

Planning, Designing, and Constructing Floating Production Systems

API RECOMMENDED PRACTICE 2FPS
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Foreword

API 2FPS is one of a series of API and other standards for offshore structures in the Gulf of Mexico. This suite of standards, hereby referenced as the API Floating Structures Standards (AFSS), are a suite of applicable "Working Stress Design" standards for structures to be deployed in U.S. waters. The suite consists of the following standards.

- API 2A-WSD, Planning, Designing and Constructing Fixed Offshore Platforms-Working Stress Design
- API Spec 2C, Specification for Offshore Cranes
- API RP 2D, Recommended Practice for Operation and Maintenance of Offshore Cranes
- API Bull 2INT-MET, Interim Guidance on Hurricane Conditions in the Gulf of Mexico
- API RP 2MOP, Marine Operations
- API RP 2RD, Recommended Practice for Design of Risers for Floating Production Systems (FPSs) and Tension-Leg Platforms (TLPs)
- API 2SIM, Structural Integrity Management of Fixed Offshore Structures
- API RP 2SK, Design and Analysis of Stationkeeping Systems for Floating Structures
- API RP 2T, Recommended Practice for Planning, Design and Constructing Tension Leg Platforms
- API Bull 2U, Stability Design of Cylindrical Shells
- API Bull 2V, Design of Flat Plate Structures
- API RP 14J, Recommended Practice for Design and Hazards Analysis for Offshore Production Facilities
- API RP 75L, Guidance Document for the Development of a Safety and Environmental Management System for Onshore Oil and Natural Gas Production Operation and Associated Activities
- AISC 360-05, Specification for Structural Steel Buildings
- AWS D1.1, Structural Welding Code - Steel

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Should: As used in a standard, "should" denotes a recommendation or that which is advised but not required in order to conform to the specification.

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Suggested revisions are invited and should be submitted to the Standards Department, API, 200 Massachusetts Avenue, NW, Suite 1100, Washington, DC 20001, standards@api.org.

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Introduction

The series of Standards applicable to types of offshore structure, constitutes a common basis covering those aspects that address design requirements and assessments of all offshore structures used by the petroleum, petrochemical and natural gas industries worldwide. Through their application the intention is to achieve reliability levels appropriate for manned and unmanned offshore structures, whatever the type of structure and the nature or combination of materials used.

It is important to recognize that structural integrity is an overall concept comprising models for describing actions, structural analyses, design rules, safety elements, workmanship, quality control procedures and national requirements, all of which are mutually dependent. The modification of one aspect of design in isolation can disturb the balance of reliability inherent in the overall concept or structural system. The implications involved in modifications, therefore, need to be considered in relation to the overall reliability of all offshore structural systems.

The series of Standards applicable to types of offshore structure is intended to provide wide latitude in the choice of structural configurations, materials and techniques without hindering innovation. Sound engineering judgment is therefore necessary in the use of these International Standards.

API 2FPS was developed in response to the offshore industry's demand for a coherent and consistent definition of methodologies to design, analyse and assess floating offshore structures of the class described in Clause 1. In particular, this standard addresses monohulls, semi-submersibles and spars.

Some background to, and guidance on, the use of this standard is provided in informative Annex A. The clause numbering in Annex A is the same as in the normative text to facilitate cross-referencing.

Planning, Designing, and Constructing Floating Production Systems

1 Scope

This document provides requirements and guidance for the structural design and/or assessment of floating offshore platforms used by the petroleum and natural gas industries to support the following functions:

- production;
- storage and/or offloading;
- drilling and production;
- production, storage and offloading;
- drilling, production, storage and offloading.

NOTE 1 Floating offshore platforms are often referred to using a variety of abbreviations, e.g. FPS, FSU, FPSO, etc. (see Clauses 3 and 4), in accordance with their intended mission.

NOTE 2 In this standard, the term “floating structure”, sometimes shortened to “structure”, is used as a generic term to indicate the structural systems of any member of the classes of platforms defined above.

NOTE 3 In some cases, floating platforms are designated as “early production platforms”. This term relates merely to an asset development strategy. For the purposes of this International Standard, the term “production” includes “early production”.

Its requirements do not apply to the structural systems of mobile offshore units (MOUs). These include, among others:

- floating structures intended primarily to perform drilling and/or well intervention operations (often referred to as MODUs), even when used for extended well test operations;
- floating structures used for offshore construction operations (e.g. crane barges or pipelay barges), for temporary or permanent offshore living quarters (floatels), or for transport of equipment or products (e.g. transportation barges, cargo barges), for which structures reference is made to relevant recognized classification society (RCS) rules.

Its requirements are applicable to all possible life-cycle stages of the structures defined above, such as

- design, construction and installation of new structures, including requirements for inspection, integrity management and future removal,
- structural integrity management covering inspection and assessment of structures in-service, and
- conversion of structures for different use (e.g. a tanker converted to a production platform) or reuse at different locations.

The following types of floating structure are explicitly considered within the context of this standard:

- a) monohulls (ship-shaped structures and barges);
- b) semi-submersibles;
- c) spars.

In addition to the structural types listed above, this standard covers other floating platforms intended to perform the above functions, consisting of partially submerged buoyant hulls made up of any combination of plated and space frame components and used in conjunction with the stationkeeping systems covered in API 2SK. These other structures can have a great range of variability in geometry and structural forms and, therefore, can be only partly covered by the requirements of this standard. In other cases, specific requirements stated in this standard can be found not to apply to all or part of a structure under design.

In all the above cases, conformity with this standard will require that the design is based upon its underpinning principles and achieves a level of safety equivalent, or superior, to the level implicit in it.

NOTE The speed of evolution of offshore technology often far exceeds the pace at which the industry achieves substantial agreement on innovation in structural concepts, structural shapes or forms, structural components and associated analysis and design practices, which are continuously refined and enhanced. On the other hand, International Standards can only capture explicit industry consensus, which requires maturation and acceptance of new ideas. Consequently, advanced structural concepts can, in some cases, only be partly covered by the provisions of standard.

This standard is applicable to steel floating structures. The principles documented herein are, however, considered to be generally applicable to structures fabricated in materials other than steel.

Similarly, while this document is directly applicable to oil and gas producing platforms operating at ambient temperature, the principles documented herein are considered to be generally applicable to structures used in conjunction with cryogenic processes, such as floating liquefied gas (FLNG) plants, with the exception of the aspects related to handling and storage of cryogenic liquids.

The structural design and fabrication of the drilling and production modules supported by a floating structure can be carried out in accordance with API 2A–WSD, 21st Edition, Errata and Supplement 3.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

API RP 2A-WSD, *Planning, Designing and Constructing Fixed Offshore Platforms—Working Stress Design*, 21st Edition

API Bull 2INT-MET, *Interim Guidance on Hurricane Conditions in the Gulf of Mexico*

API RP 2SK, *Design and Analysis of Stationkeeping Systems for Floating Structures*

API RP 14J, *Recommended Practice for Design and Hazards Analysis for Offshore Production Facilities*

API RP 75L, *Guidance Document for the Development of a Safety and Environmental Management System for Onshore Oil and Natural Gas Production Operation and Associated Activities*

ISO 13702, *Petroleum and natural gas industries — Control and mitigation of fires and explosions on offshore production installations — Requirements and guidelines*

ISO 19900:2002, *Petroleum and natural gas industries — General requirements for offshore structures*

ISO 19901-1, *Petroleum and natural gas industries — Specific requirements for offshore structures — Part 1: Metocean design and operating considerations*

ISO 19902:2007, *Petroleum and natural gas industries — Fixed steel offshore structures*

NOTE See Annex B for the API Floating Structures Suite (AFSS) of applicable working stress design standards for structures deployed on the U.S. continental shelf.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1

abnormal

condition that exceeds conventionally specified design conditions and which is used to mitigate against very remote events

3.2

accidental design situation

design situation involving exceptional conditions of the structure or its exposure

EXAMPLE Impact, fire, explosion, local failure or loss of intended differential pressure (e.g. buoyancy).

3.3

action

external load applied to the structure (direct action) or an imposed deformation or acceleration (indirect action)

EXAMPLE An imposed deformation can be caused by fabrication tolerances, settlement, temperature change or moisture variation.

NOTE An earthquake typically generates imposed accelerations.

[ISO 19900:2002]

3.4

action combination

design values of different actions considered simultaneously in design checks of the structure for a specific limit state

3.5

action effect

effect of actions on structural components

EXAMPLE Internal forces, moments, stresses, strains, rigid body motions or elastic deformations.

[ISO 19900:2002]

3.6

air gap

clearance between the highest water surface that occurs during the extreme environmental conditions and the lowest exposed part not designed to withstand wave impingement

[ISO 19900:2002]

3.7

basic variable

one of a specified set of variables representing physical quantities which characterize actions, environmental influences, geometrical quantities, or material properties, including soil properties

[ISO 19900:2002]

3.8

characteristic value

value of a basic variable, an action or a strength model having a prescribed probability of not being violated by unfavourable values

NOTE 1 In the case of actions and related properties, the characteristic value normally relates to a reference period.

NOTE 2 Adapted from ISO 19900:2002, definition 2.7.

3.9

design criteria

quantitative formulations that describe the conditions to be fulfilled for each limit state

[ISO 19900:2002]

3.10

design format

mathematical description for checks to verify non-exceedance of a limit state

NOTE In this standard, both partial factor and working stress design (WSD) formats are permitted.

3.11

design service life

assumed period for which a structure or a structural component is to be used for its intended purpose with anticipated maintenance, but without substantial repair being necessary

NOTE Adapted from ISO 19900:2002, definition 2.12.

3.12

design situation

set of physical conditions during a certain reference period for which the design demonstrates that relevant limit states are not exceeded

NOTE Adapted from ISO 19900:2002, definition 2.13.

3.13

design value

value of a basic variable, action or strength model derived from a representative value for use in a design verification procedure

NOTE 1 For a ULS design check in accordance with the partial factor design format, a design value for a strength variable or model is found by dividing the representative value of strength by a partial resistance factor, while for an action variable it is found by multiplying the representative value of the action effect by a partial action factor.

NOTE 2 For an FLS, SLS or ALS design check in accordance with the partial factor design format, all partial factors are equal to unity so that, in these cases, a design value is equal to the representative value.

NOTE 3 For any design check in accordance with the working stress design format, all partial factors are equal to unity so that, in these cases, a design value is equal to the representative value. Appropriate global safety or utilization factors are applied in design checks.

NOTE 4 In the case of actions and related properties, the value can relate to a reference period.

NOTE 5 Adapted from ISO 19900:2002, definition 2.14.

3.14

disconnectable floating structure

floating structure capable of discontinuing production and rapidly disconnecting from its ancillary components, such as risers, moorings, and/or well systems in response to the occurrence or to the detection of a threshold event

3.15

dynamic action

action that induces acceleration of a structure or a structural component of a magnitude sufficient to require specific consideration

3.16

dynamic positioning

DP

stationkeeping technique consisting primarily of a system of on-board thrusters, which generate appropriate thrust vectors to counter the mean and slowly varying induced actions

3.17**exposure level**

classification system used to define the requirements for a structure based on consideration of life-safety and of environmental and economic consequences of failure

[ISO 19900:2002]

3.18**failure**

insufficient strength or inadequate serviceability of a structure or structural component, or, in a structural check, a condition in which a structure or component thereof does not fulfil its limit state requirement

3.19

fit-for-purpose, adjective

fitness-for-purpose, noun

meeting the intent of a standard although not meeting specific provisions of that standard in local areas, such that failure in these areas cannot cause unacceptable risk to life-safety or the environment

NOTE Adapted from ISO 19900:2002, definition 2.16.

3.20**floating structure**

structure where the full weight is supported by buoyancy

[ISO 19900:2002]

NOTE The full weight includes lightship weight, mooring system pre-tension, riser pre-tension and operating weight.

3.21**freeboard**

distance measured vertically downwards between the top of the hull and the mean water surface at a given draught

3.22**green water**

overtopping of deck by water causing slamming and pressure actions to structures on deck

3.23**limit state**

state beyond which the structure no longer fulfils the relevant design criteria

[ISO 19900:2002]

3.24**mobile offshore drilling unit****MODU**

structure capable of engaging in drilling and well intervention operations for exploration or exploitation of subsea petroleum resources

3.25**mobile offshore unit****MOU**

structure intended to be relocated to perform a particular function

[ISO 19900:2002]

3.26**monohull**

floating structure consisting of a single, continuous, buoyant hull, and having a geometry similar to that of ocean-going ships, barges, etc.

3.27**nominal value**

value of a basic variable, action or strength model determined on a non-statistical basis, typically from acquired experience or physical conditions

EXAMPLE Value published in a recognized code or standard.

NOTE Adapted from ISO 19900:2002, definition 2.22.

3.28**owner**

representative of the company or companies which own a development, who can be the operator on behalf of co-licensees

3.29**platform**

complete assembly including structure, topsides and, where applicable, foundations and stationkeeping system

NOTE Adapted from ISO 19900:2002, definition 2.23.

3.30**recognized classification society****RCS**

member of the international association of classification societies (IACS), with recognized and relevant competence and experience in floating structures, and with established rules and procedures for classification/certification of installations used in petroleum or natural gas activities, located at a specific site for an extended period of time

NOTE Adapted from ISO 19901-7:2005, definition 3.23.

3.31**reliability**

ability of a structure or structural component to fulfil the specified requirements

[ISO 19900:2002]

3.32**representative value**

value of a basic variable, action or strength model, for verification of a limit state

NOTE 1 The representative value can equal a characteristic value, a nominal value, or other rationally determined value.

NOTE 2 For actions, this can relate to upper or lower characteristic values, dependent on which causes the more onerous condition. In combinations, it can involve multiplying the chosen value by a factor greater or less than unity.

NOTE 3 Adapted from ISO 19900:2002, definition 2.26.

3.33**resistance**

capacity of a structure, component or cross-section of a component to withstand action effects without exceeding a limit state

NOTE Adapted from ISO 19900:2002, definition 2.27.

3.34**return period**

average period between occurrences of an event or of a particular value being exceeded

NOTE The offshore industry commonly uses a return period measured in years for environmental events. The return period in years is equal to the reciprocal of the annual probability of exceedance of the event.

[ISO 19901-1:2005]

3.35**riser**

pipings connecting the process facilities or drilling equipment on the floating structure with the subsea facilities or pipelines, or with a reservoir

NOTE 1 Possible functions include drilling and well intervention, production, injection, subsea systems control and export of produced fluids.

NOTE 2 Adapted from ISO 19900:2002, definition 2.29.

3.36**robustness**

ability of a structure to withstand events that have a reasonable likelihood of occurring, without the structure being damaged to an extent disproportionate to the cause

NOTE Possible causes can be events like fire, explosions or impacts.

3.37**semi-submersible**

floating structure normally consisting of a deck structure with a number of widely spaced, large cross-section, supporting columns connected to submerged pontoons

NOTE Pontoon/column geometry is usually chosen to minimize global motions in a broad range of wave frequencies.

3.38**slamming**

impulsive action with high pressure peaks that occurs during impact between a portion of the structure and water

NOTE Slamming can, for example, be due to emergence and re-entry of a lower section of the hull into the water or can be due to wave impact on a structural component.

3.39**sloshing**

impact action on the boundaries of a partially filled tank due to internal fluid motion

3.40**spar platform****spar**

deep draught caisson vessel

DDCV

deep-draught, small water-plane area floating structure

3.41**special areas**

areas identified by the designer as being of critical importance to the structural integrity and safety of the structure

3.42**stability****hydrostatic stability**

ability of a floating structure to generate restoring moment after deviation from the equilibrium floating position

3.43**static action**

action that cannot cause significant acceleration of the structure or structural components

3.44**stationkeeping system**

system capable of limiting the excursions of a floating structure within prescribed limits

3.45**structure**

organized combination of connected components designed to withstand actions and provide adequate rigidity

3.46**structural component**

physically distinguishable part of a structure

[ISO 19900:2002]

3.47**structural system**

combination of structural components acting in such a manner that the components function together

NOTE Adapted from ISO 19900:2002, definition 2.32.

3.48**threshold event**

event that triggers the start and/or the completion of the process of disconnection of a floating structure

3.49**topsides**

structures and equipment placed on a supporting structure (fixed or floating) to provide some or all of a platform's functions

NOTE For a monohull, the deck is not part of the topsides.

[ISO 19900:2002]

3.50**variable action**

Q

action for which the variation in magnitude with time cannot be neglected compared with the mean value, or for which the point of application varies with time

3.51**verification**

examination made to confirm that an activity, product or service is in accordance with specified requirements

3.52**watertight**

capable of preventing the penetration of water into or through the structure with a water pressure head corresponding to that for which the surrounding structure is designed

3.53**weathertight**

capable of preventing the penetration of water into the structure during temporary exposure to water

NOTE A watertight closing appliance is also considered weathertight.

4 Symbols and abbreviated terms

4.1 Symbols

A accidental action

A area, or area per unit length, in square metres (m^2), or metres (m)

a_v vibration amplitude, in metres

B moulded breadth, in metres (m)

b	width, in millimetres (mm)
C	coefficient (non-dimensional unless otherwise specified)
D	fatigue damage ratio throughout life cycle of platform or duration of particular operational phase
d	component diameter, in metres
E	environmental action
E	material (Young's) modulus, in newtons per square metre (N/m ²)
F	action per unit length, in newtons per metre (N/m)
F_d	design value of action effect
f	frequency, in hertz (Hz)
f	distribution factor (non-dimensional)
G	permanent action
K_s	stability parameter for VIV
L	length between perpendiculars
M	bending moment or representative bending strength, in newton metres (Nm)
m	constant related to the slope of an S-N curve
m_e	effective mass per unit length (kg/m)
N	total number of cycles
P	pressure, in newtons per square metre (N/m ²)
Q	variable action
Q	shear action, in newtons (N)
R	repetitive action
R	strength, in newtons per square metre (N/m ²)
r	strength, in newtons per square metre (N/m ²)
S	stress, in newtons per square metre (N/m ²)
T	time or duration, in years
T_R	return period, in years
t	thickness, in millimetres (mm)
V	volume, or volume per unit length, in cubic metres (m ³), or square metres (m ²)
v	velocity, in metres per second (m/s)
γ	partial action or resistance factor
δ	logarithmic decrement of damping

- ξ fraction of critical damping
- η allowable utilization factor
- κ curvature, 1/m
- ρ density, in kilograms per cubic metre (kg/m³)

4.2 Abbreviated terms

- ACFM alternating current field measurement
- ACPD alternating current potential drop
- ALP articulated loading platform
- ALS accidental limit state
- AP aft perpendicular
- BOEMRE Bureau of Ocean Energy Management, Regulation, and Enforcement
- CALM catenary anchor leg mooring
- CBM conventional buoy mooring
- COW crude oil washing
- CP cathodic protection
- CVI close-up visual inspection
- DC design class
- DDCV deep draught caisson vessel
- DP dynamic positioning
- EC eddy current
- FE finite element
- FLP floating loading platform
- FLS fatigue limit state
- FMD flooded member detection
- FPS floating production system
- FPSO floating production, storage and offloading structure
- FSU floating storage unit
- GVI general visual inspection
- HAZID hazard identification
- IMO international maritime organization

MC	material category
MOM	marine operations manual
MOU	mobile offshore unit
MODU	mobile offshore drilling unit
MPI	magnetic particle inspection
NDT	non-destructive test
NPSH	net positive suction head
RAO	response amplitude operator
RCS	recognized classification society
ROV	remotely operated vehicle
RSR	reserve strength ratio
SALM	single anchor leg mooring
SAW	submerged arc welding
SCIP	structural critical inspection point
SCF	stress concentration factor
SIM	structural integrity management
SLS	serviceability limit state
STL	submerged turret loading
TLP	tension leg platform
TOFD	time-of-flight diffraction
TM	thickness measurements
UCW	ultrasonic creeping wave
ULS	ultimate limit state
USCG	United States Coast Guard
VIM	vortex-induced motions
VIV	vortex-induced vibrations
VLCC	very large crude carrier
VOC	volatile organic compound
WI	weld inspection
WSD	working stress design

5 Overall considerations

5.1 Functional requirements

Floating offshore structures are used within the petroleum and natural gas industries to support facilities and equipment necessary to fulfill their intended mission, which typically is one of the following:

- a) production;
- b) storage and/or offloading;
- c) drilling and production;
- d) production, storage and offloading;
- e) drilling, production, storage and offloading.

A floating offshore platform can take various structural forms, including

- monohulls (ship-shaped structures or barges),
- semi-submersibles,
- spars, and
- tension leg platforms (TLPs).

This standard presents specific requirements for monohulls, semi-submersibles and spars when used for the applications listed above.

In those cases where produced oil is exported by pipeline, limited oil storage is provided on the floating structure. The storage is generally accommodated in the process system as additional residence time, or in additional surge vessels.

If, on the other hand, oil export through a pipeline is not planned or available, a considerable volume of oil storage is generally required to allow export by shuttle tankers or barges. In such cases, the storage capacity is usually provided aboard the floating structure. Alternatively, storage capacity can be provided on the export tankers or barges. In this case, however, inability of the export vessel to accept the produced crude would result in a forced production shutdown, unless a backup redundant shuttle/storage vessel is provided.

5.2 Safety requirements

Key guiding principles of the activities of the petroleum and natural gas industries are safety of life, environment and property. Within the framework of this International Standard, these principles shall be enforced through

- competent design or assessment of platforms, to ensure the floating structure's ability to withstand environmental and other external actions that are likely to occur during the design service life of the structure or any extension thereof,
- definition of safe operating procedures so that risks of injuries to personnel are identified and minimized,
- identification and assessment of possible accidental events, as summarized in ISO 19900, and mitigation of their consequences,
- performance of a hazard assessment to ensure that possible malfunctions do not pose a danger to life or to the structure's integrity, and
- compliance with all relevant regulations, see 5.4.

The implications of the above items shall be incorporated in the floating structure's design philosophy and in the development of the operational philosophy.

Some of the items in the above list are usually performed as part of a formal risk assessment, which is an appropriate general procedure for identifying hazards, quantifying the associated risks and determining approaches for the mitigation of their consequences.

With regard to methods used to protect against fires and explosions, the selection of a suitable approach depends upon the function of the platform. Procedures shall conform to ISO 13702 and to any applicable national or regional requirements.

Requirements for personnel safety set by flag states and coastal state authorities (e.g. the U.S. Coast Guard) can have a substantial effect on the design of a floating structure.

In addition to the requirements identified in this clause, the provisions of the following documents shall also apply:

- API 14J;
- API 75L.

5.3 Planning requirements

5.3.1 General

Planning shall be undertaken in the initial stages of the design process in order to obtain a safe structural solution for performing the desired function.

5.3.2 Design basis

At the outset of the design process, a document (design basis) shall be created to summarize

- definition of design practices and applicable standards, regulations, codes,
- applicable limit states, design situations and design criteria (see ISO 19900),
- fabrication, transportation and installation philosophy,
- inspection and maintenance philosophy,
- service and operational philosophy, and
- platform removal philosophy.

5.3.3 Design practices

Codes, standards, RCS rules, and regulations (collectively referred to as "standards" hereafter) applicable to the design and construction of the floating structure shall be clearly identified at the commencement of the project.

Mixing of standards should, in general, be avoided. When more than one standard is utilized in the design process, differences in the standards shall be identified and a decision made concerning the appropriate measures to be undertaken. Such a decision shall be based upon sound engineering practice and include consultation with the responsible regulatory organization, as applicable.

The standards used in the design of structures shall be consistent and compatible with those utilized in the fabrication and in-service monitoring of the structure.

For innovative structural forms, or applications of unproven structural concepts where limited or no direct experience exists, appropriate analyses shall be performed to demonstrate that the safety level of the design is no lower than the safety level implicit in this standard when applied to traditional structural forms or concepts.

5.3.4 Inspection and maintenance philosophy

At the planning stage, a philosophy for inspection and maintenance shall be developed and documented, to ensure full consistency with the design basis of the floating structure and its components. The requirements for fatigue strength, corrosion control, material toughness, and inspection planning shall be consistent with the design service life of the floating structure established as part of the planning activities.

A critical assessment shall be made of the ability to actually achieve the intended inspection and maintenance objectives. Relevant provisions related to inspection and maintenance requirements are given in Clause 18.

General requirements for inspection of structures are given in ISO 19900. For detailed considerations concerning in-service condition monitoring, see Clause 18 of this standard.

5.4 Rules and regulations

5.4.1 General

The intent of this standard is to state explicitly general principles and basic requirements. The designer is then directed, through appropriate references, to make use of existing design practices and standards.

All aspects of the entire life cycle of a floating structure, including planning, design, fabrication, transportation, installation, operation and removal phases, which are not covered by this standard shall be performed in accordance with RCS rules or equivalent (i.e. applicable national/international standards, or suitably documented methods based on well-founded engineering principles applied with sound engineering judgement, such as first principle design methods). The resulting structure's safety level shall be consistent with the safety level implicit in the requirements given in this standard and in ISO 19900.

Where the floating structure is to be "flagged", the relevant flag state authority requirements also apply.

For structures to be deployed in US waters, US Coast Guard (USCG), Bureau of Ocean Energy Management, Regulation, and Enforcement (BOEMRE) and the regulations of other federal agencies (e.g. Codes of Federal Regulations) apply. RCS should be consulted for guidance.

NOTE In accordance with the current USCG interpretation, an FPSO deployed in US waters is deemed to be a vessel involved in the carriage/storage of oil cargo in bulk. Accordingly, the double hull requirements of OPA 90 apply^[186].

5.4.2 Use for project application

For a specific project application, the owner, in conjunction with the national regulator where one exists, shall identify the complete list of standards, which are regulatory documents, contractual agreements and company specifications whose requirements shall be met, clarifying areas of possible overlap and specifying the level of precedence in the enforcement of such requirements.

5.5 General requirements

5.5.1 General

A floating platform's functional requirements are generally specified by the owner, and shall be satisfied in conjunction with the principles stated in 5.2. As a consequence, the structure of a floating platform (and its stationkeeping system) shall be designed to allow the platform to

- a) fulfil its intended mission (production, drilling and production, etc.) for a specified length of time (design service life), and
- b) meet specified minimum requirements for serviceability and operability, such as keeping platform motions within prescribed limits, for a specified fraction of time.

The platform shall also be designed to provide

- adequate comfort levels for personnel onboard,
- proper functioning of the topsides equipment,

- access to subsea facilities, where applicable, and
- clearances with respect to other subsea or surface facilities, where applicable,
- while, at the same time
- maintaining floating stability,
- maintaining structural integrity,
- maintaining integrity and serviceability of drilling, production, export or other types of risers, and
- ensuring platform survival in extreme and accidental events.

Compliance of the floating structure design with these requirements shall be established using the analysis methodologies and design criteria given in Clauses 8 to 15. Action effects such as motions, accelerations, forces and stresses shall be evaluated for all defined design situations, and shall be compared with the system and component strengths to ensure the existence of reserve against loss of stability, structural failure or other undesirable occurrences.

5.5.2 Structural design philosophy

The structural system, components and details of a floating platform shall be designed, constructed and maintained so that they are suited to their intended use. Such systems shall be designed and constructed by qualified personnel utilizing sound engineering judgement.

The general requirements and conditions stated in ISO 19900 shall be fulfilled. Additionally, the following design principles apply:

- structural systems shall have ductile resistance unless the specified purpose or structural material requires otherwise;
- structures shall be designed so as to minimize stress concentrations and provide simple stress paths;
- structures shall be designed such that fabrication, including surface treatment, can be accomplished in accordance with accepted techniques and practices;
- heavy, concentrated actions on the structure shall be located such that proper framing to support these actions can be planned;
- effects of fabrication and offshore construction tolerances shall be taken into account;
- adequate allowance shall be made for corrosion when selecting materials, and corrosion shall be minimized by judicious design of structural details, selection of structural profiles and the use of suitable materials, coatings and cathodic protection systems;
- whenever practical, structures shall be designed to enable load redistribution.

A floating structure shall be designed with due consideration to minimizing the adverse effects of accidental events. Such events include fire/blast, collisions, compartmental flooding, mooring line failure, dropped objects, and fluid impacts such as green water or slamming. In this regard, particular consideration should be given to structural design, and to the layout and arrangement of facilities and equipment.

Cargo tanks and cargo systems shall be arranged so as to be separated by oil-tight cofferdams from galleys, living quarters, below-deck general cargo spaces, boiler rooms and machinery spaces where sources of ignition are normally present. Cofferdams shall be adequately vented and wide enough to allow ready access. Ballast tanks or void spaces may be considered as cofferdams.

The floating structure shall be designed to maintain global integrity during an accidental event. Furthermore, the structure shall be designed so that if structural damage does occur, the damaged structure (possibly with temporary

repairs, as applicable) is able to resist action combinations appropriate to these design situations without suffering extensive failure, free drifting, capsizing or sinking, and without causing extensive harm to the environment.

Emergency and other essential equipment (ballast pumps, generators, mooring winches, etc.), shall be designed to continue to operate at all possible platform attitudes resulting from an accident. Low-pressure piping and bulkhead penetrations can provide conduits for downflooding (and siphoning) and shall be examined for integrity under the maximum hydrostatic pressure consistent with damaged conditions.

5.5.3 Design criteria

Criteria to be met by the structural design are usually directly related to specific design situations. Factors to be considered when identifying design criteria shall include

- platform mission,
- regulatory requirements,
- RCS requirements (as applicable),
- design service life,
- duration of temporary phases,
- operating environment,
- platform response,
- consequence of failure,
- accuracy in the prediction of actions and responses,
- probability of occurrence of actions, and
- platform abandonment and/or removal.

Structures shall be designed to minimize inspection requirements in tanks that contain hazardous materials, e.g. diesel, methanol, or tanks that contain potable water. Tank piping shall be arranged so as to allow for the safe isolation of tanks prior to inspection.

5.5.4 Service and operational considerations

A marine operations manual (MOM), or equivalent, shall be prepared for use by personnel onboard the floating structure. The MOM should be as concise as reasonably practicable and shall contain pertinent information for safe operation, including all relevant limiting design criteria relating to global structural strength, compartmentation and stability.

Different hull configurations can be sensitive to variations in total weight, weight/buoyancy distribution, hydrostatic stability or any combination thereof. The designer shall ensure that weight monitoring, distribution and control procedures are clearly identified in the MOM.

Documentation noting any areas built with special steel should be onboard to identify any special welding requirements when carrying out emergency repairs.

Any changes made to the design of a floating structure subsequent to the lightship survey and/or inclining experiment should be accounted for and included in the final documentation and updated during service (see also 5.5.7 and 15.2).

5.5.5 Hydrostatic stability

The floating behaviour of the platform shall be consistent with the requirements for stability in intact and damaged configurations, for both temporary and in-service conditions, see Clause 15.

When recognized standards are used to verify stability adequacy, consideration shall also be given to the consequences of the accidental events identified as being relevant for the structure, see 7.4.

5.5.6 Compartmentation

To mitigate the consequences of possible damage, the floating structure's hull shall be subdivided into compartments so as to facilitate meeting stability requirements and reduce risks of environmental pollution and loss of the platform, see Clause 15.

5.5.7 Weight control

The hydrostatic stability and the dynamic response of a floating platform are very sensitive to the magnitude and distribution of the mass. These parameters, and the location of the centre of gravity, shall be monitored during the entire life cycle of the platform using an appropriate weight control and management process.

In particular, during the design and fabrication process:

- the weight of the structure shall be evaluated using a rational weight-estimating procedure;
- the centre of gravity of the structure, or part of the structure, shall be evaluated using a rational procedure.

Regular weight and centre of gravity reports shall be produced at various stages of the design and fabrication process, with appropriate contingency factors to allow for uncertainties connected with outstanding items to be fabricated or installed.

The weight database shall be updated to an as-built status, to provide accurate information for all pre-service temporary phases, including launch, transportation, upending and lifts.

The mass distribution of a floating platform as-built shall be verified to an appropriate degree of accuracy (see 15.2 in connection with requirements to inclining tests).

The MOM shall contain appropriate provisions for handover of the design database to the operations team, and for the continuing in-service weight control process.

NOTE Further guidance on this topic can be found in ISO 19901-5.

5.5.8 Global response

The floating structure hull shall be designed so that, in conjunction with the effects of the stationkeeping system and the riser system, the predicted excursion and motion response stays within appropriate limits, set in conjunction with the requirements for

- serviceability of all types of risers,
- comfort levels for personnel onboard,
- serviceability of the drilling, production, or other types of equipment, as applicable, and
- maintaining minimum clearances with other surface facilities or subsea infrastructure.

5.5.9 Stationkeeping

The stationkeeping system, which in general consists of a combination of mooring lines, anchors and thrusters, shall be designed to restrain the platform maximum excursion to the envelope defined by the considerations identified in 5.5.8. See Clause 17.

5.5.10 Materials

Suitable materials shall be specified. In addition to strength, due care shall be paid to ductility, toughness, weldability and corrosion resistance requirements.

Adequate ductility in the design of a structure shall be facilitated by

- meeting requisite material toughness requirements,
- avoiding failure initiation due to a combination of high stress concentrations and undetected weld defects in structural components and details,
- designing structural details and connections so as to allow a certain amount of plastic deformation, (avoiding “hard spots”),
- arranging the scantlings of structures and their components so as to avoid sudden changes in structural strength or stiffness.

5.5.11 Topsides arrangements and layout

Personnel safety is a key consideration in the layout and arrangement of topsides process equipment for offshore platforms. In addition to the provisions of API 14J and API 75L, guidance can also be provided by RCS rules. Furthermore, the following requirements or recommendations apply.

- a) Personnel accommodation should not be located directly above or below produced oil, gas storage tanks, and process vessels; additionally, personnel accommodation should not be located above or below surface trees and wellheads, and above or below the portions of risers located on the floating structure.
- b) Personnel accommodations should be positioned at as great a distance as possible from the process facilities and from the flare.
- c) Process vessels, hydrocarbon storage tanks, or other items which could become a source of fuel in the event of a fire should be located as far as possible or otherwise protected from wellheads and potential ignition sources.
- d) Arrangements and layout of the facilities, accommodations, control rooms, and life saving appliances should be such that a fire in a process area, hydrocarbon storage area, wellhead area, or other classified areas does not prevent or impede the safe exit of personnel from the accommodation through designated escape routes to boat landings or life boat locations.

5.6 Independent verification

Independent verification that the floating structure’s design and construction is in compliance with the provisions of this standard shall be carried out as a combination of independent calculations, document reviews and audits, surveys and inspections, etc., as appropriate. Particular emphasis shall be placed on the verification of structural systems and components significant to safety.

Verification activities shall be sufficiently detailed and extensive to clearly demonstrate that the design and construction are adequate. Appropriate documentation shall be maintained of the scope and extent of the verification, the procedures employed, and the relevant reports.

The above requirements may be satisfied in part, or in full, by classing by an RCS.

5.7 Analytical tools

Most of the analytical procedures and calculations described, specified, and referenced in this standard are commonly performed with the assistance of computer-aided engineering tools. Many of these consist of commercially available, widely used software suites which, when used by experienced and well-trained operators, can be considered *de facto* industry standards. For these software systems, the responsibility to perform adequate validation and verification, and maintain evidence thereof, may be delegated to, and satisfied by, the original author or distributor.

In other cases, particularly in technological areas in rapid evolution, innovative analytical approaches and techniques are more typically embedded in original, proprietary software solutions. In such cases, the developer shall validate the adequacy of the results by, for instance, comparison with closed-form solutions, test data or field measurements.

In either case, the designer shall document that the tools used in the design and analysis activities have been shown to provide results considered acceptable in terms of consistency and accuracy when compared to test data, field measurements, or to the results of other similar tools.

5.8 In-service inspection and maintenance

Comprehensive structural inspection and maintenance programmes shall be developed for the structure and emergency and other essential marine equipment (see Clause 18) in order to monitor the integrity of the floating structure throughout its service life. Such programmes shall take into account the frequency of inspection and the number of tanks open at any one time.

In-service inspection procedures shall be developed and undertaken to confirm that modifications, alterations, repairs, and maintenance are undertaken in compliance with appropriate design drawings, specifications, and procedures.

5.9 Assessment of existing floating structures

5.9.1 General

Various circumstances can lead to a requirement for an existing structure to be reassessed (e.g. when considering relocation, a change of mission, major modifications, changes in industry practice, or substantial repairs following an accidental event, etc.). In such cases, the existing structure shall be assessed for compliance with the provisions of this document. Where aspects of the design are identified as non-compliant with the requirements of this document, the provisions of ISO 19900 may be used to demonstrate adequacy on a fitness-for-purpose basis.

5.9.2 Assessment of existing floating structures designed for hurricanes

5.9.2.1 Scope

The provisions of 5.9.2.1 to 5.9.2.8 apply to the assessment of existing floating structures located in the Gulf of Mexico and designed for hurricane conditions. In the case of a disconnectable floating structure (e.g. a shipshape FPSO) these provisions apply only to the parts of the structure expected to be exposed to the hurricane conditions, typically risers, mooring buoys, spider buoys, or buoyant riser towers.

These provisions are minimum assessment requirements intended to reduce hurricane-related risks to existing floating structures.

Structures should be assessed individually as well as on an area-wide basis, in order to determine the consequences of a major structural failure on the owner and on other parties that could be affected either directly by the structure's failure or indirectly by disruption of the structure's operability (e.g. in the case of a hub platform). For critical structures, consideration should be given to exceeding the minimum acceptance criteria defined herein.

Because of their complex design, highly interactive dynamic behaviour, and strong coupling with other critical systems (e.g. risers), floating structures cannot be easily characterized by a single strength measure, such as the reserve strength ratio (RSR) used for fixed structures. A three step approach is therefore used, consisting of a design level check, a survival check and a robustness check. The three steps are described in the sections below.

5.9.2.2 Assessment initiator

An existing floating structure shall be assessed for substantial variations in site-specific (or regional) hurricane parameters with respect to the metocean parameters used in the original design that can occur due to updating applicable metocean criteria.

5.9.2.3 Assessment conditions

The metocean parameters for use in the assessment shall be as specified in API 2A-WSD and API 2INT-MET or derived from a site-specific study. Site-specific conditions are typically used to design floating structures. If the site-specific conditions used to design the structure are of equal or greater severity than the revised environmental conditions defined in API 2A-WSD and API 2INT-MET, and the structure has not been modified from the design configuration, then the structure is deemed to have passed the assessment.

5.9.2.4 Assessment process

5.9.2.4.1 General

Existing floating structures shall be assessed using 100-year hurricane conditions using one of the following approaches.

- a) By reference to the original design cases for hurricane conditions accounting for the as-is configuration of the structure.
- b) By re-analysis of the as-is configuration of the structure. A three-step assessment process is recommended as described below. Analysis methods should give accurate or conservative representations of the structure's response as validated by model tests or field data. Loads due to loss of air gap shall be included.
- c) By proven survival, in the structure's as-is configuration, of an actual hurricane event that meets or exceeds the 100-year hurricane condition (see 5.9.2.5.2).

The results of the most recent inspection including hull, mooring system and other components should be used where appropriate to update the corrosion allowances and other assumptions used for the original design of the facility.

5.9.2.4.2 Step 1 – Design level check

5.9.2.4.2.1 Current condition design check

Using the environmental conditions employed in the original design, a design level check of the structure should be performed taking into account all changes on the structure since its original installation. This check is intended to evaluate the consequences of changes in configuration that could increase or decrease the loads on, or operating envelopes of, critical structural components.

The changes considered for this check should include not only additions or removal of payload, but also any damage or corrosion incurred by the risers, by the hull or by the stationkeeping system.

5.9.2.4.2.2 Life safety and operational checks

The Life Safety and Operational Checks should be performed to evaluate the structure for conditions while manned and operating during the hurricane season.

Life safety is assessed by comparing the 100-year sudden hurricane condition (see API 2A-WSD and API 2INT-MET) to the 100-year hurricane condition used for the original design of the facility. If the 100-year sudden hurricane condition is more severe than the 100-year hurricane condition used in the original design, repeat the design check in 5.9.4.2.1 with the 100-year sudden hurricane condition.

Operational and damaged conditions used for this check should be consistent with the original criteria except that updated hurricanes conditions should be used.

Acceptance criteria are provided in 5.9.2.5.1.

5.9.2.4.3 Step 2 – Survival check

Evaluate the floating structure's ability to survive a hurricane as defined in 5.9.2.5.2, using 100-year hurricane conditions and the hurricane analyses procedure in this document. The response of the floating structure should not exceed the capacity of the critical components or cause disconnection of the stationkeeping system.

Acceptance criteria are provided in 5.9.2.5.2.

5.9.2.4.4 Step 3 – Robustness check

The robustness check for floating structures that passed the survival check in Step 2 should be performed using a return period equal to or higher than 200 years, preferably 1000 years, to determine the capacity of each critical component. Additional guidance for the robustness check can be found in 6.4.2.1. For floating structures that did not pass the survival check in Step 2, the highest acceptable return period should be determined for each critical component to identify components that control the structure's capacity.

Acceptance criteria are provided in 5.9.2.5.3

5.9.2.5 Acceptance criteria

5.9.2.5.1 Design level check acceptance criteria

The design level check should use the more severe of either the original design environmental criteria or the sudden hurricane conditions contained in API 2A-WSD and API 2INT-MET. If a structure does not meet or exceed the recommended criteria, modifications to the hurricane and damage control procedures should be evaluated to mitigate the additional risk while manned.

In addition, the original stability criteria (allowable KG) for all operating conditions shall continue to be satisfied.

5.9.2.5.2 Survival check acceptance criteria

The survival check may be performed with safety factors equal to 1.0.

Survival is defined as no failure of the floating structure, risers, pipelines, or mooring system that could lead to the catastrophic loss of the structure.

For survival acceptance, the floating structure shall meet as a minimum the following criteria.

- a) The floating stability of the structure is maintained in accordance with the approved certification criteria.
- b) For conventionally moored structures, the mooring system does not fail for the maximum tension case in the intact condition. Failure of one line does not lead to sequential failures of one line after the other, otherwise known as system unzipping. Transient analysis may consider the limited duration over which peak loads are maintained. All mooring interface hardware remains within geometric operating limits.
- c) Stresses within the primary structural elements of the hull and deck, if required for hull integrity or stability, are generally below yield with no safety factors and the structural elements are fit for purpose to prevent loss of overall stability of the floating structure. Stress redistribution to lower stress areas should be evaluated with regards to allowable strain limits and buckling.
- d) Pipelines and risers do not fail and all their interface hardware remains within geometric operating limits.
- e) No catastrophic failure occurs at critical connections that secure major production and drilling modules to the structure.

Structures that do not pass the survival check should be evaluated parametrically, to determine the highest return period for which the structure passes the survival check. This can assist in providing a clear understanding of the risks and identifying appropriate mitigating actions.

In addition, if a structure does not pass the acceptance criteria, hydrocarbon inventories on the structure and any incoming or outgoing flow should be significantly reduced to reduce environmental risks if the structure does not survive in the extreme event. Also, mitigation efforts such as payload reduction or structural strengthening should be considered.

5.9.2.5.3 Robustness check acceptance criteria

The structure component(s) that control the capacity of the structure should be identified and the associated component and global structure failure mode defined. This can be used to understand the limitations of the structure's design for hurricane conditions. Consideration should be given to making mitigating modifications to the configuration of components that fail at unusually low return periods.

The robustness check should include, as a minimum, evaluation of the structural integrity of the deck and hull, the mooring system, and the production and export risers.

Key assessment aspects should be:

- positioning of down-stop and up-stop of riser support systems (down-stop and up-stop are mechanical/structural components intended to limit the riser downstroke and upstroke);
- capacity and ductility of key riser system components;
- mooring line safety factors, and the capacity of key mooring components as well as the capacity and ductility of their support structures;
- key structural components, such as: deck to hull connection, truss to hard tank connections of a spar, or pontoon to column connections on a semi-submersible, connections of any drilling and/or production modules to the support framing of the structure;
- high-stress low-cycle fatigue of critical structural elements, or mooring components;
- global stability and downflood points (e.g. access hatches and other points) should be checked to prevent potential water ingress with regard to wave impact loads and full immersion to appropriate rule for the 100-year design wave crest conditions (see API 2A-WSD and API 2INT-MET).

5.9.2.6 Configuration changes

Modifications to the initial structural configuration, including the addition of new equipment that would cause the structure to fail the design and survival level checks (Step 1 and 2 in 5.9.2.4), shall not be implemented, except as noted in the following paragraphs.

The local structure design of any equipment installed after the change in environmental criteria shall be carried out using the revised environmental parameters. Local structure is defined as the set of structural elements whose failure would lead solely to the collapse of the support for the additional equipment.

Examples of configuration changes include additional equipment, topsides payload, additional risers, etc. Such changes are acceptable only if it can be demonstrated that the structure's global performance and the structural performance in the modified configuration still meet the acceptance criteria of the design checks. In some cases configuration changes can be made without degrading the structural performance by making suitable adjustments to the current structural configuration. Examples include removing unused equipment or modifications to ballasting or mooring.

5.9.2.7 Marine operations manual

The marine operations manual (MOM) of the structure should be updated to reflect any changes to the marine operations identified by the results of the structural assessment. Marine operations staff on-board the structure should be properly trained to assure that all procedures are followed for storm safe conditions and for hurricane evacuation.

5.9.2.8 General recommendations for all existing floating structures

5.9.2.8.1 Scope

The previous sections describe analytical assessments to be performed to determine that, following the onset of the assessment initiator defined in 5.9.2.2, a floating structure is still in a safe configuration. The assessment generally deals with global performance of the structure; if the structure does not pass the assessment, then mitigation is required. Several types of mitigation are described in this section.

In addition, a continuous mitigation process should be considered regardless of the outcome of the analytical assessment, even for structures where assessment is not required. A significant portion of post-hurricane downtime on floating structures results from damage to structures and systems that do not affect the structure's global strength. Examples include damage to topsides safety equipment and systems, especially on lower decks, subject to wave loading, and toppled deck equipment due to a combination of inadequate securing and high winds. Such damage can result in safety issues when the structure is re-boarded following a hurricane and may also result in significant repair, downtime, and economic consequences.

5.9.2.8.2 Mitigation

Preventive mitigation can help extend the life of a structure or improve its chances of survival in a design event. Mitigation typically involves reducing loads on the structure such as removing unused risers, or increasing the structure's strength. Mitigation can also include active programs to minimize the consequence of damage or failure, such as plugging and abandoning unused wells or removing inactive process equipment. Mitigation opportunities should be evaluated on a cost-benefit basis for each structure on a case-by-case basis, although many of them can be implemented at low cost or as part of the normal planned structure maintenance.

Examples of load reduction are as follows.

- relocating or removing piping and other systems located below the lowest deck;
- relocating or removing equipment on the lowest decks subject to wave loading;
- removal of unused boat landings, walkways, stairs, barge bumpers, etc.;
- removal of unused wells and risers;
- removal of process equipment, tankage or piping no longer employed in order to reduce surface areas exposed to wind and waves as well as dead load;
- raising the deck (s) to prevent wave loading on the deck;
- laying down or removing a drilling rig during hurricane season;
- operational plans to reduce hydrocarbon or other liquid inventories prior to an expected hurricane event.

Strengthening should be based upon a specific engineering assessment for the structure. Examples of strengthening are as follows:

- improved tie-down of topsides structure and equipment (see API 2TD^[187] for guidance);
- strengthening members or adding auxiliary bracing members;
- strengthening of joints.

Examples of actions that can minimize the consequences of damage or failure are as follows.

- relocating or removing piping and other systems located below the lowest deck;
- relocating or removing equipment on the lowest decks subject to wave loading;
- strengthening or shielding of piping, equipment and other systems located on the lowest decks from potential damage due to wave loading;
- plug and abandon unused wells;
- reduction of any hydrocarbons and/or chemicals on the facility;
- provision of alternate means of production if a platform is damaged or destroyed, such as pre-planning for alternate sales lines, emergency jumper lines to alternative undamaged platforms, etc.

5.9.2.8.3 Hurricane Preparedness

Advanced planning can also assist in reducing hurricane risks as well as improving post-hurricane response. Owners should develop a written hurricane preparedness plan describing general activities for their inventory of offshore structures as well as the plans for each specific structure. Check lists and platform specific guides can assist during the evacuation process. Structures with higher life safety exposure and/or economic risk may require additional consideration.

Examples of hurricane preparedness are as follows.

- a) Evacuation planning for major hurricanes, including first evacuation for platforms that are at greater risk of failure and those that are furthest from shore. Initial evacuation of non-essential personnel should begin early.
- b) Evacuation planning for sudden hurricanes, which occur at short notice, should be given special consideration, including evacuation to offshore structures that have been demonstrated to be able to safely survive conditions well in excess of the sudden hurricane, preferably the full population 100-year return event. Special considerations are related to logistics and safety of the evacuation operation and the securing of the platform against spill potential.
- c) Begin preparing structure operations for safe shut-in as early as possible including system pump down, securing equipment and control panels, reducing liquid inventories, etc.
- d) Secure loose objects and equipment that can become airborne projectiles. Store movable equipment in safe and dry areas (e.g., generators).
- e) Develop advance plans for post-hurricane access to the structure, in case normal access and safety systems such as boat landings, walkways, power, etc. are not be available or functional due to damage.
- f) Establish guidelines for safe re-boarding of a damaged structure, with minimum acceptance criteria for platform access and egress.

5.10 Reuse of existing floating structures

When a structure is relocated for use at a new site, the structure shall be assessed in accordance with the requirements of Clause 14, for the mission and conditions (including exposure level) that are applicable at the new site.

6 Basic design requirements

6.1 General

In accordance with ISO 19900, structural design shall be performed with reference to a specified set of limit states. For each limit state, design situations shall be determined and an appropriate calculation model shall be established.

Design and analysis of a floating structure requires the identification of a finite number of design situations. A sufficient number of design situations shall be considered to ensure that critical action combinations for all main load-bearing structural components are evaluated. Each phase of construction, transportation, installation, operation, and removal shall be complemented by appropriate environmental conditions. Significant effects occurring in one design phase that affect another phase shall be fully considered in the design process. Such effects could be, for example, built-in deflections or fatigue damage.

Clause 6 outlines the overall requirements for

- a) defining exposure levels (see 6.2),
- b) incorporating limit states (see 6.3),
- c) determining design situations (see 6.4).

The reliability of floating structures, i.e. their ability to satisfy appropriate structural limit states, is highly dependent upon the reliability of emergency and essential marine equipment. Risk assessments shall be conducted to demonstrate that such equipment realizes reliability levels compatible with that demanded for the structure and its components.

6.2 Exposure levels

6.2.1 General

Floating platforms vary in size, complexity, mission, performance requirements, manning levels, criticality to the asset development strategy, possible hazards, etc. In order to define appropriate design situations and design criteria for a particular floating platform, the concept of exposure levels is presented here.

A floating platform in a particular location is characterized by a specific exposure level. Associated with each exposure level are appropriate design situations and design criteria for the platform's intended function and design service life.

Exposure levels are determined taking into consideration combinations of life-safety categories and consequence categories for a given platform. Life-safety is a direct function of the platform's expected manning levels during design environmental events. Consequences are mainly related to the potential risk to life of personnel brought in to respond to any incident, the potential risk of environmental damage and the potential risk of economic losses.

6.2.2 Life-safety categories

6.2.2.1 General

For floating platforms, three life-safety categories are defined:

- a) S1 manned–nonevacuated;
- b) S2 manned–evacuated;
- c) S3 unmanned.

Selection of life-safety category involves a degree of judgement. The platform's owner shall determine the applicable category prior to the design of a new structure or the assessment of an existing structure, and shall obtain the agreement of the regulator where applicable.

6.2.2.2 S1 (manned–nonevacuated)

The manned–nonevacuated category refers to a platform that is continuously (or nearly continuously) occupied by personnel accommodated and living thereon, and whose evacuation prior to the design environmental event is either not intended or impractical. The platform shall be categorized as S1 manned–nonevacuated unless the particular requirements for S2 or S3 (see below) apply throughout the platform's design service life.

6.2.2.3 S2 (manned–evacuated)

The manned–evacuated category refers to a platform that is normally manned except during a forecast design environmental event. A platform may be categorized as manned–evacuated only if all of the following conditions apply:

- a) a reliable forecast of a design environmental event is technically and operationally feasible (e.g. tropical cyclone), and the weather conditions between any such forecast and the occurrence of the design environmental event are not likely to inhibit an evacuation;
- b) evacuation in anticipation of a design environmental event is intended, and is part of the operating procedures;
- c) sufficient time and resources exist to safely evacuate all personnel from the platform and all other platforms likely to require evacuation for the same event.

6.2.2.4 S3 (unmanned)

The unmanned category refers to a platform that is only manned for occasional inspection, maintenance, and modification visits. A platform may be categorized as unmanned only if all of the following conditions apply:

- a) visits to the platform are undertaken only for specific planned inspection, maintenance or modification operations on the platform itself; and,
- b) visits are not expected to last more than 24 hours during seasons when severe weather can be expected to occur; and,
- c) the evacuation criteria of 6.2.2.3, a) to c), are also met.

NOTE A platform in this category is often described as “not normally manned”.

6.2.3 Consequence categories

6.2.3.1 General

For floating platforms, three consequence categories are defined:

- C1 high-consequence category;
- C2 medium-consequence category;
- C3 low-consequence category.

The main criteria governing the choice of the appropriate category are the following:

- life-safety of personnel on, or near to, the platform — covering personnel brought in to react to any accidental or abnormal event, but not those who are part of the platform's normal complement;
- damage to the environment;
- anticipated losses to the owner, to other operators, to industry and/or to other third parties, as well as to society in general.

Selection of consequence category involves a degree of judgement. The applicable category shall be determined by the platform's owner prior to the design of a new structure or the assessment of an existing structure and shall be agreed to by the regulator where applicable.

6.2.3.2 C1 (high-consequence category)

The high-consequence category refers to platforms with high production rates or large processing capacity and/or those platforms that have the potential for well flow of either oil or sour gas in the event of structure/riser failure. In addition, it includes platforms where the shut-in of the oil or sour gas production is not planned, or not practical, prior to the occurrence of the design environmental event (such as areas with high seismic activity). Platforms that support trunk oil transport lines and/or storage facilities for intermittent oil shipment are also considered to be in the high-consequence category.

A platform shall be categorized as C1, high-consequence, unless the particular requirements for C2 or C3 apply throughout the platform's design service life.

6.2.3.3 C2 (medium-consequence category)

The medium-consequence category refers to platforms where production can be shut-in during the design environmental event. A platform may be categorized as C2, medium-consequence, only if all of the following conditions apply:

- a) all wells that can flow on their own in the event of structure/riser failure shall contain fully-functional subsurface safety valves, manufactured and tested in accordance with applicable specifications;
- b) oil storage is limited to process inventory, bunker fuel, and "surge" tanks for pipeline transfer;
- c) pipelines are limited in their ability to release hydrocarbons, either by virtue of inventory and pressure regime or by check valves or by seabed safety valves.

6.2.3.4 C3 (low-consequence category)

The low-consequence category refers to minimal platforms where production can be shut-in during the design environmental event. These platforms can support production departing from the platform and low volume in-field pipelines.

A platform may be categorized as C3, low-consequence, only if all of the following conditions apply:

- a) all wells that can flow on their own in the event of structure/riser failure contain fully-functional, sub-surface safety valves, manufactured and tested in accordance with applicable specifications;
- b) oil storage is limited to process inventory and bunker fuel;
- c) pipelines are limited in their ability to release hydrocarbons, either by virtue of inventory and pressure regime or by check valves or by seabed safety valves.

6.2.4 Determination of exposure level

The three life-safety categories and the three consequences categories can, in principle, be combined into nine exposure levels. However, the level to be used for the platform's categorization is the more restrictive level for either life-safety or consequence.

This results in three exposure levels, according to Table 1.

Table 1 — Determination of exposure level

Life-safety category	Exposure level (L1 to L3)		
	Consequence category		
	C1 (high-consequence)	C2 (medium-consequence)	C3 (low-consequence)
S1 (manned–nonevacuated)	L1	L1	L1
S2 (manned–evacuated)	L1	L2	L2
S3 (unmanned)	L1	L2	L3

Thus, for example, a platform categorized as S1 and C2 has an exposure level of L1, while a structure categorized as S3 and C2 has an exposure level of L2.

The platform's owner shall determine the applicable exposure level prior to the design of a new platform and shall obtain the agreement of the regulator where applicable. A platform's categorization may be revised over its design service life as a result of changes in factors affecting life-safety or consequence category. Once the exposure level is determined, appropriate design situations and design criteria for the structure's intended service can be identified.

This document provides partial safety factors exclusively for structures with exposure levels equal to L1.

For Gulf of Mexico applications, all structures covered by this standard shall be considered to have an exposure level of L1.

6.3 Limit states

6.3.1 General

The design checking for a system and its components shall be performed with reference to a specified set of limit states beyond which the structure or the system no longer satisfies the design requirements given in Clauses 7 to 14. In addition, for each limit state, watertightness and hydrostatic stability shall be ensured in accordance with Clause 15.

For each limit state, design criteria shall be established, appropriate design situations shall be defined, calculation models shall be established, and adequate procedures shall be followed to verify compliance with design requirements. These requirements cover all phases of the structure's life cycle, including construction, transportation, installation, operation and removal.

6.3.2 Limit states for floating structures

The following limit state categories shall be used in the structural design of a floating platform:

- ultimate limit states (ULS), which generally involve checking the floating structure's strength to resist extreme actions and action effects;
- serviceability limit states (SLS), which generally address the structure's performance during its normal intended use, and involve checking the floating structure's strength to resist operational actions and action effects;
- fatigue limit states (FLS), which cover the structure's strength to resist cumulative effects of repeated actions;
- accidental limit states (ALS), which investigate the structure's ability to resist accidental and abnormal events, and the structure's resistance to the effects of specified environmental actions after damage has occurred as a consequence of an accidental or abnormal event.

6.4 Design situations

6.4.1 General

Design situations include the service and operational requirements resulting from the intended use of the floating structure in conjunction with the environmental conditions affecting the floating structure's behaviour.

In particular, an environmental design situation consists of the set of actions induced by waves, wind, current, and, if applicable, earthquakes or floating ice, on the floating structure and on the mooring system, as appropriate, and is characterized by a given return period.

Criteria to be met by the design can be directly related to the specific formulation or modelling technique used to simulate the design situation. In such cases, design situations and design criteria form one whole and shall not be separated from one another. They are jointly specified in Clauses 8 to 18.

The definition of specific design situations for the floating structure shall be the responsibility of the owner in accordance with the requirements of a regulatory authority where one exists.

6.4.2 Design situations for ULS

6.4.2.1 General

The design actions to be used in the various ULS are specified in Clause 7. The design strengths and the application of the ULS are specified in Clauses 9, 11, 12 and 13.

For ULS conditions, representative metocean actions shall be established with the intention of resulting in the most onerous metocean action effects with the return period of 100 years. Different structural components can be affected to a different extent by the same design situations. Consequently, a range of design situations shall be used to ensure that the most onerous conditions for all types of structural components are identified.

6.4.2.2 Robustness check

The target of the structural design provisions of this document is to obtain reliability levels consistent with those inherent in other structures designed in accordance with other API structural standards, while accounting for hurricane-related metocean conditions.

API 2INT-MET includes wave heights, surge, and other metocean parameters for return periods for 200, 1000, 2000, and 10,000 years. This information has traditionally not been used in the design practices used in US waters, although it is part of the design practices recommended in or mandated by other national and international standards.

On the basis of the considerable experience gained in the recent past in the design and operation of floating structures for U.S. waters, a structural system robustness check is recommended for any type of floating structure. This check shall be performed using hurricane conditions with a return period not less than 1 000 years.

The objective of the system robustness check is to ensure that the designer and the owner have a clear understanding of the redundancy or robustness of the design. The system robustness check should include, as a minimum, the mooring system, and the production and export risers. The intent of the robustness check is to verify adequate margins in maintaining stationkeeping, structural integrity, and floating stability.

Key design considerations when performing a system robustness check are:

- a) degradation of floating stability through compartment flooding or otherwise;
- b) positioning of down-stop and up-stop of riser support systems;
- c) capacity and ductility of key riser components;
- d) mooring line safety factors, and the capacity of key mooring components as well as the capacity and ductility of their support structures;
- e) adequacy of key structural components, such as: deck to hull connection, truss to hard tank connections on a spar, or pontoon to column connections on a semi-submersible.

6.4.3 Design situations for SLS

The identification of SLS design situations for floating offshore structures shall be based on a number of considerations, including the following:

- unacceptable deformations can affect the efficient use of structural or non-structural components or the functioning of equipment relying on them;
- local damage (including corrosion, cracking, wear, deterioration of flex joints) can reduce the durability of the structure or affect the efficiency of structural or non-structural components;
- excessive motions, accelerations, vibrations or noise can cause discomfort to personnel and interfere with their capability to discharge their duties;
- motions, accelerations or vibrations can exceed the range of effective functionality of topsides equipment (e.g. roll and pitch angles can seriously affect the performance of separators or the serviceability of drilling equipment).

The assessment criteria associated with SLS shall typically be based on motions, deflections, or vibration limits during normal use.

The SLS criteria shall be defined by the owner of a structure, established practice, designers, or suppliers of motion-sensitive equipment, the primary aim being efficient and economical in-service performance without discomfort to onboard personnel or excessive routine maintenance.

The acceptable limits necessarily depend on the type, mission and configuration of the structure. Furthermore, in defining such limits, other disciplines such as equipment and machinery designers shall also be consulted.

6.4.4 Design situations for FLS

FLS are addressed in Clause 10, covering methods, actions, and resistances.

6.4.5 Design situations for ALS

ALS are addressed in Clauses 9, 11, 12 and 13, in respect of actions and modifications to both partial action factors and partial resistance factors. The main goal of the ALS verification is to ensure that the floating structure is designed to achieve the following:

- a) withstand specified accidental and abnormal events suffering, at worst, limited damage that shall not affect its overall structural integrity, stability and watertightness;
- b) maintain adequate structural integrity (residual strength), stability and watertightness in the event of damage from an accidental or abnormal event, for a sufficient period of time and under specified environmental conditions to enable some or all of the following activities, as applicable:

- evacuation of personnel from the structure;
- control over movement or motion of the structure;
- temporary repairs;
- fire fighting;
- control of outflow of cargo or stored material liable to cause environmental damage or pollution.

Different types of accidental or abnormal events can require different methodologies or different levels of the same methodology to assess adequacy of the structural resistance during and following such events.

ALS design situations may include consideration of a reduced extreme environmental condition. This condition should be established with the intention of resulting in the most onerous action effects for a return period of one year. Recognized structural practices accounting for local structural damage may be utilized in design for the ALS.

6.4.6 Temporary phases

During temporary phases, structural strength is generally limited as a result of partial levels of completion of the structure and/or application of action combinations that differ from those applicable to normal operation. The effects of design situations applicable to temporary phases shall be addressed during design to avoid exceedance of either ULS or SLS, and to assess contributions to FLS.

Detailed planning of erection sequences and construction methods is essential to ensure all critical conditions are identified.

Transportation and installation assessments should comply with the requirements of a qualified marine surveyor accustomed to advising on transportation of these types of structures (e.g. an insurance marine warranty surveyor) or equivalent, see 9.11.3.

When verifying the design of a floating structure during the transportation phase, representative metocean parameters should be established based on an assessment of the probability and consequence of encountering an event during the transportation phase that would cause the design limits of the structure and/or seafastening to be exceeded (see also API 2MOP^[197] or ISO 19901-6^[154]).

NOTE For the purposes of this provision, API 2MOP is equivalent to ISO 19901-6.

7 Actions and action effects

7.1 General

Clause 7 addresses actions likely to be experienced by a floating structure during its life cycle and applicable methodologies for their evaluation.

7.2 Permanent actions (*G*)

Permanent actions (see A.7.2 for examples) are those likely to act throughout a given design situation and for which variations in magnitude with time, during the life of the structure,

- a) are small in relation to the mean value, or
- b) attain some limiting value.

The representative value of a permanent action shall be taken as the mean value based on the density of the material, the volume of the structure or component based on its nominal dimensions, calculated reactions, and calculated effects of deflections and deformations, as appropriate.

In cases where the permanent action can have an upper or lower value, the representative value shall be taken as the value that produces the most unfavourable effects in the structure under consideration.

A procedure for monitoring the weight and position of the centre of gravity of the floating platform shall be incorporated into the design process. The mass distribution of a floating platform as-built shall be verified to an appropriate degree of accuracy (see 15.2 in connection with requirements to inclining tests). Monitoring of the weight and centre of gravity shall be performed during the entire life cycle of the floating platform.

NOTE For further guidance, see ISO 19901-5.

7.3 Variable actions (Q)

Variable actions generally vary in magnitude, position and direction during the life of the structure, and are usually related to operations and normal use of the platform. These actions are likely to act throughout a given design situation, but do not include environmental actions (see A.7.3 for examples).

The representative value of a variable action shall be taken as the maximum (or minimum) value that produces the most unfavourable effects in the structure under consideration. The value shall be determined either in the same manner as for permanent actions, i.e. mean or calculated, or as a specified value from a recognized source (e.g. RCS or national regulations).

Design local deck actions shall be documented on a *load plan*. This plan shall clearly show the design uniform and concentrated actions for all deck areas for each relevant mode of operation.

Design limits pertaining to tank capacities shall be documented on a *capacity plan*. As a minimum, the capacity plan shall clearly show tank layout, intended use of tanks, capacities, and the maximum design relative density of tank fluid.

Crane live loads should be included in this category.

7.4 Accidental actions (A)

7.4.1 General

Accidental actions relate to accidental events, abnormal operations or technical failure (see A.7.4.1 for examples).

The representative value of an accidental action shall correspond to a value with an annual probability of exceedance equal to 10^{-4} .

Values of accidental actions with an annual probability of exceedance less than 10^{-4} may be disregarded.

A hazard identification (HAZID) shall be carried out at the outset of the design of a floating structure to identify potential accidental events and the associated consequences. The extent of the HAZID and the assessment methods shall be determined taking into account the type of structure and the existing operational experience. HAZIDs should be conducted with appropriate expertise available. When selecting participants their experience with failure investigation in relation to these types of structures should be considered.

NOTE In certain geographic areas, abnormal environmental events are considered a hazard.

The structural configuration and equipment arrangements shall be such that damage resulting from an accidental action shall not lead to an escalation of undesirable events (e.g. as could occur if the flare tower were to be placed in the collision zone) or impair safety-critical functions.

Accidental events may be assumed to occur independently of extreme environmental design situations, see Table 2.

For temporary phases, accidental actions may normally be omitted from further checks, provided a HAZID and risk assessment have been conducted to ensure all actions likely to occur during temporary design conditions have been identified and their potential consequences assessed.

7.4.2 Collision

Collision-induced actions shall be considered in the design of all structural components that can be affected by sideways, bow or stern collision with another vessel. The vertical extent of the collision zone shall be based on the

depth and draught of the colliding vessel, and on the relative horizontal and vertical motions between the vessel and the floating structure. The magnitude of the collision-induced action shall account for added mass effects. Particular attention shall be given to collisions that can occur during offloading operations.

Structural components located in areas where marine vessels operate in close proximity to the floating structure shall be capable of absorbing the energy resulting from casual contact due to routine operations.

Emergency and essential marine equipment shall be placed away from possible collision zones.

7.4.3 Dropped objects

Accidental impact actions caused by dropped, swinging or sliding objects from cranes or other lifting devices shall be considered. Critical areas for dropped objects shall be determined on the basis of the planned movement of crane loads over the platform.

7.4.4 Fire and blast

As far as practicable, semi-enclosed locations where gas pockets can occur should be avoided in the design of a floating platform. Where this is not possible, for example in moonpool locations, the potential for gas accumulation shall be assessed and appropriate measures shall be taken to reduce the risk of explosion to an acceptable level.

Blast resistance requirements shall be addressed concurrently with fire resistance requirements, taking into account probability of occurrence, blast safety evaluation, layout and area of importance, venting system, access to escape, etc. The resistance to fire after blast shall also be addressed.

The fire/blast scenario shall be defined: for example, fire followed by blast followed by fire; or blast followed by fire. It should be demonstrated that blast wall fire insulation remains effective for the duration of the fire/blast scenario. The overall structural design shall prevent any escalation of the accidental event, including escalation events that could affect emergency and essential marine equipment and/or escape routes.

Structural support of blast walls and the transmission of the blast action into the main structural elements shall be taken into account. The effectiveness of connections and the possible outcome from the blast, such as flying debris, shall be evaluated.

7.5 Environmental actions (*E*)

7.5.1 General

Environmental actions shall be derived from environmental information appropriate to the specific locations where the floating structure is to be fabricated, transported, installed, and operated (see ISO 19901-1). The stochastic nature of environmental actions shall be adequately accounted for. Environmental actions can be repeated, sustained, or both repeated and sustained.

The representative value of an environmental action is the maximum or minimum value (whichever is the more unfavourable) corresponding to a prescribed probability of exceedance. Joint probability of occurrence of the various environmental actions may be taken into account if such information is available and can be adequately documented.

Global environmental actions are normally generated by appropriate structural analysis software or mapped from other software packages used to develop the actions, e.g. hydrodynamic software used to generate wave-induced pressures.

Actions arising from earthquakes are not normally of concern for the design of moored floating structures. However, it can be necessary to check their impact, for example, on the mooring system, particularly in shallower waters.

7.5.2 Environmental site-specific data

The phenomena and environmental characteristics listed in this subclause shall, where appropriate to the region, be taken into account in the design. These characteristics shall be described by physical parameters and, where available, statistics (see also ISO 19901-1). For the design of the structure, site-specific metocean conditions shall be selected in accordance with the provisions of API 2A-WSD and API 2INT-MET.

a) Wind

Wind is usually characterized by the mean value of its velocity over a given time interval at a given elevation above the mean water level. The frequency content shall be taken into account by means of a wind spectrum as defined in API 2A-WSD and API 2INT-MET. The variation with elevation (wind profile) and the spatial coherence should be considered.

b) Waves

Site-specific information shall be established to consider sea-state characteristics (wave height, period, duration, directions, and spectra) and the long-term statistics of these characteristics, including wind- and swell-generated waves if appropriate for the location of interest.

c) Water depth and sea level variations

The water depth shall be determined together with the magnitude of the low and high tides, and positive and negative storm surges. The possibility of ground subsidence should be considered when determining the water depth. Tidal components for design include astronomical, wind, and pressure differential tides. A high design water level (HDWL) and low design water level (LDWL) shall be established for each design event.

d) Currents

Phenomena such as tidal, wind-driven, global circulation, loop, and eddy currents shall be considered. Currents shall be described by their velocity variation (in magnitude and direction) with water depth (current profile) and persistence. The occurrence of fluid motion caused by internal waves should be considered.

e) Marine growth

Marine growth thickness, roughness, density, and variation with depth shall be defined. This information is usually provided by direct measurements and operational experience in the specific area of interest.

f) Ice and snow

The accumulation of ice and snow on horizontal and vertical surfaces (thickness and density) shall be defined, together with the appropriate parameters for the other environmental phenomena (wind, waves, and current) to be considered in conjunction with ice and snow accumulation. In addition, the possibility of ice build-up through freezing of sea spray, rain, or fog shall be considered. Sea ice and iceberg occurrences shall be considered when applicable.

g) Temperatures

The maximum, average and minimum air and sea temperatures at the site shall be determined.

h) Local sea water characteristics

Sea water properties such as oxygen content, salinity, and density shall be provided.

i) Geotechnical data

Site investigations shall be performed to define physical and engineering properties of the soil strata and to identify potential hazards (earthquakes, mudslides, etc.).

7.5.3 Wind actions**7.5.3.1 General**

Actions on a structure caused by wind shall be considered for both global analysis and local design.

Wind-induced actions shall be determined by means of wind tunnel tests and/or suitable analytical methods. Validated computational fluid dynamic methods may be used where appropriate.

The total wind velocity can be described as the sum of the mean wind component and a gust component.

7.5.3.2 Mean wind action

Mean wind actions on a floating structure may be estimated by calculating the mean wind actions on all exposed components of the structure and summing the contributions from each component. Mean wind actions on individual components may be calculated using an expression of the form given by Equation (1):

$$P_w = \frac{1}{2} \rho_a C_s v_z^2 \quad (1)$$

where

P_w is the mean wind pressure;

ρ_a is the mass density of air;

C_s is the shape coefficient, which shall be determined from appropriate sources (e.g. RCS rules or ISO 19902:2007, Clause 9);

v_z is the mean wind velocity at height z above the mean water level.

If C_s is obtained from wind tunnel measurements, all the parameters in Equation (1) shall be used in a manner consistent with the derivation of the wind tunnel results.

The wind velocity is usually given at a reference height of 10 m above the mean water level. To obtain the mean wind velocity at a different elevation, z , this value should be adjusted according to the formulation provided in ISO 19901-1. Wind velocity should be averaged over an appropriate time interval, typically 3 s for a small standard component, 1 min for stability calculations and 1 h for mean wind actions in conjunction with a frequency or time domain gust analysis.

Solidification effects shall be taken into account in cases where components are located close together in a plane normal to the wind direction.

Shielding effects may be taken into account if it can be adequately documented that the inclusion of such effects is justified.

When calculating wind actions, care shall be taken to decompose the global structure into components of sufficiently small size, so that the local wind velocity can be considered constant over the component without significant error.

For monohull structures, additional information is given in A.7.5.3.

7.5.3.3 Dynamic wind actions

Wind-induced dynamic actions fall into three categories:

- a) long-period variations in the wind intensity, which tend to engulf the whole platform and which can give rise to slow rigid body motions of the platform about its mean position;
- b) medium-period fluctuations affecting large structural components or sub-assemblies, such as flare towers;
- c) shorter-period variations associated with the shedding of vortices and aerodynamic instabilities.

Whenever appropriate data are available, aerodynamic admittance and spatial and temporal correlation of the gusts may be accounted for.

A dynamic analysis considering the time variation of wind actions and their effects shall be performed for the entire platform as well as for wind-exposed equipment and objects sensitive to varying wind actions, e.g. towers, flare booms.

The fluctuating gust component can be calculated in either the time domain or the frequency domain using an appropriate wind gust spectrum (see ISO 19901-1).

7.5.3.4 Wind-induced instability

Consideration shall be given to local aerodynamic instability. Examples of such instabilities (see ISO 19901-1) are atmospheric turbulence, gusts, and squalls. Additionally, instabilities can arise due to interaction between the air flow and structural components, e.g. vortex-induced vibration of slender components (see 7.5.6) and galloping effects.

7.5.4 Current actions

Current actions on large-volume bodies like floating structures shall be determined by model tests, relevant empirical analytical tools, and/or appropriate sources. In determining the shape coefficients, appendages (bilge keels, strakes, etc.) shall be taken into account. Actions induced by steady currents on monohull and semi-submersible structures may be determined by global coefficients, in analogy to mean wind actions, 7.5.3.2. In general, current actions on monohull structures are much larger in shallow water (with small under-keel clearance) than in deep water.

Current actions on slender components may be determined using Equation (3), see 7.5.5.3. Drag coefficients shall be determined from appropriate sources. In the absence of data indicating otherwise, the drag coefficients provided in ISO 19902:2007, Clause 9, for unshielded circular cylinders are recommended, i.e. 0.65 for smooth surfaces and 1.05 for rough surfaces.

The effects of medium-term and long-term variations of current velocity on moored floating structures shall be considered.

For monohull structures, additional information is given in A.7.5.4.

7.5.5 Wave actions

7.5.5.1 General

Actions caused by waves acting on a structure shall be considered for both global analysis and local design. Wave actions shall be determined by appropriate methods, taking into account all relevant parameters, including water depth, marine growth, type of structure, size, shape, and response characteristics.

The simultaneous effect of hydrostatic pressure, hydrodynamic local pressures, and the integrated (global) effect of still-water and wave actions shall be computed.

Adequate consideration shall be given to the relationship between the wave's dominant periods and the structure's natural period of motion or vibration. For example, for two different design situations, each having the same composite return period, it is possible that the situation characterized by lower wave heights but a longer or shorter associated period induces more severe action effects on some components.

Local hydrodynamic instability shall be investigated (see 7.5.6).

7.5.5.2 Actions on large-volume bodies

The total pressure acting on submerged structural components includes both static and dynamic contributions. The dynamic pressure at a point on the immersed surface of a structure is expressed as the superposition of the pressure associated with the following:

- incident and scattered waves;
- flow induced by the six degrees-of-freedom radiation potential due to the motion of the structure in still-water; and
- the time-varying hydrostatic pressure due to heave, roll and pitch displacements of the structure from its mean position.

For structural components with dimensions of the same order of the wave length (where, typically, the ratio between the wave length and the diameter or other characteristic dimension is < 5), the flow disturbance introduced by the large

volume body cannot be neglected in the calculation of water particle kinematics. In this case, the current/wave/body interaction shall be considered when deriving resultant actions.

The transfer functions for linear wave actions can be determined by diffraction and radiation theory.

For simple geometrical shapes, analytical solutions may be used. For structural forms where the actions cannot adequately be described by state-of-the-art methods, model tests shall be undertaken.

Hydrodynamic interactions between large-volume components shall be accounted for.

7.5.5.3 Actions on slender components

The computation of the action on a cylindrical component caused by waves, or a combination of waves and currents, depends on the ratio of the wavelength to the component diameter. If this ratio is large (> 5), the member does not significantly modify the incident wave. The action can then be computed as the sum of a drag component and an inertia component, as follows:

$$\mathbf{F} = \mathbf{F}_d + \mathbf{F}_i \quad (2)$$

where

$\mathbf{F}$ is the local action vector per unit length acting normal to the component axis;

$\mathbf{F}_d$ is the vector for the drag action per unit length acting normal to the component axis in the plane of the component axis and v

$$\mathbf{F}_d = \frac{1}{2} \rho_w C_d (v - \dot{x}) |v - \dot{x}| A \quad (3)$$

$\mathbf{F}_i$ is the vector for the inertia action per unit length acting normal to the component axis in the plane of the component axis and $\partial v / \partial t$

$$\mathbf{F}_i = \rho_w C_m V \frac{\partial v}{\partial t} - (C_m - 1) \rho_w V \ddot{x} \quad (4)$$

where

C_d is the hydrodynamic drag coefficient;

C_m is the hydrodynamic inertia coefficient;

ρ_w is the mass density of water;

A is the projected effective dimension of the cross-sectional area normal to the cylinder axis per unit length based on an effective diameter that includes marine growth;

V is the effective displaced volume of the cylinder per unit length;

v is the component of the local water particle velocity vector (due to waves and current) normal to the axis of the component;

$\frac{\partial v}{\partial t}$ is the component of local water particle acceleration vector normal to the component axis;

$\dot{x}$ is the velocity of the cylinder normal to the axis of the component;

$\ddot{x}$ is the acceleration of the cylinder normal to the axis of the component;

$||$ denotes the absolute value.

As presented here, Equation (2), in combination with Equation (3) and Equation (4), commonly (albeit incorrectly) referred to as Morison's equation, does not include hydrodynamic lift actions, slam actions and axial Froude-Krylov actions. If the above expressions are used for columns and pontoons (e.g. for semi-submersible hulls) appropriate additional terms shall be added to account for axial Froude-Krylov actions and added mass. The final analysis shall be performed using a diffraction analysis, in which case the drag effects shall be added.

The combined effect of simultaneous drag and inertia actions is obtained by vectorial addition.

The drag coefficient (C_d) depends on many parameters: Reynolds number, Keulegan-Carpenter number and roughness, amongst others.

For deterministic, global wave action calculations, the drag coefficient for circular cylinders is not to be less than the values provided in ISO 19902:2007, Clause 9, i.e. 0.65 for smooth surfaces and 1.05 for rough surfaces, where the rough surface value shall be used for members with marine growth. The value of C_d can be affected by the occurrence of VIV (see 7.5.6). For fatigue assessment, higher values of C_d can apply, see ISO 19902:2007, A.9.

Design assumptions on the absence of marine growth shall be supported by appropriate requirements in the MOM to ensure that the components in question are kept free of marine growth during the structure's life.

Solidification effects shall be taken into account in cases where components are located close together in a plane normal to the wave direction.

Shielding effects may be taken into account if it can be adequately documented that the inclusion of such effects is justified.

The inertia coefficient (C_m) for circular cylinders shall be taken to be no less than 2.0 for actions where the inertia component action is considerably higher than the drag component action. For other shapes, the inertia coefficient can be accurately determined from appropriate calculations and model tests.

The wave actions on structures composed of large-volume components and slender components may be computed by a combination of wave diffraction and radiation theory and Morison's equation. The effects on water particle velocities and accelerations due to the large volumes shall be considered when using Morison's equation on adjacent slender components.

7.5.5.4 Slamming on slender components

Structural components in the wave zone can be affected by slamming, an impulsive action whose effect shall be considered in design. Dynamic effects, particularly amplification, shall be included where appropriate.

For cylindrical members, the slamming actions may be calculated from Equation (5):

$$F_s = \frac{1}{2} \rho_w C_{sl} d v^2 \quad (5)$$

where

F_s is the slamming action per unit length in the direction of the relative velocity vector;

ρ_w is the mass density of water;

C_{sl} is the slamming coefficient;

d is the component diameter;

v is the relative water particle velocity normal to the component axis.

The slamming coefficient C_{sl} can be determined using theoretical and/or experimental methods. For smooth circular cylinders the value of C_{sl} should be assumed to be no less than 3.0 when performing a quasi-static analysis, and no less than 6.0 when quantifying dynamic behaviour.

7.5.5.5 Higher order non-linear wave actions

Some hydrodynamic phenomena, generally represented by higher-order, non-linear numerical models, give rise to actions at frequencies close to resonant frequencies of the floating structure and its stationkeeping system. These actions shall be assessed and their effects investigated, as they can be important for the design of floating structures. The nature of these phenomena is addressed in A.7.5.5.5.

Examples of the effects due to higher order hydrodynamics are

- mean drift (mean second order action).
- slow drift (time varying action).

Wave drift and wave drift damping are affected by the wave/current interaction, which shall also be considered.

7.5.5.6 Wave enhancement effects

In the vicinity of large bodies, the free surface elevation can be enhanced by motions, diffraction, radiation, wave/current interaction effects, and other non-linear wave effects. These shall be accounted for, as appropriate, in the wave action calculation and used to estimate deck clearance and freeboard, see 8.10.

7.5.5.7 Shallow water effects

If the floating structure is located in a shallow water area (i.e. water depth less than half the wavelength), wave amplitude enhancements and/or wave refraction caused by the effect of the sea bottom shall be taken into account in estimating wave actions.

7.5.5.8 Slamming and green water actions

Wave slamming against the shell structure of the hull due to local wave action, water entry slamming, and green water action caused by high relative motions of structure and wave surface are local wave action effects and are discussed in more detail in 9.8.

7.5.6 Vortex-induced vibrations and motions

A fluid flow (wind or current) past a slender component can cause unsteady flow patterns due to vortex shedding. At certain critical flow velocities the vortex-shedding frequency coincides with, or is a multiple of, a natural frequency of the component, resulting in harmonic or sub-harmonic excitations normal to the longitudinal axis of the component. This phenomenon is generally referred to as vortex-induced vibrations (VIV).

The vibrations can be in-line (in the plane of the flow velocity) or transverse (in a plane perpendicular to the flow velocity and the component axis). Transverse vibrations are usually of more concern for most structural components. The effects of VIV include

- increased drag actions on individual components,
- fatigue damage of individual components.

Furthermore, for flow velocities in certain ranges, the vibrations can affect the platform (e.g. spar and potentially semi-submersible) as a whole and result in transverse rigid body motions, i.e. vortex-induced motions (VIM).

The potential for VIV/VIM shall be assessed. The focus of a VIV analysis is generally to evaluate if the fatigue resistance of the component or system is adequate. Accordingly, the simplified (and conservative) VIV analysis described in A.7.5.6 should suffice if the resulting fatigue damage is acceptable. If the simplified analysis indicates insufficient fatigue resistance, a more sophisticated and less conservative method may be applied.

The method should be chosen according to the specific case to be investigated. Recognized semi-empirical methods may be applied if the problem characteristics are well within the validity range. Otherwise, if the problem is of high complexity (e.g. riser bundles, varying diameters or surface waves), more refined assessment methods are required.

7.5.7 Marine growth

Marine growth shall be defined by its thickness, roughness, density, and variation with depth. Additionally, the marine growth thickness to be used in the design is influenced by operational strategy (e.g. regular cleaning, use of anti-fouling coating) as well as structural behaviour (e.g. less marine growth is normally found on slender structures with significant dynamic displacements).

The presence of marine growth causes an effective increase of the component dimensions, a consequent direct increase in structure weight, in hydrodynamic drag and in added mass, and alters the roughness characteristics of the surface. In structural design, therefore, the mass, buoyancy diameter and effective drag diameter shall be adjusted to account for the specified water depth variation of marine growth. In addition, the values of the hydrodynamic coefficients (drag, C_d , and inertia, C_m) should reflect the roughness associated with the marine growth.

The design basis and the MOM can include a specific provision for periodic marine growth cleaning or anti-fouling systems during the platform life, in which case the design assumptions shall be adjusted accordingly. Any such reliance shall be documented and the cleaning programme defined over the life of the platform. The consequences of not maintaining this programme should be determined and reported.

7.5.8 Snow and ice accretion

Ice accretion on structural components from sea spray, snow, rain, and air humidity can cause increases of cross-sectional area (with consequent increase in mass and added mass) and surface roughness. These effects shall be considered when determining wind and hydrodynamic actions.

For floating structures, the effects of snow and ice accretion shall be considered, as such accretion can affect the hydrostatic stability. Appropriate instructions concerning the need for removal of ice accretion shall be included in the MOM.

7.5.9 Direct ice action

Where encounter with sea ice or impact with icebergs can occur, collision actions shall be determined through appropriate theoretical models, model laboratory tests or full-scale measurements.

When determining the magnitude and direction of actions, the following factors shall be considered:

- geometry and nature of the ice;
- mechanical properties of the ice;
- velocity and direction of the ice;
- geometry and size of the ice/structure contact area;
- ice failure mode as a function of the structure geometry;
- inertia effects for both ice and structure.

Reference should be made to ISO 19906^[157] for structures in ice conditions.

7.5.10 Temperature effects

Floating structures shall be designed for the most onerous temperature differences to which they can be exposed. This applies, but is not limited to

- storage tanks,
- structural components exposed to radiation from the flare, and
- structural components that are in contact with risers or process equipment.

The lowest anticipated sea or air temperature shall be the lowest one-hour average temperature associated with an annual probability of exceedance of 10^{-2} .

7.5.11 Tidal effects

For floating structures constrained by stiff mooring systems, tidal effects can significantly affect the mean tensions in the mooring components. Therefore, the choice of tide conditions for a static equilibrium analysis is important. Higher mean water levels tend to increase maximum mooring line tensions, hydrostatic actions, and current actions on the hull, while tending to decrease deck clearances.

The effects of tides may be taken into account by performing a static balance at the various appropriate tide levels to provide a starting point for further analysis, or by making allowances for the appropriate tide level in calculating extreme responses.

7.5.12 Geotechnical hazards

Geotechnical hazards such as earthquakes, mudslides and other geotechnical phenomena can affect anchors, mooring lines and risers, and should be considered (see also API 2SK).

7.6 Other actions

7.6.1 Stationkeeping actions

A floating structure can be kept on station by various methods, depending on site-specific criteria and operational goals. These methods include different types of stationkeeping systems such as internal and submerged turret systems, external turret, catenary anchor leg mooring (CALM), CALM buoy and hawser, spread mooring, and dynamic positioning (DP), see Clause 17. Each type of stationkeeping system imposes specific actions on the hull structure. These actions shall be considered in the platform's structural design. Specific actions induced by the stationkeeping system on the hull structure shall be consistent with the practices described in API 2SK.

7.6.2 Sloshing actions

Sloshing is the dynamic magnification of internal pressures acting on the boundaries of partially filled tanks due to internal fluid motion. Sloshing occurs if the natural periods of the fluid in a tank and of the motions of the structure are similar (see 9.8.4). In some cases, the fitting of swash bulkheads or other baffle devices can be necessary to minimize sloshing effects.

Sloshing-induced actions shall be considered in the structural design.

7.7 Repetitive actions

Repetitive actions, which can lead to significant fatigue damage, shall be evaluated. As a minimum, the following sources of cyclic action effects should be considered:

- waves, including actions caused by slamming and variable buoyancy;
- wind, especially in conjunction with vortex-induced vibrations;
- motion-induced accelerations;
- currents, especially in conjunction with vortex-induced vibrations;
- low cycle/high stress range variable action fluctuations, such as loading and discharging of cargo/ballast;
- sloshing;
- mechanical vibrations, such as those caused by operation of machinery;
- fluctuating actions imposed by the stationkeeping system;
- dynamic riser tensions.