such as deck camber knuckles.

23.3.6.4 Generally, the distance between the knuckle and the support stiffening described in 23.3.6.2 is not to be greater than 50mm.

23.3.6.5 Reinforcement is to be provided for openings and attachments associated with the means of access for inspection purposes. Such Local reinforcement is to be provided taking into account proper location and strength of all relevant openings and attachments.

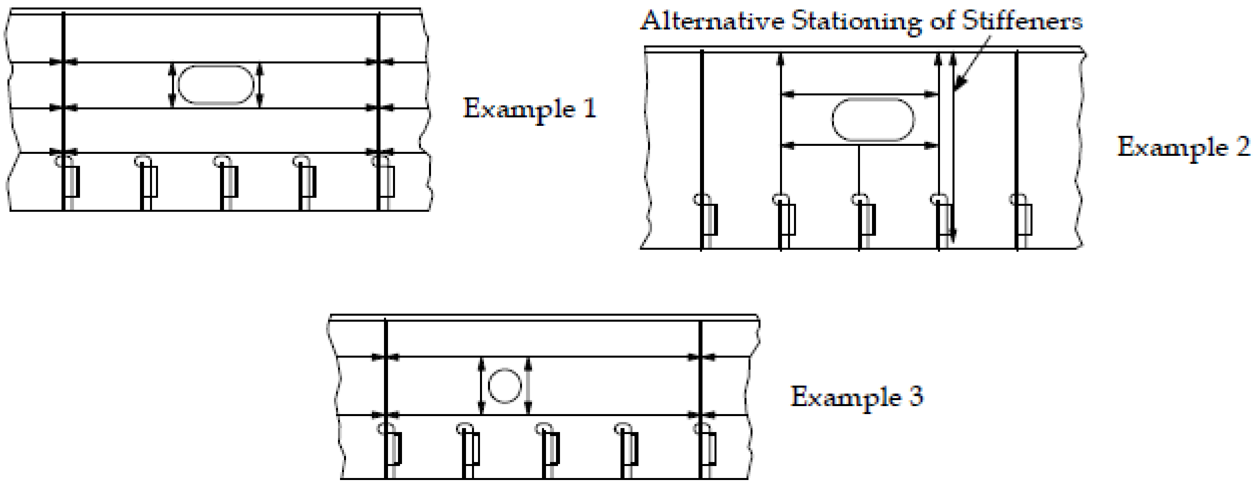


Figure 48: Web plate with large openings

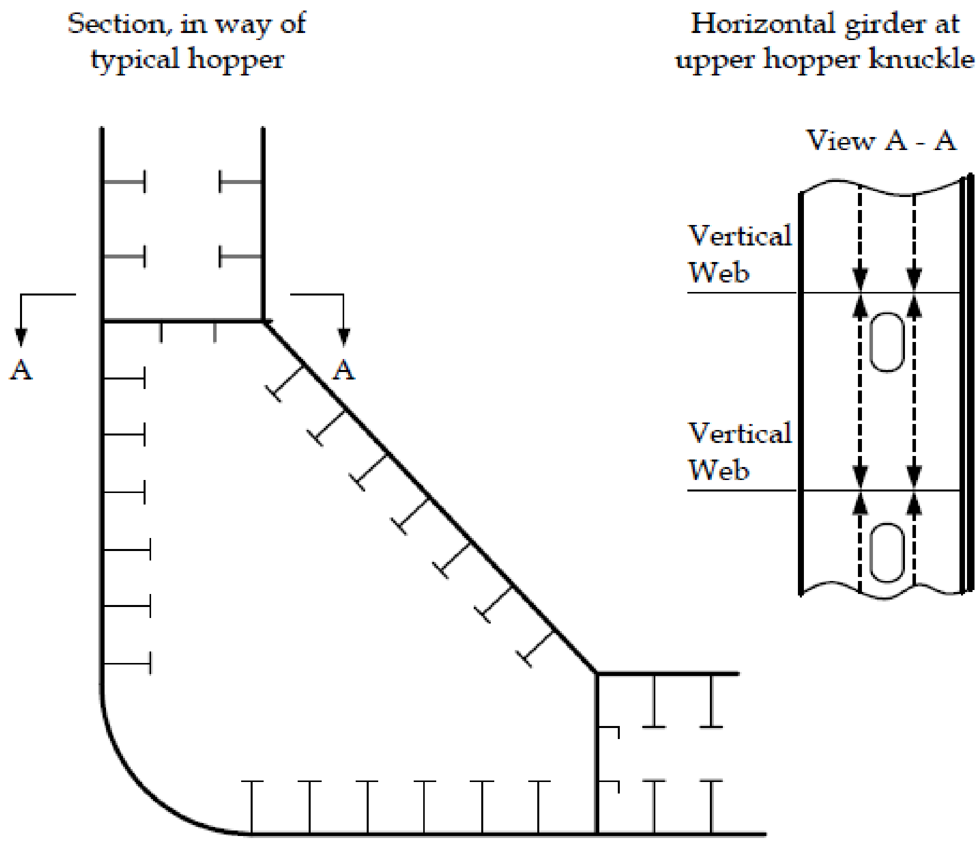


Figure 49: Example of Reinforcement at knuckles

Section 24

Hull Construction Quality and Testing

24.1 General

24.1.1 Hull Construction Quality is to be in compliance with applicable requirements in IRS Rules for Oil Tankers & Bulk Carriers, Volume 2, Part 1, Chapter 12.

24.1.2 Testing requirements are to be in compliance with IRS Rules for Bulk Carriers & Oil Tankers, Volume 1, Part 3, Chapter 2.

End of Chapter

Chapter 5

Mooring Systems and Equipment, Major Structures, Structural Foundations, Riser Systems

Contents

Section 1

General

1.1 General

1.1.1 This chapter covers the scope for Mooring systems & Equipment, Major structures and Structural Foundations which may be installed on the FOU. This chapter also contains the requirements for the riser systems structural assessment which are to be complied with in order for the Unit to be assigned the RISER class notation.

1.1.2 The definitions of "Major Structures" & "Structural Foundations" are provided in Section 3 & 4 respectively. Where such demarcations may not be unambiguously made IRS is to decide upon the applicability.

Section 2

Mooring Systems

2.1 General

2.1.1 The present section covers the requirements for mooring systems & equipment installed for position keeping of a FOU. The mooring system may be from the following:

- Position mooring
- Thruster assisted mooring

2.1.2 Mooring system configurations of novel types & features which are not within the scope of those described in 2.1.1 will be specially considered by IRS.

2.2 Position Mooring

2.2.1 The following items are covered within the scope of Position mooring

- Spread Mooring systems
- Single Point Mooring systems

2.3 Spread Mooring systems

2.3.1 The following components are covered within the scope of Spread Mooring.

- Ropes (Wire/Fiber)
- Mooring Chains (Stud-linked/Studless)
- Anchors (Drag/Embedded/Plate)
- Piles (Suction/Gravity)
- Stoppers
- Fairleads
- Bending shoes
- Shackles
- Sheaves
- Winches
- Windlasses
- Accessories
- Connectors
- Alarms & monitoring systems

The connections of the mooring system components to the FOU are also covered by the scope, as applicable.

2.4 Single Point Mooring systems

2.4.1 The following components are covered, as applicable, within the scope of Single Point Mooring in addition to the components listed in 2.3.1.

- Turret
- Turret bearings and seals
- Buoys
- Mooring arms, pivots and bearings
- Mooring yokes
- Disconnect hook (as applicable)
- Swivel stack
- Swivel stack Seals and Bearings
- Mooring Hawsers
- Attachments to the FOU hull
- Any other components as may be deemed necessary for inclusion within the scope.

2.5 Thruster assisted mooring

2.5.1 Reference is made to 2.17 for the relevant requirements for Thruster assisted mooring systems

2.6 Environmental Conditions Criteria

2.6.1 Environmental conditions for which the FOU is to be designed are to be submitted to IRS. The environmental conditions so submitted are to reflect the realistic extremes experienced at the site(s) where the FOU is to be operated with sufficient supporting information in terms of actual records or measurements carried out.

2.6.2 Environmental conditions to be considered for the design may be considered as follows but not limited to:

- Maximum Design conditions: The extreme condition for which the mooring system is designed
- Maximum operating conditions: The limiting conditions upto which the FOU can perform its normal operations.

2.6.3 The Maximum Design conditions are to reflect the return periods for which the FOU hull has been designed considering On-Site Operation conditions as listed in Chapter 4, Section 5.

2.7 Environment data

2.7.1 Environmental data is to be collected and submitted to IRS for the site(s) where the FOU is envisaged to operate. Requirements for Specific Environmental data (in the form of waves, current, wind, water depth, soil conditions, marine growth) required are to be referred from recognized standards/guidelines (for e.g. API RP 2SK).

2.8 Loading Conditions

2.8.1 Loading Conditions – Ultimate Limit State

2.8.1.1 The load conditions to be considered for assessment of the mooring system integrity are listed below. These load conditions are to be considered at different draughts of the FOU at the time of occurrence of the extreme environmental conditions. The severest combinations of environmental conditions must be considered for the analysis.

- Intact condition of moorings
- Damaged condition of mooring (any one line broken)
- Damaged condition of thruster (mechanical failure or loss of power of any one thruster) (applicable only for thruster assisted mooring).

2.8.1.2 Where deemed necessary, IRS may request for transient analysis to be carried out considering damaged conditions of mooring system (loss of any one line or mechanical failure/loss of power of any one thruster).

2.8.1.3 The loading conditions are to provide due consideration for the cases where the FOU can disconnect from the moorings.

2.8.1.4 The list of loading conditions to be finally considered for analysis is to be submitted for review.

2.8.2 Loading Conditions – Fatigue Limit State

2.8.2.1 Environmental conditions representing the actual conditions at the site to be experienced by the FOU mooring system during its service life are to be considered for fatigue analysis of mooring system components. These conditions are defined in terms of wind, wave (height and period), current, directions and their frequencies of occurrence.

2.8.2.2 For each of the environmental conditions defined in 2.8.2.1, analysis must be performed as described in 2.9 to determine tensions in the mooring chains/ropes.

2.8.2.3 Fatigue life is to be evaluated for each environmental condition in accordance with the techniques as described in API RP 2SK. Based upon the frequency of each environmental condition, the total fatigue life of the mooring system component is determined. The methodology utilized for combination of low frequency and high frequency components of the mooring rope tensions is to be submitted to IRS.

2.9 Analysis techniques and considerations

2.9.1 The purpose of the mooring analysis is to generally evaluate the following:

- Tensions in the mooring lines
- Loads on the anchors/piles
- Excursions of the FOU

Analysis techniques using recognized standards or guidelines (for e.g API RP 2SK) are considered as acceptable to IRS.

2.9.2 The analysis must consider the FOU dynamics. This may be accomplished using frequency domain or time domain approaches.

2.9.3 The mooring lines may be analysed considering quasi-static or dynamic approaches.

2.9.4 The hydrodynamic loads on the riser system are to be accounted for within the analysis. For this purpose, loads based on appropriate wave theories and current profiles are to be computed. The restraint provided by the riser systems is to be considered within the analysis. Consideration should also be given to the offsets to be maintained between the risers and the mooring anchor lines.

2.9.5 For analyses carried out using software, IRS may request additional details in order to verify the accuracy and correctness of the software utilized. Such details may consist of but not limited to the following:

- Benchmarking test cases with other validated softwares
- Benchmarking with model tests

– Benchmarking with field measurements

2.9.6 The assumptions used for the analysis, methodology and the limitations of the analyses must be clearly indicated in the analysis report and are to be agreed upon with IRS.

2.10 Acceptance Criteria

2.10.1 The excursions of the FOU are to be within the permissible limits as required for maintenance of structural integrity of the riser and mooring systems.

2.10.2 The excursions of the FOU are to be within the clearances as may be required by the operations manual.

2.10.3 The tensions in the mooring lines must not exceed those shown in Table 1. MBS is the minimum breaking strength of the lines as guaranteed by the manufacturer.

Table 1 : Acceptance Criteria – Mooring Line Tensions

Condition	**Analysis method**	**Tension (%MBS)**
Intact	Quasi-Static	50
Damaged	Dynamic	60
Intact	Quasi-Static	70
Damaged	Dynamic	80

2.10.4 In case of drag anchors, installed piles (gravity or anchor) and plate anchors the maximum of drag forces on the anchors/piles obtained from analyses performed for loading conditions described in 2.8.1 is not to exceed the drag force capacity/lateral load capacity for the anchor/pile by a factor of safety as given in API RP 2SK. (See 2.15.4, 2.15.10, Table 2 and Table 3). The drag force capacity of the anchor/pile can be evaluated as shown in API RP 2SK.

2.10.5 The fatigue life of the mooring components is not to be less than three times the service life of the mooring system.

2.10.6 Minimum Clearances between mooring lines for the FOU and mooring lines of other installations in the vicinity are to be maintained as described in API RP 2SK.

2.11 Model Tests

2.11.1 Model tests may be performed to verify the accuracy of the mooring analyses performed. Such Model tests are to consider the sea-keeping as well as the station keeping aspects. The tests will be carried out to the satisfaction of IRS.

2.11.2 The objectives, specification and details of the model tests and the testing procedures are to be agreed upon by IRS. The test facilities are to be inspected by IRS for verification of their adequacy.

2.12 Winches & Windlasses

2.12.1 Winches & Windlasses provided on the FOU are to be designed, manufactured, installed and tested in compliance with recognized codes, rules and regulations (e.g. ISO 9089, API RP 2SK). The materials of construction/fabrication must be in accordance with Chapter 3 or any recognized standards/codes which are no less stringent than the provisions in Chapter 3.

2.12.2 IRS may accept the certificates of compliance of Winches & Windlasses issued by IACS member classification societies.

2.12.3 Hull Structure in way of foundation of winches and windlasses is to be adequately reinforced. The structural integrity of the reinforcements is to be established by methods as given in Section 4.

2.12.4 Tension in the mooring lines not less than the Maximum Breaking Load is to be considered for the structural integrity evaluation as given in 2.12.3. For this purpose, the

Maximum Breaking Load may be specified by the manufacturer. In absence of data, Load corresponding to 1.25 x MBS (where MBS is the minimum breaking strength of the chain) can be considered as the Maximum Breaking Load for the initial design.

2.13 Fairleads and Stoppers

2.13.1 Fairleads and Stoppers are to be made of materials in conformance with Chapter 3. IRS may accept Fairleads and Stoppers made of a material in compliance with a recognized standard/code provided the standard/code is no less stringent than the requirements in Chapter 3.

2.13.2 Fairleads and Stoppers are to be designed for a load not less than the Maximum Breaking Strength of the Chain. In absence of data a load corresponding to 1.25 x MBS (where MBS is the minimum breaking strength of the chain) may be considered for the initial design.

2.13.3 The supporting hull structure is to be adequately reinforced to satisfy the requirements as given in Section 4 considering the design load as given in 2.13.2.

2.13.4 Adequate Protection must be provided against corrosion through the service life of the FOU.

2.14 Chains and Ropes

2.14.1 Chains are to be made of a material in compliance with requirements as provided in Chapter 3.

2.14.2 Steel ropes are to be in conformance with API Spec 9A or equivalent. Stricter requirements may be enforced by IRS if deemed necessary.

2.14.3 Fiber ropes are to be in conformance with API RP 2SM or equivalent.

2.14.4 Chains, ropes, their connecting sockets, end terminations and other miscellaneous fittings are to be designed for a load not less than that as prescribed in 2.13.2.

2.14.5 Adequate protection must be provided against corrosion throughout the service life of the FOU.

2.15 Anchors and Piles

2.15.1 Anchors and Piles to be installed are to be of made of a material which is in conformance with the requirements provided in Chapter 3. IRS may accept materials in conformance with recognized standards/codes provided they are no less stringent than the requirements in Chapter 3.

2.15.2 Drag anchors used for the mooring system are to be designed in accordance with a recognized rule or guideline. (e.g. API RP 2SK)

2.15.3 The maximum load on a Drag anchor is to be determined from the analyses as described in 2.8.

2.15.4 The capacity of the Drag anchor is to be evaluated by methods acceptable to IRS. Acceptable methods include methods and procedures described within recognized rules and guidelines such as API RP 2SK or ISO 19901 – 7. Drag Capacity evaluation based upon experimental techniques or field test results may also be considered. Minimum Factor of safety of the Drag capacity over maximum load as determined in 2.15.3 is listed in Table 2.

Table 2: Minimum Factors of Safety for Anchor Drag capacity

	Quasi-Static	**Dynamic**
Permanent		
Intact	2.0	1.5
Damaged	1.5	1.0
Temporary		
Intact	1.0	1.0
Damaged	N.A	N.A.

2.15.5 Cases of vertical uplift loads on drag anchors will be specially considered by IRS.

2.15.6 Anchor piles are to be designed in accordance with acceptable methods such as those provided within API RP 2A, API RP 2T etc. Axial Capacity, Lateral Capacity and Maximum Tip penetration and Lateral displacements shall be evaluated. The reduction of lateral capacity owing due to large lateral displacements is to be given due consideration. The calculations or analyses performed are to be submitted for review.

2.15.7 Suction piles are to be designed in accordance with acceptable methods e.g. API RP 2SK. The analyses, calculations etc. are to be submitted for review.

2.15.8 Gravity anchors are to be designed in accordance with acceptable methods. The analyses, calculations etc. are to be submitted for review.

2.15.9 Plate anchors are to be designed in accordance with acceptable methods, e.g. API RP 2SK. The analyses, calculations etc. are to be submitted for review.

2.15.10 The minimum factors of safety for the Anchor & Suction piles and Gravity anchors are to be in accordance in API RP 2SK as provided in Table 3.

Table 3: Factors of Safety for Anchor, Gravity piles and Plate Anchors

	Piles, Gravity		**Plate**
	Lateral	**Axial**	
Permanent			
Intact	1.6	2.0	2.0
Damaged	1.2	1.5	1.5
Temporary			
Intact	1.2	1.5	1.5
Damaged	1.0	1.2	1.2

2.16 Buoys

2.16.1 The design of the Buoy structure is to be in compliance with Chapters 3 – 7 of the Rules and Regulations for Construction and Classification of Single Point mooring systems and API RP 2SK. Applicable loads are to be considered as provided in Section 2.

2.16.2 Subsea buoys are to be designed considering the implications of external pressure in addition to the loads as specified within Section 2. The external hull and associated major load bearing members are to be designed in accordance with recognized codes for pressure vessels. IRS will consider approval of such buoys on a special basis.

2.17 Thruster assisted mooring

2.17.1 For thruster assisted mooring, a dynamic positioning system is to be provided onboard. The requirements for the dynamic positioning system are to be in accordance with requirements in Rules and Regulations for Construction and Classification of Steel Ships, Part 5, Chapter 24. The thruster system is to comply with requirements for class notations DP (2) or DP (3) as defined in the Steel Ship rules above.

2.17.2 The design of the mooring arrangements is to be in accordance with Section 2 considering the combined effects of the thruster and the mooring lines.

2.17.3 Additional requirement may have to be complied with as deemed necessary by IRS, to ensure the integrity of the thruster assisted mooring.

2.18 Alarms and Monitoring Systems

2.18.1 Atleast one control station on the FOU is to be provided for monitoring of the operations of the mooring system. In case of multiple control stations provided on the FOU, a central station is to be designated and it is to be ensured that these stations have effective means of communication with each other.

2.18.2 Mooring arrangements are to be accompanied with a system for measurement of mooring line tensions.

The mooring line tensions are to be monitored and alarms are to be provided to warn of a mooring line failure. The system is to be calibrated and verified for its functioning periodically and adequate records are to be maintained. Redundancy of the monitoring system is to be ensured in case of fault scenarios with one or more of the components

2.18.3 The monitoring system is to also track the FOU movement depending upon the operations as applicable. For single point mooring arrangements, the monitoring system is to track the FOU headings.

2.18.4 Redundancy of the monitoring system is to be ensured in case of fault scenarios with one or more of the components.

2.18.5 Additional monitoring system requirements are to be applied if deemed necessary by IRS.

2.19 Testing

2.19.1 Testing of the mooring system and associated monitoring systems is to be carried out in accordance with approved procedures as described in Chapter 2, Section 5.

Section 3

Major Structures

3.1 General

3.1.1 "Major Structures" are defined as those structures permanently attached to the FOU hull, but however not contributing to the longitudinal strength of the FOU hull.

Major structures are exclusive of the stiffening arrangements provided with the FOU hull. Such stiffening arrangements are to be as Structural Foundations and be compliant with requirements in Section 4.

3.1.2 The integrity of major structures is to be verified.

3.1.3 The loads transmitted by the Major Structures to the Foundations defined in 4.1.1 must be considered for the Foundation assessment (see Section 4).

3.1.4 For an FOU, the following major structures must be considered as applicable for structural analysis but not limited to:

- Topside Production Facility support frames
- Flare tower frames
- Helideck
- Pipe racks
- Offloading equipment supporting frames
- Other functional/utility modules frames.

3.1.5 The major structures to be subjected to structural integrity assessment and their demarcation with reference to 1.1.2 are to be agreed upon with IRS.

3.2 Structural analysis

3.2.1 The purpose of the structural analysis is to evaluate the bending moments, shear forces in each primary load bearing member (e.g chords, girders, braces, pillars etc.) of the Major Structures as defined in 3.1. The reactions at the supports in form of Forces and Moments are also required to evaluate the structural integrity of the Structural foundations as required in Section 4 of this chapter.

3.2.2 Calculations/reports documenting the structural integrity analyses performed are to be submitted to IRS.

3.2.3 Structural analyses may be performed considering the Major Structures as 3D truss/framed structures using software recognized by IRS as may be applicable. Link/Beam elements may be used to model the primary structure in form of girders, pillars etc. In special cases, IRS may request a 3D shell beam model to be prepared as may be deemed necessary. Structural modeling may be based on gross scantling approach.

3.2.4 Structural analyses model files are to be submitted to IRS for review.

3.3 Loading Conditions

3.3.1 Loading conditions for analysis of Major structures are to be agreed upon with IRS. Loading conditions most unfavorable for the structure are to be considered.

3.3.2 Loading conditions during transit are to be subjected to analysis for each major structure.

3.3.3 The Loading Conditions during On-Site operations for each Major Structure must be evaluated. The following loading conditions must be considered but not limited to:

- Maximum Operating Condition (s)(Specifications of limit of waves, current and wind upto which the unit can continue to operate)
- Maximum Environmental Condition(s) (Specifications of limit of waves, current and wind upto which the unit is designed for)
- Emergency Conditions
- Accidental Conditions
- Normal Operating conditions (for evaluation of fatigue life)

3.3.4 The return periods of the considered environmental loads are to be consistent with those provided in Chapter 4, Section 5.

3.4 Loads

3.4.1 Applicable loads should be considered for the analysis of the Major Structures. Such loads are listed as below but not limited to:

- Self Weight
- Live loads
- Inertial loads (due to ship motions)
- Wind Loads
- Thermal Loads (as applicable)
- Vibratory loads
- Loads due to hull deformations
- Testing loads
- Accidental Loads

3.4.2 The assumptions for the magnitudes of the loads considered and the load combination factors are to be agreed upon with IRS and clearly mentioned within the analysis report.

3.5 Acceptance Criteria

3.5.1 The stresses and deflections in tubular members within the Major Structures are to satisfy acceptance criteria as provided in API RP 2A.

3.5.2 For all members other than those mentioned in 3.5.1, the stresses and deflections are to be checked as per recognized codes & design standards such as AISC, Eurocodes etc.

Section 4

Structural Foundations

4.1 General

4.1.1 "Structural Foundations" are defined as associated hull stiffening arrangements provided which enable load transfer from Major Structures as defined in Section 3 to the FOU hull: The hull stiffening arrangements for the following as a minimum are to be considered as structural foundations:

- Cranes, Derricks, Gantries, Winches, Windlasses
- Position Mooring attachments.
- Single Point Mooring attachments
- Flare Towers
- Topsides Production Facilities interfaces
- Pipe rack foundations
- Riser connections
- Helideck
- Offloading equipment support foundations
- Any other equipment supported by the FOU hull as applicable

4.2 Structural analysis

4.2.1 The present section is applicable to Structural Foundations as defined in 4.1.1.

4.2.2 Calculations/analysis reports are to be submitted to IRS.

4.2.3 Structural analysis is to be preferably performed in form of three dimensional finite element analysis using software recognized by IRS. For preparation of the 3D model, structural idealization can be made using Shell and Beam elements depending upon the component being modeled. First principles based calculations may be accepted by IRS at its discretion in lieu of 3D FEM on a case to case basis.

4.2.4 The specific extent of the finite element modeling and the Structural idealization shall be agreed upon with IRS. In general, it would be required to model the Structural foundation to the extent such that the load transfer to the FOU primary hull structure members is sufficiently and accurately captured.

4.2.5 Details such as openings, cut-outs, brackets etc. which lead to stress concentrations are to be appropriately represented within the finite element model.

4.2.6 Modeling must be based upon the net scantlings approach as applicable. The corrosion allowances used must be detailed in the submitted calculations/analysis report. IRS may accept calculations based on gross scantling provided it is demonstrated that an equivalent level of safety as obtained from net scantlings approach is achieved.

4.2.7 Finite element model (s) are to be submitted to IRS for review.

4.3 Loading Conditions

4.3.1 Loading conditions for analysis of structural foundations are to be agreed upon with IRS.

4.3.2 Loading conditions during transit must be subjected to analysis for each structural foundation.

4.3.3 The Loading Conditions during operations for each Structural foundation are to be evaluated. The following loading conditions are to be considered but not limited to:

- Maximum Operating Condition (s)(Specifications of limit of waves, current and wind upto which the unit can continue to operate)
- Maximum Environmental Condition(s) (Specifications of limit of waves, current

and wind upto which the unit is designed for).

- Emergency Conditions
- Accidental Conditions
- Normal Operating conditions (for evaluation of fatigue life)

4.3.4 Environmental loads are to employ the considerations in 3.3.4.

4.4 Loads

4.4.1 Applicable loads are to be considered for the analysis of the Structural Foundations. Such loads are listed below but not limited to:

- Self Weight
- Live loads
- Inertial loads (due to ship motions)
- Wind Loads
- Thermal Loads (as applicable)
- Vibratory loads
- Loads due to hull deformations
- Testing loads
- Accidental Loads

4.4.2 The assumptions for the magnitudes of the loads considered and the load combination factors must be agreed upon with IRS and clearly mentioned within the analysis report.

4.5 Acceptance Criteria

4.5.1 For the present section; stress implies the combination of the local stresses obtained using the finite element analysis of the interface structure with those obtained from longitudinal strength analysis.

4.5.2 For all the considered loading conditions, the combined normal and the shear stresses in the Structural Foundations considering also the hull girder stresses must not exceed those specified within Chapter 4, Section 21.

4.5.3 The fatigue life evaluated is not to be less than that specified within Chapter 4, Section 22.

Section 5

Riser Systems

5.1 General

5.1.1 The requirements provided within the present section are to be complied with in order for the unit to be assigned "RISER' class notation.

5.2 Scope

5.2.1 For the scope of classification the riser is defined as the portion of the flexible or rigid pipe between the PLEM and the inlet flange on the FOU. The following items are within the scope of classification for the assignment of RISER notation.

- Steel/Flexible risers
- Valves, flanges & fittings
- Control systems
- Corrosion protection system
- Safety systems
- Bend stiffeners/Bend restrictors
- Buoyancy modules as applicable
- Clump weights as applicable
- Any other component important for the structural integrity of the risers

5.3 Materials

5.3.1 Materials for risers are to be suitable for the purpose considering the temperatures and the composition and corrosive nature of the fluids. The requirements for the riser pipes and fittings are to be in accordance with recognized standards (E.g API RP 2RD, ISO 13628, or applicable ASME B31 series of standards). In any case IRS is to decide upon the applicability of the standard utilized for verifying the compliance of the material.

5.3.2 Riser pipes in form of flexible pipes/hoses are to be in compliance with API RP 17B and API Spec 17J.

5.4 Environmental Data

5.4.1 Please refer Section 2.7

5.5 Loading Conditions

5.5.1 Loading conditions are to be corresponding to the different draughts of the FOU along with the severest possible combination of the environmental conditions expected at the site.

5.5.2 The limit states of ultimate strength and fatigue strength are to be checked. The design is to also be robust for the loads during testing & installation.

5.5.3 If buoyancy modules and /or clump weights are utilized; it is also to be verified that failure of any one buoyancy module or clump weight does not lead to loss of integrity of the riser when considering the conditions in 5.5.1.

5.6 Analysis techniques and consideration

5.6.1 Analyses using recognized codes/standards such as API RP 2RD or ISO 13628 – 7 are considered to be acceptable. It is recommended to use dynamic transient analysis based techniques for the analyses.

5.6.2 Hydrodynamic loads in accordance with 2.9.3 are to be considered.

5.6.3 Vortex induced vibrations are to be considered within the analysis. The choice of the model used to represent vortex induced vibrations is to be justified in the analysis report.

5.6.4 Boundary conditions at the point of connection of the risers with the FOU hull are to be chosen appropriately and justified in the analysis report.

5.6.5 The response and motions of the FOU are to be considered within the analysis.

5.7 Acceptance Criteria

5.7.1 The riser lines are not to clash with each other. In case such interference is unavoidable, the riser integrity due to such repeated impacts is to be adequately demonstrated to IRS.

5.7.2 The excursions and displacements of the risers are to be within designated limits as required by the FOU operations. The excursions and displacements are also to be delimited so that there is no interference with any other unit in the vicinity.

5.7.3 The stresses within the risers and components are to be within the allowable limits depending prescribed by the manufacturer. For layered flexible pipes, stresses are to be computed for each layer and the integrity of each layer is to be demonstrated.

5.7.4 The bend radii of the riser lines are to be within allowable limits as prescribed by the manufacturer.

5.7.5 Fatigue damage index for the riser lines at any location is to be assessed. Assessments in accordance with recognized guidelines such as API RP 2RD are considered as acceptable by IRS.

5.8 Safety Systems

5.8.1 Monitoring systems for the risers are to be installed.

5.8.2 Emergency Shutdown system is to be provided. The provision of the system is to consider and account for the applicable hazards which the risers may be subject to. Systems and procedures for the Disconnection are to be provided if the Unit is to be assigned the "DISCON" notation.

5.9 In-Service inspections

5.9.1 An inspection programme is to be submitted to IRS highlighting the following:

- Inspection schedule
- Aim, Scope and Extent of each inspection within the schedule.

5.9.2 The locations shown to be vulnerable to fatigue damage and the locations subject to high stresses as determined from the analyses in 5.6.1 are to be specially monitored within the inspections.

5.9.3 Effectiveness of the corrosion protection system is also to be gauged in the inspections.

5.9.4 General conditions of the riser lines for evidences of wear and tear are to be observed to verify that no clashing of risers is taking place during operations.

5.9.5 It is also recommended to perform inspections on the riser system after the unit has been exposed to a severe environmental event.

End of Chapter

Chapter 6

Main and Auxiliary Machinery

Contents

Section 1

General

1.1 General

1.1.1 The requirements in the Rules and Regulations for Construction and Classification of Steel Ships, Part 4, Chapter .1 are to be complied with, as applicable.

1.1.2 Deviations, Departures from the Rule requirements or use of novel features are to be brought to the attention of IRS for consideration and approval.

Section 2

Piping Design Requirements

2.1 General

2.1.1 The piping design is to comply with requirements in the Rules and Regulations for Construction and Classification of Steel Ships, Part 4, Chapter 2.

Section 3

Pumping and Piping

3.1 General

3.1.1 Pumping and piping systems are to comply with requirements in the Rules and Regulations for Construction and Classification of Steel Ships, Part 4, Chapter 3.

3.1.2 Additional requirements are to be complied with as specified in the Rules and Regulations for Construction and Classification of Steel Ships, Part 5, Chapter 2, Section 6.

3.1.3 Oil fuel systems and lubricating oil systems are additionally required to be in compliance with applicable requirements in Chapter 7, Section 4.2.

3.1.4 If the arrangements required in accordance with 3.1.3 are not practicable for construction, IRS may consider alternative arrangements provided that they provide atleast an equivalent level of safety.

Section 4

Prime Movers and Propulsion Shafting Systems

4.1 General

4.1.1 Prime Movers and propulsion shafting systems are to comply with requirements specified in the Rules and Regulations for Construction and Classification of Steel Ships, Part 4, Chapter 4.

Section 5

Boilers and Pressure Vessels

5.1 General

5.1.1 Boilers and Pressure Vessels are to comply with requirements specified in the Rules and Regulations for Construction and Classification of Steel Ships, Part 4, Chapter 5.

Section 6

Steering Gear

6.1 General

6.1.1 Steering gear are to comply with the requirements specified in the Rules and Regulations for Construction and Classification of Steel Ships, Part 4, Chapter 6.

Section 7

Cargo Handling Systems

7.1 General

7.1.1 Cargo handling systems are to comply with requirements specified in the Rules and Regulations for Construction and Classification of Steel Ships, Part 5, Chapter 2, Section 7.

Section 8

Gas Freeing and Venting Systems

8.1 General

8.1.1 Gas Freeing and Venting systems are to comply with requirements specified in the Rules and Regulations for Construction and Classification of Steel Ships, Part 5, Chapter 2, Section 8.

Section 9

Inert Gas Systems

9.1 General

9.1.1 Inert Gas systems must comply with requirements specified in the Rules and Regulations for Construction and Classification of Steel Ships, Part 5, Ch.2, Section 11.

Section 10

Vapour Control Systems

10.1 General

10.1.1 Vapour control Systems are to comply with requirements specified in the Rules and Regulations for Construction and Classification of Steel Ships, Part 5, Chapter 29.

Section 11

Cargo Tank Level Measurement Systems

11.1 General

11.1.1 Cargo Tank Level Measurement systems are to comply with requirements specified in the Rules and Regulations for Construction and Classification of Steel Ships, Part 5, Chapter 2, Section 9.

Section 12

Cargo Heating Systems

12.1 General

12.1.1 Cargo Heating systems if installed must comply with requirements specified in the Rules and Regulations for Construction and Classification of Steel Ships, Part 5, Ch.2, Section 10.

Section 13

Requirements for Fusion Welding

13.1 General

13.1.1 Fusion welding for pipes and pressure vessels is to comply with the requirements specified in the Rules and Regulations for Construction and Classification of Steel Ships, Part 4, Chapter 10.

Section 14

Spare Gear

14.1 General

14.1.1 Spare gear is to comply with the requirements specified in the Rules and Regulations for Construction and Classification of Steel Ships, Part 4, Chapter 11.

End of Chapter

Chapter 7

Control Engineering, Electrical Installations and Safety

Contents

Section 1

Control Engineering

1.1 General

1.1.1 The requirements provided within Rules and Regulations for Construction and Classification of Steel Ships, Part 4, Chapter 7 are to be complied with as applicable.

1.1.2 Requirements for Control systems provided in IEC 61892 – 2 are also to be complied with.

1.1.3 If deemed to be necessary, IRS may specify compliance with additional requirements based upon consideration of the specific case.

Section 2

Electrical Installations

2.1 General

2.1.1 Electrical installations are to comply with relevant requirements within Rules and Regulations for Construction and Classification of Steel Ships, Part 4, Chapter 8 and IEC 61892.

2.1.2 Electrical installations in hazardous areas are to comply with IEC 61892 – 7. The definitions of hazardous areas are provided in 3.2.

2.1.3 In case of conflicts between requirements as referred to in 2.1.1& 2.1.2, IRS will decide the final applicability of requirements.

2.1.4 If deemed necessary, IRS may specify compliance with additional requirements on a case to case basis depending upon the specific FOU.

2.2 Services

2.2.1 In addition to the list of secondary essential services as provided within Rules and Regulations for Construction and Classification of Steel Ships, Part 4, Chapter 8, Section 1.5, the following services are to be considered as essential services:

1. Mooring line tensions & ship motions monitoring systems
2. Systems associated for functioning of Turret mooring including relevant monitoring & safety systems.
3. Thruster systems used for assisted mooring
4. Crude oil offloading systems
5. Ballast Control Systems
6. Emergency disconnect system
7. Ventilation systems for hazardous areas
8. Safety systems for topsides

2.2.2 The essential services considered in 2.2.1 are to be considered for electrical installation design in accordance with 2.1.1 and 2.1.2

Section 3

Safety Principles, Arrangements and Systems

3.1 General Principles

3.1.1 Safety systems to be provided on the FOU are to comply with requirements within this section.

3.1.2 A suitable safety level is to be maintained through the service life of the FOU. The safety level is to be periodically verified through surveys and inspections.

3.1.3 Risk to personnel, installation and environment is to be minimized and maintained within an acceptable level. For this purpose, IRS may request risk analyses to be performed if deemed necessary for the safety of the installation. Such Risk analyses may be performed in accordance with recognized standards and guidelines (for e.g. NORSOK Z013, ISO 17776, API RP 14J)

3.1.4 This section provides generic requirements in order to ensure an acceptable safety level during the transit, installation, operation, maintenance and shutdown of the FOU. If deemed necessary, IRS may alter the requirements or specify additional requirements on a case to case basis depending upon the specific FOU.

3.2 Hazardous Areas

3.2.1 Hazardous areas are all those areas where, due to the possible presence of a flammable atmosphere arising from operations, the use without proper consideration of machinery or electrical equipment may lead to fire hazard or explosion. The areas are classified as below.

Zone 0: An area in which flammable gases or vapours of such concentrations which are liable to get ignited are continuously present or present for long periods.

Zone 1: An area in which flammable gases or vapours of such concentrations which are liable to get ignited are likely to occur in normal operating conditions.

Zone 2: An area in which flammable gases or vapours of such concentrations which are liable to get ignited are not likely to occur, and if they do occur, they will only exist for a short time.

Guidance Note:
Zone 0: Common for continuous release (Continuous release or nearly continuous release which occurs frequently and for short periods), typically more than 1000 hours per year

Zone 1: Common for primary release (release which may occur periodically or occasionally in normal operations), typically between 10 – 1000 hours per year.

Zone 2: Common for secondary release (release which is not likely to occur in normal operations), typically less than 10 hours per year.

3.2.2 Enclosed Space is a space considered to be bound by bulkheads and decks which may have doors, windows or other similar openings.

3.2.3 Semi-Enclosed space is a location where natural conditions of ventilation are notably different from those on open decks due to the presence of structures such as roofs, windbreaks and bulkheads which are so arranged so that dispersion of gas does not occur.

3.2.4 Extent of the hazardous zone is to be determined in accordance with recognized codes /standards (e.g.IP Code 15, ISO 17776, API RP 14J, 2009 IMO MODU Code).

3.2.5 Hazardous area classification is to be in accordance with recognized codes & standards (For e.g. IEC 61892 – 7, API RP 505, IMO MODU Code 2009, IP 15)

3.2.6 Except for operational reasons, access doors or other openings are not to be provided between:

- A hazardous zone and a non-hazardous zone
- Zone 1 and Zone 2 Areas.

If such access is necessary to be provided then the enclosed or semi-enclosed space with direct access door /opening leading to the hazardous area is to be classified as the area or space into which the door opens.

3.2.7 Enclosed spaces with direct access to a Zone 1 area are to be classified as Zone 2 provided that:

- Access is fitted with a self closing gas-tight door opening into the Zone 2 space.
- Ventilation is such that air flow with the door open is from the enclosed space to Zone 1.
- Loss of ventilation is alarmed at a manned station.

3.2.8 Enclosed spaces with direct access to a Zone 2 location are not considered to be hazardous provided:

- Access is fitted with a self closing gas-tight door opening into the non-hazardous location.
- Ventilation is such that air flow with the door open is from the enclosed space to Zone 2
- Loss of ventilation is alarmed at a manned station.

3.2.9 Enclosed spaces with direct access to Zone 1 location are not considered to be hazardous provided:

- Access is fitted with two self closing gas-tight doors forming an Air-Lock.
- Spaces have ventilation overpressure in relation to the hazardous space
- Loss of ventilation is alarmed at a manned location.

3.2.10 Enclosed spaces other than those as described within 3.2.7 – 3.2.9 with direct access to a zone 1 or zone 2 location are to be classified as the same as that location.

3.2.11 Hazardous enclosed spaces are to be adequately ventilated. Where mechanical ventilation is applied, the lesser enclosed hazardous spaces or non-hazardous spaces should be maintained at an overpressure in relation to the more hazardous spaces which are adjacent.

3.2.12 All air inlets for hazardous enclosed spaces are to be located in non-hazardous areas.

3.2.13 Each air outlet is to be located in an outdoor area which in the absence of considered outlet is of the same or lesser hazard than the ventilated space.

3.2.14 If a ventilation duct for a enclosed area passes through a more hazardous area, the ventilation duct is to be maintained at an overpressure. When ventilation duct for a enclosed area passes through a less hazardous area then the ventilation duct is to be maintained at an underpressure.

3.2.15 Ventilation systems for hazardous spaces are to be independent from those for non-hazardous spaces.

3.2.16 Installation of mechanical equipment in hazardous areas is to be avoided as much as possible. In case if it is necessary to install mechanical equipment in hazardous areas then its use is to be limited to that necessary for operational purposes.

3.2.17 Mechanical equipment and machinery in hazardous areas is to be constructed and installed such that risk of ignition from static electricity or friction between moving parts from high temperatures of exposed parts due to exhausts or other emissions is reduced.

3.2.18 Installation of internal combustion machinery in Zone 1 and Zone 2 is to be avoided. Installation of such machinery may be permitted if IRS is satisfied that sufficient precautions are in place to address the risk of dangerous ignition.

3.2.19 Installation of fired equipment in Zone 2 is to be avoided. However, installation of fired equipment in Zone 2 may be permitted if IRS is satisfied that sufficient precautions are in place to address the risk of dangerous ignition.

3.2.20 Piping systems are to be designed so as to preclude direct communication between hazardous areas of different classifications and also between hazardous and non-hazardous areas.

3.2.21 Electrical installations and equipment in Hazardous areas are to be provided in accordance with the requirements of Section 2.

3.3 Arrangements

3.3.1 Layout of the installation is to be arranged to ensure minimal risk of incidents, to prevent escalation of hazards/accidents. The layout is to facilitate convenience of evacuation & escape.

3.3.2 IRS may require risk analysis to be performed considering the arrangements within the unit in order to ascertain the critical risk zones and the mitigation measures pertinent to the installation of structures, machinery and equipment. In any case, risk analysis in accordance with Section 4.8 is to be performed. In general, risk mitigation and/or reduction are not to be implemented by relying solely on the training of crew and personnel.

3.3.3 Recognized standards such as Norsok Z – 013, API RP 14J, ISO 17706 may be used for performing the risk assessments as per 3.3.2.

3.3.4 Accommodations, Control Rooms, Muster stations etc. are not to be located within hazardous areas. If such arrangements are not practicable then risk analysis is to be performed in accordance with 3.3.2 so that the risks are mitigated.

3.3.5 The location of Accommodations, Control Stations, Muster stations adjacent to hazardous areas is to be avoided. If this is not practicable, an engineering evaluation is to be submitted to IRS demonstrating the effectiveness of the fire protection and blast resistance of the bulkheads and decks separating these areas from the hazardous zone.

3.3.6 Environmental factors such as winds and waves at the operating site are to be taken into account for arrangements /layout of the installation.

3.4 Fire Safety

3.4.1 Requirements for Fire safety onboard the FOU are to be in compliance with requirements in Section 4.

3.5 Escape and Egress

3.5.1 Requirements are provided in Section 4.4.

3.6 Alarm Systems

3.6.1 An alarm system is to be provided in the main machinery control room giving audible and visual indication of any fault which may require attention. The alarm system is to also satisfy the following conditions:

.1 The system is to activate an audible and visual alarm at another normally manned control station.
.2 The system is to activate the engineer's alarm (refer 3.6.2) or an equivalent alarm acceptable to IRS, if an alarm function has not received attention locally within a limited time.
.3 The system is to be designed in accordance with fail to safety principle.
.4 The system when in marine mode is to activate an audible and visual alarm on the navigating bridge for any situation which requires action by the officer on watch or which should be brought to the attention of the office on watch.

3.6.2 An engineer's alarm is to be provided to be operated from the engine control room or at the maneuvering room as appropriate and is to be clearly audible in the engineer's accommodation.

3.6.3 The alarm system is to be continuously powered and should have an automatic change-over to a standby power supply in case of loss of normal power supply.

3.6.4 Failure of normal power supply of the alarm system should be alerted.

3.6.5 The alarm system is to be capable of indicating more than one fault at the same time and the acceptance of any alarm is not to inhibit other alarms.

3.6.6 Acceptance at the position mentioned in paragraph 3.6.1 of any alarm condition is to be indicated at the positions where it has been shown. Alarms are to be maintained until they are accepted and the visual indications are to remain until the fault has been corrected, when the alarm system is to be automatically reset to the normal operating condition

3.7 Emergency Shutdown systems

3.7.1 In the event of an emergency situation such as gas leakage, where it is possible for the hazardous areas to extend beyond the extent as defined in 3.2; any equipment which needs to be operational is to be explosion protected to the satisfaction of IRS.

3.7.2 Arrangements are to be provided for the selective disconnection of

a. ventilation systems
b. non-essential electrical equipment
c. essential electrical equipment
d. main generator prime movers
e. emergency equipment including the emergency generator, except those mentioned in

3.7.3 An automatic emergency shut-down is to be initiated when gas has been detected in non-hazardous area or in ventilation intakes to HVAC systems.

3.7.4 Any equipment which is to be operational after the automatic shutdown in 3.6.3 is to be certified for installation in zone 1.

3.7.5 IRS may provide due consideration for alternative arrangements for functioning of emergency equipments in living quarters and other areas based upon risk assessments. Such risk assessments are to be submitted to IRS requesting them to be specially considered.

3.7.6 A low gas alarm detection anywhere on the FOU is to trigger the isolation of all high risk ignition sources in naturally ventilated areas. This is to also include temporary equipment.

3.7.7 Gas detection at HVAC air intake to local electrical/instrument rooms or emergency generator room is to lead to closure of inlet dampers, shutdown of fans, shutdown of heaters and isolation of all electrical equipment which are not certified to be explosion proof. No hot conductors are to be located outside the feeding switchboards of above mentioned equipment when isolated.

3.7.8 Disconnection or shutdown is to be possible from atleast two strategic locations, atleast one of these locations is to be located outside hazardous areas.

Section 4

Fire Safety

4.1 General

4.1.1 The fire safety requirements are to be in accordance with relevant requirements for Tankers within Rules and Regulations for Construction and Classification of Steel Ships, Part 6, Chapter 1. Fire safety requirements for protection of hydrocarbon process and associated systems will be specially considered.

4.1.2 In the case that arrangements & provisions of Fire Safety in compliance with Section 4 are not practicable for construction or operational purposes; IRS may provide special consideration to alternate arrangements which provide atleast an equivalent level of safety.

4.1.3 The requirements within the present section are to be complied by both self propelled FOUs and non-self propelled FOUs.

4.2 Prevention of Fire & Explosion

4.2.1 Relevant requirements for Tankers within Rules and Regulations for Construction and Classification of Steel Ships, Part 6, Chapter 2 are to be complied with. Additional requirements to be complied with are provided within the sub-section 4.2.

4.2.2 Ventilation of accommodation spaces and Control Stations is to be arranged so as to prevent ingress of flammable, toxic or noxious gases or smoke from surrounding areas.

4.3 Suppression of Fire

4.3.1 Reference is made to relevant requirements for Tankers within Rules and Regulations for Construction and Classification of Steel Ships, Part 6, Chapter 3.
Additional requirements or amendments to the above are specified in this section.

4.4 Escape

4.4.1 Reference is made to relevant requirements for Tankers within Rules and Regulations for Construction and Classification of Steel Ships, Part 6, Chapter 4 and Rules.

4.4.2 Reference is made to 4.8 for additional requirements.

4.5 Operational Requirements

4.5.1 Reference is made to relevant requirements for Tankers within Rules and Regulations for Construction and Classification of Steel Ships, Part 6, Chapter Rules.

4.6 Requirements

4.6.1 Reference is made to relevant requirements for Tankers within Rules and Regulations for Construction and Classification of Steel Ships, Part 6, Chapter 7.

4.7 Safety Systems Code

4.7.1 Reference is made to relevant requirements for Tankers within Rules and Regulations for Construction and Classification of Steel Ships, Part 6, Chapter 8.

4.8 Engineering analysis

4.8.1 A risk assessment is to be carried out to establish the effectiveness of the fire-fighting measures, layouts of the equipments, escape routes so as to ensure the safety of people, property and environment. The risk assessment as well as the EER (Escape, Evacuation & Rescue) assessment may be performed in accordance with standards such as ISO 13702.

End of Chapter

Chapter 8

Topside Production Facilities

Contents

Section 1

General

1.1 General

1.1.1 The present chapter specifies the requirements to be complied by the Topside production facilities for the Unit to be assigned the FPSO or FPU type notations.

1.1.2 Topside facilities are defined as the necessary equipment, machinery and installations which are required for the processing of the fluids recovered from the oil wells in the field. Thus all the production and related process, utility & support systems from the riser connection point on the Unit to the storage tank inlet valve (for FPSO notation) or the offloading system inlet valves (for FPU notation) are covered within the present chapter.

1.1.3 Applicable Statutory or National regulations are also to be complied with by the Topside Facilities.

1.2 Scope

1.2.1 The scope of the present chapter is generally applicable to the following components (also see 1.1.2 for the definition of topsides facilities):

.1 Topside process equipment & machinery and piping systems related to processing facilities for the fluids recovered from the wells within the field. This includes their structural foundations.

.2 Layout of the Topsides Machinery, equipment & piping systems

.3 Electrical installations for power supply to topsides facilities

.4 Control and Safety systems including those for fire safety of the topsides equipment.

.5 Evacuation and Escape Route arrangements

1.2.2 For each FOU to be assigned the FPSO type, IRS will decide the actual scope depending upon examination of the documents submitted.

1.2.3 The scope of classification as defined in the present chapter is not intended to cover or guarantee the performance of the production facilities equipment.

1.3 Documentation to be submitted

1.3.1 The documentation to be submitted for review and/or approval is listed in Chapter 1, Section 7.9.

Section 2

Layout and Arrangements

2.1 General Principles

2.1.1 The layout and arrangements of the equipment and systems are to be such that the risk to personnel and the unit is minimized as practicable. Layouts and Arrangements in accordance with NORSOK S – 001: Standard for Technical Safety are recommended.

2.1.2 Risk assessment is to be performed to ensure all hazards have been accounted for using effective preventive and mitigation measures. The risk assessment is to be carried in accordance with recognized codes and guidelines (e.g. NORSOK Z-013, ISO 13072, ISO 17776, API RP 14J). The scope of such risk assessment will be decided by IRS.

2.1.3 Hazardous area classification is to be developed in accordance with Chapter 7.

Section 3

Equipment

3.1 Equipment Classes & Certification

3.1.1 Production equipment to be installed on the topside facilities is to be classified into categories as described below:

.1 Class A: Equipment directly and critically influences the safety of the production process. Such equipment is typically custom made for a specific unit.
.2 Class B: Equipment influences the safety of production process to a lesser degree of criticality compared to Class A and hence does not qualify to be categorized under Class A.
.3 Class C: Equipment of secondary or tertiary importance which does not qualify to be categorized under Class A or Class B. This may typically be a standardized equipment which is type approved.

3.1.2 The classification of equipment into categories as described in 3.1.1 is to be submitted to IRS. The classification is to duly consider the results of the risk assessment in 2.1.2. The class assigned to each equipment has to be agreed upon with IRS.

3.1.3 The equipment categorized in accordance with classes in 3.1.1 is to be certified by IRS.

3.1.4 Class A equipment design is to be reviewed and approved by IRS. IRS will conduct inspection and surveys during the fabrication of the equipment to verify the construction is to the satisfaction of IRS surveyors. The Equipment tests are to be witnessed by IRS Surveyor(s).

3.1.5 Class B equipment design is to be reviewed and approved by IRS. IRS may carry out surveys during the equipment fabrication if deemed necessary. The Equipment tests are to be witnessed by IRS Surveyor(s).

3.1.6 Class C equipment design is to be type approved by IRS or a Classification Society holding membership of IACS. IRS may require witness of the equipment testing at the manufacturer's premises for verification of data submitted by manufacturer if deemed necessary

3.1.7 Typical classification for various equipment is shown in Appendix 1.

3.2 Equipment Design Requirements

3.2.1 Equipment is to be designed in accordance with recognized codes and standards acceptable to IRS.

3.2.2 Recognized Codes and Standards and additional Requirements for the various equipment/system components design are mentioned in Sections 3.3 – 3.13

3.2.3 IRS may specially consider equipment designed using codes and standards other than those specified in the present chapter provided their corresponding requirements are no less stringent than those of the codes and standards recommended in the present chapter.

3.2.4 Equipment is to be designed for the environmental conditions to be encountered by the Unit. The limits of the operational condition upto which the equipment can be safely operated are to be clearly demarcated.

3.3 Wellhead and Christmas Trees

3.3.1 Wellheads and Christmas Trees are to be designed, fabricated and tested in accordance with the following standards as applicable:

.1 API Spec 6A
.2 API Spec 6AV
.3 API Spec 14D
.4 API Spec 17D

3.4 Piping and Components

3.4.1 Piping and Components are to be designed, fabricated and tested in accordance with requirements within API RP 14E and ASME B31.3, B31.4 or B31.8 standards as applicable.

3.4.2 Piping and Components materials are to be selected considering the temperatures and corrosive nature of the fluids; in particular H_2S induced corrosion as applicable. Such materials are to be in accordance with requirements in the relevant ISO and NACE standards.

3.4.3 Components such as valves, flanges, other fittings etc. are to be designed, fabricated and tested in accordance with recognized standards as listed below:

.1 ISO 13623
.2 API Spec 6D
.3 API Spec 6FA
.4 API Spec 6FD
.5 API Std 594
.6 API Std 598
.7 API Std 599
.8 API Std 600
.9 API Std 602
.10 API Std 603
.11 API Std 607
.12 API Std 608
.13 API Std 609
.14 API Std 623
.15 ASME B16.5

3.5 Boilers and Pressure Vessels

3.5.1 Boilers and Pressure Vessels are to be designed, fabricated and tested in accordance with relevant requirements within ASME Boiler and Pressure Vessel code (ASME BPVC). Materials for the pressure vessels in direct contact with the well fluids are also to be selected on the considerations in 3.12.

3.6 Heat Exchangers

3.6.1 Heat Exchangers are to be designed, fabricated and tested in accordance with the following standards as applicable:

.1 ISO 13705
.2 ISO 13706
.3 ISO 15547
.4 ISO 16812
.5 API Std 660
.6 API Std 661
.7 API Std 662

3.7 Pumps

3.7.1 Pumps are to be designed, fabricated and tested in accordance with requirements in the following standards as applicable:

.1 API Std 610
.2 API Std 674
.3 API Std 675
.4 API Std 676
.5 API Std 681
.6 API Std 682

3.8 Compressors

3.8.1 Compressors are to be designed, fabricated and tested in accordance with requirements in the following standards as applicable:

.1 API Std 617
.2 API Std 618
.3 API Std 619

3.9 Gas Turbines

3.9.1 Gas turbines are to be designed, fabricated and tested in accordance with requirements in the following standards as applicable:

.1 API Std 616.

3.10 Pressure Relief and Flare Systems

3.10.1 Pressure Relief Systems and Flare Systems are to be designed, fabricated and tested in accordance with requirements in the following standards as applicable:

.1 API Std 520
.2 API Std 521
.3 API Std 526

3.11 Electrical Equipment

3.11.1 Electrical Equipment is to be designed, fabricated and tested in accordance with requirements in the following standards as applicable:

.1 IEC 61892-3
.2 API RP 14F
.3 API RP 14FZ

3.12 Materials

3.12.1 Materials selected for fabrication of equipment and components are to be suitable for their intended service considering the fluids and the corrosive (internal and external) environment expected to be present during their lifetime.

3.12.2 Materials expected to withstand sour environments (presence of H_2S) are to be in accordance with requirements in ISO 15156.

3.13 Spares

3.13.1 Spares (wherever provided) are to satisfy the certification requirements for the original installed parts as described in Section 3.1

Section 4

Systems

4.1 General

4.1.1 The present section provides requirements for various systems on the Topside production facilities.

4.1.2 Principles outlined in Section 2 are to be adhered to in general for the layout and arrangement of the various systems.

4.1.3 IRS may specially consider systems designed using Codes, Standards and Rules other than those mentioned in this section provided it is satisfactorily demonstrated that they provide an equivalent level of safety.

4.2 Design Principles

4.2.1 Systems are to be designed in order to ensure that a single failure does not lead to development of an abnormal scenario.

4.2.2 System design is to incorporate to the extent practicable, adequate safeguards and barriers of safety for prevention and mitigation of abnormal scenarios.

4.2.3 Adequate means of isolation/shutdown of systems are to be provided. These are to be composed of both remote as well as manual modes. The manual modes are to be arranged such that a system can be safely isolated or shutdown from a space outside that of the area where the equipment is located.

4.2.4 All Safety, Control and Monitoring systems and associated equipment for the Topside Production Facilities are to be connected to Emergency source(s) of power which is activated automatically on the loss of the main power source.

4.2.5 Safety, Control and Monitoring Systems are to be available at all times. The Safety Integrity Levels (SIL) of these systems are to be in accordance with requirements in IEC 61511.

4.2.6 Systems & Equipment are to be provided with adequate pressure relieving devices or systems appropriate for the purpose.

4.2.7 Piping systems for process are to be segregated from other piping systems. The Piping systems for the process systems are not to pass through spaces other than those where the process equipment and systems are located.

4.2.8 Suitable Drainage systems are to be provided for the process systems to collect any leaked fluids. Adequate arrangements are to be made for safe processing/disposal/storage of the fluids collected. The drainages from hazardous areas are to be segregated from those in non-hazardous areas.

4.2.9 The radiation exposure levels from flare system are not to exceed those as provided in API Standard 521. (Reference is made to the API Standard for the necessary evaluations)

4.2.10 Sufficient redundancy is to be provided for the safety, control and monitoring systems. (Reference is made to API RP 14C /Norsok S-001, P-001 & P-100 for additional guidance)

4.3 Process Systems

4.3.1 Process systems are to be designed using recognized Rules & Standards (e.g. NORSOK Standard P-100).

4.4 Safety Systems

4.4.1 Safety Systems are to be designed in accordance with principles as indicated in API RP 14C.

4.5 Ventilation Systems

4.5.1 Ventilation systems are to be provided in accordance with principles outlined in API RP 500 or API RP 505 as applicable.

4.5.2 Ventilation system components are to be in accordance with relevant requirements in Chapter 7.

4.6 Pressure Relief Systems

4.6.1 Requirements of Section 3.10 are to be complied with.

4.7 Fire Safety

Specific requirements for fire safety are outlined in the following sub-sections

Requirements for the Fire safety of the Topside facilities which are not explicitly specified in the present section are to be referred from the relevant sections within the following guidelines and standards as applicable

- API RP 14G
- API RP 14C
- API RP 14F
- ISO 13702
- NORSOK S-001
- IMO FSS Code
- IMO MODU Code
- NFPA Standard 10 - Standard for Portable Fire Extinguishers
- NFPA Standard 11 - Standard for Low, Medium, and High Expansion Foam
- NFPA Standard 12 - Standard on Carbon Dioxide Extinguishing Systems
- NFPA Standard 15 - Standard for Water Spray Fixed Systems for Fire Protection

4.7.1 Prevention of Fire

4.7.1.1 Arrangement of the layout of the Topside facilities are to be in accordance with the fire prevention practices as provided within API RP 14G.

4.7.2 Detection of Fire

4.7.2.1 Fixed automatic systems for detection of fire are to be provided at all locations on the Topside facilities where fire can initiate. (Reference to API RP 14G, API RP 14C and API RP 14F is recommended)

4.7.2.2 Permanently installed gas detectors of the continuous detection type are to be provided within all enclosed and semi-enclosed spaces with a potential of accumulation of combustible gases.

4.7.2.3 Permanently installed gas detectors of the continuous detection type are to be provided at all fresh air intakes into non-hazardous areas.

4.7.2.4 The number and positions of the detection heads are to be determined with due consideration of the size and layout of the compartment, volume and composition of the fluids/gases being processed within the same and redundancy (i.e. malfunction of the detector). (Reference to API RP 14C and API RP 14F is recommended)

4.7.2.5 The alarms are to be activated when the gas concentration reaches 20% LEL and shutdown functions are to be activated at gas concentration of 60% LEL.

4.7.2.6 The alarm and shutdown functions upon detection of gas are to be developed considering the risk assessment in Section 2.1.

4.7.2.7 Atleast two sets of portable gas detection equipment are to be provided which are designed, manufactured and tested in accordance with IEC 60079. These are to be appropriate to detect the gases on the topside facilities anticipated during the production phases.

4.7.2.8 For Topsides facilities where hydrogen sulphide gas may also be present in significant proportions, fixed gas detection systems are to be installed to detect the same.

4.7.2.9 Smoke detectors are to be provided in non-hazardous spaces.

4.7.2.10 The detection of gas and fire is to lead to audible and visible alarms at the following locations:

- Bridge/Central Control room for the Marine Operations
- Central Control room for the topside facilities/Non-hazardous area which is continuously manned.

4.7.2.11 The alarms described in 4.7.2.10 are to be automatically activated on the detection of gas/fire; manual means of activation are also to be provided. The manual means of activation are to be accessible at all times and outside the space within which the gas is detected.

4.7.3 Structural Fire Protection

4.7.3.1 Fire integrity of decks and bulkheads separating spaces excluding those spaces with process equipment & storage tanks is to be in accordance with Rules and Regulations for Construction and Classification of Mobile Offshore Drilling Units 2017, Chapter 14, Section 2.

4.7.3.2 Decks and bulkheads separating spaces with process equipment & storage tanks are to be provided with H-60 fire divisions.

4.7.3.3 Structural design of the decks and bulkheads is to be consider the potential loads due to explosion & pressure build-up in the spaces as may be applicable.

4.7.4 Fire Fighting & Control

4.7.4.1 Fixed firefighting systems are to be provided for the Topside Facilities.

4.7.4.2 A minimum of two fire pumps are to be provided. The pumps are to supply the maximum possible water demand for the Topside facilities. The maximum possible water demand is to be decided based upon the Risk assessment in Section 2.1.

4.7.4.3 Atleast one of the pumps is to draw power from a source which is different from the source powering the other pumps. The pumps are to be located such that fire in one location does not render all the fire pumps in-operable.

4.7.4.4 Means are to be provided to isolate damage in any section of the fire water mains, such that the system is not rendered in-operable. Such means of isolation are to be accessible at all times. Redundancy of the water supply is to be provided for.

4.7.4.5 Fixed water spray systems are to be provided for the process area locations on the Topside Facilities. (Reference to NFPA Standard 15 is recommended). The system is to be able to deliver a minimum of 11 litres/min/m^2 for exposed surface area of the process equipment. For cooling of the equipment foundation/skid structures, a lower delivery rate may be accepted by IRS.

4.7.4.6 Means are to be provided to actuate the fixed water spray system automatically and manually. For manual activation, the location is to be accessible at all times and is to be outside the space of the fire.

4.7.4.7 For FPSOs equipped with an internal turret system, IRS will specially consider the requirements in 4.7.4.6 – 4.7.4.7 based upon the specific case.

4.7.4.8 Length of the provided hoses is to be adequate for deluge systems such that it is possible to direct water jets to all the areas susceptible to fire. The number of hoses provided is to be such that atleast one hose is available at any point of time.

4.7.4.9 Foam systems are to be provided for locations used for storage of crude oil.

4.7.4.10 For all other areas which constitute a part of the topside facilities but not the process area locations, fixed firefighting system appropriate for the location is to be provided.

4.7.5 Portable Fire fighting equipment

4.7.5.1 Portable firefighting equipment of an approved type and design is to be provided for all the locations on the Topside production facilities. The type and number of units is to be appropriate for the location & its size (Reference to NFPA Standard 10 is recommended).

4.7.6 Muster Stations & Escape Routes

4.7.6.1 The topside facilities are to be provided with muster station(s) which can be used for safe refuge and disembarkation of personnel.

4.7.6.2 The muster station is to be provided adequate area and located appropriately to ensure safety of the personnel. This is to be established from the analysis in Section 6.

4.8 Electrical Systems

4.8.1 Electrical systems are to be compliant with IEC 61892, API RP 14F and API RP 14FZ.

Section 5

Structural Strength

5.1 General

5.1.1 The present section provides requirements for the Strength of Equipment and their structural supports and foundations for the topside facilities.

5.2 Loads on Structural Supports/Skids

5.2.1 The structural supports, skids and foundations for the equipment are to consider the following loads:

.1 Weight of the equipment
.2 Operational Loads
.3 Wind loads
.4 Vibratory loads
.5 Thermal loads
.6 Pressures (for pressure vessels)
.7 Loads due to ship motions
.8 Loads due to deflections of hull girder leading in differential support movement

5.3 Structural Analysis of Supports/Skids

5.3.1 Structural analysis is to be performed for the supports and foundations. The analysis may be performed in accordance with requirements in Chapter 5, Section 4.

5.4 Acceptance Criteria for Supports/Skids

5.4.1 Acceptance criteria for analysis are to be referred from Chapter 5, Section 4.

5.5 Equipment Structural Strength

5.5.1 Equipment and Components are to be designed with adequate strength to withstand anticipated loads during their lifetime. The design loads are to be determined considering the design pressures and temperatures the equipments are to be operated at and also the structural degradation of the materials during the equipment's lifetime.

5.5.2 The worst environmental conditions anticipated during the operational life of the unit are to be considered for the determination of equipment strength.

5.5.3 The mounting of equipment on the structural supports /skids/foundations is to have adequate strength.

5.6 Piping Systems

5.6.1 Stress analysis of the piping systems on the topside process facilities is to be performed.

5.6.2 The analysis is to be performed using recognized codes and standards (e.g. ASME B31.3).

5.6.3 Appropriate corrosion allowances are to be considered during analysis depending upon the materials, temperature and the nature of the fluids conveyed by the piping system.

5.6.4 Applicable loads in form of weights, pressures, temperatures, nature of support flexibilities and movements etc. are to be considered for the piping system analysis.

5.6.5 Piperacks /Supports for the piping systems are to be designed for the loads transferred by the piping systems.

Section 6

Evacuation, Escape and Rescue

6.1 Engineering Analysis

6.1.1 A Fire and Evacuation analysis is to be performed to ascertain the adequacy of the firefighting arrangements and escape routes provided. The analysis is to be performed in accordance with ISO 13702.

Section 7

Installation, Testing and Commissioning

7.1 Installation and Testing

7.1.1 Installation of the Equipment and Systems for the Topsides production facilities are to be in accordance with the requirements of recognized codes and standards as prescribed in Section 3 and 4.

7.1.2 An Installation plan and sequence for all topside equipment and systems is to be submitted to IRS. IRS will review the relevant documentations for the equipment in form of design, fabrication and reports of tests undertaken at the manufacturer/fabricators' premises (also refer Section 3.1 for the scope of surveys and documentations required).

7.1.3 IRS will witness the installation for each of the equipment and systems to conclude their satisfactory installation.

7.2 Commissioning

7.2.1 IRS will conduct a review of the topside production facilities equipment installation to conclude the satisfactory installation of all the equipment and systems before the commissioning process. For this IRS may undertake a final survey if deemed necessary.

7.2.2 A Commissioning plan is to be submitted to IRS for its review and approval. This is to include details of the various tests to be performed for each equipment in the installed condition on the unit.

7.2.3 IRS will witness the commissioning of each of the equipment and systems before the final issue of the certificate of classification as applicable.

Appendix 1

Classification of Topside Equipment

The following table provides a typical categorization of the various topside equipment classes. This categorization is however not exhaustive and is meant solely for purpose of illustration. Actual classification will be considered by IRS on a case to case basis.

Equipment	**Category**
Christmas Tree & associated valves	Class A
Separators	Class B
Gas Compressors	Class B
Dehydraters	Class B
Heat Exchangers	Class B
Process Pumps	Class B or Class C (depending upon their function and the process component they support
Pressure Vessels	Class B
Piping/Valves	Class B or Class C (depending upon the importance of the piping section in the process flow)
Flare System	Class A
Flow metering	Class B
Pig launchers and receivers	Class B
Injection Pumps	Class B
Instrumentation and Controls	Class C
ESDV	Class B
Electrical Equipment and Components	Class B or Class C (depending upon the specific equipment under consideration)

End of Chapter

Appendix 1
Sea-Keeping Analysis

A.1.1 Scope

A.1.1.1 A sea-keeping analysis is performed to determine FOU motions and calculation of wave induced load effects.

A.1.1.2 The determination of Response Amplitude operators (RAOs) which are a mathematical representation of the vessel's response and load effects to a sinusoidal wave with unit amplitude.

A.1.2 Loading Conditions

A.1.2.1 Prior to conducting a sea-keeping analysis, appropriate vessel cargo loading conditions (on-site-operations, inspection & maintenance, transit) are to be selected.

A.1.2.2 The model is to consider the effects of the mooring system, and as appropriate, the effects of risers, thrusters and the operations of offloading or support vessels. The motion analysis is to appropriately consider the effect of shallow water on vessel motions. It is recommended to have compatibility between the hydrodynamic and structural models so that the application of fluid pressures onto the finite element mesh of the structural model is facilitated.

A.1.3 Hydrodynamic Models

A.1.3 The hydrodynamic model is to accurately reflect the geometry and mass for corresponding loading conditions of the unit.

A.1.4 Sea-keeping Analysis Methods

A.1.4.1 Computation of wave induced motion and loads are to be carried out using suitable proven methods. The sea-keeping and hydrodynamic load analysis is to be performed using 2D/3D potential theory. The analysis is to account for rigid body motions in all six directions. It is recommended to calculate the response amplitude operators (RAOs, transfer functions) for motion and loads in long crested regular wave. The requirements for the range of wave headings and wave periods are to be applied in hydrodynamic analysis as stated in A.1.5.

A.1.5 Hydrodynamic Analysis

A.1.5.1 In sea-keeping analysis, the wetted body surface is to be partitioned into discrete panels or sufficient number of stations to represent a smoothed body surface. In general, the panel mesh should be fine enough to resolve radiation and diffraction waves with reasonable accuracy.

A.1.5.2 While generating the panels, care should be taken on the smooth transition of the geometry and the size of the panels. The hydrodynamic model for sea-keeping analysis includes the ship panel/facet model and the characteristics of ship weight distribution and range of elementary regular waves.

A.1.5.3 For each loading condition of unit, the draft at the FP and AP, and at the location of centre of gravity (LCG), radii of gyration and sectional mass distribution along the unit's length are to be obtained from the Trim and Stability booklet.

A.1.5.4 The free surface GM correction is to be considered for partially filled tanks. For a tank with filling levels above 98% or below 2% of tank height, the free surface GM correction may be ignored.

A.1.5.5 A sea-keeping analysis is to be performed at given design speed, wave frequency, heading angle for considered loading condition.

A.1.5.6 Consideration of frequency ranges depends on the characteristics of response; however, interval between frequencies is to be adequate to capture the unit's accurate response.

A.1.5.7 The wave heading range is to be 0 to 360 degrees in increments and increment should not exceed 30 degrees.

A.1.6 Results Verification

A.1.6.1 The evaluation of the sea-keeping analysis model should include the following:

A1.6.2 For each cargo loading condition, the hydrostatics of the vessel calculated based on the strip or panel model are to be verified.

A1.6.3 At a statically balanced loading condition, the displacement, Longitudinal Centre of Buoyancy (LCB), transverse metacentric height (GMT), longitudinal metacentric height (GML) and still water bending moment (SWBM) should be checked against the values provided in trim and stability booklet. The differences should be within the following tolerances:

- Displacement = ± 1%
- Trim = ±0.5 [Deg]
- LCB = ±0.1% of length
- GMT = ±2%
- GML = ±2%
- SWBM =±5%

Additionally, the longitudinal locations of the maximum and the minimum SWBM and still water shear force (SWSF) and, if appropriate, those of zero SWBM and zero SWSF should be checked to ensure proper distribution of the SWBM along the vessel's length.

Appendix 2

Environmental Severity Factors

A.2.1 General Assumptions

A.2.1.1 The floating offshore unit is considered to be operating at a specific site for most of its life.

A.2.1.2 The environmental factors are used to derive the dynamic load components for the intended site-specific condition and for the transit condition.

A.2.2 Methodology for determining ESF

A.2.2.1 Environmental severity factors (ESF) is calculated as a ratio of long term value (LTV) of a given load at site to the long term value of that load for North Atlantic Sea conditions as per IACS Recommendation 34.

$$ESF = \frac{LTV_{site}}{LTV_{NA}}$$

Where:

LTV_{site} : Long term value of the response for site specific operation.

LTV_{NA} : Long term value of the response calculated in accordance with IACS Recommendation 34 for worldwide unrestricted environment.

A.2.3 Long Term Analysis

A.2.3.1 The general procedure to be adopted for long term analysis is described in this section.

A.2.3.2 For various headings and applicable loading conditions; wave induced motions and loads are to be computed using sea-keeping analysis as given in Appendix 1.

A.2.3.3 Vertical bending moment and horizontal bending moment response (RAOs) are to be computed for the station close to amidships.

A.2.3.4 Vertical shear forces at stations corresponding to section *L*/4 and 3*L*/4 are to be computed; where *L* is defined in Chapter 4, Section 1.

A.2.3.5 The short term probability that the particular value of response '*X*' is exceeded in a given sea state is given as:

$$p = exp\left(\frac{-X^2}{2m_0}\right)$$

Where:

m_0 : Area under the response spectrum

From this short term probability, long term probability of the response can be evaluated as below:

$$P(x \geq X) = \sum_l \sum_k \sum_j \sum_i exp\left(-\frac{X^2}{2m_0}\right) p_{ij} p_k p_l$$

Where:

p_{ij} : Probability of occurrence of sea state (defined by H_s = significant wave height and T_1 = zero crossing period). The distribution of p_{ij} is generally given in the form of tables, known as scatter tables.

p_k : Probability of occurrence of a particular heading angle with respect to dominant direction of the wave. For these calculations seven different heading angles at an interval of 30° from 0° to 180° are to be taken. Equal probability of occurrence (1/7) is assumed for each of them.

p_l : Probability of occurrence of the loading condition; otherwise $p_l = 1$ can be assumed.

A.2.3.6 For long term analysis considering on-site operations 'P' is to be considered not more than 10^{-8} for 25 year return period. For any other return period factor for probability (f_{prob}), as defined in Ch.4, 5.6, can suitably be computed for use in wave induced load calculations formulas.

A.2.3.7 To generate response spectrum for each sea state, a two parameter ISSC spectrum (PM spectrum) is to be used.

A2.3.8 Long term values are to be computed for zero speed.

Appendix 3

Requirements for Strength Assessment using Direct Calculations

A.3.1 General

A.3.1.1 Cargo tank structural strength analysis, in accordance with Appendix 3, for the assessment of scantlings of longitudinal hull girder structural members, primary supporting structural members and transverse bulkheads in tanks within the mid-ship cargo region, is mandatory. The assessment is to be based on the maximum permissible still water (load combination S) and combined permissible still water and wave hull girder vertical shear forces (load combination S+D) between and including the forward bulkhead of the aft most cargo tank and 0.65L from AP, but not including the engine room and slop tank transverse bulkheads, see Figure A.1(a).

A.3.1.2 The assessment of longitudinal hull girder shear structural members in the forward cargo region, in accordance with Appendix 3, is mandatory. The strengthening of these structural members in way of transverse bulkheads in the tanks of the forward cargo region may be based on the maximum permissible still water (load combination S) and combined permissible still water and wave hull girder vertical shear forces (load combination S+D) at the bulkhead positions forward of 0.65*L* from AP, but not including the forward collision bulkhead, see Figure A.1(b).

A.3.1.3 Strengthening of longitudinal hull girder shear structural members in way of transverse bulkheads of the tanks in the mid-ship cargo region and the aft cargo region, in accordance with Appendix 3, may be based on the scantling result obtained from the mid-ship cargo tank analysis as described in A.3.1.1.

A.3.1.4 Alternatively, optional assessment may be carried out to determine the strengthening requirement of longitudinal hull girder shear structural members in way of individual transverse bulkheads based on the permissible still water (load combination S) and combined permissible still water and wave hull girder vertical shear forces (load combination S+D) at the transverse bulkhead position under consideration, see Figure A.1(b).

Part A – Modeling requirements for Cargo hold & Global Strength analysis

A.3.2 Finite element modeling

A.3.2.1 The objective of the finite element model is to create an accurate representation of the stiffness of the hull. This is achieved by using appropriate elements at the various locations.

A.3.2.2 All primary structural members are to be modeled using 3D Shell elements. Such members would typically include hull envelope plating, girders, longitudinal bulkheads, inner bottom and decks, cross ties and horizontal stringers, floors and deck transverses, bulkheads. For corrugated bulkheads, modeling of the corrugations has to be performed using shell elements. The support stools are also to be modeled using shell elements.

A.3.2.3 Stiffeners for the primary supporting members may be modeled using beam elements. The section properties of the beam elements are to be assigned appropriately such that the stiffness of the stiffener and attached plating are correctly represented in the finite element model.

A.3.2.3 Faceplates may be modeled using beam or link elements.

A.3.2.4 Brackets are to be modeled using shell elements.

A.3.2.5 Openings may be modeled by actual representation of the same in the finite element model or by providing equivalent properties to the plate. Requirements as provided in IRS Rules for Bulk Carriers and Oil Tankers, Volume 2, Part 1, Chapter 7, Section 2 [2.4.9] are referred to for additional guidance on modeling openings.

A.3.2.6 Shell elements to be used for the modeling are four noded elements. However, the options for the elements using common general purpose finite element software are to be carefully set. (for example, the 4 noded shell element in most common purpose finite element software is provided with the reduced integration option; this must be carefully considered while selecting the element size so as to avoid spurious deformation modes. Else such elements may be used with ESFs (Enhanced Shape functions) so that the model does not become very rigid in terms of stiffness).

A.3.3 Element Size

A.3.3.1 Element sizes are to be chosen such that the stiffness is accurately represented in the model. This is also to be achieved considering computational constraints and efficiency.

A.3.3.2 It is recommended to have atleast one shell element between two stiffeners (this applies to stiffeners on primary structural members such as hull envelope plating, decks, floors, girders, stringers, deck transverses, longitudinal and transverse bulkheads). It is recommended to have atleast three elements between two frames. It is recommended to have element aspect ratio which is close to unity. However, the aspect ratio under any circumstances is not to exceed 3.

A.3.3.3 For curved plates, it is recommended to select element sizes which represent the curvature correctly. It is recommended to avoid the use of triangular shell elements in the model.

A.3.3.4 For element sizes used for corrugated bulkhead modeling, it is recommended to refer requirements as provided in Requirements as provided in IRS Rules for Bulk Carriers and Oil Tankers, Volume 2, Part 1, Chapter 7, Section 2 [2.4.3].

A.3.4 Extent of Model

A.3.4.1 The extent of modeling requirements for cargo hold analysis is shown in Figure A.1. A three hold model is considered acceptable for the analysis.

A.3.4.2 Mid-ship cargo hold model is to be created. This is to consider all tanks with longitudinal centers of gravity between 0.3*L* to 0.7*L*.

A.3.4.3 Finite element models are to be created for assessment of shear strength of longitudinal hull girder members as shown in Figure A.1 (b). Such models are to be three hold models.

A.3.4.4 For the Global Strength analysis required for the GSA class notation, the complete FOU is to be modeled. Topside modules may not be modeled; they may be represented using equivalent masses with centers of gravities so as to simulate the correct longitudinal, vertical and transverse centre of gravity of the unit as a whole.

Part B – Modeling requirements for Local Strength analysis

A.3.5 Details to be modeled

A.3.5.1 Mandatory Details to be subjected to local strength assessment are listed in IRS Rules for Bulk Carriers and Oil Tankers, Volume 2, Part 1, Chapter 7, Section 3 [2].

A.3.5.2 If deemed necessary, IRS may impose requirements for additional details to be subjected to Local Strength analysis.

A.3.6 Finite element modeling

A.3.6.1 Requirements as provided in IRS Rules for Bulk Carriers and Oil Tankers, Volume 2, Part 1, Chapter 7, Section 3 [4] are to be complied with.

Part C – Loading Conditions & Load Combinations

A.3.7 Load Conditions and Combinations for Cargo Hold Analyses

A.3.7.1 Loading conditions to be considered for analysis for cargo hold are depicted in Tables A.1 and A.2. Loading conditions scenarios in the Table which are not applicable or not considered in the loading manual may not require to be analyzed. However, this should be accompanied with a note in the loading manual and the mid-ship section drawing clearly stating that such conditions are not permitted for the FOU.

A.3.7.2 Any loading conditions in the loading manual but not represented within Tables A.1 & A.2 are to be additionally analysed.

A.3.7.3 Loading condition to be used for cargo hold analysis considering the installation voyage will be finalized in agreement with IRS.

A.3.7.4 Dynamic load scenarios to be used within the load combinations are shown in Table A.3.

A.3.7.5 Dynamic load combination factors to be used in the direct calculations are shown in Table A.3.

A.3.7.6 In addition to conditions in Tables A.1 & A.2 analyses are to be performed for inspection /maintenance conditions as specified by the designer. Dynamic load scenarios to be considered for the inspection and maintenance conditions will be agreed upon with IRS.

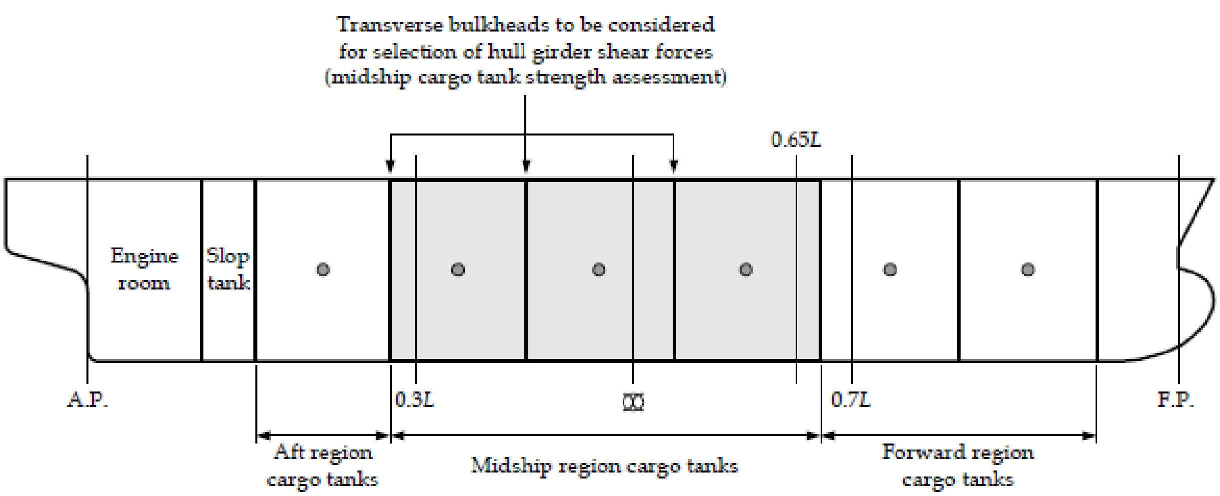


Figure A.1(a): Mid-ship Cargo Hold Model extent

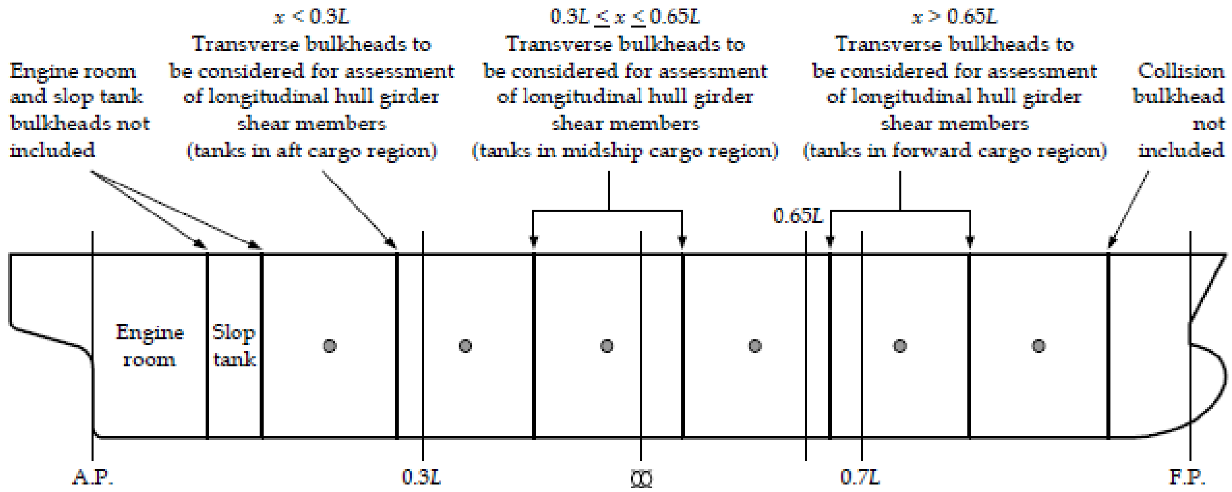
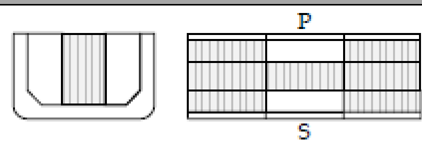
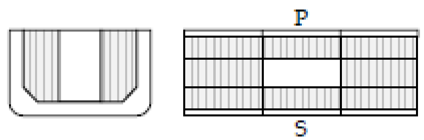
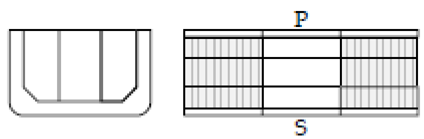
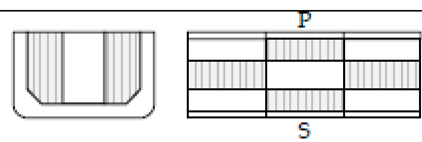
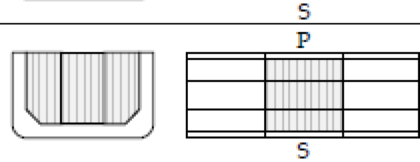
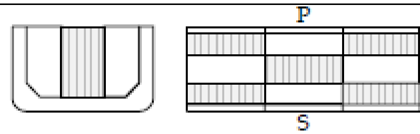
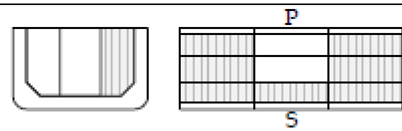
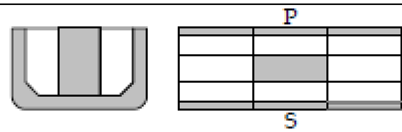
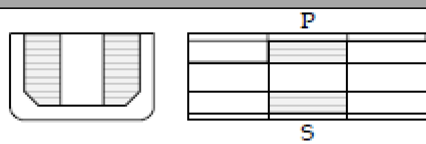
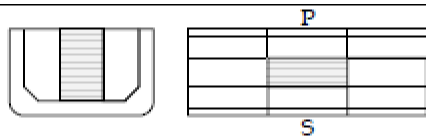
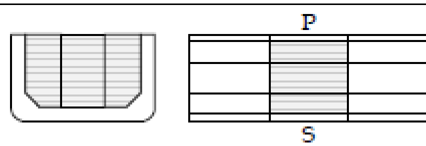
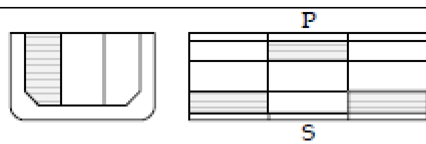
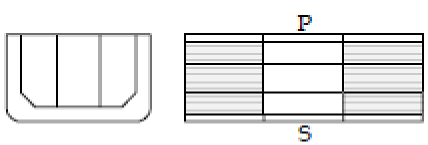


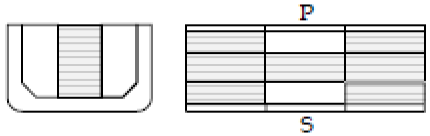
Figure A.1(b): Longitudinal shear strength assessment of members

Note
1. Tanks in the forward cargo region are defined as tanks with their longitudinal centre of gravity position forward of 0.7*L* from A.P.
2. Tanks in the mid-ship cargo region are defined as tanks with their longitudinal centre of gravity position at or forward of 0.3*L* from AP and at or aft of 0.7*L* from A.P.
3. Tanks in the aft cargo region are defined as tanks with their longitudinal centre of gravity position aft of 0.3*L* from A.P.

Table A.1: Loading conditions to be used for strength analyses: For FOUs with two oil tight longitudinal bulkheads

Loading Condition number	Illustration	Still Water Loads			Dynamic Load Scenarios		
					Strength assessment	Shear Strength assessment of longitudinal members	
		Draught	Permissible bending moment[2]	Permissible Shear force[2]	Mid-ship Region[1a]	Forward region[1b]	Aft Region[1b]
On- Site Operations							
1		$0.9T_{sc}$	100% (Sag)	See note 3	1	-	-
			100% (hog)	100% (-ve fwd) See note 4	2, 5a	-	-
2		$0.9T_{sc}$	100% (sag)	See note 3	1	-	-
			100% (hog)	100% (-ve fwd) See note 4	2, 5a	-	-
3		$0.55T_{sc}$ (see note 6)	100% (hog)	100% (-ve fwd) See note 5	2	4	2
				100% (-ve fwd) See note 4	5a	-	-
4		$0.6T_{sc}$	100% (Sag)	100% (+ve fwd) See note 4	1,5a	-	-
5		$0.8T_{sc}$ See note 7	100% (sag)	100% (+ve fwd) See note 5	1	3	1
				100% (+ve fwd) See note 4	5a	-	-

6		0.6T_{sc}	100% (hog)	100% (-ve fwd) See note 4	5a	-	-
7[8]		T_{Lc}	100% (hog)	100% (-ve fwd) See note 4	5a	-	-
8[9]		$T_{bal\text{-}em}$	100% (sag)	100% (+ve fwd) See note 4	1	-	-
Harbour & Testing Conditions							
9[13]		0.25T_{sc}	100% (sag)	100% (+ve fwd) See note 4	Only applicable to strength assessment of mid-ship region (see note 1(a))		
10[13]		0.25T_{sc}	100% (sag)	100% (+ve fwd) See note 4	Only applicable to strength assessment of mid-ship region (see note 1(a))		
11[12,13]		0.7T_{sc} See note 12	100% (sag)	100% (+ve fwd) See note 5	Applicable to strength assessment of mid-ship region (see 1(a)) and strength assessment against hull girder shear loads (see 1(b))		
12 [10,13]		0.67T_{sc}	See note 10	See note 10	Only applicable to strength assessment of mid-ship region (see note 1(a))		
13 [11,13]		0.65T_{sc} See note 11	100% (hog)	100% (-ve fwd) See note 5	Applicable to strength assessment of mid-ship region (see 1(a)) and strength assessment against hull girder shear loads (see 1(b))		

14 [13]		T_{sc}	100% (hog)	100% (-ve fwd) See note 4	Only applicable to strength assessment of mid-ship region (see note 1(a))

Note

1.

(a) For the assessment of scantlings of longitudinal hull girder structural members, primary supporting structural members and transverse bulkheads within mid-ship cargo region, see A.3.1.1

(b) For the assessment of strengthening of longitudinal hull girder shear structural members in way of transverse bulkheads for hull girder vertical shear loads, see A.3.1.2, A.3.1.3, A.3.1.4.

2. The selection of permissible SWBM and SWSF for the assessment of different cargo regions of the Unit is to be in accordance with Table A.4. The percentage of the permissible SWBM and SWSF to be applied are to be in accordance with this table.

3. The actual shear force that results from the application of static and dynamic local loads to the FE model is to be used.

4. The actual shear force that results from the application of static and dynamic local loads to the FE model is to be used. Where this shear force exceeds the target SWSF (design load combination S) or target combined SWSF and VWSF, calculated in accordance with A.3.12, (design load combination S+D) as specified in the table, correction vertical loads are to be applied to adjust the shear force down to the required value.

5. Correction vertical loads are to be applied to adjust the shear force to the required value specified.

6. For loading pattern 3, with all cargo tanks abreast empty in sea-going condition, a draught of $0.55T_{sc}$ is to be used in the analysis. Where such conditions are specified in the Unit's loading manual with a draught greater than $0.55T_{sc}$, the maximum specified draught for those loading conditions is to be used in the FE analysis.

7. For loading pattern 5, with all cargo tanks abreast fully loaded in sea-going condition, a draught of $0.8T_{sc}$ is to be used in the analysis. Where such conditions are specified in the Unit's loading manual with a draught lesser than $0.8T_{sc}$, the minimum specified draught for those loading conditions is to be used in the FE analysis.

8. Loading pattern 7 is only required to be analysed for Units with a cross tie arrangement in the centre cargo tanks if the loading manual includes a non-symmetrical loading condition with only one of the wing tanks filled. The actual draught from the loading manual for the condition is to be used in the analysis.

9. Ballast loading pattern 8 with ballast filled in one or more cargo tanks (i.e. gale ballast/emergency ballast conditions etc.) is only required to be analysed if the condition is specified in the Unit's loading manual. The actual loading pattern and draught from the loading manual for the condition is to be used in the analysis.

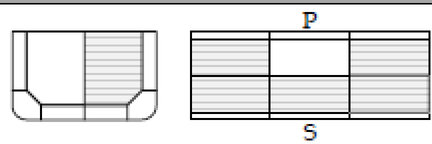
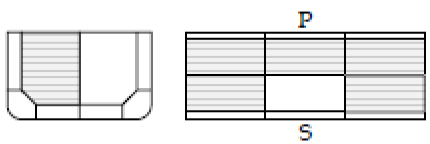
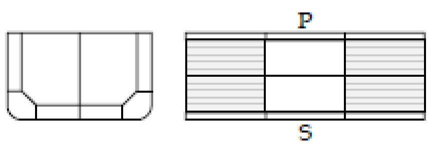
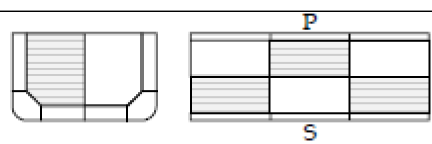
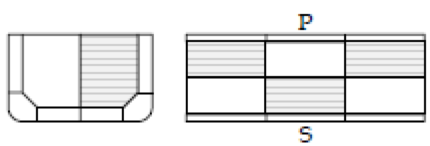
10. Loading pattern 12 is only required for Units with a cross tie arrangement in the centre cargo tanks. The actual shear force and bending moment that results from the application of local loads to the FE model are to be used. Adjusting vertical loads and bending moments are not applied.

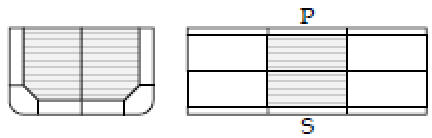
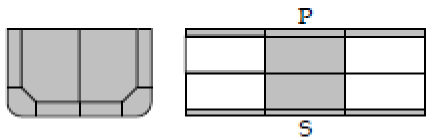
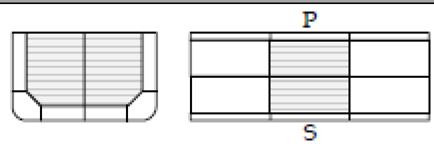
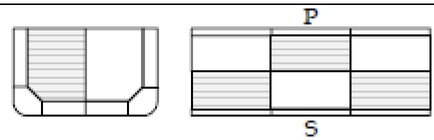
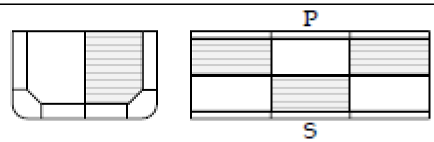
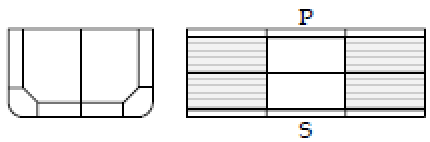
11. For loading pattern 13, with all cargo tanks abreast empty in harbour condition, a draught of $0.65T_{sc}$ is to be used in the analysis. Where such conditions are specified in the Unit's loading manual with a draught greater than $0.65T_{sc}$, the maximum specified draught for those loading conditions is to be used in the FE analysis.

12. For loading pattern A11, with all cargo tanks abreast fully loaded in harbour condition, a draught of $0.7T_{sc}$ is to be used in the analysis. Where such conditions are specified in the Unit's loading manual with a draught less than $0.7T_{sc}$, the minimum specified draught for those loading conditions is to be used in the FE analysis.

13. No dynamic loads are to be applied to Design Load Combination *S* (harbour and tank testing load cases).

Table A.2: Loading conditions to be used for strength analyses: For FOUs with one centre longitudinal bulkhead

Loading Condition number	Illustration	Still Water Loads			Dynamic Load Scenarios		
					Strength assessment	Shear Strength assessment of longitudinal members	
		Draught	Permissible bending moment[2]	Permissible Shear force[2]	Mid-ship Region[1a]	Forward region[1b]	Aft Region[1b]
On-Site Operation							
1		$0.9T_{sc}$	100% (Sag)	See note 3	1	-	-
			100% (hog)	100% (-ve fwd) See note 4	2, 5a	-	-
2[6]		$0.9T_{sc}$	100% (sag)	See note 3	1	-	-
			100% (hog)	100% (-ve fwd) See note 4	2, 5b	-	-
3		$0.9T_{sc}$	100% (hog)	100% (-ve fwd) See note 5	2	4	2
				100% (-ve fwd) See note 4	5a, 5b, 6a, 6b	-	-
4		$0.6T_{sc}$	100% (Sag)	75% (+ve fwd) See note 4	1, 5a	-	-
5 [6]		$0.6T_{sc}$	100% (sag)	75% (+ve fwd) See note 4	1, 5b	-	-

6		$0.6T_{sc}$	100% (sag)	100% (+ve fwd) See note 5	1	3	1
				100% (+ve fwd) See note 4	5a, 5b		
7 [7]		$T_{bal\text{-}em}$	100% (sag)	100% (+ve fwd) See note 4	1	-	-
Harbour & Testing Conditions							
8 [8]		$0.33T_{sc}$	100% (sag)	100% (+ve fwd) See note 5	Applicable to strength assessment of mid-ship region (see 1(a)) and strength assessment against hull girder shear loads (see 1(b))		
9 [8]		$0.33T_{sc}$	100% (sag)	75% (+ve fwd) See note 4	Only applicable to strength assessment of mid-ship region (see note 1(a))		
10 [6,8]		$0.33T_{sc}$	100% (sag)	75% (+ve fwd) See note 4	Only applicable to strength assessment of mid-ship region (see note 1(a))		
11 [8]		T_{sc}	100% (Hog)	100% (-ve fwd) See note 5	Applicable to strength assessment of mid-ship region (see 1(a)) and strength assessment against hull girder shear loads (see 1(b))		

Note

1.

(a) For the assessment of scantlings of longitudinal hull girder structural members, primary supporting structural members and transverse bulkheads within mid-ship region, see A.3.1.1.

(b) For the assessment of strengthening of longitudinal hull girder shear structural members in way of transverse bulkheads for hull girder vertical shear loads, see A.3.1.2, A.3.1.3, and A.3.1.4.

2. The selection of permissible SWBM and SWSF for the assessment of different cargo regions of the ship is to be in accordance with

Table A.4. The percentage of the permissible SWBM and SWSF to be applied are to be accordance with the present table. 3. The actual shear force that results from the application of static and dynamic local loads to the FE model are to be used. 4. The actual shear force that results from the application of static and dynamic local loads are to be used. Where this shear force exceeds the target SWSF (design load combination S) or target combined SWSF and VWSF, calculated in accordance with A.3.12, (design load combination S+D) as specified in the table, correction vertical loads are to be applied to adjust the shear force down to the required value. 5. Correction vertical loads are to be applied to adjust the shear force to the required value specified. 6. Load cases 2, 5 and 10 are only required if the structure is not symmetrical about the floating offshore unit's centerline. 7. Loading pattern 7 with ballast filled in cargo tanks (i.e. gale ballast/emergency ballast conditions etc.) is only required to be analysed if the condition is specified in the Unit's loading manual. The actual loading pattern and draught from the loading manual for the condition is to be used in the analysis, If the actual loading pattern is different from load case B7 then: (a) An operational restriction corresponding to the analysed condition is to be added in the Loading Manual. (b) 100% of the permissible SWBM is to be applied when analyzing loading pattern with ballast in cargo tanks. 8. No dynamic loads are to be applied to Design Load Combination S (harbour and tank testing load cases).

Table A.3: Dynamic Load Cases for cargo hold

Wave direction			**Head Sea**				**Beam Sea**		**Oblique Sea**	
Max Response			M_{wv} **(Sagging)**	M_{wv} **(Hogging)**	Q_{wv} **(Sagging)**	Q_{wv} **(Hogging)**	a_v		M_{wv-h}	
Dynamic Load case			**1**	**2**	**3**	**4**	**5a**	**5b**	**6a**	**6b**
Global Loads	M_{wv}	f_{mv}	-1.0	1.0	-1.0	1.0	0.0	0.0	0.4	0.4
	Q_{wv}	F_{qv}	1.0	-1.0	1.0	-1.0	0.0	0.0	0.0	0.0
	M_{wv-h}	F_{mh}	0.0	0.0	0.0	0.0	0.0	0.0	1.0	-1.0
Accelerations	a_v	f_v	0.5	-0.5	0.3	-0.3	1.0	1.0	-0.1	-0.1
	a_t	f_t	0.0	0.0	0.0	0.0	-0.6	0.6	0.0	0.0
	a_{lng}	$flng$	-0.6	0.6	-0.6	0.6	-0.5	-0.5	0.5	0.5
Dynamic Wave pressure for port side	P_{WL}	f_{WL}	-0.3	0.3	0.1	-0.1	1.0	0.4	0.6	0.0
	P_{bilge}	f_{bilge}	-0.3	0.3	0.1	-0.1	1.0	0.4	0.4	0.0
	P_{ctr}	f_{ctr}	-0.7	0.7	0.3	-0.3	0.9	0.9	0.5	0.5
Dynamic Wave pressure for starboard side	P_{WL}	f_{WL}	-0.3	0.3	0.1	-0.1	0.4	1.0	0.0	0.6
	P_{bilge}	f_{bilge}	-0.3	0.3	0.1	-0.1	0.4	1.0	0.0	0.4
	P_{ctr}	f_{ctr}	-0.7	0.7	0.3	-0.3	0.9	0.9	0.5	0.5

f_{v-mid} :dynamic load combination factor associated with the vertical acceleration of a centre cargo and ballast tank
f_{v-pt} :dynamic load combination factor associated with the vertical acceleration of a port cargo and ballast tank
f_{v-stb} :dynamic load combination factor associated with the vertical acceleration of a starboard cargo and ballast tank

Table A.4: Locations for the Determination of Loads and Accelerations

	Strength assessment [1a]	**Strength assessment against hull girder shear loads** [1b]		
	Midship cargo region	**Forward cargo region**	**Mid-ship cargo region**	**Aft cargo region**
Design load combinations *S + D* (Sea-going load cases)				
Dynamic wave pressure and green sea load	Transverse section at 0.5*L* from AP	Transverse section at 0.75*L* from AP	Transverse section at 0.5*L* from AP	Transverse section at 0.25*L* from AP
Acceleration a_v, a_t, a_{lng}	at CG position of mid-ship tanks (i.e. 0.5*L* from AP is within the tank boundary)	at CG position of forward tanks (i.e. 0.75*L* from AP is within the tank boundary)	at CG position of mid-ship tanks (i.e. 0.5*L* from AP is within the tank boundary)	at CG position of aft tanks (i.e. 0.25*L* from AP is within the tank boundary)
VWBM and SWBM (SWBM is to be based on sea-going permissible values)	at 0.5*L* from AP	at 0.75*L* from AP	at 0.5*L* from AP	at 0.25*L* from AP
HWBM	at 0.5*L* from AP	-	-	-
VWSF and SWSF (SWSF is to be based on sea-going permissible values)	at the transverse bulkhead with maximum combined seagoing permissible SWSF and VWSF in the region	at the transverse bulkhead with maximum combined seagoing permissible SWSF and VWSF in the region or at individual bulkhead position	based on mid-ship cargo tank strength assessment or seagoing permissible SWSF and VWSF at individual transverse bulkhead position	
Design load combination S (Harbour and tank testing load cases)				
SWBM (SWBM is to be based on harbour permissible values)	at 0.5L from AP	at 0.75L from AP	at 0.5L from AP	at 0.25L from AP
SWSF (SWSF is to be based on harbour permissible values)	maximum harbor permissible SWSF in the region	maximum harbor permissible SWSF in the region or at individual bulkhead position	based on mid-ship cargo tank strength assessment or harbor permissible SWSF at individual transverse bulkhead position	

Table A.4 – Note

1. The following assessments are to be carried out:
   a. For the assessment of scantlings of longitudinal hull girder structural members, primary supporting structural members and transverse bulkheads in tanks within mid-ship cargo region, see A.3.1.1.
   b. For the assessment of strengthening of longitudinal hull girder shear structural members in way of individual transverse bulkheads for hull girder shear loads, see A.3.1.2, A.3.1.3, and A.3.1.4.
2. For each FE load case, accelerations are to be calculated at the centre of gravity position of the ballast and/or cargo in accordance with this table. The acceleration calculated for each reference tank is to be applied to the 3 corresponding cargo or ballast tanks along the length of the FE model.
3. Longitudinal distances used in the calculation of loads refer to distance measured forward from the A.P.
4. Dynamic wave pressure calculated at the specified section is to be applied to the full length of the FE model
5. Dynamic load combination factors applied to dynamic loads for design load combination $S + D$ (sea-going load cases) as defined in Table A.3.
6. The SWBM and SWSF to be applied are to be in accordance with Tables A.1 and A.2.

A.3.8 Load Conditions and Combinations for Local Strength Analyses

A.3.8.1 The loading conditions and combinations as described in A.3.7 are to be considered for Local Strength analyses.

A.3.9 Load Conditions and Combinations for Global Strength Analyses

A.3.9.1 The loading conditions to be utilized for Global Strength are to be considered from the loading manual. The following conditions are to be analyzed.

.1 On-Site Operating condition with maximum draught
.2 On-Site Operating condition with minimum draught

The loading conditions must be selected maximizing the still water bending moment at the corresponding draught. If deemed necessary, IRS may also request transit conditions to be investigated in the global strength analysis.

A.3.9.2 Hydrodynamic analysis as described in Appendix 2 is to be performed for obtaining the loads for the loading conditions as described in A.3.9. For this purpose, the hydrodynamic analysis is to consider the environmental conditions at the site with the return periods as specified in Chapter 4, Section 5. Equivalent Design Wave approach is considered as acceptable for obtaining the loads. Appropriate panel methods or CFD techniques are to be used for obtaining the hydrodynamic loads.

A.3.9.3 Hydrodynamic loads calculated in A.3.9.2 may be in terms of shear force distributions and bending moment distributions along the length of the FOU. Panel pressures are also acceptable; however, notwithstanding the above, the shear force and bending moment distributions are to be evaluated.

A.3.9.4 The analysis must consider the lightship weight of the FOU with the topside modules and also the mooring system loads and the riser loads.

A.3.10 Loads

A.3.10.1 The following loads are to be applied on the finite element model as applicable for Cargo hold, Local Strength and Global Strength analyses

.1 Structural weights – This must also be inclusive of the topside modules, frames other elements. These weights are to also duly consider the FOU motions during the application. FOU motions are calculated in accordance with Chapter 4
.2 Mooring & Riser loads – Mooring and riser loads corresponding to the FOU loading condition and incumbent wave environment are to be applied.
.3 External Pressures – External pressures in accordance with Chapter 4 are to be applied
.4 Internal Pressures – Internal pressures in accordance with Chapter 4 are to be applied.

A.3.11 Boundary Conditions for Cargo Hold analyses

A.3.11.1 Boundary conditions are to be appropriately representing the actual conditions for the cargo hold model considered. Boundary conditions may be referred from IRS Rules for Bulk Carriers and Oil Tankers, Volume 2, Part 1, Chapter 7.

A.3.12 Boundary Conditions for Local Strength analyses

A.3.12.1 Boundary conditions are to be applied using nodal displacements obtained from the cargo hold model. Alternatively, boundary conditions may also be applied using equivalent nodal forces.

A.3.13 Boundary Conditions for Global Strength analyses

A.3.13.1 Boundary conditions are to be applied to constrain the rigid body motions of the FOU. The model should not be however overconstrained.

A.3.14 Balancing procedure for Cargo Hold analyses

A.3.14.1 The finite element model is to be 'balanced' so as to represent accurately the loading conditions.

A.3.14.2 The target bending moment and target shear forces are to be achieved at the specified locations. The target bending moment, target shear force and the corresponding locations are to be in accordance with A.3.13.3

A.3.14.3 It is recommended to follow the balancing procedure requirements as provided in IRS Rules for Bulk Carriers and Oil Tankers, Volume 2, Part 1, Chapter 7, Section 2 [4.4]. The target bending moments and shear forces are to be considered as provided in IRS Rules for Bulk Carriers and Oil Tankers, Volume 2, Part 1, Chapter 7, Section 2 [4.3.2 – 4.3.4].

Part D – Evaluation Criteria

A.3.15 Evaluation Criteria for Cargo Hold analyses

A.3.15.1 Evaluation criteria as required by IRS Rules for Bulk Carriers and Oil Tankers, Volume 2, Part 1, Chapter 7, Section 2 [5] are to be applied.

A.3.16 Evaluation Criteria for Local Strength analyses

A.3.16.1 Evaluation criteria as required by IRS Rules for Bulk Carriers and Oil Tankers, Volume 2, Part 1, Chapter 7, Section 3 [6] are to be applied.

A.3.17 Evaluation Criteria for Global Strength analyses

A.3.17.1 The von mises stress (as defined in IRS Rules for Bulk Carriers and Oil Tankers, Volume 2, Part 1, Chapter 7, Section 2 [5.2.1]) is not to exceed 235/k; where k is the material factor.

A.3.17.2 The buckling utilization factor (as defined in IRS Rules for Bulk Carriers and Oil Tankers, Volume 2, Part 1, Chapter 8, Section 1 [3.2]) is not to exceed 1.0.

Appendix 4
S-N Curves

A.4.1. Design S-N Curves

A.4.1.1 General

A.4.1.1.1 The capacity of welded steel joints with respect to the fatigue strength is characterized by S-N curves which give the relationship between the stress range applied to a given detail and the number of constant amplitude load cycles to failure.

A.4.2 Design S-N Curves

A.4.2.1 Unless supported by direct measurements, the U.K. HSE (previously DEn) Basic S-N Curves are to be used for determining the fatigue life. (Offshore Installations: Guidelines on design, construction and certification)

These S-N curves are applicable to steels with minimum yield strength less than 400 N/mm^2. For steels with higher yield strength, data obtained from an approved test programme are to be used (refer to A.4.4).

A.4.3 U.K. HSE S-N Curves

A.4.3.1 The HSE S-N Curves for non-tubular joints consist of eight curves, as shown in Table A.5 identified by B, C, D, E, F, F2, G and W categories. These curves give the relationship between the nominal stress range and the number of constant amplitude load cycles to failure. Each curve represents a class of welded details depending upon:

- The geometrical arrangement of the detail,
- The direction of the fluctuating stress relative to the detail
- The method of fabrication and inspection of the detail.

A.4.3.2 The fatigue life (in cycles) corresponding to a given stress range is to be evaluated as shown below:

$$S^m N = K_2$$

Where:

S : Evaluated Stress range at a given structural detail for which the fatigue life is to be evaluated

N : Number of cycles to failure

K_2 : Constant depending upon the material and weld type, type of loading, geometrical configuration and environmental conditions

m : Constant depending upon the material and weld type, type of loading, geometrical configuration and environmental conditions

A.4.3.3 The S-N curves specified in the Rules correspond to non-corrosive conditions and are specified for mean minus two standard deviations. This is demonstrated as shown below:

$$Log(N) = Log(K_2) - mLog(S)$$

where:

$$Log(K_2) = Log(K_1) - 2\delta$$

Where:

N : As defined in A.4.3.2

K_1 : Constant relating to the mean SN curve as shown in Table A.5

δ : Standard deviation of log(N)

m : Inverse slope of the SN curve as defined in A.4.3.2

S_q : Stress range corresponding to 10^7 cycles of the SN curve as shown in Table A.5

A.4.3.4 For plate thicknesses greater than 22 mm, the number of cycles N is to be evaluated as shown below:

$$Log(N) = Log(K_2) - mLog\left[\frac{S}{\left(22/t_{net50}\right)^{0.25}}\right]$$

Where

Log (N) : as defined in A.4.3.3

Log K_2 : as defined in A.4.3.3

m : as defined in A.4.3.2

S : Stress range at the structural detail corresponding to the loading condition under evaluation

t_{net50} : Net thickness considering 50% deduction of corrosion additions.

A.4.3.5 The effects of mean stress are to be accounted for during the life cycles evaluation. The consideration of benefits of weld improvements on the fatigue life is to be agreed with IRS.

A.4.3.6 The considerations in the present section are applicable for welded joints in air or exposed to sea water based upon the consideration that suitable corrosion protection in form of coating is provided. For unprotected joints exposed to sea water, the fatigue life cycles obtained from A.4.3.3 or A.4.3.4 are to be reduced by a factor of 2.

A.4.3.7 Selection of the appropriate SN curve for a structural detail can be made considering the guidelines in Table A.6 considering that the nominal stress range (S) is evaluated as shown in A.3.2. For hotspot stress ranges evaluated using FEM, the D category SN curve may be utilized.

A.4.4 Prototype testing

A.4.4.1 Prototype testing is the most direct way of assessing the fatigue strength for particular structural details. Fatigue tests may be generally performed for constant amplitude loadings and the following precautions should be taken:

A.4.4.2 The steel grade used for the test pieces should be the same as that provided for the actual structural detail under consideration,

A.4.4.3 Welding procedures should be representative of the actual conditions of welding

A.4.4.4 The size of test specimens should be such that the level of residual stress is equivalent to that of the actual structure,

A.4.4.5 The stress ratio $R = \sigma_{min}/\sigma_{max}$ should remain constant during the experiments. Generally, this ratio is to be taken between 0 and 0.1.

A.4.4.6 3D FEM structural analyses are to be performed for the test specimens with a view to validating the calculation procedure used for determination of hot spot stresses in the actual structure. In particular, theoretical stresses will have to be computed at locations where stress measurements are carried out during the fatigue testing. The fatigue testing procedure is to be approved by the Society.

Table A.5: SN Curves

SN curve Category	K_1			m	Δ		K_2	S_q (N/mm^2)
		log_{10}	log_e		log_{10}	log_e		
B	2.343E15	15.3697	35.3900	4.0	0.1821	0.4194	1.01E15	100.2
C	1.082E14	14.0342	32.3153	3.5	0.2041	0.4700	4.23E13	78.2
D	3.988E12	12.6007	29.0144	3.0	0.2095	0.4824	1.52E12	53.4
E	3.289E12	12.5169	29.8216	3.0	0.2509	0.5777	1.04E12	47.0
F	1.726E12	12.2370	28.1770	3.0	0.2183	0.5027	0.63E12	39.8
F2	1.231E12	12.0900	27.8387	3.0	0.2279	0.5248	0.43E12	35.0
G	0.566E12	11.7525	27.0614	3.0	0.1793	0.4129	0.25E12	29.2
W	0.368E12	11.5662	26.6324	3.0	0.1846	0.4251	0.16E12	25.2

Table A.6: Welded Joint Classification for SN curve

SN curve category for Joint Classification	**Description [1]**
Category B	1) Parent metal in the as-rolled condition with no flame-cut edges or with flame-cut edges ground or machined 2) Full penetration butt welds with the weld cap ground flush with the surface and with the weld proved to be free from defects by NDT.
Category C	1) Parent material in the as-rolled condition with automatic flame-cut edges and ensured to be free from cracks. 2) Butt or fillet welds made by an automatic submerged or open arc process and with no stop-start positions within their length. 3) With the weld cap ground flush with the surface and with the weld proved to be free from significant defects by NDT.
Category D	1) As C(2) but with stop-start positions within the length 2) with the welds made either manually or by an automatic process other than submerged arc and in flat position
Category E	1) Intermittent fillet welds
Category F	1) Welds made on a permanent backing strip between plates of equal width and thickness or tapered with a maximum slope of 1/4. 2) Parent material (of the stressed member) or ends of butt or fillet welded attachments (parallel to the direction of applied stresses) on stressed members : - attachment length $l \leq 150$ mm - edge distance $d \geq 10$ mm 3) Parent metal of cruciform or T Joints made with full penetration welds and with any undercut at the corners of the member ground out 4) Parent metal at the toe of weld connection of web stiffeners to girder flanges: edge distance d ≥ 10 mm As E(1) but adjacent to cut-outs.

SN curve category for Joint Classification	Description [1]
Category F2	1) Parent material (of the stressed member) or ends of butt or fillet welded attachments (parallel to the direction of applied stresses) on stressed members : - attachment length *l* > 150 mm - edge distance *d* ≥ 10 mm 2) As F(3) with partial penetration or fillet welds with any undercut at the corners of the member ground out. 3) Parent metal of load-carrying fillet welds transverse to the direction of stresses (member X): edge distance *d* ≥ 10 mm
Category G	1) Parent material (of the stressed member) at toes or ends of butt or fillet welded attachments on or within 10 mm of edges or corners. 2) Parent metal of load-carrying fillet welds transverse to the direction of stresses (member X): edge distance *d* < 10 mm 3) Parent metal of load-carrying fillet welds parallel to the direction of stresses, with the weld end on plate edge (member Y). 4) Parent metal at the toe of weld connection of web stiffeners to girder flanges: edge distance d < 10 mm
[1] For additional guidance also refer Offshore Installations – Guidance on Design, Construction and Certification: Health & Safety Executive, UK.	