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Erdöl- und Erdgasindustrie – Schwimmende Offshore-Anlagen – Teil 1: Produktions- und Lagerungsanlagen außer Tension-Leg-Anlagen (ISO 19904-1:2006); Englische Fassung EN ISO 19904-1:2006

Petroleum and natural gas industries –
Floating offshore structures –
Part 1: Monohulls, semi-submersibles and spars (ISO19904-1:2006);
English version EN ISO 19904-1:2006

Industries du pétrole et du gaz naturel –
Structures en mer flottantes –
Partie 1: Unités monocoques, unités semi-submersibles et unités spars
(ISO 19904-1:2006);
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Nationales Vorwort

Diese Europäische Norm wurde vom Technischen Komitee CEN/TC 12 „Materialien, Ausrüstungen und Offshore-Bauwerke für die Erdöl-, petrochemische und Erdgasindustrie“ (Sekretariat: Frankreich) erstellt. Es handelt sich dabei um die unveränderte Übernahme von ISO/DIS 19904-1:2004, erarbeitet von ISO/TC 67 „Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries“, Subkomitee SC 7 „Offshore-Konstruktionen“ (Sekretariat: England).

Für Deutschland hat hieran der NA 109-00-01 AA „Materialien, Ausrüstungen und Offshore-Bauwerke für die Erdöl-, petrochemische und Erdgasindustrie“ im Normenausschuss Erdöl- und Erdgasgewinnung (NÖG) mitgearbeitet.

Diese Europäische Norm enthält unter Berücksichtigung des DIN-Präsidialbeschlusses 13/1983 nur die englische Originalfassung der ISO-Norm.

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Erdöl- und Erdgasindustrie - Schwimmende Offshore-Anlagen - Teil 1: Produktions- und Lagerungsanlagen außer Tension-Leg-Anlagen (ISO 19904-1:2006)

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Foreword

This document (EN ISO 19904-1:2006) has been prepared by Technical Committee ISO/TC 67 "Materials, equipment and offshore structures for petroleum and natural gas industries" in collaboration with Technical Committee CEN/TC 12 "Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries", the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by May 2007, and conflicting national standards shall be withdrawn at the latest by May 2007.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

Endorsement notice

The text of ISO 19904-1:2006 has been approved by CEN as EN ISO 19904-1:2006 without any modifications.

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Introduction

The series of International Standards applicable to types of offshore structure, ISO 19900 to ISO 19906, 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 International 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 judgement is therefore necessary in the use of these International Standards.

International Standard ISO 19904 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 part of ISO 19904 addresses monohulls, semi-submersibles and spars.

Some background to, and guidance on, the use of this part of ISO 19904 is provided in informative Annex A. The clause numbering in Annex A is the same as in the normative text to facilitate cross-referencing.

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1 Scope

This part of ISO 19904 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 part of ISO 19904, 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 part of ISO 19904:

a) monohulls (ship-shaped structures and barges);

b) semi-submersibles;

c) spars.

In addition to the structural types listed above, this part of ISO 19904 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 ISO 19901-7. 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 part of ISO 19904. In other cases, specific requirements stated in this part of ISO 19904 can be found not to apply to all or part of a structure under design.

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In all the above cases, conformity with this part of ISO 19904 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 4 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 this part of ISO 19904.

This part of ISO 19904 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.

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.

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 19901-7:2005, *Petroleum and natural gas industries — Specific requirements for offshore structures — Part 7: Stationkeeping systems for floating offshore structures and mobile offshore units*

ISO 19902:—[1)], *Petroleum and natural gas industries — Fixed steel offshore structures*

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.

1) To be published.

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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 probablilty of not being violated by unfavorable 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 part of ISO 19904, 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.

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

[ISO 19901-7:2005]

3.15
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

3.16
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]

3.17
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

3.18
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.

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3.19
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.

3.20
freeboard
distance measured vertically downwards between the top of the hull and the mean water surface at a given draught

3.21
green water
overtopping of deck by water causing slamming and pressure actions to structures on deck

3.22
limit state
state beyond which the structure no longer fulfils the relevant design criteria

[ISO 19900:2002]

3.23
mobile offshore drilling unit
MODU
structure capable of engaging in drilling and well intervention operations for exploration or exploitation of subsea petroleum resources

[ISO 19901-7:2005]

3.24
mobile offshore unit
MOU
structure intended to be relocated to perform a particular function

[ISO 19900:2002]

3.25
monohull
floating structure consisting of a single, continuous, buoyant hull, and having a geometry similar to that of ocean-going ships, barges, etc.

3.26
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.

3.27
owner
representative of the company or companies which own a development, who can be the operator on behalf of co-licensees

[ISO 19901-7:2005]

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3.28
platform
complete assembly including structure, topsides and, where applicable, foundations and stationkeeping system

NOTE Adapted from ISO 19900:2002, definition 2.23.

3.29
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.

3.30
reliability
ability of a structure or structural component to fulfil the specified requirements

[ISO 19900:2002]

3.31
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.

3.32
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.

3.33
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]

3.34
riser
piping 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.

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3.35
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.

3.36
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.

3.37
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.

3.38
sloshing
impact action on the boundaries of a partially filled tank due to internal fluid motion

3.39
spar platform
spar
deep draught caisson vessel
DDCV
deep-draught, small water-plane area floating structure

[ISO 19901-7:2005]

3.40
special areas
areas identified by the designer as being of critical importance to the structural integrity and safety of the structure

3.41
stability
hydrostatic stability
ability of a floating structure to generate restoring moment after deviation from the equilibrium floating position

3.42
static action
action that cannot cause significant acceleration of the structure or structural components

3.43
stationkeeping system
system capable of limiting the excursions of a floating structure within prescribed limits

[ISO 19901-7:2005]

3.44
structure
organized combination of connected components designed to withstand actions and provide adequate rigidity

[ISO 19900:2002]

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3.45
structural component
physically distinguishable part of a structure

[ISO 19900:2002]

3.46
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.

3.47
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]

3.48
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

3.49
verification
examination made to confirm that an activity, product or service is in accordance with specified requirements

[ISO 19901-7:2005]

3.50
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

3.51
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.

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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)

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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/m^3)

4.2 Abbreviated terms

ACFM alternating current field measurement

ACPD alternating current potential drop

ALS accidental limit state

AP aft perpendicular

CALM catenary anchor leg mooring

COW crude oil washing

CP cathodic protection

CVI close-up visual inspection

DDCV deep draught caisson vessel

DP dynamic positioning

EC eddy current

FE finite element

FLS fatigue limit state

FMD flooded member detection

FPS floating production system

FPSO floating production, storage and offloading structure

FSU floating storage unit

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GVI	general visual inspection
HAZID	hazard identification
IMO	international maritime organization
MOM	marine operations manual
MOU	mobile offshore unit
MODU	mobile offshore drilling unit
MPI	magnetic particle inspection
NDT	non-destructive test
RAO	response amplitude operator
RCS	recognized classification society
ROV	remotely operated vehicle
SCIP	structural critical inspection point
SCF	stress concentration factor
SIM	structural integrity management
SLS	serviceability limit state
TLP	tension leg platform
TOFD	time-of-flight diffraction
TM	thickness measurements
UCW	ultrasonic creeping wave
ULS	ultimate limit state
VIM	vortex-induced motions
VIV	vortex-induced vibrations
VLCC	very large crude carrier
VOC	volatile organic compound
WI	weld inspection
WSD	working stress design

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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 fulfil 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 part of ISO 19904 presents specific requirements for monohulls, semi-submersibles and spars when used for the applications listed above.

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.

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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.

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 part of ISO 19904 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 part of ISO 19904.

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5.4 Rules and regulations

5.4.1 General

The intent of this part of ISO 19904 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 part of ISO 19904 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 part of ISO 19904 and in ISO 19900.

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

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.

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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

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— 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.

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.

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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,

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— 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.

5.6 Independent verification

Independent verification that the floating structure’s design and construction is in compliance with the provisions of this part of ISO 19904 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 part of ISO 19904 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

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 part of ISO 19904. Where aspects of the design are identified as non-compliant with the requirements of this part of ISO 19904, the provisions of ISO 19900 may be used to demonstrate adequacy on a fitness-for-purpose basis.

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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.

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6.2.2 Life-safety categories

6.2.2.1 General

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

S1 manned–nonevacuated;

S2 manned–evacuated;

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".

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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:

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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 or the assessment of an existing one, 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 part of ISO 19904 provides partial safety factors exclusively for structures with exposure levels equal to 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:

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— 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

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.

6.4.3 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).

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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 9.12.

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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.

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}.

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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.

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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 floating structures. Accordingly, these actions are not dealt with in this part of ISO 19904.

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).

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. If the frequency content is of importance it shall be taken into account. 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.

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.

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

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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):

$$P_{\mathrm{w}} = \frac{1}{2}\rho_{\mathrm{a}} C_{\mathrm{s}} v_{\mathrm{z}}^{2} \qquad (1)$$

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:—, 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 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.

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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:—, 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.

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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:

$$\boldsymbol{F} = \boldsymbol{F}_{\mathrm{d}} + \boldsymbol{F}_{\mathrm{i}} \tag{2}$$

where

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

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

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$$\boldsymbol{F}_{\mathrm{d}} = \frac{1}{2}\rho_{\mathrm{w}}\, C_{\mathrm{d}}\left(v - \dot{x}\right)\left|v - \dot{x}\right| A \tag{3}$$

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

$$\boldsymbol{F}_{\mathrm{i}} = \rho_{\mathrm{w}} C_{\mathrm{m}}\, V \frac{\partial v}{\partial t} - \left(C_{\mathrm{m}} - 1\right)\rho_{\mathrm{w}}\, V\, \ddot{x} \tag{4}$$

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:—, 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:—, 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.

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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):

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

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.

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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

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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[158] 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.

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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 ISO 19901-7).

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 (see ISO 19901-7).

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.

7.8 Action combinations

The structure's resistance shall be investigated for a range of potential combinations of permanent, variable, environmental and accidental actions, see Clause 9.

Values of environmental actions to be used in design should always be established with the intention of resulting in the most probable maximum (or minimum) response for the limit state under consideration. There can be different design events that give the most onerous response for different elements in the structure.

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8 Global analysis

8.1 General

The combination of risers, stationkeeping system and the floating structure is a complex integrated dynamic system responding to environmental actions (wind, waves, current, etc.). Therefore, the global analysis of the floating structure cannot be separated from the analysis of the stationkeeping system, and overlaps substantially with this activity, which is covered in detail in ISO 19901-7. Accordingly, Clause 8 provides an overview of the general processes, issues and requirements to be fulfilled.

For floating structures, the typical action effects controlling the structure's overall geometry and configuration, as well as the design of the stationkeeping system include structure offset, structure motions, global structural forces, minimum and maximum mooring line and riser tensions, deck clearance (air gap, freeboard) and deck level motions and accelerations.

The representative values of these action effects are usually obtained from the results of global dynamic analyses and/or model tests.

Validation of numerical results by sensitivity studies with respect to key parameters should be performed.

8.2 Static and mean response analyses

8.2.1 General

The objective of static and mean response analyses is to determine the static equilibrium position of a platform with no wind, wave or current present, and, subsequently, the mean position due to steady environmental actions on the platform. The mean position is then used as a basis for frequency domain analyses, or as the initial condition for time domain analyses.

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8.2.2 Static equilibrium in still-water condition

The determination of the static equilibrium, or weight balance, in the “still-water” condition is fundamental to sizing of the floating structure, and is the starting point for further analysis. A static equilibrium analysis shall be performed for each design situation.

Determination of the static equilibrium for each design situation shall include the following:

— the total platform weight;

— the total structure displacement (the total structure buoyancy) for each draught to be analysed;

— any riser and mooring tensions acting on the structure;

— any applicable crane hook loads.

The structural weight shall include the weight of all structural components, permanent appurtenances, and all equipment permanently mounted on the platform. In addition, the platform weight shall include all weights appropriate to the design situation being analysed. These variable actions shall include the weight of crude oil storage in various loading conditions (if applicable), temporary equipment, contents, consumable supplies, ballast, marine growth, ice, and any other appropriate temporary weights.

NOTE Different design situations can involve significant variations in temporary or removable weights and in actions to be included in the static equilibrium analysis.

8.2.3 Mean response analysis

The mean response is characterized by the position of the platform’s centre of gravity, including setdown effects (as applicable), mean orientation of the platform (particularly for monohulls), and orientation of mooring and riser system.

The estimate of the mean response shall include the same components as the still-water condition discussed in 8.2.2, as well as, as a minimum, the following:

— the mean actions due to wind;

— the mean actions due to wave drift and current on the structure;

— current actions on risers and moorings.

Mean response calculations shall be repeated for a variety of design situations.

8.3 Global dynamic behaviour

8.3.1 General

While, for the analysis discussed in 8.2, the response of the system (floating structure, risers and moorings) can be approximated by a static or quasi-static analysis, dynamic analyses shall be performed when some natural period of the system or part thereof falls within the range of periods of steady-state actions, or when the structure is exposed to transient actions.

Dynamic effects can be important, for example in connection with

— wave frequency actions,

— low-frequency effects of wind and wave actions,

— wave slamming, sloshing in tanks, and other transient wave actions,

— mechanical impacts due to ships, icebergs or dropped objects, and

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— explosion actions.

Dynamic effects resulting from rigid body motions shall be adequately accounted for in the design process.

The effects of thrusters in terms of restoring forces and possible damping should be included.

Free surface effects in tanks shall be included, where relevant.

8.3.2 Analysis models

The environmental actions on the platform are generally a function of both time and platform position. To allow a simple solution, a number of assumptions and linearizations are usually made.

A common simplifying assumption is to model the structure as a rigid body, excluding risers and moorings. The system then has six degrees of freedom. This approach is usually referred to as “uncoupled analysis” because it assumes no interaction between mooring and riser dynamic responses and the structure dynamic response, see 8.6.

More sophisticated and complex models can be developed by including a suitable number of degrees of freedom to simulate risers and moorings. Such models allow joint consideration of structure, mooring and riser dynamic behaviour and are suitable for deep water applications or when mooring lines/riser masses are a significant portion of the total system mass. This approach is usually referred to as “coupled analysis”, see 8.7.

8.3.3 Mass

The total mass used in the analyses shall include

a) the mass of structural material,

b) the mass of equipment,

c) the mass associated with variable actions (including ballast and crude oil storage, if applicable), and

d) added mass effects associated with the submerged portion of the hull.

For uncoupled analyses, the mass of the moorings and risers may be accounted for in an approximate fashion.

For coupled analyses, moorings and risers shall be modelled with a sufficient number of degrees of freedom, and the total mass shall include

— the structural riser mass,

— the mooring line mass,

— the mass of any enclosed fluids and internal lines, and

— added mass.

8.3.4 Damping

Damping is important in limiting structure resonant responses, and can have significant contributions from wave radiation and drag on the hull, bilge keels, moorings and risers. Roll damping effects should be carefully evaluated and included at the correct probability level in the hydrodynamic analysis. For spars, riser friction damping can also have an effect on the structure’s response.

8.3.5 Stiffness

The total stiffness shall contain contributions from

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a) the structure's hydrostatic characteristics,

b) geometric terms due to moorings/risers in combination with structure offset, and

c) elastic terms introduced by the mooring and riser systems.

8.3.6 Action classification

The time-varying actions on a floating platform are often categorized by their period ranges relative to the natural periods of the platform/moorings/risers system, as follows:

a) nearly steady actions that can be considered static because they vary with periods much longer than any platform natural periods;

b) slowly varying actions, with periods near the surge, sway and yaw natural periods (these responses typically have periods in the range of less than one minute to several minutes), and with roll and pitch natural periods for spars falling within a similar range;

c) actions at wave periods.

8.4 Frequency domain analysis

Frequency domain analysis, in this context, refers to the solution of the equations of motion of a floating structure by harmonic analysis or by Laplace and Fourier transforms. The result of a frequency domain analysis is a description of the variables of interest (platform motions, platform accelerations, mooring forces, etc.) in terms of amplitudes and phases as functions of frequency. The method is naturally suited to the analysis of systems subjected to random excitations because it provides a clear and direct relationship between the input spectrum (in this case, the environmental actions) and the system response spectrum. The system response spectrum can then be used to estimate the short-term statistics of the variable of interest.

8.5 Time domain analysis

The time domain analysis method consists of a numerical solution of the rigid body equations of motion for the platform, subject to external actions due to environmental phenomena (waves, current, wind, etc.), the platform stationkeeping system and other possible actions. Since a direct numerical integration of the equations of motion is performed, any non-linearities can be directly included, such as, for example, drag-induced actions, finite motion, finite wave amplitude effects, and non-linear characteristics of the stationkeeping system. The capability of dealing with higher modelling complexity comes at the expense of increased computing time.

When the input to the analysis is represented by a deterministic, periodic wave, the analysis shall be carried out for a long enough simulation time to achieve a steady-state response.

When the input is represented by a wave spectrum, which is then converted into a time history of the water surface elevation, the analysis shall be performed long enough to achieve stationary response statistics. Several such analyses shall be performed, with different water surface elevation time histories obtained from the same input spectrum, and the response characteristics shall be combined to achieve a meaningful set of response statistics. Similarly, several different wind speed time histories should be investigated when the time-varying wind-induced action effects are significant.

8.6 Uncoupled analysis

Uncoupled analysis is generally used to compute the system (structure, moorings and risers) response using a two-step approach.

In the first step, the structure's rigid body response to static, low-frequency and wave-frequency environmental actions is computed. The risers and mooring system are represented by their static restoring force characteristics and a constant low-frequency viscous damping. Assessment of the low-frequency damping is

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important for the low-frequency floating structure motion analysis. Contributions from current direct action on mooring lines and risers may be represented by a constant external action on the structure.

In the second step, the moorings and risers are analysed, considering wave- and current-induced actions on the slender members, and imposing the structure's wave-frequency (or wave-frequency and low-frequency) motion response as forced dynamic excitation.

8.7 Coupled analysis

In a coupled analysis, all interactions between floating structure motions and slender structure response can be accounted for by creating a model of the total system, including hydrodynamic action modules for both large-body and slender components, including all mooring lines and risers. This approach yields dynamic equilibrium between the actions on the structure and the slender structure response at every time instant. Consequently, there is no need for assessment of the low-frequency damping from the slender structure, as this contribution is accounted for by the slender structure dynamics.

8.8 Resonant excitation and response

Non-linear mechanisms can generate actions and action effects that interact with particular natural frequencies of the total system normally not excited by wave frequency actions. As these resonant actions are often present in conjunction with low damping levels, care shall be taken to accurately model these effects. The amplitude of the response at resonance is very sensitive to the damping estimates. The use of model tests should be considered in complex situations for validating analytical computations.

8.9 Platform offset

Generally, to ensure riser integrity and serviceability in ULS and SLS design situations, the global platform motions shall be limited within appropriate motion envelopes.

The platform offsets shall be computed in accordance with ISO 19901-7.

8.10 Air gap

When assessing air gap, the following effects shall be considered:

— wave crest elevation, including wave asymmetry;

— wave/structure interaction effects (wave enhancement, run-up, etc.);

— global rigid body motions (including dynamic effects);

— effects of interacting systems (e.g. mooring and riser systems);

— maximum/minimum operating draughts.

Structures, parts of structures, equipment and supports that are not designed for the effects of direct wave action (wave impact, slamming, etc.) shall be located at an elevation that provides an air gap $\geqslant$ 1,5 m in ULS design situations and $\geqslant$ 0,0 m in ALS design situations.

For ULS design situations, a smaller value of air gap may be used if all the non-linear effects specified in this subclause are accounted for.

For ALS design situations, a risk assessment should be performed to assess the consequences of wave impact on secondary structure and equipment.

For monohulls, freeboard requirements are addressed in 11.2.4.

8.11 Platform motions and accelerations

The platform motions and accelerations shall be checked against the restrictions imposed by the serviceability of the topsides facilities and equipment. Large motions and accelerations can affect, among others,

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a) efficiency of process equipment,

b) operability of cranes or rotating equipment,

c) comfort levels, cognition, postural stability for the personnel on board,

d) habitability of facilities,

e) operability of heliports,

f) power generation capabilities, and

g) functionality of safety-critical equipment.

The platform motions and accelerations shall be checked against the restrictions imposed by the serviceability limitations of various types of topsides equipment. For instance, the efficiency of process equipment can be affected by large inclinations and accelerations. Operability of cranes or rotating equipment can also be compromised. Comfort levels for the personnel on board can also be affected.

8.12 Model tests

Estimates of the structural response to be used for design can be obtained by model tests. Model tests can also be used either to calibrate analytical predictions or to determine responses not directly or reliably calculable. The objectives of such model tests shall be clearly defined (see A.8.12) and, because during tests extraordinary or unexpected behaviour can occur, consideration should be given to the provision of continuous monitoring equipment to record such behaviour.

When comparing the results of model tests with analytical predictions, the following potential sources of discrepancies should be considered.

a) Scale effects, such as those affecting Reynolds number, fluid interface and turbulence.

b) Viscous effects (Reynolds number-dependent fluid drag and lift components) in both model tests and analytical predictions.

NOTE In computer simulations, these coefficients can be varied in order to study their effects.

c) Wave reflections from side walls induced by radiated and reflected incident waves.

d) Limitations on the accuracy of modelling physical properties, parameters and dimensions.

e) Limitations on the accuracy of the test results resulting from finite record lengths, finite sample rates, and numerical accuracy of the data analysis procedures.

f) Assumptions made in the development of the numerical model.

NOTE An example is the assumption of linearity of the responses with respect to wave height, which is almost always made in the frequency domain analysis. This can cause significant discrepancies between the numerical and test results for very steep waves or in situations where viscous forces play an important role.

In some cases, the instrumentation itself can affect the responses. The effect of instrumentation on the model should be minimized whenever possible.

For moored floating structures, a static load deflection curve in calm water shall be measured and checked against computations to verify the accuracy of the modelling of physical properties and instrumentation.

When the objective of the test is to assess impact loads and associated action effects, the measurements should be recorded at an appropriate sampling rate.

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8.13 Design situations for structural analysis

8.13.1 General

The structure of a floating platform shall be designed for the action combinations that produce the most severe action effects on the structure. Representative values of environmental actions and action effects for design purposes can be obtained by a short-term response analysis, a long-term response analysis or a design wave analysis, as described below. The most general approach is a long-term analysis.

A search procedure shall be developed to derive reliable extreme design situations.

8.13.2 Short-term response analysis

Select a suitable set of extreme design situations, as identified in 6.4, expected to produce the most severe action effects. The combination of extreme wave, maximum storm current and maximum tide does not necessarily produce the maximum action effects. Similarly, a design situation can provide extreme values for some action effects and not for others.

Accordingly, care shall be taken to ensure that the selected short-term sea states yield the most probable maximum action effects that correspond to the target return period.

8.13.3 Long-term response analysis

A full long-term probabilistic analysis involves calculating responses to the entire suite of possible environmental conditions. Statistical analysis of these responses is then performed to predict extreme values for each action effect.

8.13.4 Design wave analysis

The methods described in 8.13.2 and 8.13.3, based on a stochastic approach, can provide extreme values for the variables of interest, but without regard to phase relationships. To predict a detailed stress distribution in the structure, however, the structure analysed shall be in equilibrium under a combination of static and dynamic actions.

One way to retain the phase information is to use a design wave (quasi-static or time-domain) approach, in which the extreme values computed from the methods above are used to identify one or more design wave. By using the design wave approach, the simultaneity of responses of global and local action effects can be accounted for.

9 Structural considerations

9.1 General

Clause 9 provides general requirements and guidance for the structural strength analysis and design of floating structures constructed in steel, while Clause 10 provides the corresponding general requirements and guidance for their fatigue analysis and design. The general requirements and conditions specified in Clauses 5 and 6 shall be fulfilled. General requirements and guidance concerning actions and global behaviour are given in Clauses 7 and 8, respectively. More specific requirements for monohulls, semi-submersibles and spars are given in Clauses 11, 12 and 13, respectively.

Structural design shall proceed on the basis of either the partial factor design format, see 9.7.3, or the working stress design (WSD) format, see 9.7.4. Background on the similarities of these two formats is given in A.9.7.1.

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