Classification of Column Stabilized Units

December 2016

Rule Note
NR 571 DT R00 E

Marine & Offshore Division
92571 Neuilly sur Seine Cedex – France
Tel: + 33 (0)1 55 24 70 00 – Fax: + 33 (0)1 55 24 70 25
Website: http://www.veristar.com
Email: veristarinfo@bureauveritas.com

MARINE & OFFSHORE DIVISION
GENERAL CONDITIONS

ARTICLE 1

1.1. - BUREAU VERITAS is a Society the purpose of whose Marine & Offshore Division (the "Society") is the classification (" Classification ") of any ship or vessel or offshore unit or structure of any type or part of it or system therein collectively hereinafter referred to as a "Unit" whether linked to shore, river bed or sea bed or not, whether operated or located at sea or in inland waters or partly on land, including submarines, hovercrafts, drilling rigs, offshore installations of any type and of any purpose, their related and ancillary equipment, subsea or not, such as well head and pipelines, mooring legs and mooring points or otherwise as decided by the Society.

The Society:

- "prepares and publishes Rules for classification, Guidance Notes and other documents (" Rules ");
- "issues Certificates, Attestations and Reports following its interventions (" Certificates ");
- "publishes Registers.

1.2. - The Society also participates in the application of National and International Regulations or Standards, in particular by delegation from different Governments. Those activities are hereafter collectively referred to as " Certification ".

1.3. - The Society can also provide services related to Classification and Certification such as ship and company safety management certification; ship and port security certification, training activities; all activities and duties incidental thereto such as documentation on any supporting means, software, instrumentation, measurements, tests and trials on board.

1.4. - The interventions mentioned in 1.1., 1.2. and 1.3. are referred to as " Services ". The party and/or its representative requesting the services is hereinafter referred to as the " Client ". **The Services are prepared and carried out on the assumption that the Clients are aware of the International Maritime and/or Offshore Industry (the "Industry") practices.**

1.5. - The Society is neither and may not be considered as an Underwriter, Broker in ship's sale or chartering, Expert in Unit's valuation, Consulting Engineer, Controller, Naval Architect, Manufacturer, Shipbuilder, Repair yard, Charterer or Shipowner who are not relieved of any of their expressed or implied obligations by the interventions of the Society.

ARTICLE 2

2.1. - Classification is the appraisement given by the Society for its Client, at a certain date, following surveys by its Surveyors along the lines specified in Articles 3 and 4 hereafter on the level of compliance of a Unit to its Rules or part of them. This appraisement is represented by a class entered on the Certificates and periodically transcribed in the Society's Register.

2.2. - Certification is carried out by the Society along the same lines as set out in Articles 3 and 4 hereafter and with reference to the applicable National and International Regulations or Standards.

2.3. - **It is incumbent upon the Client to maintain the condition of the Unit after surveys, to present the Unit for surveys and to inform the Society without delay of circumstances which may affect the given appraisement or cause to modify its scope.**

2.4. - The Client is to give to the Society all access and information necessary for the safe and efficient performance of the requested Services. The Client is the sole responsible for the conditions of presentation of the Unit for tests, trials and surveys and the conditions under which tests and trials are carried out.

ARTICLE 3

3.1. - **The Rules, procedures and instructions of the Society take into account at the date of their preparation the state of currently available and proven technical knowledge of the Industry. They are a collection of minimum requirements but not a standard or a code of construction neither a guide for maintenance, a safety handbook or a guide of professional practices, all of which are assumed to be known in detail and carefully followed at all times by the Client.**

Committees consisting of personalities from the Industry contribute to the development of those documents.

3.2. - **The Society only is qualified to apply its Rules and to interpret them. Any reference to them has no effect unless it involves the Society's intervention.**

3.3. - The Services of the Society are carried out by professional Surveyors according to the applicable Rules and to the Code of Ethics of the Society. Surveyors have authority to decide locally on matters related to classification and certification of the Units, unless the Rules provide otherwise.

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

ARTICLE 4

4.1. - The Society, acting by reference to its Rules:

- "reviews the construction arrangements of the Units as shown on the documents presented by the Client;
- "conducts surveys at the place of their construction;
- "classes Units and enters their class in its Register;
- "surveys periodically the Units in service to note that the requirements for the maintenance of class are met.

The Client is to inform the Society without delay of circumstances which may cause the date or the extent of the surveys to be changed.

ARTICLE 5

5.1. - **The Society acts as a provider of services. This cannot be construed as an obligation bearing on the Society to obtain a result or as a warranty.**

5.2. - **The certificates issued by the Society pursuant to 5.1. here above are a statement on the level of compliance of the Unit to its Rules or to the documents of reference for the Services provided for.**

In particular, the Society does not engage in any work relating to the design, building, production or repair checks, neither in the operation of the Units or in their trade, neither in any advisory services, and cannot be held liable on those accounts. Its certificates cannot be construed as an implied or express warranty of safety, fitness for the purpose, seaworthiness of the Unit or of its value for sale, insurance or chartering.

5.3. - **The Society does not declare the acceptance or commissioning of a Unit, nor of its construction in conformity with its design, that being the exclusive responsibility of its owner or builder.**

5.4. - The Services of the Society cannot create any obligation bearing on the Society or constitute any warranty of proper operation, beyond any representation set forth in the Rules, of any Unit, equipment or machinery, computer software of any sort or other comparable concepts that has been subject to any survey by the Society.

ARTICLE 6

6.1. - The Society accepts no responsibility for the use of information related to its Services which was not provided for the purpose by the Society or with its assistance.

6.2. - **If the Services of the Society or their omission cause to the Client a damage which is proved to be the direct and reasonably foreseeable consequence of an error or omission of the Society, its liability towards the Client is limited to ten times the amount of fee paid for the Service having caused the damage, provided however that this limit shall be subject to a minimum of eight thousand (8,000) Euro, and to a maximum which is the greater of eight hundred thousand (800,000) Euro and one and a half times the above mentioned fee. These limits apply regardless of fault including breach of contract, breach of warranty, tort, strict liability, breach of statute, etc.**

The Society bears no liability for indirect or consequential loss whether arising naturally or not as a consequence of the Services or their omission such as loss of revenue, loss of profit, loss of production, loss relative to other contracts and indemnities for termination of other agreements.

6.3. - All claims are to be presented to the Society in writing within three months of the date when the Services were supplied or (if later) the date when the events which are relied on of were first known to the Client, and any claim which is not so presented shall be deemed waived and absolutely barred. Time is to be interrupted thereafter with the same periodicity.

ARTICLE 7

7.1. - Requests for Services are to be in writing.

7.2. - **Either the Client or the Society can terminate as of right the requested Services after giving the other party thirty days' written notice, for convenience, and without prejudice to the provisions in Article 8 hereunder.**

7.3. - The class granted to the concerned Units and the previously issued certificates remain valid until the date of effect of the notice issued according to 7.2. here above subject to compliance with 2.3. here above and Article 8 hereunder.

7.4. - The contract for classification and/or certification of a Unit cannot be transferred neither assigned.

ARTICLE 8

8.1. - The Services of the Society, whether completed or not, involve, for the part carried out, the payment of fee upon receipt of the invoice and the reimbursement of the expenses incurred.

8.2. - **Overdue amounts are increased as of right by interest in accordance with the applicable legislation.**

8.3. - **The class of a Unit may be suspended in the event of non-payment of fee after a first unfruitful notification to pay.**

ARTICLE 9

9.1. - The documents and data provided to or prepared by the Society for its Services, and the information available to the Society, are treated as confidential. However:

- "Clients have access to the data they have provided to the Society and, during the period of classification of the Unit for them, to the **classification file** consisting of survey reports and certificates which have been prepared at any time by the Society for the classification of the Unit ;
- "copy of the documents made available for the classification of the Unit and of available survey reports can be handed over to another Classification Society, where appropriate, in case of the Unit's transfer of class;
- "the data relative to the evolution of the Register, to the class suspension and to the survey status of the Units, as well as general technical information related to hull and equipment damages, may be passed on to IACS (International Association of Classification Societies) according to the association working rules;
- "the certificates, documents and information relative to the Units classed with the Society may be reviewed during certificating bodies audits and are disclosed upon order of the concerned governmental or inter-governmental authorities or of a Court having jurisdiction.

The documents and data are subject to a file management plan.

ARTICLE 10

10.1. - Any delay or shortcoming in the performance of its Services by the Society arising from an event not reasonably foreseeable by or beyond the control of the Society shall be deemed not to be a breach of contract.

ARTICLE 11

11.1. - In case of diverging opinions during surveys between the Client and the Society's surveyor, the Society may designate another of its surveyors at the request of the Client.

11.2. - Disagreements of a technical nature between the Client and the Society can be submitted by the Society to the advice of its Marine Advisory Committee.

ARTICLE 12

12.1. - Disputes over the Services carried out by delegation of Governments are assessed within the framework of the applicable agreements with the States, international Conventions and national rules.

12.2. - Disputes arising out of the payment of the Society's invoices by the Client are submitted to the Court of Nanterre, France, or to another Court as deemed fit by the Society.

12.3. - **Other disputes over the present General Conditions or over the Services of the Society are exclusively submitted to arbitration, by three arbitrators, in London according to the Arbitration Act 1996 or any statutory modification or re-enactment thereof. The contract between the Society and the Client shall be governed by English law.**

ARTICLE 13

13.1. - **These General Conditions constitute the sole contractual obligations binding together the Society and the Client, to the exclusion of all other representation, statements, terms, conditions whether express or implied. They may be varied in writing by mutual agreement. They are not varied by any purchase order or other document of the Client serving similar purpose.**

13.2. - The invalidity of one or more stipulations of the present General Conditions does not affect the validity of the remaining provisions.

13.3. - The definitions herein take precedence over any definitions serving the same purpose which may appear in other documents issued by the Society.

RULE NOTE NR 571

NR 571
Classification of Column Stabilized Units

December 2016

Section 1 General

Section 2 Structure Design Requirements

Section 3 Design Conditions and Load Cases

Section 4 Hull scantling

Section 5 Machinery and Systems

Appendix 1 Hydrodynamic Analysis

SECTION 1 GENERAL

1 General

1.1 Application

1.1.1 The present Note provides requirements for the classification of column-stabilized units intended for various offshore services.

Note 1: Column-stabilized units are sometimes referred to as semi-submersible units (see [4.1.2]).

1.1.2 The present Note is applicable to both mobile offshore units and permanent offshore installations as defined in the Offshore rules Part A.

Note 1: A permanent installation is an installation performing its service for a duration not less than 5 years on a single site.

1.1.3 The present Note addresses the following design concepts:

- twin pontoon/tandem design
- ring pontoon design.

1.1.4 The requirements of the present Note apply to units intended to be granted the structural type notation **column-stabilized unit** specified in [1.3].

1.2 Scope

1.2.1 The present Note addresses the specificities of column stabilized units having regard to the general arrangement, the structural design and the machinery systems.

1.2.2 Any other aspect of the unit is covered by the applicable rules defined in [2.4].

1.3 Class notations

1.3.1 Structural type notation

The present Note applies to floating units intended to be granted the structural type notation **column-stabilized unit**, as defined in Pt A, Ch 1, Sec 2 of the Offshore Rules.

1.3.2 Service notations

Units covered by the present Note may be granted relevant service notation(s) defined in Pt A, Ch 1, Sec 2 of the Offshore Rules. Usual service notations for column-stabilized units are given in Tab 1 for information.

At least one service notation is to be assigned to the classed unit.

1.3.3 Additional service features

The following additional service features are mandatory for column-stabilized units:

- For permanent units:

  POSA or **POSA-HR**
- For mobile units granted with the service notation **drilling** and fitted with a passive mooring system:

  POSA-MU

Other additional service features may be assigned, depending on the service type(s) and the nature of the installations on the unit, as defined in Pt A, Ch 1, Sec 2 of the Offshore Rules.

1.3.4 Site, transit and navigation notations

Site and transit notations are to be granted in accordance with the provisions of Pt A, Ch 1, Sec 2 of the Offshore Rules.

Navigation notations are not relevant for classification of column stabilized units.

For towing/transit phase, column stabilized units are to be granted with the notation **transit-specific criteria**. Criteria for the assessment in towing/transit phase are based on data and assumptions specified by the party applying for classification, and stated in the Design Criteria Statement.

1.3.5 Additional class notations

The following additional class notation is mandatory for permanent column-stabilized units:

- **INWATERSURVEY**

Other additional class notations may be assigned depending on the service type(s) and the nature of the installations on the unit as defined in Pt A, Ch 1, Sec 2 of the Offshore Rules.

Table 1 : Usual service notations for column stabilized units

Service notation	Description
production	For units intended to oil production and fitted with production plant
gas production	For units intended to gas production and fitted with gas production plant
oil storage	For units intended to store hydrocarbons (oil) within its hull
drilling	For units intended to drilling activities and fitted with drilling equipment
accommodation	For units intended to accommodate offshore personnel
lifting	For units intended to perform lifting operations at sea
pipe laying	For units intended to perform pipe laying operations at sea

2 Classification principles

2.1 General provisions

2.1.1 Unless otherwise stated, the general provisions of Part A of the Rules for Classification of Offshore units are applicable.

2.2 Scope of classification

2.2.1 The scope of classification is based on an appraisal of the integrated unit covering in general:

a) Hull including:
   - pontoons
   - columns
   - deck structure

b) Hull attachments and appurtenances including:
   - mooring supporting structure
   - foundations for the support of topsides equipment and the hull mounted equipment
   - support structure for life saving appliances
   - passive fire protection
   - cathodic protection
   - Moonpool arrangement, when relevant

c) Intact and damage stability

d) Accommodation quarters

e) Equipment and systems installed in the hull, the failure of which may jeopardise the safety of the floating unit

f) Fire and gas detection system for the hull as well as the definition of the hazardous areas of the hull

g) Fire fighting systems for the protection of the hull.

h) Mooring system, mandatory for permanent units (additional service features **POSA** or **POSA-HR**) and mandatory for mobile drilling units having a passive mooring system (**POSA-MU**)

i) Inerting gas system, when relevant (additional service feature **INERTGAS**)

j) Drilling equipment and installations (in case of additional class notation **DRILL**)

k) Process plant and components (in case of additional class notation **PROC**)

l) Helideck (in case of additional class notation **HEL**)

m) Dynamic positioning system (in case of additional class notation **DYNAPOS**)

n) Rigid or flexible risers, as relevant (in case of additional class notation **RIPRO**)

o) Lifting appliances (in case of the additional class notation **ALM**)

p) High integrity pressure protecting systems (in case of additional class notation **HIPS**)

q) Equipment and systems necessary for the safe operation of the hull and to the safety of personnel on board as defined in the Offshore rules and related applicable Rules (taking into account the additional service features **AUTO**, and the additional class notation **LSA**).

2.3 Classification limits

2.3.1 Hull attachments and appurtenances

As a rule, all connection details for foundation, all supports or stools welded to the hull, for the portion interacting with the hull, are within the scope of the classification, independently of the additional class notations. See also Offshore rules Pt B, Ch 3, Sec 1.

2.3.2 Detailed boundaries for classification

For each project, the detailed scope and limits of the classification are defined by the Society on case-by-case basis and with reference to the requested service notation(s), additional service features and additional class notations.

2.4 Applicable rules

2.4.1 The rules applicable for the classification of column stabilized units are summarized in Tab 2.

Table 2 : Applicable requirements

Item	Applicable requirements
General arrangement	Sec 2 and Offshore Rules, Part B
Stability and subdivision	Offshore Rules, Part B, chapter 1
Structural assessment	Sec 2 to Sec 4 and Offshore Rules, Part B
Machinery and systems	Sec 5 and Offshore Rules, Part C
Electrical installations and automation	Sec 5 and Offshore Rules, Part C
Safety features	Offshore Rules, Part C
Materials and welding	NR216
Construction survey	NR426
In-service surveys	Offshore Rules, Part A

Note 1: Offshore Rules means NR445 Rules for the Classification of Offshore Units

NR216: Rules on Materials and Welding for the Classification of Marine Units

NR426: Construction Survey of steel structures of Offshore Units and Installations

2.5 Design Criteria Statement

2.5.1 Classification is based upon the design data or assumptions specified by the party applying for classification. A Design Criteria Statement is to list the services performed by the unit and the design conditions and other assumptions on the basis of which class is assigned to the unit.

2.5.2 The Design Criteria Statement is issued by the Society, based on the information provided by the party applying for classification and is referred to on the Classification Certificate.

2.5.3 The Design Criteria Statement is to be incorporated in the Operating Manual, as stated in Pt A, Ch 1, Sec 1 of the Offshore Rules.

2.5.4 Additional details about the Design Criteria Statement are given in Pt A, Ch 1, Sec 1 of the Offshore Rules.

3 Statutory requirements

3.1 Project specification

3.1.1 Prior to commencement of the review of drawings, the complete list of Rules, Codes and Statutory Requirements to be complied with must be submitted for information. This list is to detail the requirements to be complied with:

- International Conventions
- Flag state requirements
- Coastal state requirements
- Owner standards and procedures
- Industry standards.

The project specification is also to specify the list of Owner requested statutory certificates.

3.2 Conflict of Rules

3.2.1 In case of conflict between the Classification Rules and any Statutory Requirements as given by Flag state or Coastal State, the latter ones are to take precedence over the requirements of the present Rules.

4 References

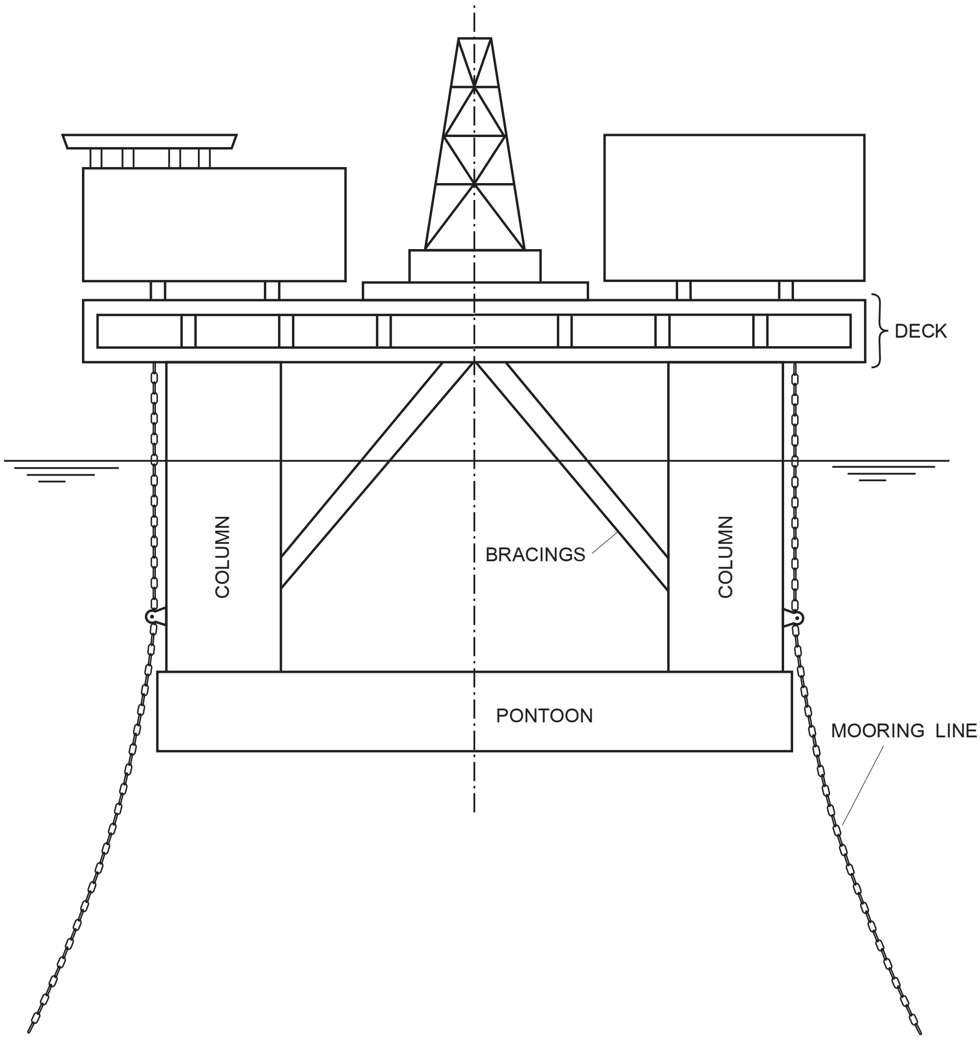
4.1 Definitions

4.1.1 Column stabilized units

Column stabilized units are units with the main deck connected to underwater hull or footings by columns or caissons. Bracings may be provided between the lower hull or footings, the columns and the deck structure. See example Fig 1.

In many contexts, column stabilized units are synonym to semi-submersible units (see [4.1.2]).

Figure 1 : Example of a Column stabilized unit



4.1.2 Semi-submersible units

Semi-submersible units are column stabilized units for which the deck structure is above the water level and the columns are partially underwater.

A semi-submersible unit is intended for use in the floating mode, unit's stability in working and storm condition being afforded by the column water plane area.

4.1.3 Twin pontoon design

Twin pontoon designs have normally two lower hulls, each supporting several vertical columns. The columns are supporting the upper deck. The number of columns is generally from 4 to 8.

The structure may be reinforced using diagonal bracings and horizontal bracings.

4.1.4 Ring pontoon design

Ring pontoon designs have generally one continuous lower hull supporting several vertical columns. The lower hull is composed by pontoons and nodes. The columns are supporting the upper deck. The number of columns is generally from 4 to 8.

4.2 Referenced documents

4.2.1 Offshore Rules

Offshore Rules means Bureau Veritas Rules for the Classification of Offshore Units (NR445). When reference is made to the Offshore Rules, the latest version of these ones is applicable.

4.2.2 Ship Rules

Ship Rules means Bureau Veritas Rules for the Classification of Steel Ships (NR467). When reference is made to the Ship Rules, the latest version of these ones is applicable.

4.2.3 NR216

When reference is made to NR216, the latest version of the Rules on Materials and Welding for the Classification of Marine Units is applicable.

4.2.4 NR426

When reference is made to NR426, the latest version of the Construction Survey of steel structures of Offshore Units and Installations is applicable.

4.2.5 NR493

When reference is made to NR493, the latest version of the Rules for Classification of mooring systems for permanent and mobile offshore units is applicable.

4.2.6 API 2A WSD

API 2A WSD means the standard published by American Petroleum Institute "Recommended Practice for Planning, Designing, and Constructing Fixed Offshore Platforms - Working Stress Design" - latest edition.

4.2.7 IMO MODU Code

IMO MODU Code means the Code for the Construction and Equipment of Mobile Offshore Drilling Units, published by the International Maritime Organization.

5 Documents to be submitted

5.1 General

5.1.1 The documents to be submitted include the following information, in addition to the documentation required in Pt A, Ch 1, Sec 4 of the Offshore Rules.

5.2 Design calculations

5.2.1 Assessment of air gap / deck clearance

An assessment of the air gap as specified in Sec 2, [2.2] is to be submitted.

SECTION 2 STRUCTURE DESIGN REQUIREMENTS

1 General

1.1 Scope

1.1.1 The present Section provides general requirements relating to the design and construction of column stabilized units covered by the present Note.

1.1.2 Units covered by the present Note are to comply with the relevant requirements of Part B of the Offshore Rules, applicable for column stabilized units, except when otherwise specified in the present Note.

1.1.3 Relevant requirements of IMO MODU Code Ch 2, applicable for column stabilized units, are adopted through the present Note and are to be considered as minimum requirements for classification purpose.

2 Hull design

2.1 Design principles

2.1.1 Units covered by the present Note are designed to sustain all loads liable to occur during transit conditions and during operating conditions. For the purpose of classification, design loading condition for which checks are required are given in Sec 3.

2.2 Deck clearance/air gap

2.2.1 General

The following air gaps are to be maintained between the underside of the topside deck and the wave crest:

- a positive air gap for the extreme design loading conditions defined in Sec 3, and
- 1,5 m for all others design loading conditions.

2.2.2 Method

Deck clearances are normally determined by appropriate model tests. Detailed hydrodynamic analysis are also accepted, provided that the following items are taken into account:

- relative motions between the unit and waves
- generally, nonlinearities of wave profile
- maximum and minimum draughts
- various environmental headings.

Note 1: Guidance is given in App 1

Deck clearances are to be checked at various points on the underside of the topside deck.

2.3 Columns and pontoons

2.3.1 Columns and pontoons may be designed as either framed or unframed shells. In either cases, framing, ring stiffeners, bulkheads or diaphragms are to be sufficient to maintain shape and stiffness under all the anticipated loadings.

Portlights or windows, including those of non-opening type, or other similar openings, are not to be fitted in columns.

2.3.2 Scantlings of columns and pontoons designed with stiffened platings are to be not less than those corresponding to watertight bulkheads, taking into account an immersion not less than maximum damaged waterline. For all areas subject to wave immersion, a minimum head of 6 m is to be considered.

2.3.3 Internal structure of columns in way of bracings is to be capable to sustain the axial strength of the bracing.

2.3.4 Special attention is to be given to structural design of columns in way of intersections with deck structures, in order to ensure smooth load redistribution.

2.4 Overall strength

2.4.1 Pontoons, columns, bracings and primary deck members are to be designed for all load cases defined in Sec 3.

When assessing overall environmental loads due to waves, due attention is to be given to the sensitivity of the structural response to direction and period of waves.

Besides, when, in the opinion of the Society, the overall arrangement of bracings does not provide for load redistribution in case of unexpected structural failure, the consideration of specific damaged situation may be required.

2.4.2 Due consideration is to be given to the fatigue strength of primary structural members, in particular in way of connections between pontoons, columns and bracings.

2.5 Local strength

2.5.1 Pontoons and columns are to be designed taking into account pressure loadings and other relevant local loads in all applicable design loading conditions defined in Sec 3.

Particular attention is to be paid to the structural details in areas subject to high local loadings resulting from, for example, wave slam, partially filled tanks or possible external damages.

2.5.2 The upper structure is to be designed taking into account the loadings indicated in the deck loading plan.

2.5.3 Bracings are normally to be watertight and are to be suitably designed to resist local forces: external hydrostatic pressure, wave and current loads. Particular consideration is to be given to the wave impact loads sustained during wet transit.

Where fitted for operational or structural protection purposes equipment penetration, housing and attachment are to be adequately designed and the bracing, if necessary, reinforced to restore the required strength particularly with respect to fatigue loading.

When bracing members are of tubular section, ring frames may be required to maintain stiffness and roundness of shape.

Adequate access for inspection of the bracings is to be provided. Local or remote leak detection devices are to be fitted to the satisfaction of the Society.

2.5.4 Local structures in way of fairleads, winches, etc., forming part of the mooring system are to be designed to the breaking strength of the mooring line.

2.6 Structural redundancy

2.6.1 The structure of the unit is to be able to withstand the loss of any bracing member without overall collapse.

2.6.2 The structural arrangement of the upper hull is to be considered with regard to the structural integrity of the unit after the failure of any primary girder.

2.7 Local reinforcements

2.7.1 Special attention is to be given to the structural design of mooring supporting structures, in order to ensure smooth redistribution of mooring concentrated loads through the hull without causing unacceptable stress concentrations.

2.7.2 Adequate reinforcements are to be provided in way of the structural foundations of items such as:

- machineries
- fairleads, winches and other towing, mooring and anchoring equipment
- equipment corresponding to the particular service of the unit, such as the drilling equipment, crane foundations, and other concentrated loads.

Sufficient strength and stiffness are to be provided in these areas, in order to withstand the loads induced in all the conditions of operation, and avoid vibration that could lead to damage of the structure.

2.8 Structural categorization

2.8.1 Definition of categories

Structural elements in welded steel are classed into three categories: second, first and special categories as listed:

- Second category: Second category elements are structural elements of minor importance, the failure of which might induce only localised effects
- First category: First category elements are main load carrying elements essential to the overall structural integrity of the unit
- Special category: Special category elements are parts of first category elements located in way or at the vicinity of critical load transmission areas and of stress concentration locations.

2.8.2 Structural categorization

Structural categories, as defined in [2.8.1], are to be indicated on drawings submitted to the Society for approval.

The Society may, when deemed necessary, upgrade any structural element to account for particular considerations such as novel design features or restrictions regarding access for quality control and in-service inspections.

2.8.3 Guidance for structural categorization

Structural categories specified in Tab 1 for various elements are given as guidance for the application of [2.8.2].

3 Materials for construction

3.1 Design temperature

3.1.1 Design temperature of structural elements is to be taken as follows:

- for the emerged part of the structure (in general, splash zone and above), the design temperature is the air temperature defined in [3.1.3]
- for the immersed part of the structure, the design temperature is the water temperature defined in [3.1.4].

3.1.2 The Society may accept values of design temperature obtained through direct calculation, provided that:

- the calculations are based on air temperature and water temperature as defined in [3.1.3] and [3.1.4]
- the calculations provide a design temperature corresponding to the worst condition of the unit during transit and operations
- a complete calculation report, including a documentation of methods and software, is submitted to the Society.

3.1.3 Air temperature requested by [3.1.1] is to be taken as the mean air temperature of the coldest day (24 h) of the year for any anticipated area of operation.

Where no particular value is specified, classification is to be based upon the following air temperature:

- 0°C for units not intended to operate in cold areas
- −10°C for units intended to operate in cold areas.

3.1.4 Water temperature requested by [3.1.1] is to be taken as the water temperature of the coldest day (24 h) of the year for any anticipated area of operation.

Where no particular value is specified, classification is to be based upon 0°C water temperature.

Table 1 : Guidance for structural categorization

Category	Structural element
Special	• Hull shell in way of intersections between columns, topside deck, pontoons; the extension is to be taken at least 1 m in all directions from the intersection • Bracing connections • Bracing in the vicinity of connections to upper hull, columns, lower pontoon and major bracing intersections • Highly stressed supports of cranes pedestals and flare booms • Derrick supporting structure, when relevant • In general, supports and stools of equipment designed without soft-toe brackets
First	• Hull shell of columns, decks and pontoons other than special category • Deck, bottom, side and bulkhead platings belonging to main structure of the upper hull • Structural elements providing reinforcement and structural continuity at intersections, other than special category • Diagonal and horizontal bracings other than special category • In general, supports of equipment designed with soft toe brackets • Helideck supporting structure • Main supporting structure of heavy substructures and equipment
Secondary	• Other structures than special and first • Substructure of laydown areas • Outfitting features • Stair towers and their substructure • Rest support structures for handling equipment • Reinforcing stiffeners, girders or bulkheads sustaining a low or moderate level of stress and easily available for inspection

3.2 Material requirements

3.2.1 Steels and products used for the construction of structural elements of column stabilized units are to meet the applicable requirements of NR216 Materials and Welding.

Steels and products manufactured to other specifications may be accepted in specific cases provided that such specifications gives reasonable equivalence to the requirements referenced above.

3.2.2 Structural elements are to comply with the requirements relating to materials for construction given in Pt B, Ch 3, Sec 2 of the Offshore Rules, taking into consideration the structural categories defined in [2.8].

3.3 Steels with specified through thickness properties

3.3.1 Steel with specified through thickness properties are to comply with Offshore Rules Pt B, Ch 3, Sec 2.

4 Inspections and checks

4.1 General

4.1.1 Materials, workmanship, structures and welded connections are to be subjected, at the beginning of the work, during construction and after completion, to inspections by the Shipyard suitable to check compliance with the applicable requirements, approved plans and standards.

4.1.2 The manufacturer is to make available to the attending Surveyor a list of the manual welders and welding operators and their respective qualifications.

4.1.3 The manufacturer's internal organisation is responsible for ensuring that welders and operators are not employed under improper conditions or beyond the limits of their respective qualifications and that welding procedures are adopted within the approved limits and under the appropriate operating conditions.

4.1.4 The manufacturer is responsible for ensuring that the operating conditions, welding procedures and work schedule are in accordance with the applicable requirements, approved plans and recognized good welding practice.

4.2 Inspection requirements

4.2.1 Requirements of Section 6 of NR426 "Construction Survey of Steel Structures of Offshore Units and Installations" are to be complied with.

4.2.2 The Society reserves the right to increase the number of non destructive examinations due to complexity of the structure and with particular attention to the intended service.

5 Net scantling approach

5.1 Principle

5.1.1 Except when otherwise specified, the scantlings obtained by applying the criteria specified in this Note are net scantlings.

5.1.2 Net thickness of plating is to be obtained by deducting the rule corrosion addition from the gross thickness indicated by the Designer. The requirement of [5.1.3] is to be considered.

5.1.3 For all finite element models, the net thickness of plating is to be obtained by deducting half of the rule corrosion addition from the gross thickness indicated by the Designer.

5.2 Corrosion addition

5.2.1 The values of rule corrosion additions are given in Tab 2. If the party applying for classification specifies values of corrosion additions greater than those defined in Tab 2, these values are to be taken into account for calculations and stated in the Design Criteria Statement.

Table 2 : Rule corrosion additions, in mm, for each exposed side

Compartment type	Rule corrosion addition (mm)
Outside sea and air	0,50
Ballast	1,00
Hydrocarbon products and fuel oil	0,75
Drilling mud, drilling brines	1,25
Dry holds	0,50
Void spaces	0,50
Other compartments	0,50

5.2.2 In general, the corrosion addition to be considered for plating forming the boundary between two compartments of different types is equal to:

- for plating with a gross thickness greater than 10 mm, the sum of the values specified for one side exposure to each compartment
- for plating with a gross thickness less than or equal to 10 mm, the smallest of the following values:
  - 20% of the gross thickness of the plating
  - sum of the values specified for one side exposure to each compartment.

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

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

6 Corrosion protection

6.1 General reference

6.1.1 The requirements of Pt B, Ch 3, Sec 5 of the Offshore Rules, relating to corrosion protection methods and design of corrosion protection systems, are to be complied with. These requirements refer to NR423 Corrosion Protection of Steel Offshore Units and Installations.

6.2 Thickness increments and additional class notation STI

6.2.1 A thickness increment of platings and, where relevant, of stiffeners may be added to the gross thickness in special areas subject to mechanical wastage due to abrasion or in areas of difficult maintenance.

$t_{net} = t_{gross} - t_c$

$t_{gross} = t_{as\text{-}built} - t_i$

where:

t_{net} : Net thickness

t_{gross} : Gross thickness

t_c : Corrosion addition as defined in [5.2]

t_i : Thickness increment.

The gross thickness plus the thickness increment is equal to the as-built thickness ($t_{as\text{-}built}$).

6.2.2 For the checking criteria specified in the present Note the thickness increments are not to be considered.

6.2.3 Notation STI requested

For a unit having the additional class notation **STI**, the thickness increments may be defined by the Owner or by the Society, as follows:

a) When the Owner specifies its own thickness increments, it is to be notified to the Society where thickness increments are provided. Thickness increments are to be stated in the Design Criteria Statement.

b) When the Owner does not provide its own thickness increments, the values to be generally considered are defined as follows:

- 1 mm for all decks
- 1 mm for the outer shell, except the splash zone
- 5 mm for shell located in the splash zone
- 1 mm for elements other than mentioned above.

Adequate indications (location, value of thickness increments) are to be given in the relevant structural drawings.

6.2.4 Notation STI not requested

When the additional class notation **STI** is not assigned to the unit, the thickness increments are to be taken equal to zero.

7 Welding and weld connections

7.1 General

7.1.1 The requirements specified in NR426 Construction Survey of Steel Structure of Offshore Units and Installations are to be applied for welding of structural elements.

7.1.2 For size of fillet welds, reference may be made to AWS D1.1 Structural Welding Code - Steel - the latest edition, which is a recognized standard for classification purpose.

SECTION 3 DESIGN CONDITIONS AND LOAD CASES

1 General

1.1 Application

1.1.1 The present Section provides requirements for design loads applied for structural assessment of column stabilized units.

1.2 General procedure

1.2.1 The set-up of loads for the assessment of column stabilized unit's structure follows generally the steps given in Tab 1.

Table 1 : General procedure for set-up of loads

Step	Description
1	Definition of loading conditions, taking into account the requirements stated in [2].
2	Performance of hydrodynamic analysis under environmental conditions by direct calculation and/or model tests. This analysis is to cover all loading conditions, in accordance with the requirements of [2].
3	Definition and selection of load cases based on the requirements given in [3]. Several load cases are defined for each loading condition.
4	Calculation of design loads and their combination for each load case. The requirements of [4] are to be complied with.

1.3 Loading manual

1.3.1 A loading manual of the unit is to be submitted for the approval of the Society.

Loading manual is a document which describes:

- all loading conditions on which the design of the unit has been based
- all permissible limits and operational limits applied for the design
- all allowable local loadings for the hull and decks.

1.4 Hydrodynamic analysis

1.4.1 Direct hydrodynamic analysis is mandatory for the classification of column stabilized units.

Guidance to perform hydrodynamic analysis is given in App 1.

1.4.2 Hydrodynamic analysis may be calibrated based on model tests. In such a case, testing procedures and method used for the extrapolation of model tests to full scale data are to be to the satisfaction of the Society. Preferably, the procedure should be reviewed and agreed before the tests are performed.

Attendance of a Surveyor to model tests will be decided at the convenience of the Society.

2 Loading conditions

2.1 General

2.1.1 Loading conditions on the basis of which the structural checks are performed cover all stages of unit's life entering under the scope of the classification. Various severities of environmental loads are also considered.

The categories of loading conditions mentioned in the present Note are given in [2.2].

2.2 Categories

2.2.1 Transit conditions

For permanent column stabilized units, transit conditions include the wet transit of the floater from the shipyard to the intended operating site or for field transit, which is by default within the scope of classification.

For mobile column stabilized units, transit conditions include the wet transit between the harbour or port and the intended operating site. The environmental conditions for transit are to include the worst routes for which the unit is designed.

Dry transit, when relevant, is to be documented. Relevant procedures and calculation reports, including the definition of loads and the assessment of hull parts are to be submitted to the Society for information.

In particular for permanent units, the attendance of a Surveyor during transit conditions not covered by the present Note will be decided at the convenience of the Society, in order to ensure that the hull and systems are in good condition after installation or transportation stages, without significant damage.

2.2.2 Normal operational conditions

The structures of the column stabilized unit and systems are checked against normal operational conditions covering normal operations of the unit on the intended operating site. Limiting operational parameters (maximum wave height and period, maximum roll and pitch, maximum offset, etc.) may be specified for services such as drilling, by the party applying for classification.

The acceptability of deflections and vibrations are to be considered under normal operating conditions.

2.2.3 Extreme conditions

The structures of the column stabilized unit and systems are checked against extreme conditions in order to determine their serviceability strength. The structure will be designed to survive extreme conditions without significant probability of compromising its serviceability.

2.3 Design environments

2.3.1 General

Design environments are associated to design loading conditions defined in [2.5].

Design environments are generally defined in terms of wind and waves. Information relating to currents may be requested on a case-by-case basis.

In the present Note, design environments are characterized by return periods.

2.3.2 Normal environments

Normal environments are expected to occur frequently during unit's life and are used for the checks in normal operating conditions.

When no limiting parameters are specified by the Designer for various operations of the column stabilized unit, the normal environments are to be associated with a typical return period of 1 year.

2.3.3 Extreme environments

Extreme environments have a low probability of being exceeded during the life of the unit. The structure is designed to withstand extreme environments in a safe operable condition.

For the purpose of the present Note, extreme environments are associated with:

- a minimum return period of 100 years for permanent units
- a minimum period of 50 years for mobile column stabilized units.

Higher return periods may be considered when requested by the party applying for classification.

2.4 System condition

2.4.1 General

Design loading conditions defined in [2.5] take into consideration the following conditions of the hull:

- intact hull
- hull damage, as defined in [2.4.2]
- bracing damage as defined in [2.4.3].

2.4.2 Hull damage - flooding

As a minimum, hull damage is to include the damage scenarios defined in the offshore rules Pt B, Ch 1, Sec 3 for damage stability calculations. The followings will be taken into account:

- any single compartment adjacent to the sea
- any two adjacent compartments at the waterline
- any horizontal flats located in the zone of damage extent
- any compartment containing ballast pumps or machinery cooled by seawater.

Special consideration will be given to the size of the supply vessels and other collision scenarios, before establishing the extent of hull damage.

2.4.3 Bracing damage

For structural redundancy purpose, structural assessment includes checks comprising the fracture of one bracing or one joint between bracings, as well as the fracture of any primary truss element of the deck.

Fracture of bracings or bracing joint are requested only for twin pontoons designs. Fractured bracings and joints are to be considered one by one, in order to cover all relevant scenarios.

2.5 Design loading conditions

2.5.1 Design loading conditions specified in [2.5.3] are to be considered for the assessment of the hull.

When some of loading conditions shown in [2.5.3] are not included in the loading manual, it must be indicated on drawings and in the loading manual that these loading conditions are not allowed. In addition, it should be demonstrated that these conditions will never happen during the life of the unit.

When loading conditions shown in [2.5.3] are foreseen in the loading manual, the analysis is to be carried out taking into account the associated draught as indicated in the loading manual.

2.5.2 In addition to [2.5.3] the Society may require to consider other conditions from the loading manual as design loading condition for structural check, when considered that these conditions are expected to be critical for structural elements of the hull. The selection will be done on a case-by-case basis, taking into account design and operational specificities of the unit.

2.5.3 Design loading conditions to be considered as a minimum are given in Tab 2.

2.6 Accidental conditions

2.6.1 General

In addition to the design loading conditions defined in [2.5], the column stabilized unit is to be assessed through relevant accidental situations, on the basis of the requirements given in Pt B, Ch 2, Sec 1 of the Offshore Rules.

Accidental scenarios are defined on a case-by-case basis, taking into account the specificities of unit's design, transit conditions and operations.

Table 2 : Design loading conditions for column stabilized units

Category **(1)**	System condition **(1)**	Environment to be considered **(1)**	Basic allowable stress factor α **(3)**
Transit	Intact	10 years return period or specified limiting parameters **(2)**	0,8
	Hull damage	10 years return period or specified limiting parameters **(2)**	1,0
	Bracing damage (only for twin pontoon designs)	1 year return period	1,0
	Primary deck truss damage	1 year return period	1,0
Normal operational condition	Intact	1 year return period or specified limiting parameters **(2)**	0,6
Extreme conditions	Intact	100 years return period for permanent units 50 years for mobile column stabilized units	0,8
	Hull damage	1 years return period	0,8
	Bracing damage (only for twin pontoon designs)	1 year return period	1,0
	Primary deck truss damage	1 year return period	1,0
Testing conditions	Intact		0,9

(1) Further information is given in [2.2] to [2.4].

(2) When limiting environmental parameters are specified by the party applying for classification for the related loading condition, they are to be used for structural checks instead of the return periods specified in the table. Such limiting environmental parameters will be stated in the Design Criteria Statement.

(3) The basic allowable stress factor is defined in Pt B, Ch 3, Sec 3 of the Offshore Rules. This factor is given in this table as an indication of safety level for each design loading condition.

2.6.2 Accidental situations

The following accidental situations are generally considered for the assessment of hull and deck:

- collisions with supply vessels or other relevant collision scenarios
- dropped objects taking into account all equipment susceptible to drop on the hull or decks during transit and operations
- relevant fire scenarios
- relevant explosion scenarios.

Guidelines for the analysis of accidental scenarios and applicable criteria are provided in Pt B, Ch 3, Sec 9 of the Offshore Rules.

The Society may require appropriate risk analysis to be submitted, in order to determine applicable loads and the probabilities of occurrence of various events considered through above accidental scenarios.

3 Load cases

3.1 General

3.1.1 Load cases consist in a combination of design loads and load parameters applicable for a specified loading condition.

As a rule, load cases are defined in order to maximize or minimize a loading effect relevant for the hull of column stabilized units.

3.1.2 For each design loading condition defined in [2.5], load cases are to be defined based on the requirements of the present Article [3].

3.1.3 Load cases for transit conditions are to be defined in the same way as for site conditions, based on the provisions of [3.3].

3.1.4 Load cases checked for classification purpose will be selected on a case-by-case basis, taking into account the specificities of unit's design and operations. The selection of load cases is subjected to the approval of the Society.

3.2 Wave response analysis

3.2.1 Individual load cases are to be defined for the maximization of each relevant loading effect of the hull.

Loading effects which are to be considered as a minimum for classification are given in [3.3].

3.2.2 The maximization of various loading effects for the hull, taking into account the simultaneity of the responses, is realized through a wave response analysis.

3.3 Load cases for hull assessment

3.3.1 Hull assessment is performed on a limited number of load cases. Envelope load cases, maximizing load effects for various hull parts will be selected based on the results of hydrodynamic analysis.

The selection of load cases for hull assessment is subjected to the approval of the Society.

3.3.2 As a minimum, load cases for hull assessment are to be defined for the maximization of the following loading effects:

- squeeze-pry effect between unit's columns
- split force between pontoons, for twin pontoons design
- torsional moments about horizontal axes
- longitudinal shear forces between the pontoons
- longitudinal acceleration of deck mass
- transverse acceleration of deck mass
- vertical acceleration of deck mass
- vertical wave bending moments of the pontoons
- column shear force (from relative displacement of deck and pontoons)
- column bending moment (from relative displacement of deck and pontoons).

3.3.3 Squeeze-pry effect

Squeeze and pry load effects are typical for column stabilized hulls under wave loads.

Squeeze effect occur when lateral loads on columns due to waves are maximum inward toward the center of the unit, "squeezing" the columns toward each other. Prying is the opposite effect, when the lateral load is outward away from the platform center.

Squeeze and pry load effects may be determinant for the connection between columns and pontoons and for the interconnection between the hull and decks.

4 Design loads

4.1 General

4.1.1 Design loads are defined in Pt B, Ch 2 of the Offshore Rules.

4.1.2 The following categories of loads are to be considered, with reference to Pt B, Ch 2 of the Offshore Rules:

- fixed loads
- operational loads
- environmental loads
- accidental loads
- testing loads
- temporary construction loads.

4.1.3 Appropriate factors are to be applied for preliminary design stages, in order to take into account the uncertainties in estimation of fixed loads and operational loads and their locations.

4.2 Fixed loads

4.2.1 Fixed load or lightweight is the weight of the complete unit with all permanently attached machineries, equipment and other items of outfit.

The lightweight of the unit includes the weights, to their normal working level, of all permanent ballast and other liquids such as lubricating oil and water in the boilers, but excludes the weight of liquids or other fluids contained in supply, reserve or storage tanks.

4.2.2 Fixed loads are to comply with the applicable requirements of Pt B, Ch 2, Sec 3 of the Offshore Rules.

4.3 Operational loads

4.3.1 Operational loads are loads associated with the operation of the unit and include:

- the weights of all moving equipment and machinery
- the weight of drill string and related pieces of equipment, when relevant
- variable loads of consumable supplies weights
- storage of cuttings from drilling, when relevant
- seawage, dirty oil and water tanks
- other storage loads
- hydrostatic loads (buoyancy)
- liquids in tanks
- ballast loads
- riser tensioner forces, when relevant
- loads resulting from lifting appliances in operation
- forces induced by production plant, when relevant.

Dynamic loads induced by equipment in operation are to be considered as operational loads.

4.3.2 Operational loads are to comply with the applicable requirements of Pt B, Ch 2, Sec 3 of the Offshore Rules.

4.3.3 Internal pressure

In order to limit the pressure head in tanks, column-stablized units may be fitted with an overflow system.

When overflow tanks complying with the relevant provisions of Sec 5 are installed, the pressure head may be taken at the top of the overflow tank instead of the top of the air pipe.

4.4 Environmental loads

4.4.1 General

Environmental loads are loads resulting from the action of the environment and include loads resulting from:

- wind
- waves
- current
- ice and snow accumulation, where relevant
- ice loads due to iceflow or icebergs, when relevant
- marine growth.

4.4.2 Environmental data

Environmental data for the intended sites of operation are to be specified for the purpose of design load definition.

The environmental data are to comply with the requirements of Pt B, Ch 2, Sec 2 of the Offshore Rules.

4.4.3 Wind loads

Wind pressures and forces acting on structural elements are to be calculated based on sustained and gust wind velocities. Reference is made to Pt B, Ch 1, Sec 2 of the Offshore Rules.

4.4.4 Wave loads

Wave loads are to be defined in accordance with the requirements of Pt B, Ch 2, Sec 3 of the Offshore Rules.

Design waves used for wave loads definition are to be described by wave energy spectra or deterministic waves having appropriate shape and size. Consideration is to be given to waves of lesser height, where, due to their period, the effect on structural elements may be greater.

Appropriate hydrodynamic analysis and model tests are mandatory for the assessment of wave loads. Additional recommendations for conduction the hydrodynamic analysis are given in App 1.

4.4.5 Current loads

Current loads are to be calculated in compliance with the requirements given in Pt B, Ch 2, Sec 2 of the Offshore Rules and Pt B, Ch 2, Sec 3 of the Offshore Rules.

4.4.6 Inertial loads

Maximum accelerations applied on structure and equipment are to be obtained from the hydrodynamic analysis.

Inertial internal pressures in liquid compartments may be calculated using the method given in Pt D, Ch 1, Sec 5 of the Offshore Rules, using accelerations as defined in the present Section.

Depending on the shape and dimensions of tanks, the Society may require to assess sloshing motions and pressures based on appropriate calculations.

4.4.7 Sea pressures

Sea pressure applied on hull are to be calculated taking into account relevant draughts. Generally, sea pressures are obtained from hydrodynamic analysis.

Simplified methods including hypothesis on pressure distribution may be accepted by the Society provided that relevant documentation justifying these methods is submitted.

4.4.8 Ice and snow

The requirements of Pt B, Ch 2, Sec 3 of the Offshore Rules are to be complied with.

4.5 Accidental loads

4.5.1 Accidental loads are defined taking into account the definition of relevant accidental condition. The requirements of [2.6] are to be taken into account.

4.6 Testing loads

4.6.1 Testing loads are loads sustained by the structure during testing phases of tanks or equipment.

4.7 Temporary construction loads

4.7.1 In accordance with the provisions of Pt A, Ch 1 of the Offshore Rules, temporary construction loads not resulting from the tests required to be performed by the applicable Rules requirements are not subject to review by the Society unless a specific request is made.

4.8 Design loads combination

4.8.1 The design loads are to be realistically combined to produce the maximum effect upon each component of the structure of the unit.

4.8.2 When a load combination liable to occur within the set of design specifications or at the specified site of operation is not considered for the design of the unit, adequate instructions are to be stated in the Operating Manual and/or appropriate procedures provided to prevent such combination from occurring.

The present requirement particularly relates to the distribution of operational loads.

4.8.3 For the purpose of load combinations, the environmental elements (wind, wave and current) are to be assumed to act simultaneously in the same direction, unless combinations of environmental elements with different directions might be more severe and liable to occur.

The most unfavourable direction, or combination of directions, for each component of the structure is to be considered.

4.8.4 For each direction, the environmental elements (wind, waves and current) are to be combined with their design values or associated design values.

For wave loads, the most unfavourable combination of wave height, wave period and water level when relevant, is to be retained.

For wind loads, the one minute sustained velocity is to be used in combination with other environmental elements for the design of the primary structure of the unit.

4.8.5 Where spectral design procedures are used, wave height and period relate to the significant height and reference period of sea state, and direction relates to the direction of highest energy density.

Then design loads and stresses are to be taken as the maximum values over a 3 h period.

4.8.6 When this is possible, the extreme environmental loads and stresses may be evaluated through long term statistics, using suitable techniques, to the satisfaction of the Society.

SECTION 4 HULL SCANTLING

1 General

1.1 Application

1.1.1 The hull scantling is to comply with the requirement of the present Section.

1.1.2 The following Industry standards may be considered applicable on a case by case basis:

- API 2A WSD: Recommended Practice for Planning, Designing, and Constructing Fixed Offshore Platforms - Working Stress Design - latest edition
- API 2U: Bulletin on Stability Design of Cylindrical Shells - latest edition
- API 2V: Design of Flat Plate Structures - latest edition
- AISC 360-05: Specifications for Structural Steel buildings - latest edition.

1.1.3 In case of conflict between the Offshore Rules and the present Note, this later is to take precedence.

1.2 Net thickness

1.2.1 All thicknesses are net, i.e. they do not include the corrosion additions specified in Sec 2.

2 Basic allowable stress factor

2.1 General

2.1.1 For structural strength calculation of hull elements, the basic allowable stress factors defined in the Offshore Rules, Pt B, Ch 3, Sec 3 are to be taken as defined in Sec 3, Tab 2.

Note 1: The basic allowable strength for normal operational conditions is increased by one-third and two-third for respectively extreme and survival conditions. The same principle is to be applied when strength assessment is requested to be checked according to industry standards mentioned in [1].

3 Global Finite Element Model

3.1 Structural modelling

3.1.1 General

The unit is to be modelled through a global finite element model.

The structural model is to represent the primary supporting members with the plating to which they are connected.

Ordinary stiffeners are also to be taken into account in the model in order to reproduce the stiffness and the inertia of the actual structure.

3.1.2 The structural analysis on fine mesh models is to be carried out by applying one of the following procedures:

- an analysis of the whole three dimensional model based on a coarse mesh model, as defined in [3.4.2], from which the nodal displacement and forces are used as boundary conditions for analyses based on fine mesh submodels. The minimum extent of fine mesh submodels is to comply with the relevant requirements of [3.4.3]
- an analysis of the whole three dimensional model based on a fine mesh model, as defined in [3.4.3].

3.1.3 When the three dimensional model is based on coarse mesh models, the following areas are to be investigated based on fine mesh models, as defined in [3.4.3]:

- typical pontoon structure
- column structure
- deck structure
- connection of pontoon with column
- connection of column with deck
- diagonal and horizontal bracings
- bracings joints
- mooring supporting structure
- typical topsides stools or supports
- risers supporting structure ends, when relevant.

Other areas may be required to be analyzed through fine mesh models, when deemed necessary by the Society, depending on unit's structural arrangement and loading conditions, as well as on the results of the coarse mesh analysis.

3.2 Model construction

3.2.1 Net scantlings

All structural elements are to be modelled with their net scantlings obtained by deducing half of the corrosion addition specified in Sec 2, [5].

3.2.2 Elements

Finite elements used in the structural model are to comply with the requirements given in [3.4], for the relevant type of finite element model.

3.3 Model extension

3.3.1 General

The complete structure of the unit is to be modelled to properly take into account the following effects in the structural analysis:

- effect of the global loads
- effects of sea pressures and pressures in internal capacities
- global and local deformations of structural items
- effects of local loads.

3.3.2 Hull structure

Finite element model of unit's hull is to include the following primary supporting members forming the pontoons, columns and deck structure:

- outer shell, longitudinal and transverse bulkhead plating
- bracings and bracing joints
- horizontal stringers
- web frames.

3.3.3 Topside supports

Topsides supporting structure is to be modelled in order to input mass and/or forces coming from topsides equipment.

3.3.4 Mass of topsides

The mass of topside equipment is to be taken into account in the model, at the satisfaction of the Society, in order to reproduce the correct lightweight distribution and inertial loads on topside supports.

3.3.5 Deckhouses and superstructures

Deckhouses and main superstructures connected to the main deck are to be included in the structural model. Their modelling is to correctly represent their weights and local effects on hull girder stiffness and deck behavior.

3.4 Finite element models

3.4.1 General

Finite element models are generally to be based on linear assumptions. The mesh is to be executed using membrane or shell elements, with or without mid-side nodes.

Bracings may be modelled using appropriate bar or beam elements.

Meshing is to be carried out following uniformity criteria among the different elements.

In general, the quadrilateral elements are to be such that the ratio between the longer side length and the shorter side length does not exceed 4 and, in any case, is less than 2 for most elements. Their angles are to be greater than 60° and less than 120°. The triangular element angles are to be greater than 30° and less than 120°.

3.4.2 Coarse mesh

The number of nodes and elements is to be such that the stiffness and the inertia of the model represent properly those of the actual hull structure, and the distribution of loads among the various load carrying members is correctly taken into account.

To this end, the structural model is to be built on the basis of the following criteria:

- ordinary stiffeners contributing to the global strength and which are not individually represented in the model are to be modelled by rod elements and grouped at regular intervals
- webs of primary supporting members may be modelled with only one element on their height
- face plates may be modelled with bars having the same cross-section
- the plating between two primary supporting members may be modelled with one element strip
- holes for the passage of ordinary stiffeners or small pipes may be disregarded
- Manholes (and similar discontinuities) in the webs of primary supporting members may be disregarded, but the element thickness is to be reduced in proportion to the hole height and the web height ratio.

In some specific cases, some of the above simplifications may not be deemed acceptable by the Society in relation to the type of structural model and the analysis performed.

3.4.3 Fine Mesh

The unit's structure may be considered as finely meshed when each longitudinal secondary stiffener is modelled; as a consequence, the standard size of the finite elements used is based on the spacing of ordinary stiffeners.

The structural model is to be built on the basis of the following criteria:

- webs of primary members are to be modelled with at least three elements on their height
- the plating between two primary supporting members is to be modelled with at least two element strips
- the ratio between the longer side and the shorter side of the elements is to be less than 3 in the areas expected to be highly stressed
- holes for the passage of ordinary stiffeners may be disregarded.

When fine mesh analysis is performed through sub-models, as stated in [3.1.2], the minimum extent of the sub-model is to be such that its boundaries correspond to locations where the deformations of the global model are accurately calculated, at the satisfaction of the Society. In general, it corresponds either to the adjacent or to the second adjacent primary supporting member.

3.5 Boundary conditions of the model

3.5.1 Boundary conditions are to be applied in order to prevent rigid body motions of the overall model, at the satisfaction of the Society. In general, boundary conditions are to respect the following requirements:

- constraints are to be applied on at least three nodes
- transverse and vertical translations are to be fixed at two nodes, and longitudinal translation at the remaining node
- all nodal rotations are to be kept free.

3.6 Load model

3.6.1 Loading condition

The loading conditions for which the structural analysis is carried out are to comply with the requirements of Sec 3.

Following the specificities of the design and/or operation of the considered unit, the Society may require the investigation of additional loading conditions considered relevant for structural check. In such a case, the additional loading conditions are to be stated in the Design Criteria Statement.

3.6.2 Loads and load combination

Loads are to be assessed and combined according the Sec 3.

3.6.3 Loading procedure

Applicable loading conditions are to be analyzed through:

- the computation of the characteristics of the finite element model under still water
- the selection of the load cases critical for the strength of the structural members. Each critical load case maximizes the value of one of the load effects specified in Sec 3 and having a dominant influence on the strength of some parts of the structure.

When equivalent design wave approach is adopted, the determination of the design wave characteristics for each load case is to be based on relevant requirements and recommendations stipulated in App 1.

3.6.4 For each loading condition, the convergence of the displacement, trim and vertical bending moment is deemed satisfactory within the following tolerances:

- 2% of the displacement
- 0,1 degree of the trim angle.

3.7 Stress calculation

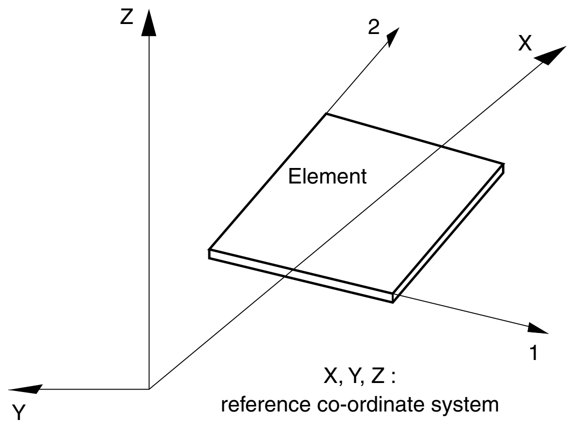
3.7.1 Stress components are generally identified with respect to the element co-ordinate system, as shown, by way of example, in Fig 1.

3.7.2 The following stress components are to be calculated at the centroid of each element from global finite element model:

- the normal stresses σ_1 and σ_2 in the directions of element co-ordinate system axes
- the shear stress τ_{12} with respect to the element co-ordinate system axes
- the Von Mises equivalent stress, obtained from the following formula:

$$\sigma_{VM} = \sqrt{\sigma_1{}^2 + \sigma_2{}^2 - \sigma_1\sigma_2 + 3\tau_{12}{}^2}$$

Figure 1 : Reference and element co-ordinate systems



3.7.3 Stress for elementary plate panel

Where an elementary plate panel is meshed by several finite plate elements, the stresses of the elementary plate panel are obtained by the following methodology:

- For each finite element, the element stresses expressed in the element co-ordinate system are projected in the co-ordinate system of the panel.
- The elementary plate panel stresses are calculated as weighted average of projected element stresses, with weighting by element areas.

3.7.4 Stress for ordinary stiffener

The global stress σ_x to be considered for the yielding and buckling check of stiffeners is to be obtained from the maximum stress between adjacent elementary plate, as defined in [3.7.3] along the direction of the considered stiffeners.

4 Local pressure assessment

4.1 General

4.1.1 The local pressure, including static and dynamic pressure if any, for the strength assessment of plating and ordinary stiffeners is to be evaluated according to [4.2] and [4.3].

In addition, the requirements of Sec 2, [2.3.2] are to be taken into account.

4.1.2 Load point

Lateral pressure is to be calculated at the lower edge of the elementary plate panel and at midspan of the ordinary stiffener considered.

4.2 Design loading conditions

4.2.1 The pressure considered for the design loading conditions specified in Sec 3 is to be evaluated from the Global Finite Element model at the location defined in [4.1.2] for the considered elementary plate panel or ordinary stiffener.

4.3 Testing conditions

4.3.1 Testing pressure for tanks intended to be water tested is to be evaluated according to Offshore Rules Pt B, Ch 3, Sec 7.

5 Plating

5.1 Net scantlings

5.1.1 The net thickness is to be obtained by deducing the corrosion addition specified in Sec 2 from the gross scantling.

5.2 Yielding strength

5.2.1 The net thickness of laterally loaded plate panels subjected to in-plane normal stress acting on the shorter sides is to be not less than the value obtained, in mm, from the following formula:

$$t = 14{,}9 c_a c_r s \sqrt{\frac{P}{\lambda_L R_Y \alpha}}$$

where:

c_a : Aspect ratio of the plate panel:

$$c_a = 1{,}21\sqrt{1 + 0{,}33\left(\frac{s}{\ell}\right)^2} - 0{,}69\frac{s}{\ell}$$

c_r : Coefficient of curvature of the panel:

$c_r = 1 - 0{,}5\ s / r$

r : Radius curvature, in mm

λ_L : Parameter equal:

- Design loading conditions:

$$\lambda_L = \sqrt{1 - 0{,}95\left(\frac{\sigma_x}{R_y}\right)^2} - 0{,}225\frac{\sigma_x}{R_y}$$

- Testing conditions

$\lambda_L = 1$

P : Pressure applying on the elementary plate panel, kN/m^2, as defined in [4]

s : Spacing of the elementary plate panel, in m

ℓ : Span of the elementary plate panel, in m

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

σ_x : Stress along the short edge of the panel, in N/mm^2, as specified in [3.7.3]

α : Basic allowable stress factor is to be taken according to [2.1.1].

5.3 Buckling

5.3.1 General

The buckling check of stiffened panels is to be performed in accordance with NI 615 "Buckling assessment of plated structures".

5.3.2 Buckling check criteria

A structural element is considered to have an acceptable buckling capacity if its buckling utilisation factor η satisfies the following criterion:

$\eta \leq \eta_{ALL}$

with:

$\eta_{ALL} = \alpha$

α : Basic allowable stress factor defined in [2].

The buckling utilisation factor η of the structural member is defined as the highest value of the ratio between the applied loads and the corresponding ultimate capacity or buckling strength obtained for the different buckling modes.

6 Ordinary stiffeners

6.1 Net scantlings

6.1.1 The net thickness is to be obtained by deducing the corrosion addition specified in Sec 2 from the gross scantling. The net shear areas and section modulus are obtained from the net thickness of the considered ordinary stiffeners.

6.2 Single span ordinary stiffeners subjected to lateral pressure and global stresses

6.2.1 The net section modulus w, in cm^3, and the net shear sectional area A_{Sh} , in cm^2, of ordinary stiffeners subjected to lateral pressure and global stresses are to be not less than the values obtained from the following formulae:

$$w = \frac{P}{12 \cdot (1,1 \cdot \alpha \cdot R_y - \sigma_x)} s \cdot l^2 \cdot 10^3$$

$$A_{Sh} = \frac{P}{1,1 \cdot \alpha \cdot R_y}\left(1 - \frac{s}{2l}\right) s \cdot l \cdot 10$$

where:

P : Pressure applying on the ordinary stiffener, in kN/m^2, as defined in [4]

s : Spacing of stiffeners, in m

l : Stiffener span, in m

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

σ_x : Stress of ordinary stiffener, in N/mm^2, as specified in [3.7.4]

α : Basic allowable stress factor to be taken according to [2].

6.3 Single span ordinary stiffeners in testing conditions or subjected to lateral pressure only

6.3.1 The net section modulus w, in cm^3, and the net shear sectional area A_{Sh}, in cm^2, of longitudinal or transverse ordinary stiffeners subjected to lateral pressure are to be not less than the values obtained from the following formulae:

$$w = \frac{P}{12 \cdot 1,1 \cdot \alpha \cdot R_y} s \cdot l^2 \cdot 10^3 \cdot$$

$$A_{Sh} = 10\frac{P}{1,1 \cdot \alpha \cdot R_y}\left(1 - \frac{s}{2l}\right) s \cdot l \cdot 10$$

where:

P : Testing pressure applying on the ordinary stiffener, in kN/m^2, as defined in [4]

s : Spacing of stiffeners, in m

l : Stiffener span, in m

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

σ_x : Stress of ordinary stiffener, in N/mm^2, as specified in [3.7.4]

α : Basic allowable stress factor to be taken according to [2.1.1].

6.4 Multi span ordinary stiffeners

6.4.1 The maximum normal stress σ and shear stress τ in a multispan ordinary stiffener are to be determined by a direct calculation taking into account:

- the distribution of still water and wave pressure and forces, to be determined on the basis of the global finite element model as stipulated in [4]
- The global stress as defined in [3.7.4]
- the number and position of intermediate supports (decks, girders, etc.)
- the condition of fixity at the ends of the stiffener and at intermediate supports
- the geometrical characteristics of the stiffener on the intermediate spans.

6.4.2 Allowable stresses

It is to be checked that the normal stress σ and the shear stress τ calculated according to [6.4.1], are in compliance with the following formulae:

$\sigma \leq 1{,}1\ \alpha R_y$

$\tau \leq 1{,}1\ \alpha R_y / 2$

where:

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

α : Basic allowable stress factor to be taken according to [2.1.1].

6.5 Buckling

6.5.1 General

The buckling check of stiffeners is to be performed in accordance with NI 615 "Buckling assessment of plated structures".

6.5.2 Buckling check criteria

A structural element is considered to have an acceptable buckling capacity if its buckling utilisation factor η satisfies the following criterion:

$\eta \leq \eta_{ALL}$

with:

$\eta_{ALL} = \alpha$

α : Basic allowable stress factor defined in [2].

The buckling utilisation factor η of the structural member is defined as the highest value of the ratio between the applied loads and the corresponding ultimate capacity or buckling strength obtained for the different buckling modes.

7 Primary supporting members

7.1 Yielding strength

7.1.1 Yielding criteria for coarse and fine mesh analysis

For coarse mesh analysis and fine mesh analysis, it is to be checked that the equivalent stress σ_{VM} , in N/mm^2, calculated according to the present section is in compliance with the criteria defined in Offshore Rules Pt B, Ch 3, Sec 3.

The basic allowable stress factor is to be taken according to [2.1.1].

7.1.2 Yielding criteria for face plates of primary supporting members and openings

For fine mesh analysis, face plates of primary supporting members and openings may be modelled by shell elements or by beam/bar elements.

When shell elements are used, the requirements of [7.1.1] are to be complied with.

When beam/bar elements are used, it is to be checked that the beam/bar element's axial stress σ_{ax}, in N/mm^2, is in compliance with the criteria defined in Pt B, Ch 3, Sec 3 of the Offshore Rules.

The basic allowable stress factor is to be taken according to [2].

7.2 Buckling

7.2.1 General

The buckling check of primary supporting members is to be performed in accordance with NI 615 "Buckling assessment of plated structures" taking into account the requirements of the present Article.

7.2.2 Compression stresses

The compression stresses to be taken into account for the checking criteria required in [7.2.5] are given as follows:

a) Compression and bending:

The compression stress σ_b, in N/mm^2, acting on side "b" of the plate panel, is to be calculated as specified in [7.2.3]

b) Shear:

The shear stress, in N/mm^2, acting on the plate panel is to be calculated as specified in [7.2.4].

c) Compression, bending and shear:

The compression stresses σ_1 and σ_2, in N/mm^2, are to be calculated as specified in [7.2.3]

The shear stress τ, in N/mm^2, is to be calculated as specified in [7.2.4].

d) Bi-axial compression, taking account of shear stress:

The compression stresses σ_1 and σ_2 , in N/mm^2, are to be calculated as specified in [7.2.3].

The shear stress τ, in N/mm^2, is to be calculated as specified in [7.2.4].

7.2.3 Combined in-plane global and local compression normal stresses

The combined in-plane compression normal stresses to be considered for the buckling check of plating are to take into account global stresses and the local stresses resulting from the bending of the primary supporting members. These local stresses are to be obtained from a direct structural analysis as specified in [3.7.3].

7.2.4 Combined in-plane global and local shear stresses.

The combined in-plane shear stresses to be considered for the buckling check of plating are to take into account the global stresses and the local stresses resulting from the bending of the primary supporting members. These local stresses are to be obtained from a direct structural analysis as specified in [3.7.3].

7.2.5 Buckling check criteria

A structural element is considered to have an acceptable buckling capacity if its buckling utilisation factor η satisfies the following criterion:

$\eta \leq \eta_{ALL}$

with:

$\eta_{ALL} = \alpha$

α : Basic allowable stress factor defined in [2].

The buckling utilisation factor η of the structural member is defined as the highest value of the ratio between the applied loads and the corresponding ultimate capacity or buckling strength obtained for the different buckling modes.

8 Bracings

8.1 General

8.1.1 Diagonal and horizontal bracings are to be checked against yielding and buckling following the requirements of Pt B, Ch 3 of the Offshore Rules.

9 Fatigue check of structural details

9.1 General

9.1.1 Fatigue analysis is to be performed to ensure adequate strength against fatigue failure during unit's design life, as defined in [9.3].

9.1.2 For units intended to receive the additional class notation **Spectral Fatigue**, reference is made to the relevant requirements of NI611.

9.1.3 Fatigue evaluations are to be carried out according to recognized methods to the satisfaction of the Society, such as:

- general methodology given in Pt B, Ch 3 of the Offshore Rules
- published articles of the Society.

Other methods may be accepted by the Society on a case-by-case basis.

9.1.4 Structural elements for which fatigue is a probable mode of failure are to be adequately designed to resist the effects of cumulative damage caused by repeated application of fluctuating stresses.

The predominant cause of fluctuating stresses leading to crack propagation and fatigue failure is normally wave loading. However, other sources of cyclic loads such as wind, rotating machinery or cranes may also induce significant fatigue loadings and are to be given due consideration where relevant.

9.2 Load cases for fatigue evaluation

9.2.1 For fatigue evaluation a sufficient number of load cases is to be considered to correctly model loads acting on the unit during its whole life, giving due consideration to:

- the various design conditions of operation of the unit
- the direction and the intensity of environmental actions, as resulting from the long term distributions of relevant environmental parameters with possible limitations corresponding to each of these conditions.

9.3 Fatigue life

9.3.1 The design of primary structural elements is to take into account the design life of the unit and for all of its conditions of operation. The design life of the structure is to be specified by the party applying for classification. It is normally to be taken not less than 20 years.

The design life of the structure is to be indicated in the Design Criteria Statement.

9.3.2 A further increase in the design fatigue life is to be considered for elements in uninspectable areas or areas where repair within the expected life time is not possible or practical.

9.4 Structural details for fatigue analysis

9.4.1 General

Structural details for fatigue analysis will be selected on a case-by-case basis, at the satisfaction of the Society. Typically, the following items are included:

- intersection of stiffeners with bulkheads and primary supporting members
- end brackets
- flanges of primary members in way of brackets
- typical details of pontoon-to-column intersections
- typical details of decks-to-column intersections
- connections of bracings
- tubular joints
- topside connections with decks
- details at corner of moonpool arrangements, when relevant
- riser supporting structure
- mooring supporting structures
- foundation of riser tensioning systems, when relevant
- crane pedestals.

9.5 Design

9.5.1 The design of beam brackets and intersection of local stiffeners with primary supporting members are to be based on the hull design principles of the Ship Rules.

9.5.2 The level of fluctuating stress is to be adequately limited.

A suitable fatigue life is best achieved by adequate joint detail design and fabrication quality control. Joint detail design is to avoid, as possible, joint eccentricities introducing secondary stresses and local restraints, abrupt section changes, re-entrant corners, notches and other stress raisers.

In fatigue sensitive areas, improved joint performance is to be achieved through, as necessary, a combination of reduction in nominal stresses, obtained by increased thicknesses, improved detailing, providing smooth transitions and suitable shape of weld joints.

9.5.3 Fatigue strength is also affected by fabrication induced (residual) stresses and by stress raisers caused by inherent weld defects, particularly surface defects.

This is normally accounted for by joint classifications, provided however that standard quality control procedures are adequately implemented.

9.5.4 Where it is not possible to improve fatigue life by another method, the Society will examine, in each separate case, weld profile improvement techniques such as grinding, shot blasting, TIG dressing and other post-welding treatments.

Where a joint performance depends upon particular fabrication and quality control requirements, adequate procedures are to be drawn up providing the necessary specifications concerning workmanship and inspection.

9.5.5 Due attention is to be given to attachment of fittings onto primary structural members. Unavoidable cut-outs or openings are to be, as far as possible, located outside high stress areas and superposition of notches is to be avoided.

9.6 Fatigue analysis

9.6.1 The long term distribution of fluctuating stresses is to be obtained from an overall structural analysis, for the relevant load cases, in accordance with [3].

Spectral analysis is generally to be used. Time domain analysis is to be preferred when both non linearities and dynamic effects are significant. Deterministic analysis may be used when appropriate.

9.6.2 Geometrical stress concentrations result from openings, transitions in properties or geometry of members, end connections and other discontinuities. When not modelled in the overall analysis, such geometrical stress concentrations may be accounted for by appropriate Stress Concentration Factors (SCF).

Proposed SCF's are to be duly documented to the satisfaction of the Society. SCF's may be obtained from analytical solutions, in some cases, or from adequately calibrated parametric equations or by direct stress analysis. The Society reserves the right to call for such analysis if found necessary.

9.6.3 Local effects, resulting from residual stresses and from weld surface defects, are to be accounted for through joint classification.

9.6.4 The cumulative fatigue damage at each spot is to be calculated using the Palgren-Miner Rule and an appropriate S-N curve, taking into account joint classification, thickness effect and the degree of corrosion protection.

9.6.5 Fracture mechanics methods may also be used for fatigue analysis subject to adequate consideration of the stress history, of the joint geometric configuration and of the following, to the satisfaction of the Society:

- selection of initial crack geometry and size
- crack propagation rate, taking into account corrosion factors
- toughness parameters governing final crack instability for which a verification by appropriate fracture mechanics testing may be required.

9.7 Checking criteria

9.7.1 For the spectral fatigue analysis, the fatigue damage ratio is to be not greater than those given in Tab 1.

Table 1 : Damage ratio for spectral fatigue analysis

Consequence of failure	Degree of accessibility for inspection, maintenance and repair		
	Not accessible **(2)**	Underwater inspection **(3)**	Dry inspection
Critical **(1)**	0,1	0.25	0,5
Non-critical	0,2	0,5	1,0

(1) Critical damage include loss of life, uncontrolled pollution, collision, other major damage to the installations and major production losses. All structural elements are to be considered as critical unless duly justified by an analysis of the consequence of failure.

(2) Includes areas that can be inspected in dry or underwater conditions but require heavy works for repair.

(3) Includes areas that can be inspected in dry conditions but with extensive preparation and heavy impact on operation.

SECTION 5 MACHINERY AND SYSTEMS

1 General

1.1 Application

1.1.1 The requirements of this Section are to be satisfied in addition to Offshore Rules, Part C, Chapter 1.

2 Ballast system

2.1 Availability of the ballast system

2.1.1 *The ballast system* on column-stabilized units *is to be capable of operating after the damage specified in the Offshore rules Pt B, Ch 1, Sec 3. This system is to have the capability of restoring the unit to a level trim and safe draught condition without taking on additional ballast, with any one pump inoperable. The Society may permit counter-flooding as an operational procedure. Counter-flooding is not to be considered as a means to improve the suction head available to the ballast pumps when considering the operability of the ballast system after the damage specified.*

2.1.2 Each ballast tank is to be capable of being pumped out by at least two independent power driven pumps, arranged so that:

- tanks can be drained at all normal operating and transit conditions
- the system remains operational in the event of failure of one of these pumps.

2.2 Ballast pumps and piping system

2.2.1 Prevention of inadvertent transfer

The ballast system is to be arranged to prevent the inadvertent transfer of ballast water from one quadrant to any other quadrant of the unit. The system is also to be arranged so that the transfer ballast water from one tank to any other tank through a single valve is not possible except where such a transfer could not result in moment shifts leading to excessive angles of heel or trim.

2.2.2 Ballast pumping capacity

The ballast system is to be capable of raising the unit, while in intact condition at deepest working draught, to the draught corresponding to severe storm condition, within three hours.

The ballast system is to be capable of operating after the damage as specified in [2.1].

When the unit cannot be towed at its normal towing draught under extreme towing conditions, the ballast system is to be capable of lowering the unit, starting from a level trim condition at normal towing draught to the draught corresponding to towing under extreme conditions within six hours.

2.2.3 Ballast pumps

The ballast pumps are to be of the self-priming type or be provided with a separate priming system. They do not need to be dedicated ballast pumps, but are to be readily available for ballasting purposes at all times.

2.3 Electrical systems

2.3.1 Power supply of ballast pumps

It is to be possible to supply each ballast pump required in [2.2] from the emergency source of power. The arrangement is to be such that the system is capable of restoring the unit from an inclination specified in the Offshore rules Pt C, Ch 1, Sec 1, Tab 4 to a level trim and safe draught condition after loss of any single component in the power supply system.

2.3.2 Enclosures for electrical components

Enclosures housing ballast system electrical components, the failure of which would cause unsafe operation of the ballast system upon liquid entry into the enclosure, are to have suitable protection against the ingress of liquids. Refer to the Offshore rules Pt C, Ch 2, Sec 3.

2.4 Control and monitoring

2.4.1 Ballast control station

A central ballast control station is to be provided. This station and any back-up stations are to be readily accessible, adequately protected from weather, and located neither under the worst damage waterline nor within the assumed extent of damage referred to in the Offshore rules Pt B, Ch 1, Sec 3. Additionally, these stations are not to be located within the assumed damaged penetration zone.

The central station is to include the following:

- a ballast pump control system
- a ballast pump status-indicating system
- a ballast valve control system
- a ballast valve position-indicating system
- a tank level indicating system
- a draught indicating system, indicating the draught at each corner of the unit or at presentative positions as required by the Society
- a power availability indicating system (main and emergency)

- a ballast system hydraulic / pneumatic pressure-indicating system
- a permanently installed means of communication, independent of the unit's main source of electrical power, between the control station and those spaces containing the ballast pumps and valves or their manual controls, or other spaces that may contain equipment necessary for the operation of the ballast system.

2.4.2 Control of ballast pumps and valves

Ballast pumps, ballast tank valves and sea chest valves are to be provided with means of remote control from central ballast control station.

Ballast pumps are to be provided with a means of local control in the pump room operable in the event of remote control failure. A manually operated independent means of control of the valves is also to be provided. The independent local control of each ballast pump and of its associated ballast tank valves are to be in the same location.

2.4.3 Valve position-indicating systems

Means to indicate whether a valve is open or closed are to be provided at each location from which the valve can be controlled. The indicators are to rely on movement of the valve spindle.

2.4.4 Tank level indicating systems

The tank level indicating system required in [2.4.1] is to provide means to:

a) indicate liquid levels in all ballast tanks. A secondary means of determining levels in ballast tanks, which may be a sounding pipe, is to be provided. Tank level sensors are not to be situated in the tank suction lines.

b) indicate liquid levels in other tanks, such as fuel oil, fresh water, drilling water or liquid storage tanks, the filling or emptying of which, in the view of the Society, could affect the stability of the unit. Tank level sensors are not to be situated in the tank suction lines.

2.4.5 Independence of the control systems

The control and indicating systems listed in [2.4.1] are to function independently of each other so that a failure in anyone system cannot affect the operation of the other systems. The ballast pump and ballast valve control systems are to be arranged so that the loss of anyone of their components does not cause the loss of operation to the other pumps or valves.

2.4.6 Fail-safe design

To ensure that uncontrolled transfer of ballast water cannot continue upon loss of power, ballast tank valves are to close automatically upon loss of power. Upon reactivating of control power, each such valve is to remain closed until the ballast control operator assumes control of the reactivated system. Ballast valve arrangements which do not fail to the closed position upon loss of power may be accepted to the satisfaction of the Society provided it considers that the safety of the unit is not impaired.

2.4.7 Means to isolate the ballast pump and valve control systems

Means are to be provided at the central ballast control station to isolate or disconnect the ballast pump control and ballast valve control systems from their sources of electrical, pneumatic or hydraulic power.

2.5 Air pipes

2.5.1 General

Air pipes are to be provided on each ballast tank sufficient in number and cross-sectional area to permit the efficient operation of the ballast pumping system.

In order to allow deballasting of the ballast tanks intended to be used to bring the unit back to from normal draught and to ensure no inclination after damage, air pipe openings for these tanks are to be above the worst damage waterline.

Such air pipes are to be positioned outside the extent of damage, as defined in the Offshore rules Pt B, Ch 1, Sec 3.

2.5.2 Name plates

All valves and operating controls are to be clearly marked to identify the function they serve.

2.6 Overflow tanks

2.6.1 General

When overflow tanks are fitted to reduce tank pressures in case of overfilling, means are to be provided to drain the overflow tank with sufficient capacity to allow uninterrupted ballasting in normal conditions.

2.6.2 Design pressure and alarms

The design head of pressure considered for the ballast tanks structural assessment may be taken as the overflow tank top level, instead of the top of the air pipe, providing that the following alarms are fitted:

- High level alarm or overflow alarm
- High-High level alarm at max 98% level with shutdown of ballast pumps.

2.6.3 Overflow tank capacity

The overflow tanks are to have a capacity $V_{overflow}$, in m3, not less than:

$$V_{overflow} = \frac{T_{filling}}{60} \times (Q_{normal} - Q_{draintotal} + Q_{drainpump})$$

Where:

$T_{filling}$: Filling time, in minute, to be taken the lesser of:

- 10 min, or
- time matching the design ballast philosophy, or

- when alarms in compliance with [2.6.2] and an automatic draining system are provided, the greatest of:
  - the time elapsed before the drain system is switched on, and
  - 3 min.

Q_{normal} : Ballast rate in normal conditions, in m^3/hr

$Q_{draintotal}$: Total drain pump rate, in m^3/hr

$Q_{drainpump}$: Rate of the largest drain pump, in m^3/hr.

Note 1: The rate of the largest pump is considered in order to cope with the single failure of a drain pump.

2.7 Pressurized ballast tanks

2.7.1 Compressed air systems used to fill or empty the ballast tanks are to be specially considered.

Adequate means to control and to mitigate the risks of overpressure are to be provided.

A description of the air pressure system is to be submitted.

3 Bilge system

3.1 Bilge pumps arrangement

3.1.1 Bilge pumps are to be so arranged that at least one bilge pump can be used normally in case of flooding. This condition is considered as fulfilled if:

- either of one of the required pumps is of a reliable submersible type having its source of power above the damage water line, or
- the pumps and their sources of power are so arranged that, under any flooding which the unit is required to withstand, at least one pump in an undamaged compartment remains available.

3.2 Control of the bilge pumps and suction valves

3.2.1 At least one of the pumps required in Offshore Rules Pt C, Ch 1, Sec 7 and pump room bilge suction valves are to be capable of both remote and local operation.

3.3 Bilge water level detection

3.3.1 Propulsion rooms and pump rooms in lower hulls are to be provided with two independent systems for high bilge water level detection providing an audible and visual alarm at the central ballast control station.

3.4 Draining of chain lockers

3.4.1 Chain lockers which are liable to substantially affect the unit's stability if flooded are to be provided with a remote means to detect flooding and a permanent installed means of dewatering. Remote indication of flooding is to be provided at the central ballast control station.

APPENDIX 1 HYDRODYNAMIC ANALYSIS

1 General

1.1 Application

1.1.1 The present Section is a guidance to perform the hydrodynamic analysis.

1.1.2 Hydrodynamic analysis should take into account the effect of the means for station keeping.

1.1.3 The analysis should be performed on the basis of method given in the present Section. Other methods may be accepted by the Society provided that relevant documentation is submitted.

1.2 Purpose

1.2.1 The purpose of hydrodynamic global behavior analysis is to determine relevant load parameters requested for the definition of load cases and design loads. Examples of such parameters are given below:

- maximum motions of the floater under environmental conditions
- deck clearance
- maximum accelerations under environmental conditions
- relative wave elevation on columns
- internal pressures and sea pressures relevant for investigated loading conditions
- specific hull effects, as required in Sec 3, [3.3.2].

1.3 Methods

1.3.1 It is important to note that nowadays the so called potential flow hydrodynamic approach based on wave diffraction radiation models are dominating the existing design methods. In some cases, these models are usually complemented by the simplified Morison method for slender parts of the structures. The pure CFD methods based on solving directly Navier Stokes or Euler equations are not used very often. The extreme CPU requirements and lack of the clear validation of the CFD methods, are probably the main reasons for this. However, the use of CFD can be helpful for some particular local applications such as: wave overtopping, impact on deck…

1.3.2 Two types of approximation are usually employed in the hydrodynamic analysis of the floating units:

- Simplified Morison model
- Wave diffraction-radiation theory.

2 Morison method

2.1 General

2.1.1 The Morison method is the simplest one and its domain of validity is limited. It is based on the so called strip approach where the structure is cut into a certain number of regular sections on which the forces are calculated by relating the local geometry and the fluid kinematics (velocities and accelerations) through the Morison formula:

$$F_M = \frac{1}{2}\rho_w C_D D\left(v_F - \frac{d\xi_B}{dt}\right)\left|v_F - \frac{d\xi_B}{dt}\right| + \frac{\rho_w \pi D^2}{4}\left[(1 + C_M)\gamma_F - C_M\frac{d^2\xi_B}{dt^2}\right]$$

where:

r_w : Water density

C_D : Drag coefficient

D : Characteristic sectional dimension (diameter)

v_F : Local fluid velocity

dx_B / dt : Local body velocity

C_M : Added mass coefficient

g_F : Local fluid acceleration

d^2x_B / dt^2: Local body acceleration.

This method can be efficiently used for slender structures only. Indeed the main diffraction-radiation effects can not be taken into account since the implicit assumption is that the structural cross section is significantly smaller than the considered wave length. There is no possibility to include higher order diffraction effects. Good point is that the nonlinear drag forces can be included.

The Morison forces include the added mass, damping and excitations effects.

It is important to mention that the Morison model can not be applied for the vertical forces on the columns.

3 Wave diffraction radiation theory

3.1 General

3.1.1 The assumptions of the potential flow are adopted. The usual methods are based on the Boundary Integral Equations Method (BIEM) in which the flow field is represented by the distribution of singularities (sources/sinks, dipoles…) over the wetted part of the body. Diffraction and radiation effects are taken into account consistently and the method can be used for linear (first order), weakly nonlinear (second order) and fully non linear calculations. Due to their complexity, the fully non linear calculations are usually employed only for very special purposes. Here below we discuss the first and second order methods only.

These methods should be applied for large bodies i.e. for the bodies which characteristic length is similar to the wave length where the diffraction radiation effects are important. For some applications the method can be combined with the Morison approach for slender members (bracings…) where the drag type forces might be important (see [2.1]).

The wave diffraction radiation theory can be applied in frequency or in time domain. Usual practice is to apply it in frequency domain and for some specific application use the hybrid frequency/time domain approach.

Usually we distinguish three independent types of models:

- Linear hydrodynamic model
- Low frequency second order hydrodynamic model (difference frequency)
- High frequency second order hydrodynamic model (sum frequency).

It is important to note that the linear calculations are prerequisite for the second order calculations and the second order calculations can not be performed if linear problem is not solved properly.

3.2 Linear diffraction-radiation numerical model in frequency domain

3.2.1 The main advantage of the frequency domain model is its relative simplicity and the low CPU time requirements. The linearization is made by assuming the small wave steepness which is reasonable assumption for most of the practical cases. Within the potential flow assumptions, and after performing the linearization, the total velocity potential is decomposed into seven components (incident, diffracted and 6 radiated components). For each of those components the dedicated Boundary Value Problem (BVP) is built. Each BVP is solved using the Boundary Integral Equation Method in which the fluid flow is represented by the distribution of singularities over the wetted part of the hull. In that respect this method requires the mesh of the underwater part of the body only, which represents great advantage when compared to other methods and in particular CFD type of methods where whole fluid domain need to be modelled. Special care should be made as to the size of the mesh in order to ensure the proper convergence of the solution. The mesh size should be proportional to the shortest considered wave length, the usual practice being 6 elements per wave length and the mesh refinement might be necessary for some parts of the model (close to the free surface, around the sharp corners…).

Once the BVP solved, the hydrodynamic pressure is evaluated and the corresponding hydrodynamic coefficients (added mass, damping and excitation) are obtained after the integration of the pressure over the wetted part of the hull. At the same time the care should be taken when evaluating the body restoring matrix.

Once the dynamic coefficients evaluated, the motion equation is written:

$$\{-\omega^2([M]+[A])-i\omega[B]+[C]\}\{\xi\} = \{F\}$$

where:

w : Wave frequency

[M] : Genuine mass matrix

[A] : Added mass matrix

[B] : Damping matrix (linearized)

[C] : Restoring matrix

{x} : Body motions

{F} : Excitation vector (diffracted + incident wave).

The solution of the motion equation gives the body motions (surge, sway, heave, roll, pitch and yaw) and the problem is formally solved. Access to any particular quantity in terms of RAO’s (pressure, accelerations at particular points, internal bending moments, shear forces…) is straightforward.

Once the different RAO’s are evaluated, spectral analysis for specific scatter diagram can be performed and the maximum probable design values can be evaluated.

3.3 Linear wave-current diffraction-radiation model in frequency domain

3.3.1 In the areas where strong current is present, the linear wave-diffraction model needs the improvements and the effects of current can become quite important. This importance is particularly visible on the results for the air gap which can be strongly influenced by the current. The numerical model, with current included, is much more complex than the one without current because of the change of the free surface condition which now includes several additional terms accounting for the current intensity and for the interaction of the steady and unsteady parts of the velocity potential.

Similar to the second order problem, the Boundary Integral Equation Method leads to the additional integral over the free surface. However, in this particular case this integral decays very rapidly so that efficient methods exist nowadays.

It is important to note that, in addition to the influence on the air gap, the solution of the wave-current interaction problem is also necessary for evaluation of the so called wave drift damping (WDD) which is important in the analysis of the low frequency simulations. Indeed the WDD is defined as the derivative of the steady drift forces with respect to the slow speed and only the above model allows for fully consistent determination of this coefficient.

3.4 Mixed diffraction - radiation - Morison model

3.4.1 In some cases, when slender elements are present, the combined diffraction-radiation-Morison model might be necessary. The idea is to use the Morison formula for slender elements by evaluating the fluid kinematics using the diffraction-radiation theory in order to account for important perturbation (diffraction-radiation) parts of the velocity potential. Due to the nonlinear character of the Morison formula (drag component) proper linearization should be performed before solving the motion equation.

3.5 Second order diffraction-radiation numerical models in frequency domain

3.5.1 It is important to note that, in addition to the linear quantities, the so called second order mean drift forces can also be evaluated using the linear results only. These mean forces are very important for mooring simulations.

Unlike the linear first order model which gives rise to the quantities at particular wave frequency and the mean drift forces, the second order model produce the high frequency (super harmonic) and low frequency (sub harmonic) wave loads.

The theory behind the second order problem is nowadays well mastered even if only few numerical codes are able to perform these calculations in a fully consistent way. Contrary to the linear problem for which it is enough to perform the calculations for each frequency independently, the generic second order problem includes the bi-chromatic wave field i.e. the quadratic interaction of the two linear wave systems with two different frequencies coming from two different directions. This makes the overall procedure of the evaluation of the second order loads for a given wave spectra extremely complex.

In the general case the second order interaction of two monochromatic waves of the frequencies (w_i , w_j) and amplitude (A_i , A_j), coming from the directions (b_i , b_j) will give rise to the second order loads (and any other second order quantities) which can be schematically written in the following form:

$F^{(2)}(t) = F_-^{(2)}(t) + F_+^{(2)}(t)$

where:

$F_-^{(2)}(t)$: Sub-harmonic (difference frequency) second order loads:

$F_-^{(2)}(t) = R\{A_iA_jf_-^{(2)}(w_i, w_j, b_i,b_j)e^{i[-(wi - wj) + qi - qj]}\}$

$F_+^{(2)}(t)$: Super harmonic (sum frequency) second order loads:

$F_+^{(2)}(t) = R\{A_iA_jf_+^{(2)}(w_i, w_j, b_i,b_j)e^{i[-(wi - wj) + qi + qj]}\}$

$f_-^{(2)}(t)$; $f_+^{(2)}(t)$:Quadratic transfer functions

q_i ; q_j : Corresponding phases of two different incident wave systems

$R\{x\}$: Real component of the quantity x.

The complex quantities $f_-^{(2)}(t)$ and $f_+^{(2)}(t)$ are called quadratic transfer functions and represents the main difficulty for the numerical calculations. Indeed very complex second order boundary value problems need to be solved for all the combinations of the frequencies and the wave directions.

In the particular case of mono-directional ($b_i = b_j$) and monochromatic wave system ($w_i = w_j$), the above expressions reduce to the second order mean drift forces for $f_-^{(2)}(t)$ and to the double frequency second order forces for $f_+^{(2)}(t)$.

The numerical method which is usually employed for solving the second order boundary value problems is also based on the Boundary Integral Equations Technique and the same type of Green function is used. The main numerical difficulty comes from the fact that the associated second order free surface boundary condition becomes non-homogeneous and the Boundary Integral Equation must include the integration over the free surface which, strictly speaking, should extend to infinity. Due to highly oscillatory behavior of this integral several convergence problems appear and should be treated with care.

In addition, for the sum frequency problem, due to very short wave lengths which can appear, the mesh requirements might become prohibitive, and special numerical treatments are necessary.

As far as the low frequency second order problem is concerned, the situation is slightly simplified by the fact that the contribution of the free surface integral to the total loads is usually not very important so that it can be neglected.

4 Time domain models

4.1 General

4.1.1 The most important advantage of the frequency domain approach is the computational efficiency and the most important limitations are the difficulties related to the linearization. Indeed the nonlinearities should be either ignored or replaced by the linear approximation. The exception are some special cases such as the second order frequency domain models in which the nonlinearities can be partially included (up to second order) but the price to pay are the complexities associated with the numerical solution of the corresponding boundary value problems.

The time domain analysis is based on the direct integration in time of the equations of motion which makes possible the inclusion of system nonlinearities at each time step. There are several types of nonlinearities which need to be included in the model and they can be of both mechanical and hydrodynamic character. The hydrodynamic nonlinearities include the higher order wave effects (second order diffraction, ringing…), nonlinear hydrostatics and different non potential effects (Morison loading, VIV, VIM…) while the nonlinear mechanical nonlinearities includes the nonlinear characteristics of the mooring system, large platform motions, dynamic effects of the risers and mooring lines.

The usual procedure for the time domain simulation models is to start with the linear frequency domain model and transfer it to the time domain using the inverse Fourier transform technique (see Note 1) where any type of nonlinearities can be added at each time step. The idea behind is that we will include the most important linear part of the hydrodynamic loading using the results from the computationally efficient frequency domain analysis and the complex nonlinear terms will be added in time domain. Within this approach, the time domain motion equation equivalent to equation in [3.2.1] becomes:

$$([M]+[A^{\infty}])\left\{\frac{d^2\xi}{dt^2}\right\}+([C])\{\xi(t)\}+\int_0^t[K(t-\tau)]\left\{\frac{d\xi}{dt}(\tau)\right\}d\tau$$

$$=\{F(t)\}+\{Q(t)\}$$

Where the different terms on the left hand side can be calculated from the frequency domain hydrodynamic database, F(t) represents the linear part of the wave excitation and Q(t) stands for the different non-linear effects.

We should be very careful when using the above equation in practice! Indeed, the difficulties is that the nonlinear terms represented by Q(t), depend directly on the solution of the motion equation (motion, velocities, acceleration) and unless some complex iteration process is involved the solution of the equation will remain inconsistent. In general it is very difficult to include consistently all the system nonlinearities, both mechanical and, especially, hydrodynamic nonlinearities. That is why, most often, the partial coupled models are used. It is important to realize that these models include only one part of the nonlinear effects i.e. the part which is believed to be the most important one for particular application.

Note 1: Cummings W.E. "The Impulse Response Function and Ship Motion" in David Taylor Model Bassin Report 1661; Washington DC (1962)

4.2 Uncoupled time domain model

4.2.1 The simplest time domain model is the uncoupled model which assumes no interaction between mooring lines or risers dynamic response and the platform dynamic response. Within this model the inertia effects of the mooring lines and risers on the platform motions is usually approximated by modification of the platform inertia while the restoring effects are modelled by simple springs.

In principle there is no need for the time domain model if only the linear terms has to be included, because the frequency domain model can do as well in a more efficient way. The advantage of the time domain model is that some non linear terms (damping, reasonably large motions…) can be included in simplified way.

4.3 Coupled time domain model

4.3.1 As already mentioned there are several types of nonlinearities which should be included in the coupled time domain model:

- Coupling of the mooring lines or risers dynamics and platform dynamics (influence increases with increased water depth)
- Large platform motions
- Drag forces on the hull and on the mooring lines and risers
- Large waves which introduce the important nonlinear hydrodynamic effects
- Nonlinear positioning
- Anchoring system.

Consistent inclusion of these nonlinear terms in the fully coupled motion equation (see [4.1.1]) is far from trivial and should be done with great care.

5 Hydrodynamic model tests

5.1 General

5.1.1 Hydrodynamic model tests in the wave basins might be an important part of the column stabilized unit design process. The numerical modelling and the model tests should be understood and used as complementary tools because both of them have important limitations. The limitations of the numerical models have been discussed in the previous sections and here below we mention few important limitations of the model tests:

- Scale effects:

  Usually the Froude scaling is used which means that the phenomena which are governed by Reynolds number will not be modelled correctly (drag, flow separation…).
- Finite dimension of the existing model basins:

  This might lead to the important reflections from the tank walls, which in turn can significantly pollute the final results.
- Accuracy of the measurements.
- Limited time records of the measurement data.
- High cost.

The responses which are usually assessed using the model tests include motions, risers motions, internal loads in the hull, air-gap and deck clearance, etc.

As already mentioned, the model tests and numerical simulations will be used in a complementary way. These complementarities include in particular the use of the model tests to provide the results for detailed validation of the numerical models, and the use of the numerical models in order to reduce the number of model tests.

The choice of the representative model tests heavily depend on the detailed column stabilized unit design.

6 Other environmental loads

6.1 Wind

6.1.1 Wind represents an important loading source. The wind is represented by its mean and dynamic (gust) components. The dynamic component is usually described by the wind spectrum. The wind condition for design should be determined from the wind data collection on the site. The wind speed and direction usually vary in time which makes its characterization rather difficult.

The wind forces are usually calculated using the simplified approach where the forcing is made proportional to the square of the relative velocity through the use of the so called shape coefficients.

$$F_w = \frac{1}{2}\rho_a C_s A \left|V + v' - \frac{dx}{dt}\right| \left(V + v' - \frac{dx}{dt}\right)$$

where:

r_a : Wind density

C_s : Shape coefficient

A : Characteristic area

V : Wind mean speed

v' : Wind fluctuating speed

dx / dt : Velocity of the structural member.

The shape coefficient can be related to particular structural elements but can also be used in a more global sense where it relates to the projected exposed area of the objects. Its determination is usually based on engineering experience otherwise the dedicated model tests might be performed.

6.2 Current

6.2.1 Depending on the site where the unit is operating, the current forces might play an important role. The site current data need to be collected and should include wind driven, tidal and background circulation components. Similar to the wind, the current data collection and current characterization is not an easy task because the current vary with the water depth both in terms of intensity and direction.

There are two main effects of current:

- Drag forces
- Vortex Induced Vibrations (Motions), VIV(M).

Even though the current effects mainly affect the risers, it has also an impact on the overall unit design. Similar to wind forces, the current induced drag forces are calculated using the simplified approach where the forces are related to the square of the relative velocity through the use of the drag coefficient:

$$F_c = \frac{1}{2}\rho_w \int_L C_D A_c \left|U - \frac{dx}{dt}\right| \left(U - \frac{dx}{dt}\right) dl$$

where:

r_w : Water density

L : Total length of the slender object (riser)

C_D : Drag coefficient

A_C : Characteristic sectional area

U : Current velocity

dx / dt : Velocity of the structural member.

7 Extreme structural response of column stabilized units

7.1 General

7.1.1 For the verification of the structural response of the hull in extreme conditions, the concept of equivalent design wave is employed.

The procedure is performed in two main steps:

a) Determination of the long term value of the critical loading parameters (frequency domain)

b) Definition of the equivalent design wave

c) Nonlinear time domain hydro-structure simulations over the equivalent wave period

d) Loading of structural model and performance of structural calculations.

7.2 Determination of the long term value of the critical loading parameters (frequency domain)

7.2.1 Critical loading parameters are first identified. This is one of the most important steps because it should ensure that the most critical situations for all structural elements will be covered using only limited number of loading parameters. The exact list of the loading parameters will highly depend on the type of the column stabilized unit hull and on the engineering experience.

7.2.2 In order to calculate the long term value of each loading parameter, frequency domain calculations are performed using the linear wave diffraction-radiation theory. The range and number of wave frequencies and wave directions should be chosen in such a way that the design scatter diagram and other environmental conditions (wind, wave directions…) can be covered with sufficient accuracy. Usually this means at least 50 frequencies per wave direction. The outcomes of these calculations are the transfer functions (RAO's) of different loading parameters. Once the RAO's are evaluated, spectral analysis is performed for each sea state in the scatter diagram and long term values are obtained.

7.3 Definition of the equivalent design wave

7.3.1 The equivalent design wave is defined by dividing the long term value of the considered loading parameter by its maximum RAO value. For each loading parameter this gives the wave length, wave direction and wave amplitude of the design wave. In the cases where the peak wave length gives obviously unreasonable conservative results the wave length might need to be adjusted. This will depend on the engineering experience which might be supported by some dedicated calculations of the structural response.

7.4 Nonlinear time domain hydro-structure simulations over the equivalent wave period

7.4.1 Once the design wave characteristics are determined the hydrodynamic loading is transferred from the hydrodynamic model to the structural finite element model. This includes the transfer of:

- hydrodynamic pressures
- inertia loads.

The equilibrium of load components is to be ensured.

It is important to note that, even if the long term analysis is based on the linear frequency domain approach, the application of the design wave should be done in a weakly nonlinear sense. This means that at least the non linear Froude Krylov pressures the non linear hydrostatics and the large body motions should be included.

In the cases where the Morison equation is used for some parts of the structure, these loading should also be transferred to the FE model in an efficient way and should not introduce any unbalance of the FE model.