GUIDE FOR

LOAD AND RESISTANCE FACTOR DESIGN (LRFD) CRITERIA FOR OFFSHORE STRUCTURES

JULY 2016

American Bureau of Shipping
Incorporated by Act of Legislature of
the State of New York 1862

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Foreword

This Guide provides structural design criteria in a Load and Resistance Factor Design (LRFD) format for specific types of Mobile Offshore Drilling Units (MODUs), Floating Production Installations (FPIs) and Mobile Offshore Units (MOUs). The LRFD structural design criteria in this Guide can be used as an alternative to those affected criteria in Part 3 of the ABS *Rules for Building and Classing Mobile Offshore Drilling Units* and Part 5B of the ABS *Rules for Building and Classing Floating Production Installations*, where the criteria are presented in the Working Stress Design (WSD) format, also known as the Allowable Stress (or Strength) Design (ASD) format.

This Guide becomes effective on the first day of the month of publication.

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GUIDE FOR

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CHAPTER 1 General

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CHAPTER 1 General

SECTION 1 Introduction

1 Scope of This Guide

This Guide provides structural design criteria in a Load and Resistance Factor Design (LRFD) format for specific types of:

- Mobile Offshore Drilling Units (MODUs) addressed in the ABS *Rules for Building and Classing Mobile Offshore Drilling Units (MODU Rules)*
- Floating Production Installations (FPIs) in the ABS *Rules for Building and Classing Floating Production Installations (FPI Rules)*
- Mobile Offshore Units (MOUs) in the ABS *Guide for Building and Classing Mobile Offshore Units (MOU Guide)*

The applications of this Guide to specific types of MODUs, MOUs and FPIs are defined in 1-1/3.

General principles of the LRFD-based design are described in Chapter 1, Section 2. The LRFD-based structural design criteria are specified in Chapters 2 and 3.

3 Applications

The LRFD-based structural design criteria in this Guide can be used as an alternative to those affected criteria in Part 3, Chapter 2 of the *MODU Rules* and Part 5B of the *FPI Rules*, where the criteria are presented in the Working Stress Design (WSD) format, also known as the Allowable Stress (or Strength) Design (ASD) format. 1-1/Table 1, below, summarizes the applications of the LRFD-based structural design criteria specified in this Guide as well as the corresponding WSD-based criteria in the *MODU Rules* and the *FPI Rules*. The WSD and LRFD versions of structural design criteria are considered equally valid, and either may be used to satisfy part of the ABS classification requirements. However, except as directed herein, it is not permissible to mix parts of the WSD and LRFD criteria.

TABLE 1
References of LRFD and WSD Structural Design Criteria

Type of Structures		*LRFD Criteria*	*WSD Criteria*
MODU or MOU (1)	Self-Elevating (Drilling) Unit	This Guide: Chapter 1, and Chapter 2 Sections 1 and 2	*MODU Rules*: Part 3, Chapter 1 and Sections 3-2-1, 3-2-2 and 3-2-3
	Column-Stabilized (Drilling) Unit	This Guide: Chapter 1, and Chapter 2 Sections 1 and 3	*MODU Rules*: Part 3, Chapter 1 and Sections 3-2-1, 3-2-2 and 3-2-4
FPI (2)	Column-Stabilized Installation	This Guide: Chapter 1, and Chapter 3 Sections 1 and 2	*FPI Rules*: Section 5B-1-1 and 5B-1-2
	Spar Installation	This Guide: Chapter 1, and Chapter 3 Sections 1 and 3	*FPI Rules*: Sections 5B-3-1, 5B-3-3, 5B-3-4 and 5B-3-5

Notes:

1 The definitions of MODU and MOU and the specific types of these Units referenced in the table can be found in Part 3, Chapter 1 of the *MODU Rules* and Chapter 2 of the *MOU Guide*.

2 The definitions of FPI and the specific types of FPIs referenced in the table can be found in Part 5B Chapters 1 and 3 of the *FPI Rules*.

The structural design criteria of this Guide, the *MODU Rules* and the *FPI Rules* rely on references to other standards, in particular the ABS *Guide for Buckling and Ultimate Strength Assessment for Offshore Structures (Buckling Guide)*. ABS has issued different WSD and LRFD versions of the *Guide for Buckling and Ultimate Strength Assessment for Offshore Structures*. Only the version of the Guide that is compatible with the selected format of structural design criteria is to be used.

5 Terms and Definitions

For the purpose of this Guide, the following terms and definitions apply. Additional applicable terms and definitions can be found in the *MODU Rules*, the *FPI Rules*, and the *MOU Guide*.

5.1 Terminology

5.1.1 Characteristic Value

A value of load or resistance established with respect to a prescribed probability of not being violated by an unfavorable value.

5.1.2 Design Value

A value of load or resistance obtained from a representative value that has been modified by the appropriate load or resistance factors.

5.1.3 Factored Load

The representative value of a load multiplied by a load factor, which may be greater than, less than, or equal to 1.0.

5.1.4 Factored Resistance

The representative value of a resistance divided by a resistance factor usually greater than 1.0.

5.1.5 Limit State

A state beyond which the structure, or some part of the structure, no longer fulfils specified design criteria

5.1.6 Load Effect

An effect of a load on the structure, for example, internal forces, internal moments, stresses, strains, rigid body motions, and elastic deformations.

5.1.7 Nominal Value

A value of load or resistance that may not have a statistical basis. It is based on applicable experience or is obtained from a recognized reference standard or recognized code (i.e., criteria mandated by the cognizant governmental authority).

5.1.8 Representative Value

A value of load or resistance that is used to verify the limit state. The representative value can be a characteristic or nominal value or other rationally determined value of the variable. The representative value of a load can relate to upper or lower bound characteristic values.

5.1.9 Resistance

The capacity of a structural component, the cross-section of a component, or a structural detail to withstand the effects of loads.

5.1.10 Unfactored (Load or Resistance)

Where the load or resistance factor to be applied is 1.0.

5.3 Abbreviations

ABS	American Bureau of Shipping
AISC	American Institute of Steel Construction
ALS	Accidental Limit State
API	American Petroleum Institute
ASD	Allowable Stress (or Strength) Design
FPI	Floating Production Installation
FLS	Fatigue Limit State
ISO	International Organization for Standardization
LRFD	Load and Resistance Factor Design
MOU	Mobile Offshore Unit
MODU	Mobile Offshore Drilling Unit
NACE	National Association of Corrosion Engineers
SLS	Serviceability Limit State
ULS	Ultimate Limit State
WSD	Working Stress Design

7 References

References are made in this Guide to ABS Rules and other criteria issued by ABS and other organizations. Unless otherwise noted, the applicable edition of a reference is the one officially issued and available on the date the Agreement for Classification is accepted by ABS. Where a particular edition or date associated with a reference is given, it means that particular edition is relevant to the topic being presented in this Guide. Use of a later edition may be permitted upon consultation with ABS. ABS may consider at its discretion, upon the request of the Owner, the application of other appropriate alternative methods and recognized codes of practice.

i) ABS *Rules for Building and Classing Floating Production Installations (FPI Rules)*

ii) ABS *Rules for Building and Classing Mobile Offshore Drilling Units (MODU Rules)*

iii) ABS *Guide for Building and Classing Mobile Offshore Units (MOU Guide)*

iv) ABS *Rules for Conditions of Classification – Offshore Units and Structures (Part 1)*

v) ABS *Rules for Materials and Welding (Part 2)*

vi) ABS *Rules for Building and Classing Steel Vessels (Steel Vessel Rules)*

vii) ABS *Guide for Buckling and Ultimate Strength Assessment for Offshore Structures (LRFD Version) (LRFD Buckling Guide)*

viii) ABS *Guide for Certification of Lifting Appliances (Lifting Appliance Guide)*

ix) ABS *Guide for the Class Notation Coating Performance Standard (CPS)*

x) ABS *Guide for the Fatigue Assessment of Offshore Structures (Fatigue Guide)*

xi) ABS *Guidance Notes on the Dynamic Analysis for Self-Elevating Units*

xii) AISC Specification (LRFD), *Specification for Structural Steel Buildings*, ANSI/AISC-360-10, 2010 (Only the LRFD formatted criteria are relevant to this Guide)

xiii) API RP 2A-LRFD, *Recommended Practice for Planning Designing and Constructing Fixed Offshore Platforms – Load and Resistance Factor Design*, First Edition, 1993, and Supplement 1, 1997 *xiv)* API Specification 2C, *Specification for Offshore Pedestal Mounted Cranes*

xv) ISO 19902, *Petroleum and natural gas industries – Fixed steel offshore structures,* 2007

xvi) ISO 19904-1, *Petroleum and natural gas industries – Floating offshore structures – Part 1: Monohulls, semi-submersibles and spars,* 2006

xvii) ISO 19905-1, *Petroleum and natural gas industries – Site-specific assessment of mobile offshore units – Part 1: Jack-ups,* 2012

CHAPTER 1 General

SECTION 2 Principles of the LRFD Method

1 LRFD Criteria Format

In the framework of LRFD-based design method, the adequacy of a design is verified by demonstrating that the effects of the factored loads do not exceed the factored resistance for each limit state under consideration.

The factored loads are normally defined through a combination of the representative values of loads in various load categories modified by relevant load factors. Load factors can be greater than, less than, or equal to 1.0.

The effects of the factored loads are the responses of the structure subjected to the factored loads. The structural responses are typically expressed in the form of, for instance, internal forces, internal moments, stresses, strains, rigid body motions, and elastic deformations.

The factored resistance is the representative value of the resistance divided by a resistance factor usually greater than 1.0.

3 Limit States

A limit state is defined as a condition beyond which a structure, or some part of the structure, exceeds a specified design criterion. The common limit states in structural design are those for: serviceability, ultimate resistance to loads (i.e., strength), fatigue endurance, and the ability of the structure to survive an accidental event. Accordingly, these limit states are referred to by the names Serviceability Limit State (SLS), Ultimate Limit State (ULS), Fatigue Limit State (FLS), and Accidental Limit State (ALS).

i) *Ultimate Limit State (ULS)* – The ultimate limit state relates to conditions when a structure loses its ability to carry load in the manner assumed in the structural design and analysis. The ultimate limit state can occur due to yielding or buckling.

ii) *Fatigue Limit State (FLS)* – The fatigue limit state relates to the failure of a structural component due to cyclic load effects leading to fracture.

iii) *Accidental Limit State (ALS)* – The accidental limit state relates to criteria to be satisfied for specified damage conditions.

iv) *Serviceability Limit State (SLS)* – The serviceability limit state primarily deals with issues that could affect such things as: appearance, comfort, excessive deformations, etc. These are not ordinarily within the scope of Classification as described in the *MODU Rules* or the *FPI Rules*. General guidance on SLS is provided in Chapter 2 and Chapter 3 of this Guide.

The limit states related to ultimate strength, fatigue resistance and accidental conditions (ULS, FLS and ALS) are those addressed in this Guide.

5 Load Categories

The main load categories are referred to by the symbols *D*, *L*, *E*, and *S* for Permanent, Variable, Environmental, and Supplementary loads, respectively. The use of the symbols *D* and *L* for Permanent and Variable loads reflects common usage in many other standards for offshore structures, such as those published by API and ISO. Historically, the Permanent and Variable load categories were respectively called Dead and Live loads; hence the symbols *D* and *L*.

In LRFD criteria, different load factors may be applied to these different categories of load. The Permanent and Variable load categories comprise the gravitational loads, and there may be different load factors assigned to these load categories for the different required design load combinations.

7 Resistances

Resistance is the capacity of a structural component, the cross-section of a component, or a structural detail to withstand the effects of loads.

The resistances of steel structural components, as considered herein for ULS and ALS, are based on the usual assumption of linear elastic behavior with modifications to account for inelastic effects in buckling and plastic behavior of a member's cross-section.

The resistance of a steel structural detail to fatigue fracture, as considered herein for FLS, is most commonly established in terms of the S-N curve approach coupled with a linear cumulative damage method (Palmgren-Miner's Rule).

The values for structural responses and resistances are assumed to be calculated independently. In the case where non-linear analysis is used and structural responses and resistances are calculated simultaneously, equivalent levels of safety to those implicit in this Guide are to be maintained.

CHAPTER 2 Structural Design of Mobile Offshore Units

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CHAPTER 2 Structural Design of Mobile Offshore Units

SECTION 1 General Design Considerations

1 Structural Analysis

1.1 Analysis of Primary Structure

The adequacy of the scantlings specified in Chapter 2, Sections 3 and 4 for self-elevating units and column-stabilized units and of the other effective structural elements of the primary frame of the unit is to be analyzed in accordance with 2-1/1. The term "Unit" used in this Chapter refers to the specific type of MODU and MOU addressed in this Guide.

The primary structure of the Unit is to be analyzed using the loading conditions stipulated below and the resultant stresses or internal forces and moments are to be determined. To determine critical cases, conditions representative of all modes of operation are to be considered. Calculations for critical conditions are to be submitted for review. The analysis is to be performed using recognized calculation methods and is to be fully documented and referenced.

For each loading condition considered, the following stresses or internal forces and moments are to be determined, and are not to exceed the ULS criteria in 2-1/3.

i) Stresses or internal forces and moments due to static loadings only, where the static loads include operational gravity loadings and weight of the Unit, with the Unit afloat or resting on the sea bed in calm water.

ii) Stresses or internal forces and moments due to combined loadings, where the applicable static loads in *i)* are combined with relevant environmental loadings, including acceleration and heeling forces.

iii) For a self-elevating unit when 2-3/5.7 applies, the stresses or internal forces and moments due to preloading.

1.3 Consideration of Local Load Effects

Local load effects are to be combined with primary stresses or internal forces and moments, where applicable, to determine total load effects.

1.5 Combination of Load Effect Components

The scantlings are to be determined on the basis of a method included in a recognized standard which combines the individual load effect components acting on various structural elements of the Unit.

1.7 Consideration of Buckling

The possibility of buckling of structural elements is to be considered.

1.9 Determination of Bending Stresses

1.9.1 Effective Flange Area

The required section modulus of members such as girders, webs, etc., supporting frames and stiffeners is to be obtained on an effective width of plating basis in accordance with the following criteria.

i) The section is to include the structural member in association with an effective width of plating not exceeding one-half the sum of spacing on each side of the member or 33% of the unsupported span ℓ, whichever is less.

ii) For girders and webs along hatch openings, an effective breadth of plating not exceeding one-half the spacing or 16.5% of the unsupported span ℓ, whichever is less, is to be used.

iii) The required section modulus of frames and stiffeners is assumed to be provided by the stiffener and a maximum of one frame space of the plating to which it is attached.

1.9.2 Eccentric Axial Loading

Where appropriate, elastic deflections are to be taken into account when determining the effects of eccentricity of axial loading. The resulting bending moments are to be superimposed on the bending moments computed for other types of loadings.

1.11 Determination of Shear

When computing shear in structural members, only the effective shear area of the web of the member is to be considered as being effective. In this regard, the total depth of the member may be used as the web depth.

1.13 Stress Concentration

The effect of notches, stress raisers and local stress concentrations is to be taken into account when considering load carrying elements. When stress concentrations are considered to be of high intensity in certain elements, the acceptable stress levels will be subject to special consideration.

1.15 Analysis and Details of Structural Connections

Unless connections of structural members are specifically detailed as hinged joints, proper consideration is to be given in the structural analysis to the degree of restraint at such connections. Structural connections are to be detailed in such a manner as to achieve full transmission of load effects between members joined, and to minimize stress concentrations. The following details are to be considered, as may be appropriate:

i) Shear web plates, continuous through the joint, to transmit tension and compression loads between members by means of shear in the web plate

ii) Flaring or transitioning of the joint, to lower stress concentrations of stress

iii) Thicker joint material, high strength steel, or both, consistent with good weldability, to reduce the effect of high load effects

iv) Brackets or other supplemental transition members, with scallops and proper end attachment details to minimize high stress concentrations

Critical connections that depend upon the transmission of tensile stresses through the thickness of the plating of one of the members may result in lamellar tearing and are to be avoided wherever possible. Where unavoidable, plate material with suitable through-thickness (Z direction) properties may be required with appropriate inspection procedures.

1.17 Fatigue Analysis

The possibility of fatigue damage due to cyclic loading is to be considered in the design of the major structure of self-elevating units and column-stabilized units.

The type and extent of the fatigue analysis will be dependent on the intended mode and areas of operations to be considered in the Unit's design. An appropriate loading spectrum, in accordance with accepted theories, is to be used in the fatigue analysis.

The calculated fatigue life (see 2-1/3.11.1) of the structure is to be at least the design life of the Unit, but not less than 20 years.

1.19 Plastic Analysis

Plastic analysis methods will be subject to special consideration.

3 Load and Resistance Factor Design Criteria

3.1 General

The adequacy of a design is to be verified by demonstrating that the effects of the factored loads do not exceed the factored value of the resistance for each limit state under consideration.

3.3 Limit States

Limit states related to ultimate strength, fatigue resistance and accidental conditions (i.e., ULS, FLS, and ALS as specified in 1-2/3) are addressed in this Chapter. Accidental limit states (ALS) are included as Classification requirements to check the reserved strength (redundancy) of a column-stabilized unit with assumed structural overloads and damages.

Note: The concentration on structural strength and fatigue resistance reflects existing criteria in the *MODU Rules*. As guidance, in a situation where SLS is considered, a load factor of 1.0 is typically used. The resistance factor is also typically taken as 1.0 to reflect nominal parameters such as structural stiffness when calculating deflections; but in general the load and resistance factors should be specially considered depending on the particular situation being assessed.

3.5 Load Categories

3.5.1 General

The main load categories, as described in 1-2/5, are referred to by the symbols *D*, *L*, *E*, and *S* for Permanent, Variable, Environmental and Supplementary loads, respectively. Definitions of the load categories to be used in LRFD criteria for mobile offshore units are as follows.

3.5.2 Permanent (*D*) loads

For a particular design situation, permanent (*D*) loads are those for which variations in magnitude with time during the life of the structure are small in relation to the mean value, or the load attains some limiting value. Permanent loads include the self-weight of the structure including:

i) The weight in-air of the structure including any permanent ballast

ii) Weight of equipment and other permanently mounted objects

iii) The weight of water enclosed in the structure

Note: The weight of water in a compartment that is intended to be unflooded should be considered if specified damage assumptions would lead to compartment flooding, or water leak detection for the compartment is not provided.

iv) Weights of mooring and riser systems

v) The weight of equipment that can be added or removed from the Unit

vi) The weight of living quarters, helideck and other life-support equipment, diving equipment, utilities that can be added and removed from the Unit

vii) Mooring and riser pretensions

Note: Some systems, such as those used for mooring and drilling, and marine risers have monitoring and control features that limit the maximum forces that may be applied to the structure. In such a case it might be more appropriate to categorize the load as "Supplementary", and to use the load factor associated with the maximum force.

viii) *Hydrostatic Pressure.* Hydrostatic pressure is to be considered for all submerged structural members. Also to be considered is the fluid pressure of a permanent nature on local structure of tanks, considering overflow and vent heights, and overpressure protection device settings.

ix) *Inclination Induced Loads.* Gravity loads considering appropriate components from heel and trim in static conditions.

Note: These are not the additional lateral displacements of the global structure of a self-elevated unit known as the *P-Δ* effect, nor the indirect environmentally-induced load effects, as described in 2-1/3.5.4, arisen from the floating Unit's offsets and rotations from "still-water" positions that can produce vertical and lateral components of gravity loads. The second order *P-Δ* effect is accounted for in all categories of applied factored loads (*D*, *L*, *E*, and *S*), by various means; such as by modifying the global stiffness of the structure to produce the increased (amplified) structural load effects that are subsequently evaluated in the LRFD criteria in 2-1/3.11, below.

3.5.3 Variable (*L*) loads

Variable (*L*) loads generally vary in magnitude, position and direction during the life of the structure, and are usually related to operations and normal use of the structure. The representative value of a variable load is to be taken as the maximum (or minimum) value that produces the most unfavorable effects in the structure under consideration. They include:

i) The weight of consumables, supplies, and fluids in pipes, tanks and equipment. The weight is calculated using the heaviest Unit weight of the items to be handled in the largest volumes or quantities for each considered mode of operation of the Unit.

ii) Variable ballast

iii) The weights of ice and snow

iv) Variable uniform loads on the decks

Unless specified otherwise by the Owner, the following minimum loadings are to be used for designing the local and global aspects of the deck structure. However, the total variable load on a floating Unit is to be established considering the required floating position in still water and the intact and damage stability requirements.

- Crew spaces (walkways, general traffic area, etc.)

  4510 N/m^2 (460 kgf/m^2, 94 lbf/ft^2) or 0.64 m (2.1 ft) head

- Work areas

  9020 N/m^2 (920 kgf/m^2, 188 lbf/ft^2) or 1.28 m (4.2 ft) head

- Storage areas

  13000 N/m^2 (1325 kgf/m^2, 272 lbf/ft^2) or 1.84 m (6.0 ft) head

v) Short term forces exerted on the structure from operations such as lifting, machinery operation, vessel mooring and helicopter landing. The nominal value to be used in design is to be the maximum capacity of the machine involved and is to include, as applicable, dynamic and impact effects.

vi) *Operational or Functional Loads.* As applicable, loads induced by the operations of drilling, production, storage, and offloading.

Note: Some systems, such as those used for mooring and drilling, and marine risers have monitoring and control features that limit the maximum forces that may be applied to the structure. In such a case it might be more appropriate to categorize the load as "Supplementary", and to use the load factor associated with the maximum force.

Particular attention is to be given to the last two mentioned types of variable loads. The design of local structure may entail consideration of impact, usually by the use of an "impact factor" applied to equipment, lifting or other operating load. The factored design load would then be the product of the load factor for the variable load category multiplied by the value of the load that has been increased by the impact factor. However, when considering the global strength of the Unit, consideration of local impact effects is usually not required.

3.5.4 Environmental (*E*) Loads

Loads in this category include those produced directly and indirectly from environmental actions.

Direct loads are imposed by wind, waves, current and other pertinent environmental effects acting on the structure. The effects of icing and snow-fall are to be considered when they are anticipated to significantly alter the direct environmental load due to wind on the structure.

Indirect environmental loads are caused by environmentally-induced load effects. For a floating structure, the environmentally-induced load effects arise from the effects of global motions on the structural system. Examples of these effects include:

i) Displacements (i.e., the Unit's offsets and rotations from "still-water" positions that can produce vertical and lateral gravity load components of weights)

ii) Accelerations (resulting in inertial loads); and

iii) Changes in mooring line forces that result from the Environmental loads.

In addition to the global responses of a floating structure to environmentally-induced loads, the dynamic response of a floating or bottom-founded structure may also need to be considered where significant. For a bottom-founded structure, see 2-3/5.9 concerning wave-induced dynamic responses. Indirect environmentally-induced load effects for a bottom-founded structure arise from the structural system's excitations. These effects include displacements, velocities and accelerations which result in inertial loads.

It should be especially noted that since a structure subjected to motions or dynamic excitations can induce inertial loads that may need to be accounted for explicitly in design, the distinction between these inertia loads from weights and forces that are not associated with mass needs to be observed. For the load combinations specified in 2-1/Table 1, below, *E* is used to designate the environmental loads, which are determined based on the Owner specified environmental criteria.

Note: Because of the geometric configuration of a hull (e.g., a multi-hull of a column-stabilized unit) the maximum wave induced global load effects (e.g., bending moments in the structure connecting the multi-hulls) may be produced by a steep wave that has a height less than the maximum value specified by the Owner; see (3-1-3/1.5 and Appendix 3-2-A2 of the *MODU Rules*).

3.5.5 Supplementary (*S*) Load Category

Considering the nature and possible loadings of a Unit, a supplementary load category is used to recognize the loads arising from two additional sources:

- The first are the load effects produced by imposed deformations of the structure. This has relevance, for example, in the analysis of local structures where the boundary displacements are input to simulate relative deflections.
- The second are the load effects arising from limited, monitored and controlled global loads that do not have the same variability as the *D* and *L* load categories and may therefore be considered separately. In general, suitable mechanisms or devices need to be installed to monitor and control these loads.

Examples of Supplementary (*S*) loads include, as applicable:

i) Taut Mooring pre-tensioning forces, provided that the pre-tensioning forces are suitably monitored so as not to exceed specified values,

ii) The reactions from tensioning devices, such as those used for a riser or drill string, which provide load monitoring and assurance that a specified maximum life-time load will not be exceeded, and

iii) The load effects resulting from the life-time maximum specified or calculated values of settlement or displacement.

In the structural design of components for the position keeping (e.g., mooring) system and its foundation, the breaking strength of the mooing line is the representative design load. This is not a category *S* load, unless a recognized "load release mechanism" is provided.

When calculating the load effects produced from imposed boundary deformations, the factored values of the other, coexisting load categories are to be used.

Note: This is different from a "Serviceability" check of structural deformations to an Owner's specifications where unfactored loads are used.

3.5.6 Special Load Situations

For a self-elevating unit, load cases related to overturning of the unit in the elevated condition and preload may apply; see 2-3/5 concerning these situations.

3.7 Resistances

3.7.1 General

Resistances of steel structural components are to be defined for the ULS, ALS, and FLS, as required in 1-2/7. Definitions of the resistances to be used in LRFD criteria for mobile offshore units are as follows.

3.7.2 Resistances for ULS

The ULS deals with yielding and buckling. The resistance to yielding is usually stated in terms of the yield strength of a structural component. See 2-1/3.15 regarding the required resistance of plated structure subjected to more than one component stress. The criteria applicable to individual beams and plate stiffeners subjected to tensile axial loads and bending can be found in Subsection 2/5 of the *LRFD Buckling Guide*.

Buckling strength is needed to resist compression and shear. The buckling resistance of a structural component is categorized based on the type and usage of the structural component. The ABS *LRFD Buckling Guide* provides the resistance of: individual structural members (rolled shapes and tubulars); stiffened and unstiffened flat plate structures; and stiffened and unstiffened cylindrical shells.

Other recognized standards may be used to obtain representative values of resistance for pertinent member types; such other standards include: API RP 2A-LRFD, ISO19902, ISO 19904-1, ISO 19905-1 and AISC Specification (LRFD). Reference can be made to ISO 19905-1 for determining representative values of resistance for the specialized leg chord cross-sections used in the legs of self-elevating units. See 1-1/7 regarding the applicable editions of these cited references.

3.7.3 Resistances for ALS

The representative resistances of steel structural components for the ALS are to be taken the same as described above for the ULS.

3.7.4 Resistances for FLS

The FLS addresses the fatigue fracture of structural details. The resistance to fatigue fracture is most commonly established in terms of the *S-N* curve approach coupled with a linear cumulative damage method (Palmgren-Miner's Rule). The *Fatigue Guide* provides the FLS resistance criteria.

3.9 Design Conditions for LRFD

The LRFD design conditions for the Unit are to include:

i) Static Loadings (represented by ULS-a in 2-1/Table 1, 2-1/Table 2, and 2-1/Table 3), where the static loads include the *D*, *L*, and *S* categories of load, with the Unit considered afloat or resting on the sea bed in calm water.

ii) Combined Loadings (represented by ULS-b in 2-1/Table 1, 2-1/Table 2, and 2-1/Table 3), where the applicable static loads in *i)* are combined with relevant environmental loadings, including accelerations and heeling forces.

For column-stabilized units, an additional design condition for Structural Redundancy (represented by ALS in 2-1/Table 2) is to be assessed to verify the Unit's ability to withstand the loss of a slender bracing member without causing overall collapse of the Unit's structure.

The ULS and ALS criteria in terms of load combination, load factor and resistance factor are specified in 2-1/Table 1 and 2-1/Table 2 for self-elevating and column-stabilized units, respectively, and 2-1/Table 3 for common structures.

3.11 Format of LRFD Criteria

3.11.1 General

The ULS or ALS criterion is expressed as follows; a structural component is satisfactory if the design load effects, Q, are less than or equal to the design resistance, R_d, or:

$$Q \leq R_d$$

The total factored load, F_d, used to establish the design load effect, Q, is determined from the following load combination

$$F_d = \gamma_{f,D}D + \gamma_{f,L}L + \gamma_{f,E}E + \gamma_{f,S}S$$

where

$\gamma_{f,*}$ = load factor appropriate to the load categories, [* = D, L, E, or S]

D = representative values of permanent loads

L = representative values of variable loads

E = representative values of environmental loads

S = representative values of supplementary loads

The design resistance (i.e., factored resistance, for ULS and ALS), R_d, is obtained as:

$$R_d = R_k/\gamma_R$$

where

R_k = representative value of component or structural strength

γ_R = resistance factor, typically greater than 1.0 for ULS and ALS

The load combinations and the corresponding load and resistance factors for self-elevating units, column-stabilized units and common structures are specified in 2-1/Table 1, 2-1/Table 2 and 2-1/Table 3, respectively.

For the FLS, the acceptance criterion is typically stated as:

$$T_f \geq T \times FDF$$

where

T_f = calculated fatigue life of a detail (using unfactored loads, as required in 2-1/3.13)

T = design life of the Unit

FDF = Fatigue Design Factor

The criteria to obtain values of calculated fatigue life and FDF are specified in the *Fatigue Guide*.

3.11.2 Nonlinearity and Dynamic Response

The responses of a free-floating Unit, such as a column-stabilized unit, are in general linear to the applied gravity and environmentally-induced loads. Thus, the total design load effects resulting from the combined factored loads, F_d, can be considered as a linear combination of the individual component load effects.

Where nonlinearities are present, such as in the case of a self-elevating unit in the elevated condition where there may be significant nonlinearity arising from leg-hull and spudcan-soil interactions and P-Δ effects, they can be appropriately considered by linearizing their characteristics (e.g., stiffness) using representative values. Unless unfactored loads produce a more stringent result, linearization is to consider factored loads such that the combined factored loads, F_d, is determined prior to undertaking the structural response analysis to obtain the load effects.

Where dynamic response due to waves, or waves combined with current, is to be determined for a self-elevating unit in the elevated condition, the application of load factors depends on the dynamic response analysis method employed. In the 2-step deterministic approach (see the ABS *Guidance Notes on the Dynamic Analysis for Self-Elevating Units* or ISO 19905-1), the first step establishes Dynamic Amplification Factors (DAFs) obtained for the base shear force and the overturning moment. The DAFs are used to represent inertia loads arising in the dynamic response. In this first step analysis, the load factors for all category of load are to be 1.0. In the second step, a linear quasi-static analysis of the structure is to be performed using the load factors found in 2-1/Table 1. The load factor for the *E* category applies to both the deterministic, quasi-static wave, wind and current loads and the inertia loads.

3.13 Load Factors, Resistance Factors and Load Combinations

For each ULS and ALS limit state under consideration, the design load combinations, load factors and resistance factors are as stipulated in 2-1/Table 1, 2-1/Table 2 and 2-1/Table 3 below.

When permanent loads and variable loads are well defined and documented, reduced values of load factor $\gamma_{f,D}$ and $\gamma_{f,L}$ may be used for the ULS-a (Static Loadings) in 2-1/Table 1, 2-1/Table 2 and 2-1/Table 3 and will be subjected to special consideration.

When a permanent load or a variable load is considered as a favorable load that reduces total load responses, a partial safety factor of 1.0 is to be applied to this load. When a variable load is considered a favorable load, the minimum value of this variable load is to be used in the load combination.

For the FLS in any design condition, the load factors for all load categories are 1.0 (i.e., using unfactored loads). See the *Fatigue Guide* for the fatigue resistance criteria.

The resistance factors are to take appropriate account of the uncertainties associated with:

- The modeling of resistances (i.e., strength uncertainties)
- The structural dimensions
- Material properties

For an ULS of a steel structure, the resistance factor, γ_R, is to be taken as 1.05, except as noted under 2-1/Table 1.

TABLE 1
Structure Load Combinations and Corresponding Load Factors (γ_f) and Resistance Factors (γ_R) for Self-Elevating Units

<table>
<tr><th rowspan="3">Design Conditions</th><th rowspan="3">Limit States</th><th colspan="5">Load Combinations</th><th rowspan="3">Resistance Factors γ_R</th></tr>
<tr><th colspan="4">Load Factors $\gamma_{f,*}$ (* = D, L, E or S)</th><th rowspan="2">Environmental Events</th></tr>
<tr><th>D</th><th>L</th><th>E</th><th>S</th></tr>
<tr><td>Static Loadings</td><td>ULS-a</td><td>1.30</td><td>1.50</td><td>--</td><td>1.00</td><td>No Environmental loads, calm water cases</td><td>1.05</td></tr>
<tr><td>Combined Loadings</td><td>ULS-b</td><td>1.10</td><td>1.10</td><td>1.35</td><td>1.00</td><td>The design load cases are to consider:
• The minimum wind conditions of the MODU Rules 3-1-3/1.3.1 with Owner specified accompanying environmental events including inertial loads induced by the Unit's dynamic response; and
• Owner specified wind, wave, current, and other environmental events including inertial loads induced by the Unit's dynamic response.</td><td>1.05</td></tr>
</table>

TABLE 2
Structure Load Combinations and Corresponding Load Factors (γ_f) and Resistance Factors (γ_R) for Column-Stabilized Units

Design Conditions	*Limit States*	*Load Combinations*					*Resistance Factors* γ_R
		Load Factors $\gamma_{f,*}$ (* = D, L, E or S)				*Environmental Events*	
		D	*L*	*E*	*S*		
Static Loadings	ULS-a	1.45	1.45	--	1.00	No Environmental loads, calm water cases	1.05
Combined Loadings	ULS-b	1.10	1.10	1.35	1.00	The design load cases are to consider: • The minimum wind conditions of the *MODU Rules* 3-1-3/1.3.1 with Owner specified accompanying environmental events; and • Owner specified wind, wave, current, and other environmental events.	1.05
Structural Redundancy	ALS	1.00	1.00	0.80	1.00	Same as the Combined condition	1.00

TABLE 3
Structure Load Combinations and Corresponding Load Factors (γ_f) and Resistance Factors (γ_R) for Common Structures

Design Conditions	*Limit States*	*Load Combinations*					*Resistance Factors* γ_R
		Load Factors $\gamma_{f,*}$ (* = D, L, E or S)				*Environmental Events*	
		D	*L*	*E*	*S*		
Static Loadings	ULS-a	1.50	1.50	--	1.00	No Environmental loads, calm water cases Variable loads to include those from maximum owner or manufacturer specified operational and functional loads including impact and dynamic response effects; see 2-1/3.5.3.	1.05
Combined Loadings	ULS-b	1.10	1.10	1.35	1.00	The design load cases are to consider: • Owner specified loads due to environmental events including inertial loads induced by the Unit's dynamic response • The loads resulting from transit	1.05

3.15 Equivalent Stress Criterion for Plated Structures

For plated structures, members may be designed according to the equivalent stress criterion:

$$\sigma_{eqv} \le \varphi F_y/\gamma_R$$

$$\sigma_{eqv} = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x\sigma_y + 3\tau_{xy}^2}$$

where

σ_{eqv} = equivalent stress

σ_x = calculated in-plane stress in the *x* direction due to the factored loads

σ_y = calculated in-plane stress in the *y* direction due to the factored loads

τ_{xy} = calculated in-plane shear stress due to the factored loads

φ = adjustment factor

= 1.15

γ_R = resistance factor from 2-1/Table 1, 2-1/Table 2 or 2-1/Table 3, as appropriate

F_y = specified minimum yield point or yield strength, as defined in Chapter 1 of the ABS *Rules for Materials and Welding (Part 2)*.

Note: When stress components account for surface stresses due to lateral pressures, these criteria will be specially considered.

3.17 Representative Values of Loads

Representative values of loads are to be used with the load factors for limit state checks. 2-1/Table 4, below specifies the representative loads for each load category.

Where variable and environmentally-induced loads occur simultaneously, the representative values may be determined based on their joint probability distribution.

TABLE 4
Representative Values of Loads

Load Category	*Representative Values*	
	ULS-a	*ULS-b*
Permanent (*D*)	Mean(1), specified(2) or calculated value	Mean(1), specified(2) or calculated value
Variable (*L*)	Mean(1), specified(2) or calculated value	Mean(1), specified(2) or calculated value
Supplementary (*S*)	Specified value(2)	Specified value(2)
Environmental (*E*)	None	Specified value(2)

Notes:

1 Arithmetic mean or average

2 A nominal value; or as appropriate, an Owner Specified value

CHAPTER 2 Structural Design of Mobile Offshore Units

SECTION 2 Common Structures

1 General

1.1 Materials

This Guide, except where specified otherwise, is intended for Units constructed of steel, manufactured and having the properties as specified in Chapter 1 of the ABS *Rules for Materials and Welding (Part 2)*. Where it is intended to use steel or other material having properties differing from those specified in Chapter 1 of the above referenced Part 2, the use of such material and the corresponding scantlings will be specially considered.

1.3 Scantlings

Scantlings of the major structural elements of the Unit are to be determined in accordance with This Guide. Scantlings of structural elements which are subjected to local loads only, and which are not considered to be effective components of the primary structural frame of the Unit, are to comply with the applicable requirements of the *Steel Vessel Rules* or the ABS *Rules for Building and Classing Steel Barges (Barge Rules)*.

1.5 Protection of Steel Work

Unless otherwise approved, all steel work is to be suitably coated.

Tanks or preload spaces intended for seawater ballast are to have a corrosion-resistant hard coating on all internal surfaces. Where a long retention of seawater ballast is expected due to the type of the Unit, special consideration for the use of inhibitors or sacrificial anodes may be given.

A corrosion protection and control system utilizing anodes and coating in accordance with the recognized industry standards such as API and NACE is to be provided for the wetted hull structure. The effectiveness of the corrosion protection and control system is to be sustainable for the design life of the Unit. The use of an impressed current cathodic protection (ICCP) system may be considered as an alternative to the anodes. In the splash zone as defined in 7-2-1/3.21.1 of the *MODU Rules*, corrosion allowance is to be added to the external shell plating.

In cases where scantlings are based on 2-1/1 and 2-1/3, and corrosion control methods are not provided, the scantlings are to be suitably increased.

1.5.1 Performance Standards for Protective Coating (PSPC)

Where requested by the Owner, a Unit with protective coatings which are found to comply with the requirements in the ABS *Guide for the Class Notation Coating Performance Standard (CPS)* will be assigned and distinguished in the *Record* with the class notation **CPS**.

3 Helicopter Deck

The Helicopter deck is to comply with the requirements of 3-2-2/3 of the *MODU Rules*.

5 Structures Supporting the Drilling Derrick

5.1 Substructures

Substructures supporting the drilling derrick, drill floor and associated equipment are to be analyzed for the following design loading conditions, as required by 2-1/1. The ULS criteria of 2-1/Table 3 are to be satisfied.

5.1.1 Static Loading Conditions (ULS-a)

Individual loads to be considered in the ULS-a are the operating loads specified by the Owner or designer and should include, but are not limited to the following, as applicable.

- *D* – Permanent load (steel weight, fixed equipment)
- *L* – Variable load (personnel, moveable equipment, material)
- *L* – Snow or ice weights
- *L* or *S*, as appropriate, see 2-1/3.5 – Hook, setback, rotary table and riser tensioner loads

5.1.2 Combined Loading Conditions (ULS-b)

Environmental loads due to wind, including severe storm wind load, are to be combined with the individual loads indicated to reflect the applicable operational requirements for the range of anticipated conditions. Increased wind projected areas due to the presence of ice and snow are to be taken into account. Loads due to Unit's motions are to be considered for all afloat conditions and the load factor for environmental loads *E* is to be used with the motion induced loads.

5.3 Substructure Supporting Arrangement

Moveable cantilevers(1) and skid beams(2) supporting substructures are to be analyzed for the same design loading conditions for substructure as required by 2-1/1. The ULS criteria of 2-1/Table 3 are to be satisfied. Loads imposed on the hull structure are to include maximum reactions from the cantilever or skid beam.

Notes:

1 Moveable cantilever structures are those which extend beyond the hull structure during drilling operations.

2 Moveable skid beam structures are those which are fully supported by hull structure during drilling operations.

7 Watertight Bulkheads and Watertight Flats

7.1 General

Watertight bulkheads and flats are to be in accordance with this Section. In all cases, the plans submitted are to clearly indicate the location and extent of the watertight bulkheads and watertight flats.

For self-elevating units, the watertight bulkheads and watertight flats are to comply with the applicable requirements of Section 3-2-9 of the *Steel Vessel Rules* or Section 3-2-6 of the *Barge Rules*.

For column-stabilized units, the scantlings of the watertight bulkheads and watertight flats are to be indicated on the appropriate plans and are to be made effective to the extent necessary to meet the requirements of damage stability.

7.3 Plating

The plating thickness of watertight boundaries is not to be less than that obtained from the following equation:

$$t = \frac{0.84sk}{c}\sqrt{\frac{\gamma_L P_n}{Y/\gamma_M}} + f \quad \text{mm (in.)}$$

but not less than 6 mm (0.24 in.) or s/200 + 2.5 mm (s/200 + 0.10 in.), whichever is greater.

where

t = thickness in mm (in.)

f = 1.5 mm (0.06 in.)

s = spacing of stiffeners in mm (in.)

k = $(3.075\sqrt{\alpha} - 2.077)/(\alpha + 0.272)$ for $1 \le \alpha \le 2$

= 1.0 for $\alpha > 2$

α = aspect ratio of the panel (longer edge/shorter edge)

c = factor to account for plate edge support condition

= 2.0 for plate edges rotationally restrained

P_n = nominal pressure in N/mm² (kgf/mm², psi)

= $[10.055/10^3]h$ ($[1.025/10^3]h$, $[64/144]h$)

Y = specified minimum yield point or yield strength, in N/mm² (kgf/mm², psi) not to exceed 72 % of the ultimate tensile strength

h = distance, in m (ft), from the lower edge of the plating to the bulkhead deck at center. Also, see 2-2/7.1 for column-stabilized units.

γ_L = load factor

= 1.50

γ_M = resistance factor

= 1.05

7.5 Stiffeners and Beams

The section modulus, *SM*, of each bulkhead stiffener or beam on a watertight flat, in association with the plating to which it is attached, is not to be less than that obtained from the following equation:

$$SM = \frac{0.92c\gamma_L P_n s\ell^2}{8Y_0/\gamma_M} K \quad \text{cm}^3\ (\text{in}^3)$$

where

c = 0.56 for stiffeners with ends attached

= 0.60 for stiffeners with no end attachment

K = 10^6 (1728)

P_n = nominal pressure in N/mm² (kgf/mm², psi)

= $[10.055/10^3]h$ ($[1.025/10^3]h$, $[64/144]h$)

s = spacing of stiffeners, in m (ft)

Y_0 = specified minimum yield strength of ordinary strength steel

= 235 N/mm² [24 kgf/mm², 34 ksi]

h = distance, in m (ft), from the middle of ℓ to the bulkhead deck at center; where the distance is less than 6.1 m (20 ft), h is to be taken as 0.8 times the distance in m plus 1.22 (0.8 times the distance in ft plus 4). Also see 2-2/7.1 and 2-4/5 for column-stabilized units.

ℓ = length of stiffeners, in m (ft); where brackets are fitted with a slope of approximately 45 degrees and thickness given in 2-2/Table 1, the length of ℓ may be measured to a point on the bracket equal to 25% of the length of the bracket.

γ_L = load factor

= 1.50

γ_M = resistance factor

= 1.05

For Units under 45 m (150 ft) in length, the above values for c may be 0.46 and 0.58, respectively, and h may be taken as the distance in m (ft) from the middle of ℓ to the bulkhead deck at center. For Units between 45 and 61 m (150 and 200 ft) in length, interpolated values for c may be used.

TABLE 1
Thickness and Flange Width of Brackets and Knees

The thickness of brackets is to be increased in cases where the depth at throat is less than two-thirds of the knee.

Millimeters

Depth of Longer Arm	*Thickness*		*Flange Width*
	Plain	*Flanged*	
150	6.5		
175	7.0		
200	7.0	6.5	30
225	7.5	6.5	30
250	8.0	6.5	30
275	8.0	7.0	35
300	8.5	7.0	35
325	9.0	7.0	40
350	9.0	7.5	40
375	9.5	7.5	45
400	10.0	7.5	45
425	10.0	8.0	45
450	10.5	8.0	50
475	11.0	8.0	50
500	11.0	8.5	55
525	11.5	8.5	55
550	12.0	8.5	55
600	12.5	9.0	60
650	13.0	9.5	65
700	14.0	9.5	70
750	14.5	10.0	75
800		10.5	80
850		10.5	85
900		11.0	90
950		11.5	90
1000		11.5	95
1050		12.0	100
1100		12.5	105
1150		12.5	110
1200		13.0	110

Inches

Depth of Longer Arm	*Thickness*		*Flange Width*
	Plain	*Flanged*	
6.0	0.26		
7.5	0.28		
9.0	0.30	0.26	$1^1/_4$
10.5	0.32	0.26	$1^1/_4$
12.0	0.34	0.28	$1^1/_2$
13.5	0.36	0.28	$1^1/_2$
15.0	0.38	0.30	$1^3/_4$
16.5	0.40	0.30	$1^3/_4$
18.0	0.42	0.32	2
19.5	0.44	0.32	2
21.0	0.46	0.34	$2^1/_4$
22.5	0.48	0.34	$2^1/_4$
24.0	0.50	0.36	$2^1/_2$
25.5	0.52	0.36	$2^1/_2$
27.0	0.54	0.38	$2^3/_4$
28.5	0.56	0.38	$2^3/_4$
30.0	0.58	0.40	3
33.0		0.42	$3^1/_4$
36.0		0.44	$3^1/_2$
39.0		0.46	$3^3/_4$
42.0		0.48	4
45.0		0.50	$4^1/_4$

7.7 Corrugated Bulkheads

7.7.1 Plating

The plating thickness of corrugated bulkheads is to be as required by 2-2/7.3, with the following modification. The spacing to be used is the greater of the dimensions *a* or *c* as indicated in 2-2/Figure 1. The angle ϕ is to be 45 degrees or greater.

7.7.2 Stiffeners

The section modulus of a corrugated bulkhead, as a stiffener, is to be as required by 2-2/7.5 using the coefficient c = 0.56. The developed section modulus, *SM*, may be obtained from the following equation, where *a*, *t* and *d* are as indicated in 2-2/Figure 1, in cm (in.).

$$SM = td^2/6 + adt/2$$

The above equation is only valid for identical corrugations at both sides of the bulkhead. For other arrangements, the developed section modulus will be specially considered. The spacing of stiffeners in connection with the above equation is to be taken as $a + b$ as indicated in 2-2/Figure 1.

7.7.3 End Connections

The structural arrangements and size of welding at the ends of corrugations are to be designed to develop the required strength of corrugated stiffeners. Joints within 10% of the depth of corrugation from the outer surface of corrugation, d_1, are to have double continuous welds with fillet weld leg size *w* not less than 0.7 times the thickness of bulkhead plating or penetration welds of equal strength. See also 3-2-6/3 of the *MODU Rules* and 2-2/Figure 2.

FIGURE 1
Corrugated Bulkhead

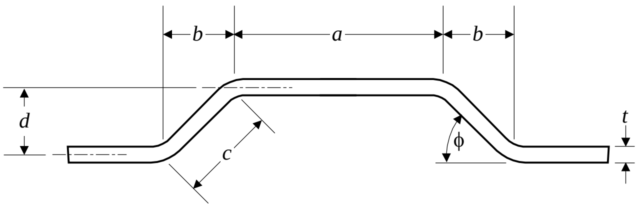
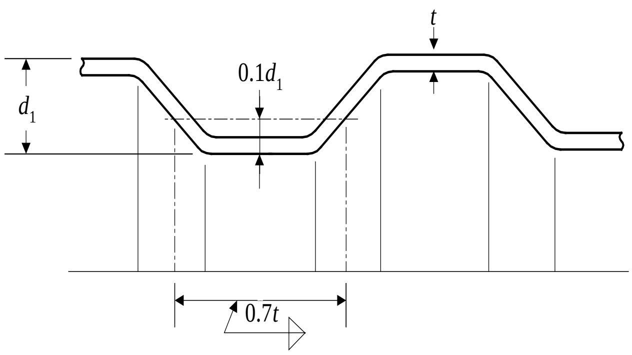


FIGURE 2
Corrugated Bulkhead End Connections



7.9 Girders and Webs

7.9.1 Strength Requirements

Girders and webs which support framing members on watertight bulkheads and flats are to be in accordance with the requirements given in this paragraph. In addition, the girders and webs are to meet the requirements of 2-3/3 or 2-4/3, where applicable. The section modulus, *SM*, of each girder or web is not to be less than that obtained from the following equation:

$$SM = \frac{0.85c\gamma_L P_n s\ell^2}{12Y_0/\gamma_M}K \quad \text{cm}^3\ (\text{in}^3)$$

where

c	=	1.0
K	=	10^6 (1728)
P_n	=	nominal pressure in N/mm^2 (kgf/mm^2, psi)
	=	$[10.055/10^3]h$ ($[1.025/10^3]h$, $[64/144]h$)
s	=	sum of half lengths, in m (ft) (on each side of girder or web), of the stiffeners or beams supported
Y_0	=	specified minimum yield strength of ordinary strength steel
	=	235 N/mm^2 [24 kgf/mm^2, 34 ksi]
h	=	distances, in m (ft), from the middle of the area supported to the bulkhead deck at center, where that distance is less than 6.1 m (20 ft), the value of h is to be 0.8 times the distance in meters plus 1.22 (0.80 times the distance in feet plus 4). (See 2-2/7.1 and 2-4/5 for column-stabilized units.)
ℓ	=	length, in m (ft), between supports, where brackets are fitted at shell, deck or bulkhead supports, and the brackets are in accordance with 2-2/Table 1 and have a slope of approximately 45 degrees, the length ℓ may be measured to a point on the bracket located at the distance from the toe equal to 25% of the length of the bracket.
γ_L	=	load factor
	=	1.50
γ_M	=	resistance factor
	=	1.05

7.9.2 Proportions

Girders and webs are to have a depth not less than ℓ/12. The thickness is not to be less than one percent of depth plus 3 mm (0.12 in.), but need not exceed 11 mm (0.44 in.). In general, the depth of girders or webs is not to be less than twice the depth of cutouts.

7.9.3 Tripping Brackets

Girders and webs are to be supported by tripping brackets at intervals of about 3 m (10 ft) and near the change of the section. Where the width of the unsupported face plate exceeds 200 mm (8 in.), the tripping brackets are to support the face plate.

7.11 Openings

Where stiffeners are cut in way of watertight doors, the openings are to be framed and bracketed to maintain the full strength of the bulkheads without taking the strength of the doorframes into consideration. Reference is made to 6-1-2/9 of the *MODU Rules* for watertight door construction, inspection and testing.

9 Tank Bulkheads and Tank Flats

9.1 General

The arrangement of all tanks, together with their intended service and the height of the air and overflow pipes, are to be clearly indicated on the plans submitted for approval. Tank boundary bulkheads and flats are to have scantlings in accordance with the requirements of this section, where they exceed the requirements of 2-2/7 for watertight bulkheads and flats. However, tight divisional bulkheads and flats between tanks, which will be subjected to equal pressure from both sides at all times, may have scantlings based on 2-2/7. In such cases, the tanks are to be provided with suitable means to ensure that the divisions are subjected to equal pressure from both sides at all times.

When the specific gravity of the liquid contents of a tank is greater than 1.0, the head, *h*, specified below, is to be increased by a factor equal to the ratio of the specific gravity to 1.0.

9.3 Plating

Plating is to be the thickness derived from the following equation:

$$t = \frac{0.95sk}{c}\sqrt{\frac{\gamma_L P_n}{Y/\gamma_M}} + f \quad \text{mm (in.)}$$

but not less than 6.5 mm (0.25 in.) or $s/150 + 2.5$ mm ($s/150 + 0.10$ in.), whichever is greater.

where

t = thickness, in mm (in.)

f = 2.5 mm (0.1 in.)

s = spacing of stiffeners, in mm (in.)

k = $(3.075\sqrt{\alpha} - 2.077)/(\alpha + 0.272)$ for $1 \le \alpha \le 2$

= 1.0 for $\alpha > 2$

α = aspect ratio of the panel (longer edge/shorter edge)

c = factor to account for plate edge support condition

= 2.0 for plate edges rotationally restrained

P_n = nominal pressure in N/mm^2 (kgf/mm^2, psi)

= $[10.055/10^3]h$ ($[1.025/10^3]h$, $[64/144]h$)

h = greatest of the following distances, in m (ft), from the lower edge of the plate to:

i) a point located two-thirds of the distance from the top of the tank to the top of the overflow;

ii) a point located 0.91 m (3 ft) above the top of the tank;

iii) a point representing the load line;

iv) a point located at two-thirds of the distance to the freeboard deck.

Y = specified minimum yield point or yield strength, in N/mm^2 (kgf/mm^2, psi) not to exceed 72 % of the ultimate tensile strength

γ_L = load factor

= 1.50

γ_M = resistance factor

= 1.05

When the specific gravity of the liquid contents of a tank is greater than 1.0, the head, *h*, specified above is to be increased by a factor equal to the ratio of the specific gravity to 1.0.

9.5 Stiffeners and Beams

The section modulus, *SM*, of each bulkhead stiffener or beam on a flat, in association with the plating to which it is attached, is not to be less than that obtained from the following equation:

$$SM = \frac{0.92 c \gamma_L P_n s \ell^2}{8 Y_0 / \gamma_M} K \quad \text{cm}^3 \ (\text{in}^3)$$

where

c	=	0.9	for stiffeners having clip attachments to decks or flats at the ends or having such attachments at one end with the other end supported by girders
	=	1.0	for stiffeners supported at both ends by girders

K = 10^6 (1728)

P_n = nominal pressure in N/mm² (kgf/mm², psi)

= $[10.055/10^3]h$ ($[1.025/10^3]h$, $[64/144]h$)

s = spacing of stiffeners, in m (ft)

h = greatest of the distances, in m (ft), from the middle of ℓ to the same points to which h for plating is measured (see 2-2/9.3)

ℓ = length, in m (ft) between supports; where brackets are fitted at shell, deck or bulkhead supports, and the brackets are in accordance with 2-2/Table 1 and have a slope of approximately 45 degrees, the length ℓ may be measured to a point on the bracket located at a distance from the toe equal to 25% of the length of the bracket

Y_0 = specified minimum yield strength of ordinary strength steel

= 235 N/mm² [24 kgf/mm², 34 ksi]

γ_L = load factor

= 1.50

γ_M = resistance factor

= 1.05

9.7 Corrugated Bulkheads

Where corrugated bulkheads are used as deep-tank boundaries, the scantlings may be developed from 2-2/7.7. The plating thickness t and values of h are to be as required by 2-2/9.3 and 2-2/9.5, respectively, and $c = 0.90$.

9.9 Girders and Webs

9.9.1 Strength Requirements

Girders and webs which support framing members on tank bulkheads and flats are to be in accordance with the requirements given in this paragraph. In addition, the girders and webs are to meet the requirements of 2-3/3 or 2-4/3, where applicable. The section modulus, *SM*, of each girder or web is not to be less than that obtained from the following equation:

$$SM = \frac{0.85 c \gamma_L P_n s \ell^2}{12 Y_0 / \gamma_M} K \quad \text{cm}^3 \ (\text{in}^3)$$

where

c = 1.5

K = 10^6 (1728)

P_n = nominal pressure in N/mm^2 (kgf/mm^2, psi)

= $[10.055/10^3]h$ ($[1.025/10^3]h$, $[64/144]h$)

s = sum of half lengths, in m (ft) (on each side of girder or web), of the stiffeners or beams supported

h = greatest of the distances, in m (ft), from the middle of s in the case of girders or from the middle of ℓ in the case of webs, to the same points to which h for plating is measured (see 2-2/9.3)

ℓ = length, in m (ft), between supports; where brackets are fitted at shell, deck or bulkhead supports, and the brackets are in accordance with 2-2/Table 1 and have a slope of approximately 45 degrees, the length ℓ may be measured to a point on the bracket located at a distance from the toe equal to 25% of the length of the bracket

Y_0 = specified minimum yield strength of ordinary strength steel

= 235 N/mm^2 [24 kgf/mm^2, 34 ksi]

γ_L = load factor

= 1.50

γ_M = resistance factor

= 1.05

Where efficient struts connecting girders or webs on each side of the tanks are fitted, the spacing of the struts is to be not more than four times the depth of the girder or web, and the section modulus, *SM*, for each girder or web may be one-half that obtained from the above.

9.9.2 Proportions

Girders and webs are to have a depth not less than 0.125ℓ where no struts or ties are fitted, and 0.0833ℓ where struts are fitted. The thickness is not to be less than 1 percent of depth plus 3 mm (0.12 in.), but need not exceed 11 mm (0.44 in.). In general, the depth is not to be less than 2.5 times the depth of cutouts.

9.9.3 Tripping Brackets

Girders and webs are to be supported by tripping brackets at intervals of about 3 m (10 ft) near the change of the section. Where the width of the unsupported face plate exceeds 200 mm (8 in.), tripping brackets are to support the face plate.

9.11 Drainage and Air Escape

Limber and air holes are to be cut in all parts of the structure as required to ensure the free flow to the section pipes and the escape of air to the vents. Efficient arrangements are to be made for venting the tops of tanks.

11 Appurtenant Structure

11.1 General

Structures which do not contribute directly to the overall strength of the Unit (i.e., their loss or damage would not impair the structural integrity of the Unit) are considered appurtenant structures.

Appurtenant structures, which are necessary components of safety systems covered by this Guide, or designed to support heavy loads, are to be adequate for the nature and magnitude of applied loads in all modes of operation. Raw Water (seawater intake) structure, flare boom support structure, lifeboat platform for life saving, crane pedestal and pipe racks are considered in this category. Unless noted otherwise, the ULS criteria specified in 2-1/3 are to be satisfied, except for those structural parts whose primary function is to absorb energy during deformation, in which case, sufficient ductility is to be demonstrated.

11.3 Lifeboat Platform

The strength of the lifeboat platform structure supporting the lifesaving appliances is to be designed to meet the following requirements:

i) The most adverse combination of list and trim for which life boat launching is possible with Safe Working Load (total weight of lifeboat, passengers and supplies). The load factors are taken as unity. The representative value of the resistance is the Ultimate Tensile stress and the resistance factor is 4.5.

ii) The most critical motion at the transit draft meeting the Ultimate Limit State criteria (ULS-b) specified in 2-1/Table 3. For self-elevating units the worst motion can be taken as 15° single amplitude rolling or pitching with 10 second period without a motion calculation.

11.5 Crane Pedestal and Foundation

The crane pedestal is to be designed in accordance with the recognized standard that the crane is certified to, such as Chapter 2, "Guide for Certification of Cranes" of the ABS *Lifting Appliance Guide*, or API Specification 2C. The hull structure supporting the pedestal is to be designed to resist the same applied loads as the pedestal using the criteria in the *MODU Rules*.

In addition, the crane pedestal should also be designed to meet the ULS criteria in 2-1/Table 3 considering motion-induced loads in severe storm, normal operating and transit conditions and the operating limits of the crane. The hull structure supporting the pedestal is also to be designed to resist the same applied loads as the pedestal using the ULS criteria in 2-1/Table 3.

11.7 Pipe Racks

Pipe racks including the reinforcements for the hull are to be designed to adequately resist the load effects of drill pipes or risers imposed on the pipe rack supports in the severe storm, normal operating and transit conditions considering the ULS criteria in 2-1/Table 3. Considerations should also be given to the Unit in damaged conditions, where the pipe racks are to withstand the load effects caused by the trim and heel of the Unit with the ULS criteria in 2-1/Table 3, but with a load factor of 1 and a resistance factor, γ_R, of 1.0.

13 Higher-strength Materials

13.1 General

In general, applications of higher-strength materials for stiffeners, beams, girders and webs are to meet the requirements of this Section, but may be modified as permitted by the following paragraphs. Calculations are to be submitted to show adequate provision to resist buckling.

13.3 Watertight Bulkheads and Flats and Tank Bulkheads and Flats

Each stiffener, beam, girder and web of higher-strength material, in association with the higher-strength plating to which it is attached, is to comply with the requirements of the appropriate preceding paragraphs of this Section and is to have a section modulus SM_{hts} not less than obtained from the following equation:

$$SM_{hts} = SM \times Q$$

where

SM = required section modulus in ordinary-strength material as determined in 2-2/7.5, 2-2/7.9, 2-2/9.5, and 2-2/9.9, respectively

Q = See 2-2/Table 2 below

The above criteria is also applicable to the required section modulus for corrugated watertight and tank bulkheads of higher-strength material, as determined in 2-2/7.7.2 and 2-2/9.7, respectively.

TABLE 2
Values of *Q*

Specified Minimum Yield Stress, N/mm^2 *(kgf/mm*^{2}*, ksi)*	*Q*
235 (24, 34)	1.0
265 (27, 38)	0.93
315 (32, 46)	0.78
340 (35, 49)	0.74
355 (36, 51)	0.72
390 (40, 57)	0.68

Notes:

1 Intermediate values are to be calculated by linear interpolation.

2 *Q* factors for steels having a yield stress higher or lower than shown above will be specially considered.

CHAPTER 2 Structural Design of Mobile Offshore Units

SECTION 3 Self-Elevating Units

1 Application

This Section applies to Self-Elevating Drilling Units, as defined in 3-1-1/3.1 of the *MODU Rules*, and Self-Elevating Units, as defined in 2-1/5.1 of the *MOU Guide.*

3 General Requirements for Materials and Scantlings

3.1 Material Selection and Welding

Material selection for self-elevating units is to comply with 3-2-3/3.1 of the *MODU Rules.* Section 3-2-6 of the *MODU Rules* is to be used to establish the welding requirements for the hull.

3.3 Scantlings

Scantlings of the major structural elements of a self-elevating unit are to be determined in accordance with the requirements of Chapter 2, Sections 1 and 2. Where applicable, and except as outlined below, scantlings are also to meet the requirements of the *Steel Vessel Rules* or the *Barge Rules*. The section modulus requirement for framing members, in general, may be determined from the equations in 2-4/3, where the values of c, h, s and ℓ are as indicated in 2-3/Figure 1.

5 Units Elevated Modes

5.1 General

In elevated modes, the self-elevating unit is to have sufficient positive downward gravity loading to withstand overturning and an adequate air gap to prevent waves from striking the hull. Each leg is to be adequately preloaded to the maximum anticipated vertical reaction at the spudcan. The requirements in 2-3/5.3, 2-3/5.5 and 2-3/5.7 are to be complied with for a unit in elevated modes.

5.3 Safety Against Overturning

Self-elevating units which are to rest on the sea bed are to have sufficient positive downward gravity loadings on the support footings or mat to withstand the overturning moment, *OTM*, due to the combined environmental loads from any direction with the lateral deflection of the legs taken into consideration.

The safety against overturning is to be assessed using the most unfavorable direction and combination of environmental, permanent, and variable loads in both normal drilling and severe storm conditions.

Self-elevating units with individual footings are to have righting moments, *RM*, calculated about the most unfavorable axis through the center of one or more footings. Both *RM* and *OTM* are calculated using loads for the conditions specified below in 2-3/5.3.1 and a load factor for all categories of loads of 1.0. The *RM* is to satisfy the following relationship.

$$RM \geq 1.1OTM$$

Self-elevating units with a mat are to have righting moments, *RM*, calculated about the most highly stressed edge of the mat. Both *RM* and *OTM* are calculated using loads for the conditions specified below in 2-3/5.3.1 and a load factor for all categories of loads of 1.0. The *RM* is to satisfy the following relationship.

$$RM \geq 1.3OTM$$

5.3.1 Nominal Loading Conditions for Calculation of Safety Against Overturning

5.3.1(a) Normal Drilling Condition. Self-elevating units are assumed to have minimum design variable loads and the cantilever in the most unfavorable position with the associated design drilling load.

5.3.1(b) Severe Storm Condition. Self-elevating units are assumed to have minimum design variable loads and the cantilever in the design position.

5.5 Wave Clearance

A crest clearance of either 1.2 m (4 ft) or 10% of the combined storm tide, astronomical tide, and height of the maximum wave crest above the mean low water level, whichever is less, between the underside of the self-elevating unit in the elevated position and the crest of the wave is to be maintained. This crest elevation is to be measured above the level of the combined astronomical and storm tides.

5.7 Preload

5.7.1 Capability

Self-elevating units without bottom mats are to have the capability of being preloaded such that the vertical leg reaction achieved on each leg is at least equal to the computed maximum vertical leg reaction due to the maximum gravity and functional loads plus overturning load of the severe storm condition. To establish the vertical leg reaction representing the preload, a load factor of 1.0 is applied to all categories of load.

5.7.2 Structural Strength

The self-elevating unit is to have adequate strength to withstand the preload condition. The ULS of the structure is to be assessed by applying a load factor of 1.20 to the preload described in 2-3/5.7.1, and the resistance factor of 1.05.

5.9 Wave-Induced Dynamic Responses

Consideration is to be given to the possibility of structural vibrations induced by the action of waves in the case of self-elevating units in elevated condition. The dynamic response induced by the actions of waves or waves acting with current is to be considered if either of the following conditions is met:

i) The natural vibratory period, T_n (in seconds), of the self-elevating unit in a global translational mode (i.e., either lateral deck sway or surge displacement) is in the range 0.9 to 1.1 times the wave period, T (in seconds).

ii) The dynamic amplification factor (*DAF*), obtained in the manner described below is greater than 1.10.

T_n can be determined from the following equation applied to one leg:

$$T_n = 2\pi \sqrt{(M_e / K_e)} \quad \text{second}$$

where

M_e = effective mass associated with one leg, based on the weight given in N (kgf, lb)

This is to consider: the mass representing the Total Elevated Load (see 3-1-1/16 of the *MODU Rules*) divided by the number of legs; the mass of a leg above its effective clamping location; and one half the mass of a leg below the effective clamping location, excluding the spudcan, but including the added mass of water displaced by the leg. Unfactored loads are to be used to determine the effective mass.

K_e = effective bending stiffness of one leg to resist horizontal displacement at the level of the elevated hull, in N/mm^2 (kgf/mm^2, psi).

The determination of the leg bending stiffness is to consider the leg as being pin-ended at least 3 m (10 ft) below the sea bed, the hull to leg stiffness, and the effects of lateral frame displacement on the leg with the highest compressive load due to the supported weight and the other environmental load effects acting with considered wave and current.

The dynamic amplification factor, *DAF* is determined from the following equation:

$$DAF = \left\{ \left[1 - \left(\frac{T_n}{T} \right)^2 \right]^2 + \left[2c \left(\frac{T_n}{T} \right) \right]^2 \right\}^{-0.5}$$

where

c	=	fraction of critical damping (to be taken ≤ 7 percent)
T	=	wave period, in second

In the case where T_n calculated using the above equation is greater than 1.1 times the wave period, the effect of the rotational stiffness due to spudcan-soil interaction is to be taken into account in the calculation of T_n.

7 Legs

7.1 Legs in Elevated Condition

7.1.1 Leg Types

Legs may be either shell type or truss type. Shell type legs may be considered as either stiffened or unstiffened shells. Legs may have individual footings or may be attached to a bottom mat.

7.1.2 Leg Scantlings

Legs are to be designed to adequately resist the anticipated total elevated loads and environmental loads for all elevated modes of operation. Leg scantlings are to be determined in accordance with an acceptable method of rational analysis. Calculations are to be submitted for review.

When assessing the adequacy of leg strength, the maximum overturning moment or base shear on the self-elevating unit, using the most adverse combination of applicable variable loadings together with the environmental loadings as outlined in Section 3-1-3 of the *MODU Rules* is to be considered for the design conditions described in Section 2-1/3.9. Forces and moments due to lateral frame deflection of the legs (P-Δ effect) and wave induced dynamic response as outlined in 2-3/5.9 are to be taken into account.

7.1.3 Spudcan-Soil Interaction

Legs without mats, which may penetrate the sea bed, are to be considered pinned at least 3 m (10 ft) below the sea bed. However when considering a loading condition that includes the self-elevating unit's dynamic response, credit may be given to the added stiffness provided by spudcan-soil interaction in accordance with 2-3/7.1.4 below. But where use is made of the added spudcan-soil stiffness to offset the effects of dynamic response, it is required that the limiting wave or wave with current condition that satisfies this Guide without the added stiffness is to be established.

7.1.4 Sea Bed Conditions

Where it is desired, as permitted in 2-3/7.1.3, to consider the added stiffness provided by the spudcan-soil interaction, the rotational stiffness from the interaction is limited to a maximum value based on the equations below. The Owner may select individual values of the rotational stiffness from zero (representing the pinned condition) to the maximum as the basis of the conditions that are reviewed in the self-elevating unit's classification and listed in the Operating Manual.

Note: It is suggested that the sensitivity of the self-elevating unit's strength and dynamic response be investigated using a range of values for the spudcan-soil stiffness.

The maximum extent to which this rotational stiffness can be applied to the system, $K_{rs,\ \text{maximum}}$ is defined by the following equations.

$$K_{rs,\ \text{maximum}} = \frac{EI / L}{C_{\min}} \quad \text{N-m/rad (Kip-ft/rad)}$$

$$C_{min} = \frac{1.5 - J}{J + F}$$

$$J = 1 + \frac{7.8I}{A_s L^2}$$

$$F = \frac{12IF_g}{AY^2}$$

where:

I	=	equivalent leg moment of inertia, in m^4 (ft^4)
A	=	equivalent leg axial area, in m^2 (ft^2)
A_s	=	equivalent leg shear area, in m^2 (ft^2)
L	=	leg length, in m (ft), taken as the sum of the distance from the underside of the hull to the sea bed plus the sea bed penetration [min. of 3 m (10 ft)]. The minimum leg lengths to be used in determination of values of $K_{rs,\,maximum}$ is $L_{min} = 4.35\ (I/A_s)^{0.5}$. For leg lengths less than L_{min}, the $K_{rs,\,maximum}$ is to be set at the value obtained when the leg length is L_{min}.
E	=	elastic modulus of the leg material as 200 GPa (4.176×10^6 Kip/ft^2) for steel
F_g	=	parameter to reflect the number of legs
	=	1.125 (for 3 leg self-elevating unit), 1.0 (for 4 leg self-elevating unit)
Y	=	for a 3-leg self-elevating unit, is the distance, in m (ft), between the centerline of one leg and a line joining the centers of the other two legs
	=	or for a 4-leg self-elevating unit, is the distance, in m (ft), between the centers of leeward and windward rows of legs; in the direction being considered

7.3 Legs in Transit Condition

7.3.1 Legs in Field Transit Condition

Leg strength is to be developed to withstand a bending moment caused by a 6-degree single amplitude roll or pitch at the natural period of the self-elevating unit plus 120% of the gravity moment at that angle of inclination of the legs. Special consideration, based on submitted data, will be given to angles of inclination less than 6 degrees when the separation between the bottom of the hull and the top of the mat or the lower tip of the spudcan exceeds 15% of the maximum separation. The structural adequacy of the legs is to be investigated for any anticipated vertical position with respect to the hull during transit moves. The ULS of the leg is to be assessed by applying a load factor of 1.20 to the bending moment specified above and a resistance factor of 1.05.

7.3.2 Legs in Severe Storm Transit Condition

Legs are to withstand acceleration and gravity bending moments resulting from the motions in the most severe anticipated environmental transit conditions, together with wind moments corresponding to a velocity of not less than 51.5 m/s (100 kn). The motions may be determined by acceptable calculation or model test methods. The ULS of the leg is to be assessed using the ULS-b criterion defined in 2-1/Table 1.

Alternatively, legs are to withstand a bending moment caused by minimum criteria of a 15 degree single amplitude roll or pitch at a 10 second period plus 120% of the gravity moment at that angle of inclination of the legs. The structural adequacy of the legs is to be investigated for any anticipated vertical position with respect to the hull during transit moves. For severe storm transit conditions, it may be necessary to reinforce the legs or to remove leg sections. The ULS of the leg is to be assessed by applying a load factor of 1.20 to the bending moment specified above and a resistance factor of 1.05.

9 Hull Interface Structure with Legs

Jackcases and associated supporting bracing systems are to have adequate strength to properly transmit the loads between the legs and the hull using the ULS criteria defined in 2-1/Table 1.

In no case are the unfactored loads imposed at the holding mechanism of the jacking system or the fixation system to exceed the holding capacity defined by the manufacturer of the device for all modes of operation. See Section 6-1-9 of the *MODU Rules*.

For the purpose of providing loading guidance in the operations manual required in Section 1-1-5 of the *MODU Rules* Supplement to the ABS *Rules for Conditions of Classification – Offshore Units and Structures (Part 1)*, friction losses directly related to the leg interfaces are to be considered when establishing the loads imposed on a jacking system during lifting operations. Values for friction losses such as those at the leg guides and at the rack and pinion mesh are to be provided by the relevant designer. Alternatively, for rack and pinion systems, the minimum total friction allowance for the leg interface may be taken as not less than 8% of the torque available on the climbing pinion shaft.

11 Hull Structure

The hull is to be considered as a complete structure having sufficient strength to resist all induced stresses while in the elevated position and supported by all legs using the ULS criteria in 2-1/Table 1. Special attention is to be paid to the maximum total elevated load in the normal operating condition. The total elevated load including gravity and variable loads is to be distributed in accordance with each load's distribution and point of action. The scantlings of the hull are then to be determined consistent with this load distribution, but the scantlings are not to be less than those required by 2-3/3.3.

13 Spudcan and Bottom Mat

13.1 Spudcan

13.1.1 General

The structure of a spudcan is to be designed for the loads imposed on it in both the afloat and the elevated modes of operation. In the afloat mode, the structure is to be capable of withstanding the hydrostatic pressure, taking into account whether or not the spudcan is freely vented to the sea once it is submerged. In the elevated mode, the structure is to be capable of withstanding the loads imposed on it by the leg in accordance with the ULS criteria defined in 2-1/Table 1, and be able to transfer these loads effectively to the foundation beneath it. These loads are composed of the gravity load of the leg and hull; variable and functional loads; the environmental loads from wind, waves, and current acting on the leg and hull; and the effects of any applicable preload conditions. It is important to note that the leg-to-spudcan connections represent a primary load path, and they are to be carefully designed to avoid stress concentrations. It is equally important to consider that a self-elevating unit may be sited in a wide variety of sea bottom conditions, including rocky foundations with virtually zero penetration, soft clay bottoms with deep penetrations, hard sandy bottoms which are prone to scour, and sloping strata that lead to eccentric contact area and therefore eccentric loading on the spudcan.

13.1.2 Afloat Mode Loading Conditions

To address the afloat mode loading conditions, the scantlings of a spudcan are to be designed using the deep tank requirements with appropriate design heads, h. The following values of h are to be used in the formulas given in 2-2/9.3 and 2-2/9.5.

i) For a spudcan that is vented freely to the sea:

a) *Plating:* h = the distance from the lower edge of the plate to the free flooding point or 15.3m [50 ft], whichever is greater.

b) *Stiffeners:* h = the distance from the middle of ℓ to the same points to which h for plating is measured (see above)

c) *Girders:* h = the distance from the middle of ℓ to the same points to which h for plating is measured (see above) *ii)* For a spudcan that is not vented freely to the sea:

a) *Plating:* h = the distance from the lower edge of the plate to the maximum water level, taking into consideration the astronomical and storm tides

b) *Stiffeners:* h = the distance from the middle of ℓ to the same points to which h for plating is measured (see above)

c) *Girders:* h = the distance from the middle of ℓ to the same points to which h for plating is measured (see above)

13.1.3 Elevated Mode Loading Conditions

To address the elevated mode loading conditions, the scantlings of the plating, stiffeners, and girders of the spudcan are to be adequate to resist a load equal to the maximum required preload, evenly distributed over 50% of the bottom area. In addition, the spudcans, including the leg-to-spudcan connections, are also to be adequate to transmit the forces and moments from the leg to the foundation, as follows:

i) *Preload Condition*

The spudcan and the leg-to-spudcan connections are to be designed for a load equal to the maximum required preload, concentrically distributed over a range of bearing areas, from the minimum design penetration up to and including full embedment. The ULS of the spudcan in this condition is to be assessed by applying a load factor of 1.20 to the maximum required preload and the resistance factor of 1.05.

ii) *Normal Operating and Severe Storm Conditions.*

Pin-ended support. The spudcan and the leg-to-spudcan connections are to be designed for the maximum vertical reaction and the associated horizontal reaction in conjunction with 35% of the maximum calculated moment at the lower guide, (to account for the eccentric effects of possible scour and uneven bottom conditions) acting in the most unfavorable direction. The maximum lower guide bending moment is to be calculated with pin-ended conditions.

Partially-fixed support. The spudcan and the leg-to-spudcan connections are to be designed for the following loads:

- The maximum vertical reaction, in conjunction with the associated horizontal reaction and spudcan-soil fixity moment, acting in the most unfavorable direction.
- The maximum spudcan-soil fixity moment in conjunction with the associated vertical and horizontal reactions, acting in the most unfavorable direction.

Notes:

1 If the spudcans are not freely vented to the sea, the effects of hydrostatic pressure are to be included when checking the strength of the spudcans in the preload, normal operating, severe storm, and uneven bottom conditions.

2 The above requirements are for the design of the spudcan and leg-chord-to-spudcan connections. See Chapter 2, Section 1 for loading and strength requirements for self-elevating unit global structural analysis and 2-3/7.1.4 for assumptions of sea bed conditions to be used for structural analyses. The strength requirements of 2-1/Table 3 are to be satisfied.

13.3 Bottom Mat

Mat compartments are to be in accordance with 2-3/3. Particular attention is to be given to the attachment, framing and bracing of the mat in order that loads are properly transmitted between the legs and mat. (See 2-2/9.11 regarding drainage and air escape.) The boundary plating of the tanks which are not vented freely to the sea is not to be less in thickness than would be required for tanks, using a head to the maximum water level, taking into account the astronomical and storm tides. The mat is to be further investigated while resting on the sea bed with 20% of the bottom bearing area washed away due to scouring. See 2-4/5.9.4. Where skirt plates are provided, consideration will be given to their effectiveness in preventing such loss of bottom support due to scouring.

15 Deckhouses

15.1 General

Deckhouses on the main deck are to have sufficient strength for their size and location. When a self-elevating unit is in elevated mode, deckhouses are subjected to the load effects caused by wind, permanent and variable loads. However, when the self-elevating unit is in the transit mode, deckhouses are subjected to the load effects caused by waves in addition to the load effects in the elevated mode. The load effects caused by waves include motion induced inertia and gravity effect due to self-elevating unit's static inclinations.

Deckhouses are to be designed to adequately resist these load effects in accordance with the following Paragraphs. Paragraphs 2-3/15.3 through 2-3/15.11 provide the requirements for basic scantlings of the deckhouses in association with their locations on the deck and functions. Paragraph 2-3/15.13 provides the requirements for the overall strength of the deckhouse in transit.

Note: The basic scantling requirements presented below are nominal and do not reflect either the WSD or LRFD formatted criteria. To be consistent with other ABS Rules and Guides that present criteria for deckhouse structures, the scantling formulas in these Rules and Guides are adopted here. The use of recognized alternative criteria may be considered.

Deckhouses, which are used as protection for openings leading to spaces below main deck, are also to be designed as a watertight boundary. For deckhouses that are cantilevered over the bow of a self-elevating unit, the possibility of wave slamming and impact during transit is also to be considered.

15.3 Design Head

The design head for side and end bulkhead plating and stiffeners of deckhouses on the freeboard deck is to be obtained from the following:

$$h = c\,h_b$$

where

h = design head, in m (ft)

h_b = $0.133L - 3.0$ m ($L \le 100$ m)

= $0.133L - 9.8$ ft ($L \le 328$ ft)

but not to be less than 2.8 m (9.2 ft)

c = 1.0 for front bulkheads

= 0.6 for aft bulkheads

= See 2-3/15.9 for side bulkheads

L = length of the self-elevating unit, in m (ft)

15.5 Plating

The plating thickness is not to be less than that obtained from the following equation:

$t = 3s\sqrt{h}$ mm $\qquad$ $t = s/50\sqrt{h}$ in.

In no case is the plate thickness to be less than $5.0 + 0.01L$ mm ($0.2 + 0.00012L$ in.).

where

s = spacing of stiffeners, in m (ft)

h = design head, as defined in 2-3/15.3

15.7 Stiffeners

Each stiffener in association with the plating to which it is attached is to have a section modulus, *SM*, not less than that obtained from the following equation:

$SM = 3.5sh\ell^2$ cm^3 $\qquad$ $SM = 0.00185sh\ell^2$ in^3

where

s = spacing of stiffeners, in m (ft)

h = design head, as defined in 2-3/15.3

ℓ = tween deck height, in m (ft)

15.9 House Sides

Side bulkheads of houses are generally to have scantlings based on the requirements for after bulkheads of houses. Where they are close to the side shell of the self-elevating unit, they may be required to conform to the requirements of bulkheads of unprotected house fronts.

15.11 End Attachment

Both ends of the webs of lowest tier bulkhead stiffeners are to be efficiently attached.

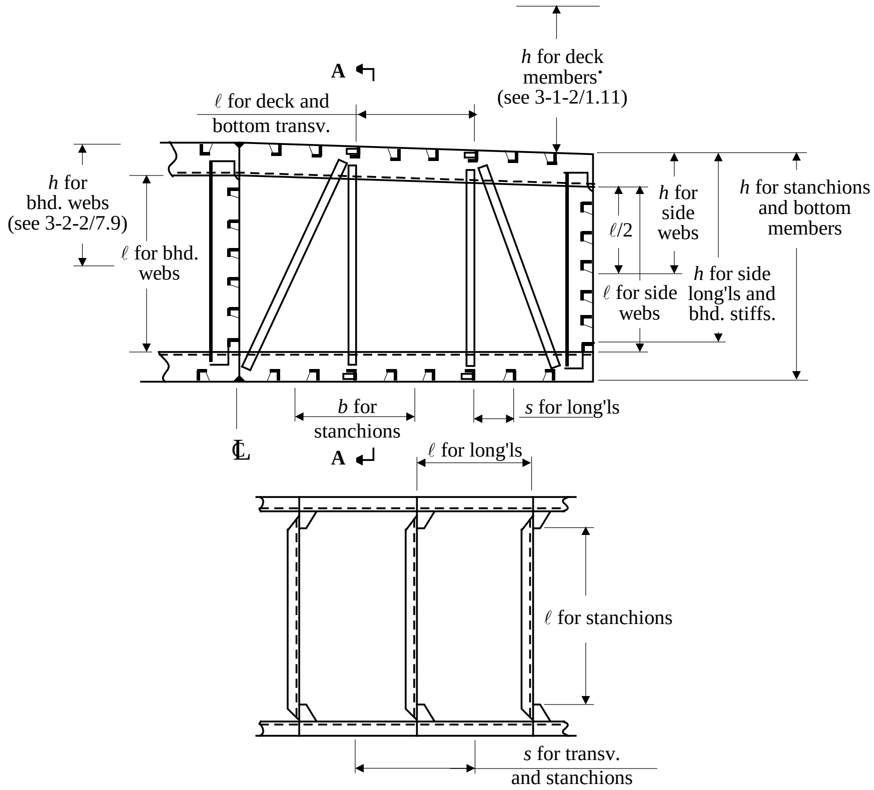
15.13 Racking Resistance

Partial bulkheads, deep webs, etc. are to be fitted at the sides and ends of large deckhouses to provide resistance to racking caused by the most adverse combination of the load effects in 2-3/15.1. Calculations using FEM and the ULS criteria in 2-1/Table 3 to demonstrate the adequacy of the yielding and buckling strength of the large deckhouse may be required to be submitted for review.

17 Structures Supporting the Drilling Derrick

Structures supporting the drilling derrick are to comply with 2-2/5.

FIGURE 1
Typical Hull Construction



Section A-A

*Not to be less than $L/50 + 0.762$ meters ($L/50 + 2.5$ feet), maximum 2.9 m (9.5 ft) where L is the length of the self-elevating unit in m (ft).

Note: Typical transverse section (longitudinal framing) shown.

Bottom transverses (or girders)	$c = 1.50$	Bottom long’ls (or frames)	$c = 1.34$
Side webs (or girders)	$c = 1.50$	Side long’ls (or frames)	$c = 1.00$
Deck transverses (or girders)	$c = 1.00$	Deck long’ls (or beams)	$c = 0.60$
Bulkhead webs (or girders)	$c = 1.00$	Bulkhead stiffeners	$c = 0.70$

Stanchions $W = fbhs$ kN (tf, Ltf)

$f = 10.5$ (1.07, 0.03)

b, h and s in meters (feet)

In way of tanks, scantlings are also to meet the requirements of 2-2/9.

CHAPTER 2 Structural Design of Mobile Offshore Units

SECTION 4 Column-Stabilized Units

1 General

1.1 Application

This Section applies to Column-Stabilized Drilling Units, as defined in 3-1-1/3.3 of the *MODU Rules*, and Column-Stabilized Units, as defined in 2-1/5.3 of the *MOU Guide*.

1.3 Scantlings and Special Considerations Regarding Stresses

Scantlings of the major structural elements of a column-stabilized unit are to be determined in accordance with the requirements of Chapter 2, Sections 1 and 2. Column-stabilized units are to be designed to adequately resist the anticipated total variable loads and environmental loads for all modes of operation. The LRFD design loading conditions depicted in 2-1/3.9 together with appropriate load factors according 2-1/Table 2 are to be used to form the load combinations for the ULS criteria checks.

On column-stabilized units, the highest load effects in some members may be associated with environmental conditions less severe than the maximums specified by the Owner. Where considered necessary, such load effects and the increased probability of their occurrence are to be taken into account and detailed investigation of the fatigue properties are to be performed in order to evaluate the possibility of higher load effects in association with probability of occurrence.

Particular attention is also to be given to the structural details in critical areas such as bracing members, joint connections, etc., where the scantlings may need to be increased or the structural details may need to be modified based on the structural analysis results.

1.5 Effect of Mooring Forces on Local Structure

Local structure in way of fairleads, winches, etc., forming part of the position mooring system, is to be designed for the breaking strength of the mooring line increased by a load factor of 1.2 considering a resistance factor of 1.05 for the steel structure.

1.7 Material Selection and Welding

Material selection for column-stabilized units is to comply with 3-2-4/1.7 of the *MODU Rules.* Section 3-2-6 of the *MODU Rules* is to be used to establish the welding requirements for the hull.

3 Upper Structure

3.1 General

The upper structure is the structure built on top of the columns to provide areas for operations and living quarters for the crew. The upper structure also ties all columns, braces, and lower hull together to form the global strength of a column-stabilized unit. The upper structure can be in a form of a barge hull or a single deck.

The scantlings of the upper structure are not to be less than those required by the following Subparagraphs in association with the loadings indicated on the deck loading plan. These loadings are not to be less than the minimums specified in 2-1/3.5.2 and 2-1/3.5.3. In addition, when any portion of the upper structure is considered to be an effective member of the overall structural frame of the column-stabilized unit, the scantlings are to be sufficient to withstand actual local loadings plus any additional loadings superimposed due to frame action, while satisfying the criteria of 2-1/3.

Note: The basic scantling requirements presented below are nominal and do not reflect either the WSD or LRFD formatted criteria. To be consistent with other ABS Rules and Guides that present criteria for deckhouse structures, the scantling formulas used in the other version of these Rules are used here. The use of recognized alternative criteria may be considered by ABS.

3.3 Deck Plating

3.3.1 General

The thickness of deck or platform plating is not to be less than that required for the purposes of overall strength of the column-stabilized unit, and for local loading.

3.3.2 Storage Area Decks

The thickness of the deck plating in storage areas is to be adequate for the intended service and is not to be less than that obtained from the following equation:

$$t = K S_b \sqrt{h} + a \quad \text{mm (in.)} \qquad \text{but not less than 5.0 mm (0.20 in.)}$$

where

K = 0.0039 (0.00218)

S_b = spacing of deck beams, in mm (in.)

a = 1.5 mm (0.06 in.)

h = tween deck height, in m (ft). When a design load is specified, h is to be taken as p/n, where p is the specified design load, in kN/m^2 (kgf/m^2, lbf/ft^2) and n is defined as 7.05 (715, 45)

3.3.3 Decks in Way of Tanks

In way of tanks, the deck plating thickness is not to be less than that required by 2-2/9.3.

3.3.4 Provision for Fork-Lift Trucks

Where provision is to be made for the use of forklift trucks, and after all other adjustments have been made, the thickness of plated steel decks may be determined as indicated in Section 3-2-3 of the *Steel Vessel Rules*.

3.5 Beams

Each beam, in association with the plating to which it is attached, is to have a section modulus, *SM*, not less than that obtained from the following equation:

$$SM = fchs\ell^2 \quad \text{cm}^3 \text{ (in}^3\text{)}$$

where

f = 7.8 (0.0041)

c = 0.6 for beams clear of tanks

= 1.00 for beams in way of tanks

h = height, in m (ft), equivalent to the design loading, as specified on the design loading plan, but not less than the height specified in 2-1/3.5.2 and 2-1/3.5.3, or in the case of beams of over tanks, two-thirds of the distance, in m (ft), from the top of the tank to the top of the overflow, if that be greater. In cases where the specific gravity of the liquid is greater than 1.0, the required *SM* is to be multiplied by the specific gravity.

s = spacing of beams, in m (ft)

ℓ = length, in m (ft), from the inner edge of the beam knee to the nearest line of girder support, or between girder supports, whichever is greater.

3.7 Girders

3.7.1 Strength Requirements

Each deck or platform girder is to have a section modulus, *SM*, not less than that obtained from the following equation:

$$SM = fchb\ell^2 \quad \text{cm}^3\ (\text{in}^3)$$

where

f = 4.74 (0.0025)

c = 1.0 for girders clear of tanks

1.5 for girders in way of tanks

h = height, in m (ft), as required by 2-4/3.5

b = mean breadth of the area of the deck supported

ℓ = length, in m (ft), of the area of the deck supported between the stanchion and bulkhead; where brackets are fitted at the bulkhead, and the brackets are in accordance with 2-2/Table 1 and have a slope of approximately 45 degrees, the length ℓ may be measured to a point on the bracket equal to 25% of the length of the bracket.

3.7.2 Proportions

Girders on bulkheads and decks clear of tanks are to have a depth not less than 0.0583ℓ and, in general, the depth of girders clear of tanks is not to be less than twice the depth of the cutouts for beams and stiffeners. Girders in tanks are to have a depth not less than 0.125ℓ and, in general, the depth of girders in tanks is not to be less than 2.5 times the depth of the cutout. The thickness is not to be less than 1 percent of depth plus 3 mm (0.12 in.), but need not exceed 11 mm (0.44 in.), provided adequate shear area is maintained as necessary.

3.7.3 Tripping Brackets

Girders are to be supported by tripping brackets at intervals of about 3 m (10 ft), and where the width of the unsupported face plate exceeds 200 mm (8 in.), the tripping brackets are to support the face plate.

3.9 Stanchions and Pillars

3.9.1 Permissible Load

The permissible load, W_a, on a stanchion, pillar or strut is to be obtained from the following equation which will, in all cases, be equal to or greater than the calculated load, W.

$$W_a = (m - n\ell/r)A \quad \text{kN (tf, Ltf)}$$

where

ℓ = unsupported span of the stanchion or pillar, in cm (ft)

r = least radius of gyration, in cm (in.)

A = area of the stanchion or pillar, in cm^2 (in^2)

m = 12.09 (1.232, 7.83)

n = 0.0444 (0.00452, 0.345)

3.9.2 Length

The length, ℓ, for use in the equation is to be measured from the top of the deck or other structure on which the stanchions are based to the underside of the beam or girder supported.

3.9.3 Calculated Load

The calculated load, *W*, for a specific stanchion or pillar is to be obtained from the following equation:

$$W = fbhs \quad \text{kN (tf, Ltf)}$$

where

f = 7.04 (0.715, 0.02)

b = mean breadth of the area supported, in m (ft)

h = height above the area supported, as defined in 2-4/3.5

s = length of the area supported by the pillar, in m (ft)

3.9.4 Pillars under the Tops of Tanks

Pillars under the tops of tanks are not to be less than required by the foregoing. They are to be of solid sections and to have not less area than $1.015W$ cm^2 or $0.16W$ in^2, where *W* is obtained from the following equation:

$$W = fbhs \quad \text{kN (tf, Ltf)}$$

where

f = 10.5 (1.07, 0.03)

b = breadth of the area at the top of the tank supported by the pillar, in m (ft)

h = height, as required by 2-4/3.5, for the beams of the top of the tank, in m (ft)

s = length of the area of the top of the tank supported by the pillar, in m (ft)

3.11 Non-buoyant Upper Structure Not Subjected to Wave Loading

Where it can be shown that the upper structure is not subject to wave loading, not required in any mode of operation to be watertight, nor within the watertight integrity [see plan to be submitted under 1-1-4/1 of the *MODU Rules* Supplement to the ABS *Rules for Conditions of Classification – Offshore Units and Structures (Part 1)*], the scantlings can be determined not taking into consideration of the watertightness nor the effects of the wave loads.

3.13 Buoyant Upper Structure

Where the upper structure is designed to be buoyant in any mode of operation, or to meet any stability requirement, it will be subject to special consideration. The upper structure is to be designed in accordance with the requirements for watertight bulkheads and watertight flats in 2-2/7 using the final damaged waterline.

3.15 Upper Structure Subjected to Wave Loading

Unless adequate wave clearance (2-4/9) can be achieved for all afloat modes of operation, the effect of wave impact is to be taken into account in determining the scantlings of upper structure.

5 Columns, Lower Hulls, and Footings

5.1 General

Main stability columns, lower hulls or footings may be considered either as framed or unframed shells. Ring stiffeners, bulkheads or other suitable diaphragms which are used are to be adequate to maintain shape and stiffness under all anticipated loadings in association with established shell analysis methods.

5.3 Scantlings of Framed Shells

Where the components of columns, lower hulls or footings incorporate stiffened plating, the minimum scantlings of plating, framing, girders, etc., for shells and interior boundary bulkheads and flats may be determined in accordance with the requirements for tanks, as given in 2-2/9, in association with the following.

5.3.1 Tank Space

Where the internal space is a tank, the head, *h*, is to be taken to a point located at two-thirds of the distance from the top of the tank to the top of the overflow, or to a point 0.91 m (3 ft) above the top of the tank, whichever is greater. For tanks intended to carry contents with a specific gravity in excess of 1.0, the head is to be suitably increased in accordance with 2-2/9.1.

5.3.2 Void Compartment Spaces

Where the internal space is a void compartment, the head is to be taken to the maximum permissible draft of the column-stabilized unit in service.

5.3.3 Areas Subject to Wave Immersion

For all areas subject to wave immersion, the minimum head is to be 6.1 m (20 ft).

5.3.4 Minimum Scantlings

In general, the scantlings of boundaries are not to be less than those required by 2-2/7, in association with a head to the maximum damaged waterline.

5.5 Scantlings of Unframed Shells

Where columns, lower hulls or footings do not incorporate framing members, the minimum scantlings of shell plating and ring stiffeners are to be determined on the basis of established shell analysis methods using the heads given in 2-4/5.3 and the strength criteria appropriate to the method employed. Interior boundary bulkheads and flats are to be considered on the basis of framed shells, as given in 2-4/5.3.

5.7 Scantlings of Structural Flats

Scantlings of structural flats which are not required to be watertight are to be determined in accordance with the applicable requirements of 2-4/3.

5.9 Additional Structural Requirements

5.9.1 Provision for Wave and Current Loadings

Scantlings of columns, lower hulls and footings, as determined above, are minimum requirements for hydrostatic loads. Where wave and current loadings are superimposed, the scantlings of the local structure of the shell are to be increased as necessary, to meet the strength criteria of 2-1/3.

5.9.2 Provision for Frame Action

When the column, lower hull or footing is considered to be an effective member of the overall structural frame of the column-stabilized unit, the scantlings are to be sufficient to meet the requirements of 2-4/5, plus any additional stresses superimposed due to frame action, while satisfying the criteria of 2-1/3.

5.9.3 Consideration for High Local Loadings

Particular consideration is to be given to structural details, reinforcement, etc., in areas subject to high local loadings, or to such loadings that may cause shell distortion, for example:

i) Bottom bearing loads, where applicable

ii) Partially filled tanks

iii) Local strength against external damage

iv) Wave impacts

5.9.4 Scouring Consideration

For column-stabilized units intended to rest on the sea bed, the effect of scouring and possible loss of bottom support is to be considered, as follows.

i) For a broad mat type (lower hull) support, 20% of the bottom bearing area is to be considered unsupported.

ii) When there are individual footings or pads, any one such support is to be considered unsupported on 50% of its bottom bearing area.

iii) Other configurations will be specially considered.

Where skirt plates are provided, consideration will be given to their effectiveness in preventing loss of bottom support due to scouring.

5.11 Bracing Members

5.11.1 General

Stresses in bracing members due to all anticipated loadings are to be determined in accordance with the following requirements in conjunction with the relevant requirements of Chapter 2, Section 1.

5.11.2 Loading Conditions

Bracing members are to be capable of transmitting loadings and making the overall structure effective against environmental forces, and when the column-stabilized unit is supported by the sea bed, against the possibility of uneven bottom bearing loads. Although considered primarily as brace members of the overall structure under the designated loadings, the bracing is also to be investigated for superimposed local bending stresses due to buoyancy, wave and current forces, if applicable.

5.11.3 Effect of Wave Impact

Where relevant, consideration is to be given to local stresses due to wave impact.

5.11.4 Reinforcement of Tubular Bracing Members

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

5.11.5 Watertight Bracing Members

When bracing members are watertight, they are to be suitably designed to prevent collapse from external hydrostatic pressure. Underwater bracing members are normally to be made watertight and have a leak detection system to make it possible to detect fatigue cracks at an early stage.

5.13 Openings in Columns

Portlights or other similar openings are not to be fitted in columns.

7 Deckhouses

7.1 General

Deck houses which are not an integral part of the upper deck structure are to have sufficient strength for their size, function and location, with due consideration given to the environmental conditions to which the column-stabilized unit may be exposed. Special considerations should be given to deck houses which act as foundations for vital machinery or equipment.

In general, deckhouses are subjected to the load effects of wind forces, motion-induced inertial forces, live loads, dead weight, and inclination of the column-stabilized unit. Hence, they are to be designed adequately to resist these load effects while satisfying the criteria of 2-1/3 for combined loadings. Depending on the upper structures, the following should also be taken into consideration when designing the deckhouses:

7.1.1 Deckhouses on an Upper Structure Not Subjected to Wave Loading

Deckhouses installed on a non-buoyant upper structure not subjected to wave loading (2-4/3.11) are to be designed to resist the load effects mentioned in 2-4/7.1 above.

7.1.2 Deckhouses on an Upper Structure Subjected to Wave Loading

Deckhouses installed on an upper structure that will be subjected to wave loading (2-4/3.15) are to take the possibility of wave impact loading into consideration in addition to the load effects mentioned in 2-4/7.1 above.

7.1.3 Deckhouses on a Buoyant Upper Structure

Deckhouses installed on a buoyant upper structure (2-4/3.13) should take the required stability requirements into consideration. If the deckhouses are required to be buoyant, they should also be designed as a watertight boundary in accordance with 2-2/7 using the final damage waterline in addition to the load effects mentioned in 2-4/7.1.1 or 2-4/7.1.2 above.

7.3 Storage Tanks on Upper Structure

Storage tanks built into or on upper structure are to have scantlings as required for tanks, as given in 2-2/9.

9 Wave Clearance

9.1 Afloat Modes of Operation

Unless the upper structure and deckhouses are satisfactorily designed for wave impact, reasonable clearance between the deck structures and the wave crests is to be ensured for all afloat modes of operation, taking into account the predicted motion of the column-stabilized unit relative to the surface of the sea. Calculations, model test results or prototype experiences are to be submitted for consideration.

9.3 On-Bottom Modes of Operation

For on-bottom modes of operation, clearances are to be in accordance with those specified in 2-3/5.5 for self-elevating units.

11 Structural Redundancy

11.1 Assumed Damage

When assessing structural redundancy for column-stabilized units, the unit's structure is to be able to withstand the loss of a slender bracing member without causing overall collapse of the unit's structure.

11.3 Analysis

Structural redundancy analyses will be based on the applicable criteria of 2-1/Table 2, noting that:

i) The ALS of the structure after the loss of a slender bracing member can be based on a resistance factor of 1.0. The ALS criterion may be exceeded for local areas, provided redistribution of forces due to yielding or buckling is taken into consideration.

ii) When considering environmental factors, the applied loads are not to be less than 80% of the loads associated with the severe storm condition. (See 3-1-1/17.3 of the *MODU Rules*.)

11.5 Upper Structure

The structural arrangement of the upper structure is to be considered with regard to the structural integrity of the column-stabilized unit after the failure of any relevant element of any primary structural component. Where considered necessary, a structural analysis may be required with loading conditions and strength criteria as in 2-4/11.3.

13 Structures Supporting the Drilling Derrick

Structures supporting the drilling derrick are to comply with 2-2/5.

15 Higher-strength Materials

15.1 General

In general, applications of higher-strength materials for beams and girders are to meet the requirements of this Section, but may be modified as permitted by the following Paragraphs. Calculations are to be submitted to show adequate provision to resist buckling.

15.3 Upper Structure

Each beam and girder of higher-strength material, in association with the higher-strength plating to which it is attached, is to comply with the requirements of the appropriate preceding paragraphs of this Section and is to have a section modulus SM_{hts} not less than obtained from the following equation:

$$SM_{hts} = SM \times Q$$

where

SM = required section modulus in ordinary-strength material as determined in 2-4/3.5 and 2-4/3.7, respectively

Q = See 2-2/Table 2

CHAPTER 3 Structural Design of Floating Production Installations

CONTENTS

CHAPTER 3 Structural Design of Floating Production Installations

SECTION 1 General Design Considerations

1 General

This Chapter provides the LRFD-based structural design criteria for two types of floating production installations (FPIs) (i.e., column-stabilized installations and Spar installations), as defined in 5B-1-1/3 and 5B-3-1/3 of the *FPI Rules*, respectively. The term "Installation(s)" used in this Chapter refers to the specific types of FPIs addressed in this Guide.

The application of the LRFD criteria in this Guide and the WSD criteria in the *FPI Rules* is to be in accordance with 1-1/3. LRFD or WSD structural design criteria are to be applied independently and are not to be used together in the same FPI project. This means LRFD or WSD criteria are to be applied independent of each other in the structural design of hull, topside, non-integrated or integrated deck structures of the Installation. However, in accordance with current industry practice, design criteria for the structural design of mooring systems and helicopter deck structures will continue to use WSD-based criteria, even when the hull, topside, and deck structure are designed to the LRFD-based criteria given in this Guide. Should the designer choose to use recognized LRFD-based design criteria for the mooring systems and helicopter deck structures as an alternative to the criteria given in Part 6 of the *FPI Rules*, this will be specially considered by ABS.

Both the LRFD and the WSD approaches are based on the assumption that design values for responses and resistances are calculated separately. In cases where non-linear analysis is used and responses and resistances are calculated simultaneously, care should be taken to verify that equivalent levels of safety to those implicit in these Rules are obtained.

When considering different modes of operation for a floating structure, all realistic variations in load combinations are to be determined to account for the maximum (or minimum, if more onerous) load effects, whether alone or in combination.

3 Design Conditions

The definition of structural design conditions needs to reflect the Installation's different design phases from Load-out to the Post-installation Operating condition.

"Post-installation" conditions are referred to herein as the *In-place* conditions. The *In-place* conditions are to include the consideration of both intact and damaged conditions.

Design conditions that occur before final installation of the Installation are referred to as the *Temporary* conditions.

5 Environmental Criteria

The Installation is to be designed to withstand a specified extreme storm in the Design Environmental Condition (DEC) and operate in the Design Operating Condition (DOC). Additionally, the Installation is also to be designed for all operations in pre-service conditions such as load out, transportation and installation. The environmental conditions for load out and installation are to be Calm Conditions or as specified by the Owner. The environmental conditions for transportation is to be of a 10-year return event of the selected transit route, unless a weather routing plan is implemented for the voyage.

The above mentioned environmental conditions are defined as follows:

- *Design Environmental Conditions (DEC).* Refer to 3-2-3/1.1 of the *FPI Rules*. For structural strength design, environmental conditions that produce the responses having a minimum return period of 100 years are to be used.
- *Design Operating Conditions (DOC).* Refer to 3-2-3/1.3 of the *FPI Rules*. For structural strength design, environmental conditions that produce responses having a minimum return period of 1 year are to be used.
- *Calm Conditions.* Environmental conditions under which the effects of wind, waves and current are insignificant and can be ignored. Where such a situation exists, the design case is permitted to use calm conditions.

7 Load and Resistance Factor Design Criteria

7.1 General

The adequacy of a design is to be verified by demonstrating that the effects of the factored loads do not exceed the factored value of the resistance for each limit state under consideration.

7.3 Limit States

Limit states related to ultimate strength, fatigue resistance and accidental conditions (i.e., ULS, ALS, and FLS as specified in 1-2/3) are addressed in this Chapter.

Notes: The concentration on structural strength and fatigue resistance reflects existing criteria in the *FPI Rules* for the types of installations addressed in this Guide. As guidance, in a situation where SLS is considered, a load factor of 1.0 is typically used. The resistance factor is also typically taken as 1.0 to reflect nominal parameters such as structural stiffness when calculating deflections; but in general the load and resistance factors should be specially considered depending on the particular situation being assessed.

7.5 Design Conditions for LRFD

The LRFD design conditions are to include the *In-place* and *Temporary* conditions, as defined in 3-1/3.

The Installation's strength for the *In-place* intact condition is to be designed for the ULS criteria for the Design Environmental Condition (DEC) and the Design Operating Condition (DOC). The Installation's strength for the *In-place* damaged condition is to be designed for the ALS criteria.

The design *Temporary* condition is to include loadout, transportation, field transit, upending and topside installation, as applicable, and the Installation's strength for the *Temporary* condition is to be designed for the ULS criteria.

The ULS and ALS criteria in terms of load combinations, load factors and resistance factors are shown in 3-1/Table 1 and 3-1/Table 2. The use of these tables is described in 3-1/7.11 and 3-1/7.13.

7.7 Load Categories

7.7.1 General

The main load categories, as described in 1-2/5, are referred to by the symbols D, L, E, and S for Permanent, Variable, Environmental and Supplementary loads, respectively.

For a structure directly subjected to buoyancy (i.e., the hull structure of the Installation) it is necessary to combine the unfactored Permanent and Variable loads ($D + L$) to compute the resulting buoyancy, and, as applicable, to account for mooring forces. This combination is referred to as the "still-water" loading, and a load factor is then applied to the still-water load combination.

The magnitudes in each load category may also be different for conditions before or after the Installation's on-site installation. For example, the Variable loads associated with an Installation's operational life in the *In-place* conditions may be very different from those of the *Temporary* conditions, for which additional dynamic load considerations due to lifting, etc., should be considered for the D and L loads. Therefore, load magnitudes are to realistically reflect actual conditions expected.

Definitions of the load categories to be used in the LRFD criteria for column-stabilized installations and Spar installations are as follows.

7.7.2 Permanent (*D*) loads

For a particular design situation permanent (*D*) loads are those for which variations in magnitude with time during the life of the structure are small in relation to the mean value, or the load attains some limiting value. Permanent loads include the self-weight of the structure including:

i) The weight in-air of the structure including any permanent ballast

ii) Weight of equipment and other permanently mounted objects, which do not change with the mode of operation of the Installation

iii) The weight of water enclosed in the structure.

Note: The weight of water in a compartment that is intended to be unflooded should be considered if specified damage assumptions would lead to compartment flooding, or water leak detection for the compartment is not provided.

iv) Weights of mooring and riser systems

v) The weight of equipment that can be added or removed from the Installation

vi) The weight of living quarters, helideck and other life-support equipment, diving equipment, and utilities that can be added and removed from the Installation

vii) *Buoyancy.* The buoyancy force is the result of immersion in water to a draft sufficient to balance the vertical permanent and variable weights and mooring forces, including as applicable, initial mooring forces or pretensions.

viii) Mooring and Riser Pretensions

Note: Some systems such as those used for mooring and marine risers have monitoring and control features that limit the maximum forces that may be applied to the structure. In such a case it might be more appropriate to categorize the load as “Supplementary”, and to use the load factor associated with the maximum force.

ix) *Hydrostatic Pressure.* Hydrostatic pressure is to be considered for all submerged structural members. Also the fluid pressure of a permanent nature on local structure of tanks, considering overflow and vent heights, and overpressure protection device settings.

x) *Inclination Induced Loads.* Gravity loads considering appropriate components from heel and trim in static conditions.

Note: These are not the indirect environmentally-induced load effects, as described in 3-1/7.7.5, arisen from the Installation's offsets and rotations from “still-water” positions that can produce vertical and lateral gravity load components of weights.

7.7.3 Variable (*L*) loads

Variable (*L*) loads generally vary in magnitude, position and direction during the life of the structure, and are usually related to operations and normal use of the structure. The representative value of a variable load is to be taken as the maximum (or minimum) value that produces the most unfavorable effects in the structure under consideration. Variable Loads include:

i) The weight of consumables, supplies, and fluids in pipes, tanks and equipment; the weight is calculated using the heaviest unit weight of the fluids to be handled in the largest volumes for each considered mode of operation of the Installation.

ii) Variable ballast

iii) Weights of ice and snow

iv) Variable uniform loads on the topside decks – unless specified otherwise by the Owner – the following minimum loadings should be used for designing the local and global aspects of the topside deck structure. However, the total variable load on a floating Installation is to be established considering the required floating position in still water and the intact and damage stability requirements.

- Crew spaces (walkways, general traffic area, etc.)

  4510 N/m^2 (460 kgf/m^2, 94 lbf/ft^2) or 0.64 m (2.1 ft) head

- Work areas

  9020 N/m^2 (920 kgf/m^2, 188 lbf/ft^2) or 1.28 m (4.2 ft) head

- Storage areas

  13000 N/m^2 (1325 kgf/m^2, 272 lbf/ft^2) or 1.84 m (6.0 ft) head

v) Short term forces exerted on the structure from operations such as lifting, machinery operation, vessel mooring and helicopter landing. The nominal value to be used in design is to be the maximum capacity of the machine involved and is to include, as applicable, dynamic and impact effects.

vi) *Operational Loads.* As applicable, loads induced by the operations of drilling, production, storage and offloading.

Note: Some systems such as those used for mooring and drilling, and marine risers have monitoring and control features that limit the maximum forces that may be applied to the structure. In such a case it might be more appropriate to categorize the load as 'Supplementary', and to use the load factor associated with the maximum force.

7.7.4 Combined Permanent & Variable Loads ($D + L$) for Structures Directly Subjected to Buoyancy

To obtain values of buoyancy for floating structures directly subjected to buoyancy, gravity loads and other relevant loads such as mooring pretensions need to be combined. The individual D and L load components remain unfactored when combined to obtain buoyancy. The resultant gravity and buoyancy combination is traditionally referred to as a "still-water" loading, which for itself has a load factor for each Load Combination. In this Guide, the ($D + L$) load category will have the same load factor in each load combination used to assess Ultimate Limit States, and the definitions of D and L load categories, as given above, include gravity, mooring system weights and pretensions and buoyancy related forces.

Since the same load factor is applied to the D and L loads in the ($D + L$) category, it is not critical to categorize individual loads into the D or L categories. However the magnitudes and distributions of these loads are to be accurately modeled to obtain the appropriate still-water buoyancy distribution; draft, list and trim of the hull; and mooring line forces.

7.7.5 Environmental Loads (E_*)

Loads in this category include those produced directly and indirectly from environmental actions. Direct loads are imposed by wind, waves, current and other pertinent environmental effects acting on the structure. Indirect environmentally-induced load effects for a floating structure arise from the effects of platform motions. These effects include displacements (i.e., the Installation's offsets and rotations from 'still-water' positions which will produce vertical and lateral components of weights) and accelerations (resulting in inertial loads); and changes in mooring line forces that result from the Environmental Loads.

It should be especially noted that since a floating structure subjected to motions can induce inertial loads that may need to be accounted for explicitly in design, the distinction between these inertia loads and a load from a weight or from a force that is not associated with a mass needs to be observed.

The "*" subscript in (E_*) signifies that the magnitude of the environmentally-induced loads depends on the return period required to characterize these loads; or as permitted for some design conditions, by an Owner specified return period or limiting value of sea-state, wind speed, etc. Return periods are specified with respect to the assessment of ULS and ALS.

- As required in 3-1/5 of this Guide and 3-2-3/1.1 of the *FPI Rules*, the return period associated with the *In-place* Design Environmental Condition (DEC) uses a return period of 100 years. The *In-place* Design Operating Condition (DOC) has a minimum return period of 1 year. For an Ocean Transit (Dry Tow) condition, the route specific return period is 10 years. For the *Temporary* conditions including loadout, field transit (wet tow), upending and topside installation; the Return Period may be specified by the Owner. The Owner is to assure that operational plans and environment monitoring for the *Temporary* conditions are compatible with the environmental condition used in the design.

- For the load combinations specified in 3-1/Table 1 or 3-1/Table 2, E_E is used to designate the environmental loads for the DEC; E_O is associated with the DOC; E_{OT} is associated with the Ocean Transit condition; and E_{OS} designates Owner specified values.

  Note: Because of the geometric configuration of a hull (e.g., a multi-hull such as a column stabilized) the maximum wave induced global load effects (e.g., bending moments in the structure connecting the multi-hulls) may be produced by a steep wave that has a height corresponding to a return period less than 100 years. This possibility is to be assessed, and the loads produced by the lower, steep and more frequent wave are to be considered for the DEC.

Directionality of wind, waves and current may be considered if accurate data are available. Where there is no accurate data available, the directionality of wind, waves and current that generates the most unfavorable local and global load effects are to be used for design. Adequate headings for the environment are to be analyzed such that the most critical heading for the environment can be covered.

The dynamic response characteristics of global and local structure are to be appropriately considered when deciding whether an environmentally-induced load can be treated as static or quasi-static. Where warranted, the dynamic response is to be accounted for in the analysis and design of the structure.

The susceptibility of structure to vortex-induced-vibration (VIV) or vortex-induced-motions (VIM) is to be considered, especially for a Spar hull. Loads and fatigue strength are to be fully assessed for structures and the mooring system subject to VIV and VIM effects.

The above mentioned loads are required to be considered in the global and local design of the structure. However, there are other environmentally-induced loads that may be treated as a local load and accounted for in design by special criteria that are derived for such loads. Included in this type of load are: fluid sloshing pressure in tanks, and green-water and other wave impact (slamming) loads. For these specialized loads that are not otherwise directly considered in the *E* category, structural design is to be accomplished using the particular criteria that have been issued to address them, and they are not to be combined with other load categories in the required load combinations specified in this 3-1/7.13.

7.7.6 Supplementary (*S*) Load Category

Considering the nature and possible loadings of the Installations, a supplementary load category is introduced to recognize the loads arising from two additional sources:

- The first are the load effects produced by imposed deformations of the structure. This has relevance, for example, in the analysis of local structures where the boundary displacements are input to simulate relative deflections or differential settlement of foundations.
- The second are the load effects arising from limited, monitored and controlled global loads that do not have the same variability as the *D* and *L* load categories and may therefore be considered separately. In general, suitable mechanisms or devices need to be installed to monitor and control these loads.

Examples of Supplementary (*S*) loads include, as applicable:

i) The reactions from tensioning devices, such as those used for a riser or drill string, which provide load monitoring and assurance that a specified maximum life-time load will not be exceeded; and

ii) The load effects resulting from the life-time maximum specified or calculated values of settlement or displacement.

In the structural design of components for the position keeping (e.g., mooring) system and its foundation, the breaking strength of the mooring line is the representative design load. This is not a category *S* load, unless a recognized 'load release mechanism' is provided; see 3-2/7 and 3-3/7 on the treatment of this load.

When calculating the load effects produced from imposed boundary deformations, the factored values of the other, coexisting load categories are to be used.

Note: This is different from a "Serviceability" check of structural deformations to an Owner's specifications where unfactored loads are used.

7.9 Resistances

7.9.1 General

The resistances of steel structural components are to be defined for the ULS, ALS and FLS (see 1-2/7). Definitions of the resistances to be used in LRFD criteria for column-stabilized installations and Spar installations are as follows.

7.9.2 Resistances for ULS

The ULS deals with yielding and buckling. The resistance to yielding is usually stated in terms of the yield strength of a structural component. Buckling strength is needed to resist compression and shear. The buckling resistance of a structural component is categorized based on the type and usage of the structural component. The ABS *LRFD Buckling Guide* provides the resistance of: individual structural members (rolled shapes and tubulars); stiffened and unstiffened flat plate structures; and stiffened and unstiffened cylindrical shells. Other recognized standards may be used to obtain representative values of resistance for pertinent member types; such other standards include: API RP 2A-LRFD, ISO19902, ISO 19904-1 and AISC Specification (LRFD). See 1-1/7 regarding the applicable editions of these cited references.

7.9.3 Resistances for ALS

The representative resistances of steel structural components for the ALS are to be taken the same as described above for the ULS.

7.9.4 Resistances for FLS

The FLS deals with the fatigue fracture of structural details. The resistance to fatigue fracture is most commonly established in terms of the S-N curve approach coupled with a linear cumulative damage method (Palmgren-Miner's Rule). The *Fatigue Guide* provides the FLS resistance criteria.

7.11 Format of LRFD Criteria

7.11.1 General

A typical ULS or ALS criterion can be expressed as follows; a structural component is satisfactory if the design load effects, Q, are less than or equal to the design resistance, R_d, or:

$$Q \le R_d$$

7.11.2 Buoyant Structure

This provision applies to the structural design of a buoyant structure, for which both the hull and topside deck structures are analyzed to obtain load effects in a combined model that suitably accounts for the interaction between the hull and topside structures.

The total factored load, F_d, used to establish the design load effect, Q, is determined from the following load combination:

$$F_d = \gamma_{f,SW}(D + L) + \gamma_{f,E}E + \gamma_{f,S}S$$

where:

$\gamma_{f,*}$	=	load factor to be applied to still-water, environmental and supplementary loads, [* = SW, E or S]
D	=	representative values of permanent loads
L	=	representative values of variable loads
E	=	representative values of environmental loads
S	=	representative values of supplementary loads
SW	=	$D + L$
	=	still-water loads representing the combined permanent and variable loads on the buoyant structure for the *In-place* conditions and the *Temporary* conditions

The design resistance for ULS and ALS, R_d, is obtained as:

$$R_d = R_k/\gamma_R$$

where

R_k	=	representative value of component or structural strength
γ_R	=	resistance factor, typically greater than 1.0 for ULS and ALS

The load combinations and the corresponding load and resistance factors for buoyant structures are specified in 3-1/Table 1.

For the FLS, the acceptance criterion is typically stated as:

$$T_f \geq T \times FDF$$

where

T_f	=	calculated fatigue life of a detail (using unfactored loads as required in 3-1/7.13)
T	=	design life of the Installation
FDF	=	Fatigue Design Factor

The criteria to obtain values of calculated fatigue life and *FDF* are specified in the *Fatigue Guide*.

7.11.3 Local Structure

When a local structural assemblage (e.g., machinery or equipment foundations, mooring winches, fairleads, chain stoppers, riser guides, riser supports) can be considered isolated from the interaction with the buoyant hull, the total design load, F_d, is to be determined from the following load combination:

$$F_d = \gamma_{f,D}D + \gamma_{f,L}L + \gamma_{f,E}E + \gamma_{f,S}S$$

where

$\gamma_{f,*}$	=	load factor appropriate to the load components, [* = *D*, *L*, *E* or *S*]
D	=	representative values of permanent loads
L	=	representative values of variable loads
E	=	representative values of environmental loads
S	=	representative values of supplementary loads

The load combinations and the corresponding load and resistance factors for the local structures are specified in 3-1/Table 2.

7.11.4 Nonlinear Considerations

The response characteristics of a free-floating installation, in general, are linear to the applied gravity and wave loads. Thus, the total design load effects resulting from the combined factored loads, F_d, can be considered as a linear combination of the individual component load effects.

Where dynamic response (e.g., due to waves, or waves combined with current) is to be determined, and it is permissible to linearize resistance properties (e.g., structural stiffness) considering load-deflection relationships, the linearized property is to be based on factored loads, unless using unfactored loads would result in a more stringent requirement.

7.13 Load Factors, Resistance Factors and Load Combinations

For each considered limit state, the design load combinations, load factors and resistance factors are as stipulated below.

For buoyant structures as described in 3-1/7.11.2, 3-1/Table 1 specifies the design load combinations, load factors and resistance factors for ULS and ALS after the Installation is installed, (i.e., the *In-place* conditions), and for ULS for various operations that comprise the Installation's offshore installation (i.e., the *Temporary* conditions). No ALS condition is required for the *Temporary* conditions.

The combinations of the design conditions and the limit states specified in 3-1/Table 1 are to be applied in accordance with the following:

i) For ULS of the *In-place* conditions, at least two load combinations are to be considered: ULS-a reflects gravitational load-dominated conditions that employ operating environmental loads (E_O) based on a return period of at least one-year; ULS-b reflects extreme environmental load-dominated loads (E_E) that consider the 100-year return period. These two load combinations are denoted the Design Operating Conditions (DOC) and Design Environmental Conditions (DEC), respectively (see 3-1/5).

ii) ALS represents the structure in the damaged conditions. See 3-2/5.1.4 and 3-3/5.1.4.

iii) For the *Temporary* conditions, ULS-a includes loadout, upending and topside installation conditions where applicable, the Owner will specify and control operations so that the environmental loading specified by the Owner (E_{OS}) will not be exceeded.

iv) For the *Temporary* conditions, ULS-b is to be applied to longer-term operations such as a dry tow from a fabrication yard to an offshore installation site or an outfitting yard. The environmental loads (E_{OT}) are to be established using a return period of at least 10 years, as required in 3-1/5.

v) For the *Temporary* conditions, field transit (wet tow) is designated to use the ULS-b load factors considering the Owner specified limiting environmental conditions (E_{OS}). Use of the specified loads and resistances factors for this condition presumes that the operation is a short duration, once in a life time event that will be carried out in accordance with industry practice.

For local structures as described in 3-1/7.11.3, 3-1/Table 2 specifies the design load combinations, load factors and resistance factors for ULS after the Installation is installed (i.e., the *In-place* conditions), and for ULS for various operations that comprise the Installation's offshore installation (i.e., the *Temporary* conditions). The consideration of the design conditions and the limit states is to be in accordance with the requirements as specified above, except that no ALS condition is required for the *In-place* and *Temporary* conditions.

When permanent loads and variable loads are well defined and documented, reduced values of load factor $\gamma_{f,D}$ and $\gamma_{f,L}$ may be used for the ULS-a in 3-1/Table 1 and 3-1/Table 2 and will be subjected to special consideration.

When a permanent load or a variable load is considered as a favorable load that reduces total load responses, a partial safety factor of 1.0 is to be applied to this load. When a variable load is considered a favorable load, the minimum value of this variable load is to be used in the load combination.

For a FLS in any design condition and the ALS defined in 3-1/7.13, the load factor for all load categories is to be taken as 1.0 (i.e. use unfactored loads).

The resistance factors are to take appropriate account of the uncertainties associated with: the modeling of resistances (i.e., strength uncertainties), the structural dimensions, and material properties. For the ULS of a steel structure, the resistance factor, γ_R, is to be taken as 1.05. For the ALS of a steel structure, the resistance factor, γ_R, is to be taken as 1.25.

TABLE 1
Buoyant Structure Load Combinations and Corresponding Load Factors (γ_f) and Resistance Factors (γ_R)

Design Conditions	*Limit States*	*Load Combinations*				*Resistance Factors*
		Load Factors			*Environmental Events*	
		SW (D+L)	*E*	*S*		
In-place Conditions						
Design Operating Condition (DOC)	ULS-a	1.45	1.20 E_O	1.00	1 year return period storm as a minimum	1.05
Design Environmental Condition (DEC)	ULS-b	1.10	1.35 E_E	1.00	100 year return period storm	1.05
Damaged Condition	ALS	1.00	1.00 E_O	1.00	1 year return period storm	1.25
Temporary Conditions						
Loadout	ULS-a	1.45	1.20 E_{OS}	1.00	Calm or specified by Owner	1.05
Ocean Transit (Dry Tow)	ULS-b	1.10	1.35 E_{OT}	1.00	10 year return storm for the selected route condition or specified by the Owner if a weather routing plan is implemented for the voyage	1.05
Field Transit (Wet Tow)	ULS-b	1.10	1.35 E_{OS}	1.00	1 year return period storm for the selected route condition or specified by the Owner	1.05
Upending	ULS-a	1.45	1.20 E_{OS}	1.00	1 year return period storm or specified by the Owner	1.05
Topsides Installation	ULS-a	1.45	1.20 E_{OS}	1.00	Calm or specified by the Owner	1.05

Note: See 3-3/7.7.1 and 3-1/7.13 for the definition of E_O, E_E, E_{OS}, and E_{OT}

TABLE 2
Local Structure Load Combinations and Corresponding Load Factors (γ_f) and Resistance Factors (γ_R)

Design Conditions	*Limit States*	*Load Combinations*					*Resistance Factors*
		Load Factors				*Environmental Events*	
		D	*L*	*E*	*S*		
In-place Conditions							
Design Operating Condition (DOC)	ULS-a	1.30	1.50	1.20 E_O	1.00	1 year return period storm as a minimum	1.05
Design Environmental Condition (DEC)	ULS-b	1.10	1.10	1.35 E_E	1.00	100 year return period storm	1.05
Temporary Conditions							
Loadout	ULS-a	1.30	1.50	1.20 E_{OS}	1.00	Calm or specified by the Owner	1.05
Ocean Transit (Dry Tow)	ULS-b	1.10	1.10	1.35 E_{OT}	1.00	10 year return period storm for the selected route condition or specified by the Owner if a weather routing plan is implemented for the voyage	1.05
Field Transit (Wet Tow)	ULS-b	1.10	1.10	1.35 E_{OS}	1.00	1 year return period storm for the selected route condition or specified by the Owner	1.05
Topsides Installation	ULS-a	1.30	1.50	1.20 E_{OS}	1.00	Calm or specified by the Owner	1.05

Note: See 3-1/7.7.5 and 3-1/7.13 for the definition of E_O, E_E, E_{OS}, and E_{OT}

7.15 Representative Values of Loads

7.15.1 General

Representative values of loads are to be used with the load factors for limit state checks. The representative loads specified in 3-1/Table 3 and 3-1/Table 4 apply to the *In-place* and *Temporary* conditions, respectively.

Where Variable and Environmental loads occur simultaneously, the representative values may be determined based on their joint probability distribution.

7.15.2 Representative Values of Loads for the *In-place* Conditions

For the *In-place* conditions and for each relevant limit state, representative values of permanent, variable, environmental, supplementary and accidental loads are to be as specified in 3-1/Table 3.

For ALS, the Accidental Limit State condition represents the structure after the ALS event when the structure is in the specified damaged condition.

7.15.3 Representative Values of Loads for the *Temporary* Conditions

For the *Temporary* conditions and each relevant limit state, representative values of permanent, variable, and environmental loads are to be as specified in 3-1/Table 4. Additional requirements for the representative values of Environmental loads for the *Temporary* condition are specified in 3-1/Table 1 and 3-1/Table 2 as well as 3-1/7.13.

The required safety level for any *Temporary* condition is to be consistent with those specified for the *In-place* conditions in 3-1/Table 1 or 3-1/Table 2, as applicable.

9 Global Performance Analyses

Global performance analyses of the Installation are aimed at determining the global effects of environmental loads on the overall platform and its components. Global performance analyses are to be performed in accordance with 5B-1-1/7 of the *FPI Rules* for column-stabilized installations and 5B-3-1/7 of the *FPI Rules* for Spar installations.

11 Structural Design of Mooring and Foundation System

11.1 Mooring System

Design of the mooring system is to meet the requirements in Sections 6-1-1 and 6-1-3 of the *FPI Rules*, and applicable requirements in API RP 2SK.

11.3 Foundation System

The design criteria of the foundation system (i.e., drag anchors, pile anchors, vertically loaded anchors (VLAs) and suction piles) are to be in accordance with the requirements described in Sections 6-1-1 and 6-1-3 of the *FPI Rules.*

13 Corrosion Protection and Control

A corrosion protection and control system utilizing anodes and coating in accordance with the recognized industry standards such as API and NACE is to be provided. The design life of the corrosion protection and control system is to equal the design life of the Installation. In the splash zone, corrosion allowance is to be added to the external shell plating.

TABLE 3
Representative Values of Loads for the *In-place* Conditions

Load category	*Representative Values*		
	ULS-a	*ULS-b*	*ALS*
Permanent (*D*)	Mean(1), specified(2) or calculated value	Mean(1), specified(2) or calculated value	Mean(1), specified(2) or calculated value
Variable (*L*)	Mean(1), specified(2) or calculated value	Mean(1), specified(2) or calculated value	Mean(1), specified(2) or calculated value
Supplementary (*S*)	Specified value(2)	Specified value(2)	Specified value(2)
Environmental (*E*)	1 year return period storm as a minimum	100 year return period storm	1 year return period storm as a minimum

Notes:

1 Arithmetic mean or average

2 A nominal value; or as appropriate, an Owner Specified value

TABLE 4
Representative Values of Loads for the *Temporary* Conditions

Load Category	*Representative Values*	
	ULS-a	*ULS-b*
Permanent (*D*)	Mean(1), specified(2) or calculated value	Mean(1), specified(2) or calculated value
Variable (*L*)	Mean(1), specified(2) or calculated value	Mean(1), specified(2) or calculated value
Supplementary (*S*)	Specified value(2)	Specified value(2)
Environmental (*E*)	Owner Specified value(3)	1 year or 10 year return period storm or Owner Specified value(4)

Notes:

1 Arithmetic mean or average

2 A nominal value, or as appropriate, an Owner Specified value

3 Owner specified value may be a calm condition, where justified and where shown to be consistent with operational planning and monitoring for the affected operation.

4 See 3-1/7.13, 3-1/Table 1 and 3-1/Table 2 for additional requirements.

CHAPTER 3 Structural Design of Floating Production Installations

SECTION 2 Column-Stabilized Installations

1 Structural Design

The design of the Installation is to be based on the applicable portions of the *MODU Rules*. Where the conditions at the installation site are less than those for a mobile vessel that are the bases of the *MODU Rules*, the design criteria for various components of the Installation's structure may be reduced to reflect these differences. However, when the Installation's site conditions produce more arduous demands, it is mandatory that the design criteria be increased appropriately.

1.1 Primary Structures

The scantlings of the Installation's primary structures, including topside deck structure, columns, braces, and pontoons are to be designed in accordance with 3-2/3 and the strength of the Installation is to be demonstrated in accordance with the criteria given in 3-2/5.

1.3 Modules and Buildings on the Topside Deck

The modules and buildings on the topside deck are to be designed for the maximum anticipated loads in accordance with the ULS criteria outlined in 3-1/Table 2. The motion-induced inertia loads and inclination induced lateral gravitational forces are to be considered. The relative deformations among module and building supports are to be included in the analysis if their effects on the module are significant. Thus, the Supplementary (S) loads should be included in the load combination for the ULS.

The module and building supporting structures on the topside deck are to be designed for the same loading criteria and shown explicitly on the drawings so that the construction of the module and building supports can be consistent with those assumed in the structural analysis. Means are to be provided to verify that the module and building design reactions and conditions are identical with those used in the topside deck design.

1.5 Helicopter Deck

The design of the helicopter deck is to comply with the requirements of 3-2-2/3 of the *MODU Rules* and 3-8/9.9 of the *Facilities Guide*.

1.7 Protection of Openings in Decks and Columns

All openings of the top of columns are to comply with Section 3-2-15 of the *Steel Vessel Rules*. Portlights or other similar openings are not to be fitted in columns.

1.9 Guards and Rails

Guards and rails are to comply with the requirements of 5-3-1/5 of the *MODU Rules*.

1.11 Appurtenances

Main appurtenances attached to the exterior of the hull are to be designed in accordance with the ULS criteria outlined in 3-1/Table 2 taking into account the effects of local drag and inertia loads together with any appropriate consideration of global action of the Installation and the VIV and VIM effect, if relevant. The supports and backup structures are also to be designed for the same loads, as a minimum.

1.13 Other Major Structures

Structures built on the Installation and designed for properly transferring the loads between Installations and mooring system, Installation and riser system, or Installation and deck-mounted machinery/equipment are to be designed in accordance with the criteria given in 3-2/7.

1.15 Temporary Structures

Structures built for temporary use in the pre-service conditions are not subjected to ABS review. However, the arrangements and details of these structures are to be submitted for reference to verify the adequacy of the local and global strength of the Installation to support these temporary structures during operation in the pre-service condition. The design of backup structures is to be in accordance with the applicable *Temporary* ULS conditions in 3-1/Table 2.

3 Scantling Design of the Primary Structures

The initial scantling design of the hull and topside deck structure is to be determined in accordance with 3-2/3.1 through 3-2/3.5 for the hull structure and 3-2/3.7 for the topside deck structure; and on the applicable portions of the *MODU Rules* and the *Steel Vessel Rules*. The aspects that are not covered by this Guide are to be based on the recognized codes and standards.

3.1 Hull – Pontoons, Columns, and Braces

Pontoons, columns, and braces may be considered either as framed or unframed shells. Ring girders, bulkheads, or other suitable diaphragms are to be adequate to maintain shape and stiffness under all anticipated loadings in association with established analysis methods.

3.1.1 Scantlings of Framed Shells

Where the components of braces, columns, or pontoons incorporate stiffened plating, the minimum scantlings of plating, stiffeners, girders, etc., for shells and interior boundary bulkheads and flats may be determined in accordance with the requirements for tanks, as given in 3-2/3.5, in association with the following.

3.1.1(a) Tank Space. Where the internal space is a tank, the head, *h*, is to be taken to a point located at two-thirds of the distance from the top of the tank to the top of the overflow, or to a point 0.91 m (3 ft) above the top of the tank, whichever is greater. For tanks intended to carry contents with a specific gravity in excess of 1.0, the head is to be suitably increased by a factor equal to the ratio of the specific gravity to 1.0.

3.1.1(b) Void Compartment Spaces. Where the internal space is a void compartment, the head is to be taken to the maximum permissible draft of the installation in service.

3.1.1(c) Areas Subject to Wave Immersion. For all areas subject to wave immersion, the minimum head is to be 6.1 m (20 ft).

3.1.1(d) Minimum Scantlings. In general, the scantlings of boundaries are not to be less than those required by 3-2/3.3, in association with a head to the maximum damaged waterline.

3.1.2 Scantlings of Unframed Shells

Where braces, columns, or pontoons do not incorporate framing members, the minimum scantlings of shell plating and ring girders are to be determined on the basis of established shell analysis methods using the heads given in 3-2/3.1.1 and the load and resistance factors appropriate to the methods employed. Interior boundary bulkheads and flats are to be considered on the basis of framed shells, as given in 3-2/3.1.1.

3.1.3 Additional Structural Requirements for Scantlings

Scantlings of braces, columns, and pontoons as determined above are minimum requirements for hydrostatic loads. Where wave and current loadings are superimposed, the scantlings of the local structure of the shell are to be increased as necessary, to meet the strength requirements of 3-2/5.1.5.

3.3 Watertight Boundary Formula

3.3.1 Plating

The plating thickness of watertight boundaries is not to be less than that obtained from the following equation:

$$t = \frac{0.84sk}{c}\sqrt{\frac{\gamma_L P_n}{Y/\gamma_M}} + f \quad \text{mm (in.)}$$

but not less than 6 mm (0.24 in.) or s/200 + 2.5 mm (s/200 + 0.10 in.), whichever is greater.

where

t	=	thickness in mm (in.)	
f	=	1.5 mm (0.06 in.)	
s	=	spacing of stiffeners in mm (in.)	
k	=	$(3.075\sqrt{\alpha} - 2.077)/(\alpha + 0.272)$	for $1 \le \alpha \le 2$
	=	1.0	for $\alpha > 2$
α	=	aspect ratio of the panel (longer edge/shorter edge)	
c	=	factor to account for plate edge support condition	
	=	2.0 for plate edges rotationally restrained	
P_n	=	nominal pressure in N/mm^2 (kgf/mm^2, psi)	
	=	$[10.055/10^3]h$ $([1.025/10^3]h$, $[64/144]h)$	
Y	=	specified minimum yield point or yield strength, in N/mm^2 (kgf/mm^2, psi)	
h	=	distance, in m (ft), from the lower edge of the plating to a point defined in 3-2/3.1	
γ_L	=	load factor	
	=	1.50	
γ_M	=	resistance factor	
	=	1.05	

3.3.2 Stiffeners and Beams

The section modulus, SM, of each bulkhead stiffener or beam on a watertight flat, in association with the plating to which it is attached, is not to be less than that obtained from the following equation:

$$SM = \frac{0.92c\gamma_L P_n s\ell^2}{8Y_0/\gamma_M}K \quad \text{cm}^3 \text{ (in}^3\text{)}$$

where

c	=	0.56	for stiffeners with ends attached
	=	0.60	for stiffeners with no end attachment
K	=	10^6 (1728)	
P_n	=	nominal pressure in N/mm^2 (kgf/mm^2, psi)	
	=	$[10.055/10^3]h$ $([1.025/10^3]h$, $[64/144]h)$	
h	=	distance, in m (ft), from the middle of ℓ to a point defined in 3-2/3.1	
s	=	spacing of stiffeners, in m (ft)	

ℓ = length of stiffeners, in m (ft); where brackets are fitted with a slope of approximately 45 degrees and thickness given in 3-2-2/Table 2 of the *MODU Rules*, the length of ℓ may be measured to a point on the bracket equal to 25% of the length of the bracket.

Y_0 = specified minimum yield strength of ordinary strength steel

= 235 N/mm^2 [24 kgf/mm^2, 34 ksi]

γ_L = load factor

= 1.50

γ_M = resistance factor

= 1.05

3.3.3 Girders and Webs

The section modulus, *SM*, of each girder or web is not to be less than that obtained from the following equation:

$$SM = \frac{0.85c\gamma_L P_n s\ell^2}{12Y_0/\gamma_M}K \quad \text{cm}^3 \text{ (in}^3\text{)}$$

where

c = 1.0

K = 10^6 (1728)

P_n = nominal pressure in N/mm^2 (kgf/mm^2, psi)

= $[10.055/10^3]h$ ($[1.025/10^3]h$, $[64/144]h$)

h = distances, in m (ft), from the middle of the area supported to a point defined in 3-2/3.1

s = sum of half lengths, in m (ft) (on each side of girder or web), of the stiffeners or beams supported

ℓ = length, in m (ft), between supports, where brackets are fitted at shell, deck or bulkhead supports, and the brackets are in accordance with 3-2-2/Table 2 of the *MODU Rules* and have a slope of approximately 45 degrees, the length ℓ may be measured to a point on the bracket located at the distance from the toe equal to 25% of the length of the bracket.

Y_0 = specified minimum yield strength of ordinary strength steel

= 235 N/mm^2 [24 kgf/mm^2, 34 ksi]

γ_L = load factor

= 1.50

γ_M = resistance factor

= 1.05

3.5 Tank Boundary Formula

3.5.1 Plating

Plating is to be the thickness derived from the following equation:

$$t = \frac{0.95sk}{c}\sqrt{\frac{\gamma_L P_n}{Y/\gamma_M}} + f \quad \text{mm (in.)}$$

but not less than 6.5 mm (0.25 in.) or s/150 + 2.5 mm (s/150 + 0.10 in.), whichever is greater.

where

t	=	thickness, in mm (in.)
f	=	2.5 mm (0.1 in.)
s	=	spacing of stiffeners, in mm (in.)
k	=	$(3.075\sqrt{\alpha} - 2.077)/(\alpha + 0.272)$ for $1 \le \alpha \le 2$
	=	1.0 for $\alpha > 2$
α	=	aspect ratio of the panel (longer edge/shorter edge)
c	=	factor to account for plate edge support condition
	=	2.0 for plate edges rotationally restrained
P_n	=	nominal pressure in N/mm^2 (kgf/mm^2, psi)
	=	$[10.055/10^3]h$ ($[1.025/10^3]h$, $[64/144]h$)
h	=	distance, in m (ft), from the lower edge of the plating to a point defined in 3-2/3.1
Y	=	specified minimum yield point or yield strength, in N/mm^2 (kgf/mm^2, psi)
γ_L	=	load factor
	=	1.50
γ_M	=	resistance factor
	=	1.05

When the specific gravity of the liquid contents of a tank is greater than 1.0, the head, h, specified above is to be increased by a factor equal to the ratio of the specific gravity to 1.0.

3.5.2 Stiffeners and Beams

The section modulus, SM, of each bulkhead stiffener or beam on a flat, in association with the plating to which it is attached, is not to be less than that obtained from the following equation:

$$SM = \frac{0.92c\gamma_L P_n s\ell^2}{8Y_0/\gamma_M}K \quad \text{cm}^3\ (\text{in}^3)$$

where

c	=	0.9	for stiffeners having clip attachments to decks or flats at the ends or having such attachments at one end with the other end supported by girders
	=	1.0	for stiffeners supported at both ends by girders
K	=	10^6 (1728)	
P_n	=	nominal pressure in N/mm^2 (kgf/mm^2, psi)	
	=	$[10.055/10^3]h$ ($[1.025/10^3]h$, $[64/144]h$)	
h	=	distance, in m (ft), from the middle of ℓ to a point defined in 3-2/3.1	
s	=	spacing of stiffeners, in m (ft)	
ℓ	=	length, in m (ft), between supports; where brackets are fitted at shell, deck or bulkhead supports, and the brackets are in accordance with 3-2-2/Table 2 of the *MODU Rules* and have a slope of approximately 45 degrees, the length, ℓ, may be measured to a point on the bracket located at a distance from the toe equal to 25% of the length of the bracket.	

Y_0	=	specified minimum yield strength of ordinary strength steel
	=	235 N/mm^2 [24 kgf/mm^2, 34 ksi]
γ_L	=	load factor
	=	1.50
γ_M	=	resistance factor
	=	1.05

3.5.3 Girders and Webs

The section modulus, *SM*, of each girder or web is not to be less than that obtained from the following equation:

$$SM = \frac{0.85c\gamma_L P_n s\ell^2}{12Y_0/\gamma_M} K \quad \text{cm}^3 \ (\text{in}^3)$$

where

c	=	1.5
K	=	10^6 (1728)
P_n	=	nominal pressure in N/mm^2 (kgf/mm^2, psi)
	=	$[10.055/10^3]h$ ($[1.025/10^3]h$, $[64/144]h$)
h	=	distances, in m (ft), from the middle of the area supported to a point defined in 3-2/3.1
s	=	sum of half lengths, in m (ft) (on each side of girder or web), of the stiffeners or beams supported
ℓ	=	length in m (ft), between supports, where brackets are fitted at shell, deck or bulkhead supports, and the brackets are in accordance with 3-2-2/Table 2 of the *MODU Rules* and have a slope of approximately 45 degrees, the length, ℓ, may be measured to a point on the bracket located at the distance from the toe equal to 25% of the length of the bracket.
Y_0	=	specified minimum yield strength of ordinary strength steel
	=	235 N/mm^2 [24 kgf/mm^2, 34 ksi]
γ_L	=	load factor
	=	1.50
γ_M	=	resistance factor
	=	1.05

3.7 Topside Deck Structure

The initial scantlings of the topside deck structure can be designed based on the following loads as minimums:

- Crew spaces (walkways, general traffic area, etc.)

  4510 N/m^2 (460 kgf/m^2, 94 lbf/ft^2) or 0.64 m (2.1 ft) head

- Work areas

  9020 N/m^2 (920 kgf/m^2, 188 lbf/ft^2) or 1.28 m (4.2 ft) head

- Storage areas

  13000 N/m^2 (1325 kgf/m^2, 272 lbf/ft^2) or 1.84 m (6.0 ft) head

3.9 Higher-strength Materials

In general, applications of higher-strength materials for beams and girders are to meet the requirements of this Section, but may be modified as permitted by the following paragraphs. Calculations are to be submitted to show adequate provision to resist buckling.

Each beam and girder of higher-strength material, in association with the higher-strength plating to which it is attached, is to comply with the requirements of the appropriate preceding paragraphs of this Section and is to have a section modulus SM_{hts} not less than obtained from the following equation:

$$SM_{hts} = SM \times Q$$

where

SM = required section modulus in ordinary-strength material as determined in 3-2/3.3.2, 3-2/3.3.3, 3-2/3.5.2 and 3-2/3.5.3, respectively

Q = See 2-2/Table 3

5 Engineering Analysis of Primary Structures

5.1 Hull and Topside Deck Structure

5.1.1 General

Documents necessary to verify the structural strength, including the ULS, ALS, and FLS of the hull and the topside deck structure are to be submitted for review. The criteria in this subsection relate to the analyses required to verify the scantlings selected in the initial design in 3-2/3. The analysis results cannot be used to reduce the initial design scantlings.

Depending on the specific features of the Installation, additional analyses to verify and help design other portions of the Installation structural components will be required. Such additional analyses include the hull interfaces with the position mooring and riser systems and the topside deck interface with the deck-mounted machinery/equipment. Analysis criteria for these additional structural components are given in 3-2/7.

The details of the main intersections are difficult to adequately capture in the global strength model. To design these areas, local FEM analyses are to be used, as required. These main intersections include connections of pontoon to pontoon, column to pontoon, and column to topside deck structure. For twin-pontoon column stabilized Installations, special attention should be given to brace connections to: braces, columns, pontoons, and topside structure.

5.1.2 Ultimate Limit State (ULS)

ULS analysis is to be performed in accordance with the design conditions and required resistance factors given in this Subparagraph. The objective is to verify the adequacy of the scantlings selected in the initial design of 3-2/3, when the structural responses induced by the global motions, environmental loads, variable loads and permanent loads are considered simultaneously.

The ULS analysis is to be performed for the *In-place* intact and *Temporary* conditions as required in 3-1/7.5, verifying that the strength of the hull complies with the acceptance criteria in 3-2/5.1.5. The environmental conditions and loads described in 3-1/5 and 3-1/7 are to be used to establish the design load cases for the *In-place* intact and *Temporary* conditions.

The *In-place* intact condition includes Design Operating Conditions (DOC) and Design Environmental Conditions (DEC), as defined in 3-1/5. The *Temporary* conditions include: load out, transportation (both wet and dry tows) and installation (topside deck mating) conditions. Some structural component design could be governed by transportation and installation loads. The structural analysis and design for the *In-place* intact and *Temporary* conditions are to be based on the ULS criteria specified in 3-1/Table 1.

3-1/Table 1 shows the required load combinations, load factors, environmental events and resistance factors to be considered for each design condition in the ULS analysis.

5.1.2(a) Critical Responses for ULS Analysis. The global strength of the Installation is to be designed to withstand the responses induced by the loads specified in 3-1/7 multiplied by the corresponding load factor for each category in 3-1/Table 1. The responses that typically control the hull strength design are the prying/squeezing loads, deck inertia loads, torsional moments, and longitudinal shear forces between pontoons. The critical responses that control the topside deck structure strength design are the deck inertia loads. As indicated 3-1/Table 1, the *In-place* intact strength is to be designed for responses from a 100-year return period for the Design Environmental Condition.

The highest wave may not always produce the most critical responses. To determine the most critical responses, a sufficient number of design cases are to be used considering the following permutations:

i) Variation in environmental conditions and headings

ii) Variation in variables (topside deck live loads)

iii) Variation in ballasting distributions

iv) Variation in riser arrangements

5.1.3 Fatigue Limit State (FLS)

FLS analysis is to be performed to verify that there are adequate resistances against fatigue failure within the Installation's design life. The fatigue analysis is to be carried out with a load factor of 1.0 for each load category considering the envisioned loading situations of the Installation, including the *Temporary* and *In-place* conditions.

Special attention is to be given to the main intersections mentioned above. For twin-pontoon Installations, special attention should be given to brace connections to: braces, columns, pontoons and topside structure.

Attention is also to be given to the designs of structural notches, cutouts, attachments and abrupt changes of structural sections which are prone to fatigue damages.

5.1.4 Accidental Limit State (ALS)

ALS analysis is required to verify that there is adequate redistribution of stress in the damaged conditions. The *In-place* damaged conditions are to consider loss of one compartment buoyancy. Special attention is to be given to twin-pontoon Installations where a loss of one main load carrying brace should be considered. The structural analysis and design for the *In-place* damaged conditions are to be based on the ALS criteria specified in 3-1/Table 1.

5.1.5 Acceptance Criteria

The criteria for checking the acceptability of an Installation in each limit state are provided in this Subsection.

5.1.5(a) Ultimate Limit State (ULS) Acceptance Criteria. The customary format of the ULS criterion is expressed in such a way that a structural component is satisfactory if the design load effects, Q, due to total factored load, F_d, are less than or equal to the design resistance, R_d, or $Q \le R_d$. The ULS acceptance criteria for yielding and buckling are specified below for various types of steel structural components.

i) *Plates, Stiffened Panels and Corrugated Panels.* The strength against yielding may be designed according to the von Mises equivalent stress criterion, where the design load effect, Q, represented by the equivalent stress, σ_{eqv}, defined as follows, is not to exceed the design resistance, $R_d = F_y/\gamma_R$:

$$\sigma_{eqv} \le \varphi F_y/\gamma_R$$

$$\sigma_{eqv} = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x\sigma_y + 3\tau_{xy}^2}$$

where

σ_{eqv} = equivalent stress

σ_x = calculated in-plane stress in the *x* direction due to total factored load, F_d

σ_y = calculated in-plane stress in the *y* direction due to total factored load, F_d

τ_{xy} = calculated in-plane shear stress due to total factored load, F_d

F_y = specified minimum yield point or yield strength, as defined in Chapter 1 of the ABS *Rules for Materials and Welding (Part 2)*

φ = adjustment factor

= 1.15

γ_R = resistance factor

= 1.05

The strength against buckling is to be designed for compliance with the *LRFD Buckling Guide*.

ii) *Other Types of Structural Components Including: Individual Structural Members and Cylindrical Shells.* The *LRFD Buckling Guide* is to be complied with. Alternatively, the representative strength may be established using other recognized LRFD-based standards acceptable to ABS. However, the design load combinations and resistance factors specified in 3-1/Table 1 are to be used with the representative strengths that are obtained from alternative standards.

The following recognized LRFD-based standards are acceptable to ABS and can be used to establish representative values of resistance:

- For non-tubular members – AISC Specification (LRFD) or ISO 19905-1
- For tubular members – API RP 2A-LRFD
- For tubular joints – API RP 2A-LRFD

5.1.5(b) Fatigue Limit State (FLS) Acceptance Criteria. For the fatigue sensitive areas in the hull, including but not limited to the main intersections listed in 3-2/5.1.1, the fatigue damage is to be calculated using the ABS Offshore S-N curves for environment in air, in seawater with cathodic protection and in seawater free corrosion, as specified in the *Fatigue Guide*. The S-N curves are applicable to thicknesses that do not exceed the reference thickness of 22 mm ($^7/_8$ in.). For members of greater thickness, thickness correction is required with an exponent of 0.25. Other recognized standards, equivalent to the ABS requirements, may also be acceptable.

The minimum required fatigue life is determined by Fatigue Design Factors (*FDF*s) and the design life of the Installation. The specified *FDF*s depend on the inspectability, reparability, redundancy, the ability to predict failure damage, as well as the consequence of failure of the structure. Minimum *FDF* requirements for the hull, integrated deck, and column top frame are listed in 3-2/Table 1.

For topside deck structures, the ABS Offshore S-N curves, as specified in the *Fatigue Guide*, and AWS S-N curves are to be used. Minimum *FDF* requirements for topside deck structures are listed in 3-2/Table 2.

Any areas determined to be critical to the structure are to be free of cracks, and the effects of stress risers is to be determined and minimized. Critical areas may require special analysis and survey.

TABLE 1
Minimum Fatigue Design Factors for Hull, Integrated Deck, and Column Top Frame

Importance	*Inspectable and Field Repairable*	
	Yes	*No*
Non-critical	3	5
Critical	5	10

Note: "Critical" implies that failure of these structural items would result in the rapid loss of structural integrity and produce an event of unacceptable consequence.

TABLE 2
Minimum Fatigue Design Factors for Topside Deck Structures

Importance	*Inspectable and Field Repairable*	
	Yes	*No*
Non-critical	2	5
Critical	3	10

Notes: "Critical" implies that failure of these structural items would result in the rapid loss of structural integrity and produce an event of unacceptable consequence.

5.1.5(c) Accidental Limit State (ALS) Acceptance Criteria. The acceptance checks are to follow the ULS acceptance criteria in 3-2/5.1.5(a) with the resistance factor being 1.25.

7 Analysis and Design of Other Major Structures

The analysis and design criteria to be applied to the other pertinent features of the Installation's structural design are to conform to recognized practices acceptable to ABS. For Installations, there will be a need to consider in the hull and topside deck structure design the interface between the mooring system and the Installation, the interface between the riser system and the Installation, and the effects of structural support reactions from deck-mounted equipment/machinery. The criteria to be applied for these cases are presented in this Subsection. The requirements for the interface of the topside deck structure with the deck modules and buildings are provided in 3-2/1.3.

7.1 Hull Interface with Riser System (Riser Porches, Supports, and Guides)

The riser foundation and guide and back-up structures are to be designed for the maximum anticipated riser loads for the Design Environmental Condition (DEC) and the Design Operating Condition (DOC) increased by a load factor of and 1.2 and 1.6, respectively, considering a resistance factor of 1.05.

Fatigue strength is to be designed to meet the requirements in 3-2/5.1.5(b) taking into account the effects of both local drag and inertia loads on the risers and the global motions of the Installation. Contacts between hull and riser buoyancy components may cause cyclic impact loads to the hull. Fatigue due to such cyclic impacts is to be adequately considered in the design.

7.3 Hull Interface with Mooring System (Fairlead, Chain Stopper, and Winch Foundations)

Each individual foundation and back-up structure of the fairlead, chain jack and winch is to be designed for the breaking strength of the mooring line increased by a load factor of 1.2 considering a resistance factor of 1.05 for the steel structure. The foundation and back-up structure for multiple fairleads, chain jacks or winches is to be designed for the maximum anticipated mooring loads for the Design Environmental Condition (DEC) and the Design Operating Condition (DOC) increased by a load factor of and 1.2 and 1.6, respectively, considering a resistance factor of 1.05.

Fatigue strength is to be designed to meet the requirements in 3-2/5.1.5(b) taking into account the effects of both local drag and inertia loads on the mooring lines and the global motions of the Installation.

7.5 Topside Deck Structure Interface with Deck Mounted Equipment/Machinery

The interface of the topside deck structure with machinery or equipment subject to high concentrated or cyclic loading, such as crane and drilling facilities, if applicable, is to be designed to provide satisfactory strength for the reaction forces specified by the manufacturer or the maximum anticipated reaction forces caused by the environmental conditions and operations of the machinery or equipment during the entire service life of the Installation, in accordance with the ULS criteria in 3-1/Table 2.

3-1/Table 2 provides the design load combinations and load factors that are required for establishing the reaction forces for the ULS design. The motion-induced inertia loads and inclination induced lateral gravitational forces are to be considered in establishing the reaction forces. The global load effects, if significant, are to be considered in combining with the effects of the reaction forces. Fatigue strength is to be designed to meet the requirements in 3-2/5.1.5(b) taking into account the effects of the global motions and the global load effects, if significant.

If a crane is designed to Chapter 2, "Guide for Certification of Cranes" of the ABS *Lifting Appliance Guide*, or a recognized standard such as API Specification 2C, the foundation strength should be designed to the reaction forces calculated according to the standard with the safety factors or resistance factors required by that standard.

9 Materials and Welding

Materials and welding for the Column-Stabilized Installation are to comply with 5B-1-2/9 of the *FPI Rules*.

CHAPTER 3 Structural Design of Floating Production Installations

SECTION 3 Spar Installations

1 Structural Design

The design of the Spar installation is to be based on the applicable portions of the *MODU Rules*. Where the conditions at the installation site are less than those for a mobile vessel that are the basis of the *MODU Rules*, the design criteria for various components of the Spar may be reduced to reflect these differences. However, when the installation site conditions produce more arduous demands, it is mandatory that the design criteria be increased appropriately.

1.1 Primary Structures

The scantlings of Spar's primary structures including hard tank, soft tank and mid-section (truss with heave plates or free flooding cylindrical column) are to be designed in accordance with 3-3/3 and the scantlings are subsequently to be verified with the strength requirements given in 3-3/5.

1.3 Modules and Buildings on the Topside Deck

The modules and buildings on the topside deck are to be designed for the maximum anticipated loads in accordance with the ULS criteria outlined in 3-1/Table 2. The motion-induced inertia loads and inclination induced lateral gravitational forces are to be considered. The relative deformations among module and building supports are to be included in the analysis if their effects on the module are significant. Thus, the Supplementary (*S*) loads should be included in the load combination for the ULS.

The module and building supporting structures on the topside deck are to be analyzed and shown explicitly on the drawings so that the construction of the module and building supports can be consistent with those assumed in the structural analysis. Means are to be provided to verify that the module and building design reactions and conditions are identical with those used in the topside deck design.

The structural fire protection aspects of the design of topsides modules and buildings, including the arrangement of the hydrocarbon process area, are to be in accordance with Chapter 3, Section 8 of the ABS *Rules for Building and Classing Facilities on Offshore Installations (Facilities Rules)*.

The designs of the piping system on the topside deck are to comply with Part 4, Chapter 2 of the *MODU Rules* and applicable requirements of the *Facilities Rules*.

1.5 Helicopter Deck

The design of the helicopter deck is to comply with the requirements of 3-2-2/3 of the *MODU Rules* and 3-8/9.9 of the *Facilities Rules*.

1.7 Protection of Spar Deck Openings

All openings on the Spar deck are to comply with Section 3-2-15 of the *Steel Vessel Rules*.

1.9 Guards and Rails

Guards and rails are to comply with the requirements of 5-3-1/5 of the *MODU Rules*. The above mentioned section is to be used for the perimeters of the Spar, including the hull, topside deck and center well on the Spar deck. Alternative arrangements, such as a minimum 42-inch high and two tier evenly spaced handrail with a kickboard, may be considered by ABS, provided they are also acceptable to the local authority.

1.11 Vortex Shedding Strakes

Vortex shedding strakes are designed to reduce the VIM effects on the Spar hull. They are to be designed in accordance with the ULS criteria outlined in 3-1/Table 2 and 3-3/5.1.5(a) as well as the FLS criteria outlined in 3-3/5.1.3 and 3-3/5.1.5(b) taking into account the effects of local drag and inertia loads together with the effects of global motions.

1.13 Appurtenances

Main appurtenances attached to the exterior of the hull are to be designed in accordance with the ULS criteria outlined in 3-1/Table 2 taking into account the effects of local drag and inertia loads together with any appropriate consideration of global action of the Installation and the VIV and VIM effect if relevant. The supports and backup structures are also to be designed for the same loads, as a minimum.

1.15 Other Major Structures

Other structures on the Installation include those that provide interfaces between the position mooring system and hull, between hull and the riser system, and which support the reactions from deckhouses and deck-mounted equipment/machinery. These other structures are to be designed in accordance with the criteria given in 3-3/7.

1.17 Temporary Structures

Structures built for temporary use in the pre-service conditions are not subjected to ABS review. However, the arrangements and details of these structures are to be submitted for reference to verify the adequacy of the local and global strength of the Installation to support these temporary structures during operation in the pre-service condition. The design of backup structures is to be in accordance with the applicable *Temporary* ULS conditions in 3-1/Table 2.

3 Scantling Design of the Hull Structure

The initial scantling design of the hull that incorporates stiffened plating is to be determined in accordance with 3-3/3.1 and based on the applicable portions of the *MODU Rules* and the *Steel Vessel Rules*. The aspects that are not covered by this Guide are to be based on the recognized codes and standards. For curved shells, the minimum scantlings of shell girders are to be determined on the basis of established shell analysis methods, using the heads given in 3-3/3.1 and the load and resistance factors appropriate to the method employed. As a minimum, a detailed local analysis is to be performed, considering the ULS criteria in 3-3/5.1.5.

3.1 Hull Structure

3.1.1 Upper Hull – Hard Tank

Where the components of the hard tank, such as external shell, center well bulkheads and top (Spar deck) and bottom decks, incorporate stiffened plating, the minimum scantlings of plating, stiffeners, girders, etc. may be determined in accordance with the requirements for tanks as given in 3-3/3.1.5, in association with the following heads:

3.1.1(a) Tank Spaces. Where the internal space is a tank space, the head, *h*, is to be taken:

i) To a point located at two-thirds of the distance from the top of the tank to the top of the overflow,

ii) To a point 0.91 m (3 ft) above the top of the tank, or

iii) To a point representing the maximum permissible operating draft, including offset operation draft.

For tanks intended to carry contents with a specific gravity in excess of 1.0, the head, *h*, is to be increased by a factor equal to the ratio of the specific gravity to 1.0.

3.1.1(b) Void Compartment Spaces. Where the internal space is a void compartment or a tank without liquid in it, the head is to be taken to a point representing the maximum permissible operating draft.

3.1.1(c) Areas Subject to Wave Immersion. For all areas subject to wave immersion, the minimum head is to be 6.1 m (20 ft).

3.1.1(d) Minimum Scantlings. The scantlings of the boundaries are not to be less than those required by 3-3/3.1.4 as watertight boundary in association with

i) A head to the maximum damaged waterline, or

ii) A head to a point representing the installation draft.

Where the interior boundaries of the hard tank, such as radial bulkheads and other bulkheads and flats that separate two tank spaces, incorporate stiffened plating, the minimum scantlings of plating, stiffeners, girders, etc. may be determined in accordance with the requirements for the tank spaces of the hard tank, as given in 3-3/3.1.5.

Where the interior boundaries of the hard tank, such as radial bulkheads and other bulkheads and flats that separate two void spaces, incorporate stiffened plating, the minimum scantlings of plating, stiffeners, girders, etc., may be determined in accordance with the requirements for watertight bulkheads and flats, as given in 3-3/3.1.4, in association with a head to the maximum damaged waterline or a point representing the installation draft.

3.1.2 Mid-Section – Free Flooded Column and Truss Space Frame with Heave Plates

3.1.2(a) Free Flooded Column. Where the components of the mid-section incorporate stiffened plating, the minimum scantlings of plating, stiffeners, girders, etc., may be determined in accordance with the requirements for tank bulkheads and flats as given 3-3/3.1.5, in association with the maximum anticipated hydrostatic and hydrodynamic pressures during the wet tow and in the *In-place* conditions.

3.1.2(b) Truss Space Frame with Heave Plates. The scantlings of the chords and braces of the truss frame may be initially determined in accordance with API RP 2A for the hydrostatic collapse requirements, in association with the installation and maximum operating drafts.

Where the components of the heave plates incorporate stiffened plating, the minimum scantlings of plating, framing, girders, etc., may be determined in accordance with the requirements for tank bulkheads and flats, as given in 3-3/3.1.5, in association with the maximum anticipated pressures in wet tow, upending and in the *In-place* conditions.

3.1.3 Lower Hull – Fixed Ballast and Flotation Tank

Where the components of the fixed ballast and flotation tanks incorporate stiffened plating, the minimum scantlings of plating, stiffeners, girders, etc., may be determined in accordance with the requirements for tank bulkheads and flats, as given in 3-3/3.1.5, in association with the following:

i) The maximum anticipated hydrostatic pressures in wet tow and upending, and

ii) Equivalent hydrostatic head due to fixed ballast weight.

3.1.4 Watertight Boundary Formula

3.1.4(a) Plating. The plating thickness of watertight boundaries is not to be less than that obtained from the following equation:

$$t = \frac{0.84sk}{c}\sqrt{\frac{\gamma_L P_n}{Y/\gamma_M}} + f \quad \text{mm (in)}$$

but not less than 6 mm (0.24 in.) or s/200 + 2.5 mm (s/200 + 0.10 in.), whichever is greater.

where

t = thickness, in mm (in.)

f = 1.5 mm (0.06 in.)

s = spacing of stiffeners, in mm (in.)

k = $(3.075\sqrt{\alpha} - 2.077)/(\alpha + 0.272)$ for $1 \leq \alpha \leq 2$

= 1.0 for $\alpha > 2$

α = aspect ratio of the panel (longer edge/shorter edge)

c = factor to account for plate edge support condition

= 2.0 for plate edges rotationally restrained

P_n = nominal pressure in N/mm^2 (kgf/mm^2, psi)

= $[10.055/10^3]h$ $([1.025/10^3]h$, $[64/144]h)$

h = distance, in m (ft), from the lower edge of the plating to a point defined in 3-3/3.1.1 through 3-3/3.1.3

Y = specified minimum yield point or yield strength, in N/mm^2 (kgf/mm^2, psi)

γ_L = load factor

= 1.50

γ_M = resistance factor

= 1.05

3.1.4(b) Stiffeners and Beams. The section modulus, *SM*, of each bulkhead stiffener or beam on a watertight flat, in association with the plating to which it is attached, is not to be less than that obtained from the following equation:

$$SM = \frac{0.92c\gamma_L P_n s\ell^2}{8Y_0/\gamma_M}K \quad \text{cm}^3 \text{ (in}^3\text{)}$$

where

c = 0.56 for stiffeners with ends attached

= 0.60 for stiffeners with no end attachment

K = 10^6 (1728)

P_n = nominal pressure in N/mm^2 (kgf/mm^2, psi)

= $[10.055/10^3]h$ $([1.025/10^3]h$, $[64/144]h)$

h = distance, in m (ft), from the middle of ℓ to a point defined in 3-3/3.1.1 through 3-3/3.1.3

s = spacing of stiffeners, in m (ft)

ℓ = length of stiffeners, in m (ft); where brackets are fitted with a slope of approximately 45 degrees and thickness given in 3-2-2/Table 2 of the *MODU Rules*, the length of ℓ maybe measured to a point on the bracket equal to 25% of the length of the bracket.

Y_0 = specified minimum yield strength of ordinary strength steel

= 235 N/mm^2 [24 kgf/mm^2, 34 ksi]

γ_L = load factor

= 1.50

γ_M = resistance factor

= 1.05

3.1.4(c) Girders and Webs. The section modulus, *SM*, of each girder or web is not to be less than that obtained from the following equation:

$$SM = \frac{0.85c\gamma_L P_n s\ell^2}{12Y_0/\gamma_M}K \quad \text{cm}^3 \ (\text{in}^3)$$

where

c	=	1.0
K	=	10^6 (1728)
P_n	=	nominal pressure in N/mm^2 (kgf/mm^2, psi)
	=	$[10.055/10^3]h$ ($[1.025/10^3]h$, $[64/144]h$)
h	=	distances, in m (ft), from the middle of the area supported to a point defined in 3-3/3.1.1 through 3-3/3.1.3
s	=	sum of half lengths, in m (ft) (on each side of girder or web), of the stiffeners or beams supported
ℓ	=	length, in m (ft), between supports, where brackets are fitted at shell, deck or bulkhead supports, and the brackets are in accordance with 3-2-2/Table 2 of the *MODU Rules* and have a slope of approximately 45 degrees, the length ℓ may be measured to a point on the bracket located at the distance from the toe equal to 25% of the length of the bracket.
Y_0	=	specified minimum yield strength of ordinary strength steel
	=	235 N/mm^2 [24 kgf/mm^2, 34 ksi]
γ_L	=	load factor
	=	1.50
γ_M	=	resistance factor
	=	1.05

3.1.5 Tank Boundary Formula

3.1.5(a) Plating. Plating is to be the thickness derived from the following equation:

$$t = \frac{0.95sk}{c}\sqrt{\frac{\gamma_L P_n}{Y/\gamma_M}} + f \quad \text{mm (in.)}$$

but not less than 6.5 mm (0.25 in.) or $s/150 + 2.5$ mm ($s/150 + 0.10$ in.), whichever is greater.

where

t	=	thickness, in mm (in.)	
f	=	2.5 mm (0.1 in.)	
s	=	spacing of stiffeners, in mm (in.)	
k	=	$(3.075\sqrt{\alpha} - 2.077)/(\alpha + 0.272)$	for $1 \le \alpha \le 2$
	=	1.0	for $\alpha > 2$
α	=	aspect ratio of the panel (longer edge/shorter edge)	
c	=	factor to account for plate edge support condition	
	=	2.0 for plate edges rotationally restrained	

P_n = nominal pressure in N/mm^2 (kgf/mm^2, psi)

= $[10.055/10^3]h$ $([1.025/10^3]h, [64/144]h)$

h = distance, in m (ft), from the lower edge of the plating to a point defined in 3-3/3.1.1 through 3-3/3.1.3

Y = specified minimum yield point or yield strength, in N/mm^2 (kgf/mm^2, psi)

γ_L = load factor

= 1.50

γ_M = resistance factor

= 1.05

When the specific gravity of the liquid contents of a tank is greater than 1.0, the head, *h*, specified above, is to be increased by a factor equal to the ratio of the specific gravity to 1.0.

3.1.5(b) Stiffeners and Beams. The section modulus, *SM*, of each bulkhead stiffener or beam on a flat, in association with the plating to which it is attached, is not to be less than that obtained from the following equation:

$$SM = \frac{0.92c\gamma_L P_n s\ell^2}{8Y_0/\gamma_M}K \quad \text{cm}^3\ (\text{in}^3)$$

where

c = 0.9 for stiffeners having clip attachments to decks or flats at the ends or having such attachments at one end with the other end supported by girders

= 1.0 for stiffeners supported at both ends by girders

K = 10^6 (1728)

P_n = nominal pressure in N/mm^2 (kgf/mm^2, psi)

= $[10.055/10^3]h$ $([1.025/10^3]h, [64/144]h)$

h = distance, in m (ft), from the middle of ℓ to a point defined in 3-3/3.1.1 through 3-3/3.1.3

s = spacing of stiffeners, in m (ft)

ℓ = length, in m (ft), between supports; where brackets are fitted at shell, deck or bulkhead supports, and the brackets are in accordance with 3-2-2/Table 2 of the *MODU Rules* and have a slope of approximately 45 degrees, the length ℓ may be measured to a point on the bracket located at a distance from the toe equal to 25% of the length of the bracket.

Y_0 = specified minimum yield strength of ordinary strength steel

= 235 N/mm^2 [24 kgf/mm^2, 34 ksi]

γ_L = load factor

= 1.50

γ_M = resistance factor

= 1.05

3.1.5(c) Girders and Webs. The section modulus, *SM*, of each girder or web is not to be less than that obtained from the following equation:

$$SM = \frac{0.85c\gamma_L P_n s\ell^2}{12Y_0/\gamma_M}K \quad \text{cm}^3\ (\text{in}^3)$$

where

c	=	1.5
K	=	10^6 (1728)
P_n	=	nominal pressure in N/mm^2 (kgf/mm^2, psi)
	=	$[10.055/10^3]h$ $([1.025/10^3]h$, $[64/144]h)$
h	=	distances, in m (ft), from the middle of the area supported to a point defined in 3-3/3.1.1 through 3-3/3.1.3
s	=	sum of half lengths, in m (ft) (on each side of girder or web), of the stiffeners or beams supported
ℓ	=	length in m (ft), between supports, where brackets are fitted at shell, deck, or bulkhead supports, and the brackets are in accordance with 3-2-2/Table 2 of the *MODU Rules* and have a slope of approximately 45 degrees, the length, ℓ, may be measured to a point on the bracket located at the distance from the toe equal to 25% of the length of the bracket.
Y_0	=	specified minimum yield strength of ordinary strength steel
	=	235 N/mm^2 [24 kgf/mm^2, 34 ksi]
γ_L	=	load factor
	=	1.50
γ_M	=	resistance factor
	=	1.05

3.3 Higher-strength Materials

In general, applications of higher-strength materials for beams and girders are to meet the requirements of this Section, but may be modified as permitted by the following paragraphs. Calculations are to be submitted to show adequate provision to resist buckling.

Each beam and girder of higher-strength material, in association with the higher-strength plating to which it is attached, is to comply with the requirements of the appropriate preceding paragraphs of this Section and is to have a section modulus SM_{hts} not less than obtained from the following equation:

$$SM_{hts} = SM \times Q$$

where

SM	=	required section modulus in ordinary-strength material as determined in 3-3/3.1.4(b), 3-3/3.1.4(c), 3-3/3.1.5(b), 3-3/3.1.5(c), respectively
Q	=	See 2-2/Table 3

5 Structural Analysis and Design of Primary Structures

5.1 Hull Structure – Hard Tank, Mid-section and Soft Tank

5.1.1 General

Documents necessary to verify the structural strength, including the ULS, ALS and FLS of the hull are to be submitted for review. The criteria in this Subsection relate to the analyses required to verify the scantlings selected in the initial design in 3-3/3. The results of analyses that are required in this Subsection cannot be used to reduce the scantlings established from 3-3/3 of this Guide.

Depending on the specific features of the Spar installation, additional analyses to verify and help design other portions of the Spar structural components will be required. Such additional analyses include the hull interfaces with the position mooring and riser systems. Analysis criteria for these additional structural components are given in 3-3/7.

The details of the main intersections are difficult to adequately capture in the global strength model. To design these areas, local FEM analyses are to be used, as required. These main intersections include connections of hard tank to topside legs, hard tank to truss and truss to soft tank (or keel tank). For the truss space frame of the mid-section, the design of unstiffened tubular joints, stiffened tubular joints and transition joints is to comply with the ABS *LRFD Buckling Guide* or API RP 2A-LRFD.

5.1.2 Ultimate Limit State (ULS)

ULS analysis is to be performed in accordance with the design conditions and required resistance factors given in this Subparagraph. The objective is to verify the adequacy of the scantlings selected in the initial design of 3-3/3, when the structural responses induced by the global motions, environmental loads, variable loads and permanent loads are considered simultaneously.

The ULS analysis is to be performed for the *In-place* intact and *Temporary* conditions as required in 3-1/7.5, verifying that the strength of the hull complies with the acceptance criteria in 3-3/5.1.5(a). The environmental conditions and loads described in 3-1/5 and 3-1/7 are to be used to establish the design load cases for the *In-place* intact and *Temporary* conditions.

The *In-place* intact condition includes Design Operating Conditions (DOC) and Design Environmental Conditions (DEC), as defined in 3-1/5. The *Temporary* conditions include: load out, transportation (both wet and dry tows) and installation (topside deck mating and hull upending) conditions. Some structural component design could be governed by transportation, upending and installation loads. The structural analysis and design for *In-place* intact and *Temporary* conditions are to be based on the ULS criteria specified in 3-1/Table 1, which provides the required load combinations, load factors, environmental events and resistance factors to be considered for each design condition in the global strength analysis.

5.1.2(a) Critical Responses for ULS analysis. The global strength of the hull is to be designed to withstand the responses induced by the loads specified in 3-1/7 multiplied by the corresponding load factor for each category in 3-1/Table 1. The responses that typically control the hull strength design are the global bending moments and shears.

Special attention is to be given to the low frequency loads and the heeling and trimming induced loads in calculating these responses.

The highest wave may not always produce the most critical responses. To identify the most critical responses, a sufficient number of design cases are to be used considering the following permutations:

i) Variation in environmental conditions and headings

ii) Variation in variables (topside deck live loads)

iii) Variation in ballasting distributions

iv) Variation in riser arrangements

5.1.3 Fatigue Limit State (FLS)

FLS analysis is to be performed to verify that there are adequate resistances against fatigue failure within the design life of the Spar installation. The fatigue analysis is to be carried out with a load factor of 1.0 for each load category considering the envisioned loading situations of the Spar installation, including the *Temporary* and *In-place* conditions.

Attention is to be given to the low frequency loads and global motions induced by these loads, which are important to fatigue damages at the main intersections of connections between topside deck to hard tank, hard tank to mid-section, mid-section to soft tank (or keel tank) and truss joints.

Attention is also to be given to the designs of structural notches, cutouts, attachments and abrupt changes of structural sections which are prone to fatigue damages.

5.1.4 Accidental Limit State (ALS)

ALS analysis is required to verify that there is adequate redistribution of stress in the damaged conditions. The *In-place* damaged condition includes design cases such as loss of one mooring line or one compartment flooded. The structural analysis and design for the *In-place* damaged conditions are to be based on the ALS criteria specified in 3-1/Table 1.

5.1.5 Acceptance Criteria

The criteria for checking the acceptability of a Spar installation in each limit state are provided in this Subsection.

5.1.5(a) Ultimate Limit State (ULS) Acceptance Criteria. The customary format of the ULS criterion is expressed in such a way that a structural component is satisfactory if the design load effects, Q, due to total factored load, F_d, are less than or equal to the design resistance, R_d, or $Q \le R_d$. The ULS acceptance criteria for yielding and buckling are specified below for various types of steel structural components.

i) *Plates, Stiffened Panels and Corrugated Panels.* The strength against yielding may be designed according to the von Mises equivalent stress criterion, where the design load effect, Q, represented by the equivalent stress, σ_{eqv}, defined as follows, is not to exceed the design resistance, R_d (= F_y/γ_R):

$$\sigma_{eqv} \le \varphi F_y/\gamma_R$$

$$\sigma_{eqv} = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x\sigma_y + 3\tau_{xy}^2}$$

where

σ_{eqv} = equivalent stress

σ_x = calculated in-plane stress in the x direction due to total factored load, F_d

σ_y = calculated in-plane stress in the y direction due to total factored load, F_d

τ_{xy} = calculated in-plane shear stress due to total factored load, F_d

F_y = specified minimum yield point or yield strength, as defined in Chapter 1 of the ABS *Rules for Materials and Welding (Part 2)*

φ = adjustment factor

= 1.15

γ_R = resistance factor

= 1.05

The strength against buckling is to be designed for compliance with the *LRFD Buckling Guide*.

ii) *Other Types of Structural Components Including: Individual Structural Members, Cylindrical Shells, and Tubular Joints.* The *LRFD Buckling Guide* is to be complied with. Alternatively, the representative strength may be established using other recognized LRFD-based standards acceptable to ABS provided that the design load combinations and resistance factors specified in 3-1/Table 1 are to be used with the representative strengths that are obtained from alternative standards.

The following recognized LRFD-based standards are acceptable to ABS and can be used to establish representative values of resistance:

- For non-tubular members – AISC Specification (LRFD) or ISO 19905-1
- For tubular members – API RP 2A-LRFD
- For tubular joints – API RP 2A-LRFD

5.1.5(b) Fatigue Limit State (FLS) Acceptance Criteria. For the hull, including the hard tank connections to the truss space frame mid-section, the topside deck legs and the soft tank (or keel tank) connections to the truss space frame mid-section, the fatigue damage is to be calculated using the ABS Offshore S-N curves for environment in air, in seawater with cathodic protection and in seawater free corrosion, as specified in the *Fatigue Guide*. The S-N curves are applicable to thicknesses that do not exceed the reference thickness of 22 mm ($^7/_8$ in). For members of greater thickness, thickness correction is required with an exponent of 0.25. Other recognized standards, equivalent to the ABS requirements, may also be acceptable.

For the truss space frame mid-section, the API RP 2A S-N curves can be used.

The minimum required fatigue life is determined by Fatigue Design Factors (*FDF*s) and the design life of the Spar installation. The specified *FDF*s depend on the inspectability, reparability, redundancy, the ability to predict failure damage, as well as the consequence of failure of the structure. Minimum *FDF* requirements are listed in 3-3/Table 1.

TABLE 1
Minimum Fatigue Design Factors for Hull Structures

Importance	*Inspectable and Repairable*	
	Yes	*No*
Non-critical	3	5
Critical	5	10

Notes: "Critical" implies that failure of these structural items would result in the rapid loss of structural integrity and produce an event of unacceptable consequence.

Any areas determined to be critical to the structure are to be free from cracks, and stress concentration factors are to be determined and minimized. Critical areas may require special analysis and survey.

5.1.5(c) Accidental Limit State (ALS) Acceptance Criteria. The acceptance checks are to follow the ULS acceptance criteria in 3-3/5.1.5(a) with the resistance factor being 1.25.

5.3 Topside Deck

5.3.1 General

The designs of topside deck structural members such as deck girders, columns, beams, braces, stiffeners, deck plating, etc., are to be based on the applicable portions of the ABS *LRFD Buckling Guide* or API RP 2A-LRFD. The loads on the structure, as indicated in 3-1/7, as applicable, are to be determined, and the resulting structural responses are not to exceed the criteria given in 3-3/5.3.

The use of design methods and associated acceptance criteria other than those specifically covered in 3-3/5.3 may be acceptable provided it can be demonstrated that the use of such alternative methods will result in a structure possessing an equivalent or greater level of safety.

5.3.2 Ultimate Limit State (ULS)

5.3.2(a) Load Combinations. Load combinations which produce the most unfavorable effects on the topside deck structure for the *In-place* and *Temporary* conditions are to be considered. The environmental conditions and applicable loads described in 3-1/5 and 3-1/7 are to be used to establish the design load cases for the *In-place* and *Temporary* conditions. The ULS criteria outlined in 3-1/Table 1 are to be considered for the topside deck design. For a given topside payload (sum of the topside Permanent and Variable loads), the most critical responses for the topside deck may be due to the Spar's motions, which will produce acceleration and the inclination-induced loads.

5.3.2(b) Structural Analysis. A space frame analysis of the deck structure is to be performed to obtain the structural response. The structural model can be either the overall Spar installation with a detailed deck model or a standalone deck structural model. In the latter case, the boundary conditions of the model are to be properly simulated in the analysis. In modeling the deck structures, all relevant structural components are to be included. The nature of loads and loading combinations, as well as the local environmental conditions, are to be taken into consideration in the selection of design methods. Methods of analysis and their associated assumptions are to be compatible with the overall design principles. Linear, elastic methods are generally employed in design and analysis.

5.3.2(c) Ultimate Limit State (ULS) Acceptance Criteria. The ULS acceptance criteria are given in 3-3/5.1.5(a). The lifting analysis of the topside structure is to adequately account for equipment and fabrication weight increase with dynamic amplification factors recommended in API RP 2A-LRFD. Other lift analysis criteria will be considered on a case by case basis.

5.3.3 Fatigue Limit State (FLS)

5.3.3(a) Fatigue Analysis. A detailed fatigue analysis is to be performed for deck structures. Rational fatigue analysis methods are acceptable if the forces and member stresses can be properly represented. The dynamic effects are to be taken into consideration if they are significant to the structural response. For the frame members of the deck, the S-N curves specified in the *Fatigue Guide* are to be used. The Stress Concentration Factors (SCFs) for tubular joints can be calculated based on applicable empirical formulas. For the complex critical connections, the SCFs should be calculated by means of a fine mesh finite element analysis.

5.3.3(b) Acceptance Criteria. The results of the assessment are to indicate a minimum expected fatigue life of at least two times the design life of the structure where sufficient structural redundancy exists to prevent catastrophic failure of the structure of the member or connection under consideration. Where such redundancy does not exist, the result of a fatigue assessment is to indicate a minimum expected fatigue life of at least three times the design life of the structure. General Fatigue Design Factor (*FDF*) requirements on fatigue life are specified in 3-3/Table 2. For the deck to hull connections, see 3-3/5.1.5(b).

Any areas determined to be critical to the structure are to be free from cracks, and stress concentration factors are to be determined and minimized. Critical areas may require special analysis and survey.

TABLE 2
Minimum Fatigue Design Factors for Topside Deck Structures

Importance	*Inspectable and Field Repairable*	
	Yes	*No*
Non-critical	2	5
Critical	3	10

Notes: "Critical" implies that failure of these structural items would result in the rapid loss of structural integrity and produce an event of unacceptable consequence.

5.3.4 Accidental Limit State (ALS)

5.3.4(a) ALS Analysis. ALS analysis is required to verify that there is adequate redistribution of stress in the damaged conditions. The *In-place* damaged condition includes design cases such as loss of one mooring line or one compartment flooded. The structural analysis and design for the *In-place* damaged conditions are to be based on the load combinations, load factors, environmental event and resistance factors of the ALS specified in 3-1/Table 1.

5.3.4(b) Acceptance Criteria. The acceptance checks are to follow the ULS acceptance criteria in 3-3/5.1.5(a) with the resistance factor being 1.25.

5.3.5 Stresses in Connections

Connections of structural members are to be developed to achieve effective load transmission between connected members to minimize stress concentration and to prevent excessive punching shear. Connection details are also to be designed to minimize undue constraints against overall ductile behavior and to minimize the effects of post-weld shrinkage. Undue concentration of welding is to be avoided. The design of tubular joints is to be in accordance with the ABS *LRFD Buckling Guide* or API RP 2A-LRFD, including punching shear. The LRFD provisions of AISC Specification (LRFD) can be used for the design of non-tubular joints.

7 Analysis and Design of Other Major Structures

The analysis and criteria to be applied to the other pertinent features of the Spar structural design are to conform to recognized practices acceptable to the ABS. For Spar installations, the following needs to be considered in the structural design: the interface between the position mooring system and hull, the interface between hull and the riser system and the effects of structural support reactions from deckhouses and deck-mounted equipment/machinery. The criteria to be applied for these cases are presented below.

7.1 Hull Interface with Mooring System (Fairlead, Chain Stopper and Winch Foundations)

Each individual foundation and back-up structure of the fairlead, chain jack and winch is to be designed for the breaking strength of the mooring line increased by a load factor of 1.2 considering a resistance factor of 1.05 for the steel structure. The foundation and back-up structure for multiple fairleads, chain jacks or winches is to be designed for the maximum anticipated mooring loads for the Design Environmental Condition (DEC) and the Design Operating Condition (DOC) increased by a load factor of and 1.2 and 1.6, respectively, considering a resistance factor of 1.05.

Fatigue strength is to be designed to meet the requirements in 3-3/5.1.5(b) taking into account the effects of both local drag and inertia loads on the mooring lines and the global motions of the Spar.

7.3 Hull Interface with Riser System (Riser Guides and Riser Supports)

The riser foundation and guide and back-up structures are to be designed for the maximum anticipated riser loads for the Design Environmental Condition (DEC) and the Design Operating Condition (DOC) increased by a load factor of and 1.2 and 1.6, respectively, considering a resistance factor of 1.05.

Fatigue strength is to be designed to meet the requirements in 3-2/5.1.5(b) taking into account the effects of both local drag and inertia loads on the risers and the global motions of the Installation. Contacts between hull and riser buoyancy components may cause cyclic impact loads to the hull. Fatigue due to the cyclic impacts is to be adequately considered in the design.

7.5 Topside Deck Structure Interface with Deck Mounted Equipment/Machinery

The interface of the topside deck structure with machinery or equipment subject to high concentrated or cyclic loading, such as crane and drilling facilities, if applicable, is to be designed to provide satisfactory strength for the reaction forces specified by the manufacturer or the maximum anticipated reaction forces caused by the environmental conditions and operations of the machinery or equipment during the entire service life of the Installation, in accordance with the ULS criteria in 3-1/Table 2.

3-1/Table 2 provides the design load combinations and load factors that are required for establishing the reaction forces for the ULS design. The motion-induced inertia loads and inclination induced lateral gravitational forces are to be considered in establishing the reaction forces. The global load effects, if significant, are to be considered in combining with the effects of the reaction forces.

Fatigue strength is to be designed to meet the requirements in 3-3/5.1.5(b) taking into account the effects of the global motions of the Spar installation and the global load effects, if significant.

If a crane is designed to the Chapter 2, "Guide for Certification of Cranes" of the ABS *Lifting Appliance Guide*, or a recognized standard such as API Specification 2C, the foundation strength should be designed to the reaction forces calculated according to the standard with the safety factors or resistance factors required by that standard.

9 Materials and Welding

Materials and welding for the Spar Installation are to comply with Section 5B-3-5 of the *FPI Rules*.