

Topsides Structure

ANSI/API RECOMMENDED PRACTICE 2TOP
FIRST EDITION, AUGUST 2019

ISO 19901-3:2010 (Modified), Petroleum and natural gas industries — Specific requirements for offshore structures — Part 3: Topsides structure



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

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Foreword

The International Organization for Standardization (ISO) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing international standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and nongovernmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare international standards. Draft international standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an international standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 19901-3 was prepared by technical committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*, Subcommittee 7, *Offshore structures*.

ISO 19901 consists of the following parts, under the general title *Petroleum and natural gas industries — Specific requirements for offshore structures*:

- *Part 1: Metocean design and operating considerations*
- *Part 2: Seismic design procedures and criteria*
- *Part 3: Topsides structure*
- *Part 4: Geotechnical and foundation design considerations*
- *Part 5: Weight control during engineering and construction*
- *Part 6: Marine operations*
- *Part 7: Stationkeeping systems for floating offshore structures and mobile offshore units*

ISO 19901 is one of a series on international standards for offshore structures. The full series consists of the following international standards:

- ISO 19900, *Petroleum and natural gas industries — General requirements for offshore structures*
- ISO 19901 (all parts), *Petroleum and natural gas industries — Specific requirements for offshore structures*
- ISO 19902, *Petroleum and natural gas industries — Fixed steel offshore structures*
- ISO 19903, *Petroleum and natural gas industries — Fixed concrete offshore structures*
- ISO 19904-1, *Petroleum and natural gas industries — Floating offshore structures — Part 1: Monohulls, semi-submersibles and spars*
- ISO 19905-1, *Petroleum and natural gas industries — Site-specific assessment of mobile offshore units — Part 1: Jack-ups*
- ISO/TR 19905-2, *Petroleum and natural gas industries — Site-specific assessment of mobile offshore units — Part 2: Jack-ups commentary and detailed sample calculation*
- ISO 19906, *Petroleum and natural gas industries — Arctic offshore structures*

Introduction

The API Subcommittee on Offshore Structures (SC 2) voted to adopt a modified version of ISO 19901-3:2010 (corrected version, December 15, 2011) as American National Standard (ANSI)/API Recommended Practice 2TOP. SC 2 has also ensured that 2TOP is consistent with ISO 19901-3:2014, which was issued subsequent to the initial draft of this document.

API decided to adopt a modified version of ISO 19901-3 covering the design of topsides structures on offshore platforms, including certain planning and construction considerations, using a limit state approach with partial load and resistance factors. The result is this recommended practice (RP), API 2TOP. The modifications of the aforementioned ISO standard have been incorporated directly into the text.

API 2TOP reflects the evolution in structural design methodology from allowable strength design (ASD) to load and resistance factor design (LRFD). ASD, also known as working stress design (WSD), essentially utilizes a uniform factor of safety, whereas LRFD utilizes different partial factors to better capture the level of certainty with which the various loads and resistances are known. Whereas API 2TOP covers topsides structures, other API documents cover the design of the associated supporting substructures, either fixed (2A-LRFD) or floating (2FPS, etc.). ASD/WSD and LRFD are two separate and distinct design methodologies, which shall not be mixed when designing a given facility, including the topsides and substructure. API 2A-WSD continues to be an acceptable, alternate design choice, and it shall be followed when executing allowable strength or WSD.

The API offshore structures standards constitute a common basis covering those aspects that address design requirements and assessments of offshore structures used by the petroleum and natural gas industries worldwide. Through their application, the intention is to achieve consistent reliability levels appropriate for manned and unmanned offshore structures, whatever the type of structure and the nature of the 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 offshore structural systems.

The API and international standards for offshore structures are intended to provide wide latitude in the choice of structural configurations, materials, and techniques without hindering innovation. Sound engineering judgment is therefore necessary in the use of these standards.

API 2TOP is focused on the topsides structures of offshore platforms. Other standards are focused on the substructures supporting the topsides, whether they be fixed or floating. Previous national and international standards for offshore structures have concentrated on design aspects of the substructures, and the approach to the many specialized features of topsides has been variable and inconsistent, with good practice poorly recorded.

Historically, the design of structural components in topsides has been performed to national or regional codes for onshore structures, modified in accordance with experience within the offshore industry, or to relevant parts of classification society rules. While API 2TOP permits use of national or regional codes, and indeed remains dependent on them for the formulation of component resistance equations, it provides modifications that result in a more consistent level of component safety between substructures and topsides structures.

In some respects, the requirements for topsides structures are the same as, or similar to, those for fixed steel structures; in such cases, reference is made to API 2A-LRFD, Second Edition, with modifications where necessary. Annex A provides background to, and guidance on, the use of API 2TOP and is intended to be read in conjunction with the main body of API 2TOP. The clause numbering in Annex A follows the same structure as that in the body of the normative text in order to facilitate cross-referencing.

Annex B provides an example of the use of national standards for onshore structures in conjunction with this document.

The modifications to ISO 19901-3 that have been made for API 2TOP are based on industry practices applicable to US waters. Regional information relevant to US waters is provided in Annex C.

A comparison of the API documents corresponding to the aforementioned ISO documents is given in the table below, as applicable. In API 2TOP, the relevant API document is referenced wherever appropriate. Where there is not an appropriate API document to reference, the relevant ISO document is referenced.

API/ISO Document Comparison

Topic	API Document	ISO Document
General/Introduction	N/A	19900
Topsides Design	2TOP	19901-3
Fixed Steel Structures—LRFD	2A-LRFD	19902
Fixed Steel Structures—WSD	2A-WSD	N/A
Concrete Structures	N/A	19903
Floating Structures	2FPS	19904-1
TLP	2T	N/A
Mobile Offshore Units—Part 1: Jack-ups	N/A	19905-1
Metoccean Considerations	2MET	19901-1
Seismic Design	2EQ	19901-2
Structural Integrity Management (SIM)	2SIM	19902 (as pertains to fixed steel structures) 19904-1 (as pertains to floating structures)
Arctic Offshore Structures	2N	19906
Marine Operations	2MOP	19901-6
Fire and Blast	2FB	19901-3
Weight Control	N/A	19901-5
Plates	2V	N/A
Shells	2U	N/A
NOTE 1 N/A = not applicable or not available.		
NOTE 2 There are additional API and ISO documents not listed, including for geotechnical/foundations (API 2GEO), stationkeeping, floating MODUs, and riser design. See ISO 19900 for information on these documents as well as for general information on the basis of the various documents.		

Topsides Structure

1 Scope

This document provides requirements for the design, fabrication, transportation, installation, modification, and structural integrity management for the topsides structure for an oil and gas platform; API 2TOP complements API 2A-WSD, API 2A-LRFD, ISO 19903, API 2FPS, API 2T, ISO 19905-1, and API 2N, which give requirements for various forms of substructures. It is based on ISO 19901-3:2010 (Corrected version, 15-Dec-2011) and is consistent with ISO 19901-3:2014 to the fullest extent possible and modified only where needed for API purposes. Requirements in this standard concerning modifications and maintenance relate only to those aspects that are of direct relevance to the structural integrity of the topsides structure.

The actions on the topsides structure and structural components are derived from this document and where necessary, in combination with API, other international standards and the ISO 19900 series. The resistances of structural components of the topsides structure are determined by the use of international or national building codes, as specified in this document. If the topsides structure is integrated with the supporting substructure to help resist global platform forces, the requirements of this standard are supplemented with applicable requirements of the associated substructure such as API 2A-LRFD for fixed steel structures and API 2FPS for floating structures. This document is applicable to:

- topsides of fixed offshore structures;
- topsides on the hulls of floating offshore structures and mobile offshore units as long as interface displacements and internal forces associated with the hull or substructure are correctly accounted for in the analysis (see A.1).

For those parts of floating offshore structures and mobile offshore units that are chosen to be governed by the rules of a recognized classification society, the corresponding class rules supersede the associated requirements of this standard.

This document has limited guidance on corrosion control, alternate structural materials, and other miscellaneous topics that the structural engineer often has to consider.

This document contains requirements for, as well as guidance and information on, the following aspects of topsides structures:

- design, fabrication, transportation, installation, and modification;
- in-service inspection and structural integrity management;
- assessment of existing topsides structures;
- reuse;
- decommissioning, removal, and disposal;
- prevention, control, and assessment of fire, explosions, and other accidental events.

This document applies to structural components including the following:

- structural components in decks, module support frames, and modules;
- flare structures;
- crane pedestal and other crane support arrangements;
- helicopter landing decks (helidecks);

- permanent bridges between separate offshore structures;
- masts, towers, and booms on offshore structures.

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 amendments) applies.

API Recommended Practice 2A-LRFD, *Planning, Designing, and Constructing Fixed Steel Offshore Structures—Load and Resistance Factor Design*

API Recommended Practice 2A-WSD, *Planning, Designing, and Constructing Fixed Offshore Platforms—Working Stress Design*

API Recommended Practice 2EQ, *Seismic Design Procedures and Criteria for Offshore Structures*

API Recommended Practice 2FB, *Design of Offshore Facilities Against Fire and Blast Loading*

API Recommended Practice 2FPS, *Planning, Designing, and Constructing Floating Production Systems*

API Recommended Practice 2MET, *Derivation of Metocean Design and Operating Considerations*

API Recommended Practice 2MOP, *Marine Operations*

API Recommended Practice 2N, *Planning, Designing, and Constructing Structures and Pipelines for Arctic Conditions*

API Recommended Practice 2SIM, *Structural Integrity Management of Fixed Offshore Structures*

API Recommended Practice 2T, *Planning, Designing, and Constructing Tension Leg Platforms*

API Specification 2C, *Offshore Pedestal-mounted Cranes*

AISC 360-10 ¹, *Specification for Structural Steel Buildings*

AWC ² *National Design Specification (NDS) for Wood Construction—2015*

ISO 2631-1 ³, *Mechanical vibration and shock — Evaluation of human exposure to whole-body vibration — Part 1: General requirements*

ISO 2631-2, *Mechanical vibration and shock — Evaluation of human exposure to whole-body vibration — Part 2: Vibration in buildings (1 Hz to 80 Hz)*

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

ISO 19903, *Petroleum and natural gas industries — Fixed concrete offshore structures*

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

¹ American Institute of Steel Construction, 130 East Randolph, Chicago, Illinois 60601, <https://www.aisc.org>.

² American Wood Council, 222 Catoctin Circle SE, Leesburg, Virginia 20175, <http://www.awc.org>.

³ International Organization for Standardization, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, www.iso.org.

3 Terms and Definitions

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

3.1

abnormal environmental event

Environmental hazardous occurrence considered in an abnormal design situation.

NOTE Abnormal environmental events are most typically associated with probabilities of occurrence less than 10^{-3} per annum (return periods more than 1000 years). A hurricane with a return period greater than 1000 years is one example.

3.2

action

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

3.3

accidental event

Unexpected or unintended hazardous occurrence considered in an accidental design situation.

NOTE 1 Accidental events, as defined in this document, are associated with a substantial release of energy, such as vessel collisions, fires, and explosions, most typically associated with probabilities of occurrence less than 10^{-3} per annum (return periods more than 1000 years).

NOTE 2 Lesser accidents that could be expected during the life of the structure, such as the more probable dropped objects and low energy impact, are termed incidents and are addressed under operational design situations.

3.4

active fire protection

System of fire protection that reacts to a fire by discharging water or an inert or reactive substance in the vicinity of the fire to extinguish it.

NOTE There is a possibility that such a system fails to operate as designed.

3.5

caisson

Appurtenance used for abstracting water from the sea or for utilization as a drain.

NOTE For context as a structural component, see definition of "braced caisson" in API 2A-LRFD.

3.6

conductor

Tubular pipe set into the ground to provide the initial stable structural foundation for a borehole or oil well, protecting the well string from metocean actions.

NOTE 1 A conductor is generally vertical and is continuous from below the sea floor to the wellbay in the topsides and can be laterally supported in both the substructure and topsides structure. The vertical support is in the seabed.

NOTE 2 In a few cases, conductors are rigidly attached to the topsides or to the substructure above sea level. In these cases, the conductor's axial stiffness can affect the load distribution within the overall structure.

3.7

critical component

Structural component, failure of which would cause failure of the whole structure or a significant part of it, or render it structurally unsafe or on the verge of collapse, or compromise emergency response systems.

NOTE 1 A "failure critical component", as used in fatigue assessments, is synonymous with a structural critical component as defined here.

NOTE 2 A critical component is part of the primary structure. One example of a compromise of emergency response systems is failure of a primary member in the flare boom/tower that would compromise operation of the flare under an emergency situation.

3.8

design accidental action

Action that results from an accidental event (see 3.3).

3.9

design service life

Planned period for which a structure is used for its intended purpose with anticipated maintenance, but without substantial repair being necessary.

3.10

design situation

Set of physical conditions for which the design is verified.

NOTE A design event is an occurrence that results in an action or a group of actions, whereas a design situation is a relevant combination of jointly occurring events that results in a set of physical conditions for which the design is verified.

3.11

design value

Value derived from the representative value for use in design verification.

3.12

explosion

Rapid chemical reaction of gas or dust in air.

NOTE An explosion results in increased temperatures and pressure impulses. A gas explosion on an offshore platform is usually a deflagration in which flame speeds remain subsonic.

3.13

exposure level

Classification system used to define the requirements for a structure based on consideration of life safety and consequences of failure.

NOTE The method for determining exposure levels is described in API 2A-LRFD. An exposure level 1 (L1) platform is the most critical and an exposure level 3 (L3) the least. A normally manned platform, which cannot be reliably evacuated before a design event, or a platform with high consequences of failure is an exposure level 1 (L1) platform.

3.14

extreme value

Value of a parameter used in ultimate limit state checks, in which a structure's global behavior is intended to stay in the elastic range.

NOTE Extreme values and events have probabilities of exceedance of the order of 10^{-2} per annum.

3.15

load case

Compatible load arrangements, sets of deformations and imperfections considered simultaneously with permanent actions and fixed variable actions for a particular design or verification.

NOTE 1 This is similar to a design situation (see 3.10).

NOTE 2 Load arrangements are the identification of the position, magnitude, and direction of a free action.

3.16

mitigation

Action taken to reduce the likelihood and/or consequences of a hazardous event.

EXAMPLE Provision of fire or explosion walls; use of water deluge on gas detection; structural strengthening

3.17**nominal value**

Value assigned to a basic variable determined on a nonstatistical basis, typically from acquired experience or physical conditions.

3.18**owner**

Representative of the company or companies owning or leasing a development.

NOTE The owner is often the operator on behalf of co-licensees.

3.19**passive fire protection****PFP**

Coating on the surface of a structural component that improves the structural component's resistance to fire.

3.20**platform**

Complete assembly of structural and nonstructural systems, including topsides, substructure (whether fixed or floating), foundations (excluding soils), and stationkeeping systems.

3.21**regulator**

Authority established by a national governmental administration to oversee the activities of the offshore oil and natural gas industries within its jurisdiction, with respect to the overall safety to life and protection of the environment.

NOTE 1 The term "regulator" can encompass more than one agency in any particular territorial waters.

NOTE 2 The regulator can appoint other agencies, such as marine classification societies, to act on its behalf, and in such cases, "regulator" as it is used in this document includes such agencies.

NOTE 3 In this document, the term "regulator" does not include any agency responsible for approvals to extract hydrocarbons, unless such agency also has responsibility for safety and environmental protection.

3.22**reliability**

Ability of a structure or a structural component to fulfill the specified requirements.

NOTE When reliability is used in the context of limit states, it can be expressed as the probability that the limit is not exceeded.

3.23**representative value**

Value assigned to a basic variable in a design situation.

3.24**return period**

Average time 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.

3.25**riser**

That part of an offshore pipeline extending from the seabed to a termination point on the platform.

NOTE 1 For a fixed structure, the termination point is usually the topsides. For floating structures, the riser can terminate at other locations on the platform.

NOTE 2 A riser can be supported both laterally and vertically in the topsides structure and transmit actions from thermal effects, wave action, permanent and variable actions, and variations in fluid flow to the topsides structure.

3.26**risk reduction process****RRP**

Process of reducing the level of risk to the point where the economics of further reduction measures become grossly disproportionate to the additional risk reduction obtained.

NOTE RRP is effectively equivalent to the ALARP process, but the RRP term and definition is thought to better capture the risk reduction process involved.

3.27**robustness**

Ability of a structure to withstand events that have a reasonable likelihood of occurring, including abnormal environmental and accidental design events, without being damaged to an extent that renders it structurally unsafe or on the verge of collapse.

3.28**safety-critical element****SCE**

Item of structure, piping, or equipment, the failure of which can result in major accidents or which is provided to prevent or mitigate against them.

EXAMPLE Primary structure, pressure-containing equipment, blow-down and other safety systems, vessels and pipework containing hazardous materials, fire and gas detection systems, supports for SCE.

3.29**structural component**

Physically distinguishable part of a structure.

EXAMPLE Column, beam, stiffened plate, tubular joint, or foundation pile, or an assembly of such parts.

3.30**substructure**

Structure supporting the topsides.

NOTE The substructure can take many forms including fixed steel (see API 2A-LRFD), fixed concrete (see ISO 19903), floating (see API 2T and API 2FPS), mobile offshore units (see ISO 19905-1), or the various forms of arctic structures (see API 2N).

3.31**topsides**

Structures and equipment placed on a substructure (fixed or floating) to provide some or all of a platform's functions.

NOTE 1 For a ship-shaped floating structure, the hull main deck is not part of the topsides.

NOTE 2 For a jack-up, the hull is not part of the topsides.

NOTE 3 For the purposes of this standard, a module support frame is considered to be part of the topsides.

4 Symbols and Abbreviated Terms**4.1 Symbols**

<i>a</i>	acceleration
<i>A</i>	accidental action
<i>b</i>	spacing of stiffeners

D_e	equivalent quasi-static action representing dynamic response effects to the extreme environmental action, E_e
D_o	equivalent quasi-static action representing dynamic response effects to the operating environmental action, E_o
E	quasi-static environmental action
E_e	extreme quasi-static environmental action due to wind, waves, and current
E_o	quasi-static environmental action due to wind, waves, and current for an operating condition under consideration
F_d	design action
F_r	representative action
g	acceleration due to gravity
G	permanent action
I	explosion impulse
l	span or length
K_c	building code correspondence factor
p	instantaneous explosion overpressure
$p(t)$	variation of overpressure with time
P	probability
Q	variable action
R	resistance
R_D	design resistance
R_K	representative resistance
S	internal force or moment
S_d	design internal force or moment
t	time from ignition of an explosion
t_d	duration of positive explosion pressure pulse
T	fundamental period of vibration of a component or structure
$T_{C,max}$	maximum allowable temperature in a component
δ	thickness of a structural component, plate, or finite element
γ	partial safety factor
γ_f	partial action factor

γ_{FD}	partial damage design factor
γ_R	partial resistance factor
Δ	deflection
ε_{cr}	critical average strain
σ	stress
θ	temperature

4.2 Abbreviated Terms

ALARP	as low as reasonably practicable (This term has been replaced by RRP throughout 2TOP.)
ALE	abnormal level earthquake
ALS	accidental limit states
ASD	allowable strength design
AVM	antivibration mounting
CFD	computational fluid dynamics
CTOD	crack tip opening displacement
CVI	close visual inspection
DLB	ductility level blast
ELE	extreme level earthquake
FEA	finite element analysis
FLS	fatigue limit states
FPSO	floating production storage and off-loading
GVI	general visual inspection
LRFD	load and resistance factor design
MC	material category
MPI	magnetic particle inspection
MTOW	maximum take-off weight
PFP	passive fire protection
RRP	risk reduction process
SCE	safety-critical element
SDOF	single degree of freedom

SLB	strength level blast
SLS	serviceability limit states
SPJ	steel-piled jacket
SSS	substructure standard
SWLH	safe working load hook
TLP	tension leg platform
ULS	ultimate limit states
UR	utilization ratio
WSD	working stress design

5 Overall Considerations

5.1 Design Situations

Design situations cover the sets of physical conditions for which the design is being verified including relevant operational events and incidents, extreme and abnormal environmental events, accidental events, and pertinent pre-service conditions. Adequate planning shall be undertaken before detailed design is started in order to obtain a workable and economical topsides layout and structure to perform its functions. The initial planning shall include the determination of all criteria upon which the design of the topsides will be based.

The extent and magnitude of possible fire and explosion actions, which can be affected by the structural and equipment layouts, congestion, and containment, should be addressed during the initial planning of the topsides layout.

5.2 Codes and Standards

5.2.1 Limit State and Allowable Stress Design Philosophies

This standard is based on limit state design using the partial factor design format, and it is aligned with API 2A-LRFD, which governs fixed steel substructures that are also designed using the limit state methodology. The ISO 19900 series⁴ of international standards follows the requirements of ISO 2394^[60] and as such is intended to be a limit state design standard. Limit state methods are commonly known as load and resistance factor design (LRFD).

Within the ISO 19900 series, ISO 19902 and ISO 19903 are explicit limit state design standards. ISO 19904-1 allows either allowable strength design (ASD) or limit state design methods, but limit state methods for ships are only currently being finalized in LRFD formats. Within the API recommended practice series, API 2FPS and API 2N permit the use of either ASD or limit state design, although ASD has been more commonly utilized for floating facilities.

NOTE ASD methods are also known as working stress design (WSD) and permissible stress design methods.

⁴ The ISO 19900 series consists of the following international standards: ISO 19900, ISO 19901 (all parts), ISO 19902, ISO 19903, ISO 19904 (all parts), ISO 19905 (all parts), and ISO 19906. These standards have all been prepared by ISO/TC 67/SC 7 for offshore structures for the petroleum and natural gas industries.

This standard is based on the use of the limit state method. However, where the substructure is designed using ASD, the ASD method shall also be used for the topsides structural design utilizing API 2A-WSD.

Thus, ASD and LRFD standards shall not be mixed in the structural design of an offshore platform. Either ASD or LRFD shall be used to design the entire platform, including the topsides and associated substructure.

If the user chooses to design a fixed platform structure based on ASD/WSD, then they shall follow the latest edition of API 2A-WSD for designing both the topsides and the substructure. With respect to floating facilities, API 2FPS states that structural design of floating platforms shall be based on either the partial factor design format or the WSD format unless directed otherwise by the classification society. It is noted that the partial factors presented in API 2FPS have been derived from a calibration process focused mainly on North Sea environmental conditions, as explained in that document. Therefore, use of these partial factors for the Gulf of Mexico or for sites other than the North Sea can yield an uncalibrated design. Consequently, in the absence of partial factors specifically derived for the intended environment, floating structures in US waters should be designed utilizing the WSD format following the provisions given in API 2FPS regarding the use of this format, as agreed by the owner and the local regulatory authority.

5.2.2 Use of National Codes and Standards

The detailed design for a topsides structure shall be based on national or regional building codes. These should normally be those for the nation or region in which the platform is to be located, but may, with the agreement of the owner and the regulator, be those from other nations or regions. The standards used for fabrication should be consistent with and compatible with those used for design. In the case of this document, the reference national building code or specification is AISC 360-10.

NOTE As stated in Clause 1, this document does not apply to those parts of floating offshore structures and mobile offshore units that are governed by the rules of a recognized classification society and that are wholly within the class rules.

In order to realize a consistent level of reliability, the partial action factors shall be taken from the relevant standard governing the substructure on which the topsides is mounted and shall be used unmodified. The partial resistance factors shall be taken from the reference national building code, AISC 360-10, and modified by the application of a building code correspondence factor (see 8.1).

Floating structures and production jack-ups that are registered as vessels are also subject to the requirements of the prospective flag state or classification society acting on behalf of the flag state.

5.3 Deck Elevation and Green Water

For fixed structures, see the *Deck Elevation* clause in API 2A-LRFD for deck elevation requirements and for guidelines to determine wave forces on topsides components that shall unavoidably be placed below the lowest deck and below the design wave crest such as minor subcellars, sumps, drains, or certain production piping. In addition, see the *Deck Force Calculation Procedure* outlined in API 2SIM for a specific procedure to calculate wave forces on those topsides deck components that could be impacted by a wave. Hydrodynamic actions related to topsides components placed below the lowest deck should be identified and coordinated with the substructure designer as early as possible. The annex to the *Deck Elevation* clause in API 2A-LRFD contains additional guidance on air gap provisions. In any case, the 1000-year return period maximum crest elevation specified in the normative clause of 2A-LRFD covers the air gap requirement for new platforms in the Gulf of Mexico.

When assessing the air gap for floating structures, see the clause entitled *Air Gap* in API 2FPS. However, for tension leg platforms (TLPs), in particular, see the clause entitled *Minimum Deck Clearance Criteria* in API 2T.

5.4 Exposure Level

The exposure level for the topsides structure shall be the same as for the substructure and shall be determined in accordance with the provisions given in API 2A-LRFD, API 2A-WSD, API 2FPS, API 2T, API 2N, API 2SIM, ISO 19903, and ISO 19905-1, as appropriate.

5.5 Operational Considerations

5.5.1 Function

The structural engineer shall be aware of the functional requirements of the platform including drilling, process, access, safety, and auxiliary systems. In particular, the integrity of the structure shall conform to the platform's safety philosophy and any defined performance standards.

5.5.2 Spillage and Containment

Provisions for handling spills, overflows, and potential contaminants should be made in the design. A deck drainage system should be considered that collects and stores liquid spillages and overflows for subsequent handling.

5.6 Selecting the Design Environmental Conditions

The design environmental conditions (metocean, ice and seismic) for the topsides shall be those selected for the substructure. Less onerous environmental conditions may be adopted for specific short-term operations.

The wind speed shall be modified in accordance with API 2MET, depending upon the dimensions and elevation of the part of the structure or the component being considered.

EXAMPLE The short-term installation of specific pieces of equipment can be considered with lower environmental conditions if an assessment of the risks and consequences of exceeding the environmental criteria are considered.

5.7 Assessment of Existing Topsides Structures

Assessments of existing topsides structures to confirm that they comply with this document shall be performed in accordance with the assessment requirements of API 2A-LRFD, API 2A-WSD, API 2FPS, API 2N, API 2SIM, API 2T, ISO 19900, ISO 19903, and ISO 19905-1, as appropriate.

5.8 Reuse of Topsides Structure

Existing topsides structures may be removed and relocated for use at a new location. When this is considered, the topsides structure shall be evaluated in accordance with the requirements of API 2A-LRFD, API 2A-WSD, API 2FPS, API 2N, API 2T, ISO 19900, ISO 19903, and ISO 19905-1, as appropriate, for the use (including exposure level) and conditions that are applicable at the new location. Necessary repairs or modifications shall be in accordance with the requirements of this document.

5.9 Modifications and Refurbishment

Where modifications or refurbishment of an existing topsides structure are planned, the structure shall be assessed for the revised configuration in accordance with the assessment requirements of API 2A-LRFD, API 2A-WSD, API 2FPS, API 2N, API 2SIM, API 2T, ISO 19900, ISO 19903, and ISO 19905-1, as appropriate. All changes shall be documented (see 11.4). In some cases, the justification of a strengthening or stiffening modification requires the use of techniques that are outside the scope of this document.

6 Design Requirements

6.1 General

This clause presents the overall minimum requirements for design of topsides. The general principles on which structural design requirements are based are given in ISO 19900.

6.2 Materials Selection

Materials selection shall be in conformance with Clause 10 where the material category (MC) approach is specified for carbon steel, as described in API 2A-LRFD, and where guidance and requirements for alternate materials, including stainless steel, aluminum alloys, fiber-reinforced composites, and timber are also given.

6.3 Design Conditions

The topsides shall be designed to resist permanent and variable actions; wind, wave, and current actions; earthquake actions; temperature and deformation effects, temporary conditions, and accidental conditions—all of which can occur during its service life. These actions shall include both actions directly applied to the topsides and also the effects of actions on the substructure (such as waves, currents, and earthquakes). In addition, actions due to the motions of the substructure shall be addressed; these are particularly significant for floating structures.

The nominal values of these actions, or the derivation of these values, are given in Clause 7. Each mode of operation of the platform, such as drilling, production, work-over, or anticipated combinations thereof, shall be considered. In areas where icing can occur, the effects of both the weight of ice accretion and the increase in effective dimensions of components due to the ice, resulting in increased wind actions, shall be included.

6.4 Structural Interfaces

Topsides structural design shall address the following interfaces:

- a) interfaces between different structures in order to ensure adequate alignment when fabrication and installation tolerances are taken into account;
- b) compatibility of stiffnesses, distortions, and displacements during fabrication, transportation, installation, and in-service conditions.

The effects of displacements on different structures supported on one or more separate structures shall be considered.

EXAMPLE 1 The flexing of a ship-shaped floating structure can cause differential movements, which may be significant, between adjacent modules supported on the hull of the structure.

EXAMPLE 2 Jacket installation tolerances affecting bridge landing design and various system interfaces between a substructure or hull and the associated topsides are other examples.

6.5 Design for Serviceability Limit States

6.5.1 General

The serviceability of the topsides structures can be affected by excessive relative displacement or vibration (vertical or horizontal). Limits for either can be dictated by:

- a) discomfort to personnel;
- b) integrity and operability of equipment or connecting pipework;
- c) control of deflection of supported structures, e.g. flare structures and telecommunication masts;
- d) damage to architectural finishes; or
- e) operational requirements for drainage (free surface or piped fluids).

The vibration limits are specified in 6.5.2, and the deflection limits are specified in 6.5.3.

Assessments of serviceability shall be based on the relevant unfactored actions and unfactored resistance parameters such that all factors are set equal to 1.0, comparable to ASD.

6.5.2 Vibrations

6.5.2.1 Sources of Vibration

Potential sources of vibration shall be evaluated in the design of the topsides structure. As a minimum, the following shall be addressed for their effect on the structure:

- a) operating mechanical equipment, including that used in drilling operations;
- b) vibrations from variations of fluid flow in piping systems, in particular slugging;
- c) vortex-induced vibrations on slender tubular structures due to wind;
- d) global motions due to environmental actions on the total platform structure;
- e) vibrations due to earthquake and accidental events.

6.5.2.2 Design Limits

Design limits for vibration shall be established from operational limits set by equipment suppliers and the requirements of personnel comfort and health and safety.

The design limits for horizontal and vertical vibration effects on personnel shall not exceed those given in ISO 2631-1 and ISO 2631-2. More onerous limits can be required by the owner or by the regulator.

6.5.2.3 Long-period Vibrations

Long cantilevers (whether formed by simple beams or trusses) forming an integral part of the topsides, but excluding masts or booms, should be proportioned to have a natural period of less than 1 s in the operating condition.

6.5.2.4 Dynamic Analysis and Avoidance of Resonance

Analytical techniques should be used to assess the dynamic response of various parts of the topsides to ensure that resonance is avoided. The dynamic behavior of long cantilevers can be calculated by eigenvalue analysis. Such analysis should include unfactored static and imposed actions. Where heavy rotating or reciprocating machinery is installed (such as variable speed pump skids, compressors, etc.), three-dimensional vibration analysis should be performed. To avoid resonance, the cantilevered local structure should be designed such that the natural frequencies of the deck do not lie between 0.65 times and 1.5 times the operating frequency of the equipment supported.

6.5.3 Deflections

The final deflected shape, $\Delta_{\max}$, of an element, structural component or structure comprises three parts as follows:

$$\Delta_{\max} = \Delta_1 + \Delta_2 - \Delta_0 \quad (1)$$

where

Δ_0 is any pre-camber (hogging) of a beam or element prior to the addition of any permanent or variable actions;

Δ_1 is the deflection from permanent actions;

Δ_2 is the deflection from the variable actions and any time-dependent deformations from permanent actions.

Vertical deflections shall not exceed the values presented in Table 1.

Table 1—Maximum Vertical Deflections

Structural Component	Maximum Deflection	
	$\Delta_{\max}$	Δ_2
Floor beams	$\frac{l}{200}$	$\frac{l}{300}$
Cantilever beams	$\frac{l}{100}$	$\frac{l}{150}$
Deck plate	—	2δ or $\frac{b}{150}$ (whichever is smaller)
l span. δ deck plate thickness. b stiffener spacing.		

More onerous limits can be required by the owner or by the regulator or can be specified for individual items of equipment in order to facilitate shaft alignment or mitigate vibration issues, for example.

Lower limits can be necessary to limit ponding of surface fluids and ensure that drainage systems function correctly; ponding should be avoided by cambering deck plating in areas susceptible to icing of surface water.

The alignment of telecommunications equipment can be critical for their reliable operation, and due consideration should be given to maintaining the required tolerances for such equipment in terms of the related support structure design.

Relative horizontal deflections between floors should be limited to 0.3 % of the height between floors. For multifloor modules, the total horizontal deflection should not exceed 0.2 % of the total height of the topsides structure. More onerous limits can be necessary to limit pipe stresses.

Higher deflections can be acceptable for cladding panels and other components where serviceability is not compromised by deflection.

6.6 Design for Ultimate Limit States

To obtain design actions, an action factor shall be applied to each of the representative applied actions in the combinations given in Clause 7. The action factors are given in the relevant standard for the supporting substructure on which the topsides is mounted, as described in Clause 7. For example, for fixed steel platforms, the relevant standard is API 2A-LRFD, and, for floating platforms, the relevant standard is API 2FPS.

The combination of factored representative actions results in factored internal forces and moments, S .

A resistance factor is applied to the representative strength of each component to determine its design strength. Each component shall be proportioned to have sufficient factored strength to resist S . The appropriate strength and stability criteria shall be taken from the appropriate national or international building code and shall be modified by a correspondence factor to account for differences in approach between the building code and the

applicable supporting substructure standard (SSS). This is to ensure that a similar level of reliability for topsides design is achieved to that implied in the SSS.

In some conditions, particularly during construction and installation, the internal forces should be computed from unfactored representative actions and then modified by appropriate action factors to arrive at S (see the relevant SSS).

6.7 Design for Fatigue Limit States

The design actions to be used in the fatigue limit states (FLS) are addressed in the international standard in the ISO 19900 series that is applicable to the substructure. Additional considerations for specific systems are given in Clause 9. The fatigue methodology in API 2A-LRFD, API 2FPS, API 2N, ISO 19903, and ISO 19905-1, as appropriate, shall be followed in the design of the topsides structure; in cases where the SSS does not provide adequate fatigue provisions for a topsides structure, the requirements of API 2A-LRFD shall apply.

The fatigue damage design factors provided in Table 2 are recommended.

Table 2—Partial Damage Design Factors, γ_{FD}

Failure Critical Component	Inspectable and Repairable	Not Inspectable or Repairable
No	2	5
Yes	5	10

NOTE See the definition of a critical component in 3.7.

Where the topsides structure is subjected to a long sea transportation or to a potentially major single storm event during sea transport that could govern the design of certain primary structural components, particular attention shall be given to the fatigue performance of structural details that do not normally see significant fatigue actions. Note that transportation fatigue and in-place fatigue should be added when evaluating structure fatigue damage.

6.8 Design for Accidental Limit States

Accidental limit states (ALS) are addressed in 7.10, where requirements and recommendations are given for determining the conditions and actions, the partial action factors, and the partial resistance factors related to ALS.

6.9 Robustness

The topsides shall incorporate robustness through consideration of the effects of hazards and their probabilities of occurrence to ensure that damage is not disproportionate to the cause. Damage from an event with a reasonable likelihood of occurrence shall not lead to complete loss of integrity of the structure. In such cases, the structural integrity in the damaged state shall be sufficient to allow a process system close-down, or a safe evacuation, or both. Framing patterns should be designed to provide alternative loading paths to minimize the effects of overloading the structure upon occurrence of a hazardous event.

Robustness can be achieved by the following:

- designing the structure in such a way that each load-bearing component remains capable of carrying its normal design actions without causing collapse of the structure or part of it when exposed to a hazard;
- ensuring by design or by protective measures that no critical component exposed to a hazard can be made ineffective; using a design measure, this can be accomplished by providing alternate loading paths to redistribute the load so that, if any failure mechanisms occur, they will be of a ductile instead of a brittle nature; using a protective measure, this can be accomplished by applying passive fire protection (PFP) to a critical member that might be impinged by a jet fire, for example; or

- c) a combination of (a) and (b) above.

Reference A.6.9 for additional guidance concerning ways to help ensure the robustness of topsides, including safety critical secondary or tertiary structure.

6.10 Corrosion Control

The design of structural details should, whenever possible, avoid corrosion traps and provide for free drainage of liquids.

The design of corrosion protection for the topsides structure should account for the following:

- a) corrosion allowance (if any) considered in the design;
- b) design life and requirement for planned maintenance;
- c) access for maintenance of corrosion protection systems;
- d) protection of details sensitive to crevice corrosion (e.g. bolted connections and the interface between piping and pipe supports);
- e) protection of voids vulnerable to corrosion (e.g. by plugging vent holes in pipe supports after welding and by sealing off difficult-to-maintain spots using seal plates unless such seal plates would block needed inspection access);
- f) specification of requirements for corrosion protection;
- g) avoidance of galvanic corrosion (e.g. between carbon steel framework and aluminum helidecks and between carbon steel framework and stainless steel process pipework and vessels).

Where structural components are also used for fluid storage, e.g. diesel tanks within crane pedestals, a suitable corrosion control system shall be installed.

Where a corrosion allowance is incorporated in a component, the allowance shall be documented for use in inspection planning and assessment (see Clause 14).

Particular attention shall be paid to the prevention of water leakage and subsequent corrosion under lagging systems and under PFP systems.

Further requirements and recommendations for corrosion control are given in Clause 12.

6.11 Design for Fabrication and Inspection

The designers shall be familiar with, and anticipate likely methods of, fabrication, welding, and erection to execute the design, and they shall provide a design that accommodates these through the provision of appropriate material thicknesses, clearances, access, and stability at all stages of construction. Accordingly, the design shall evaluate actions/loading from installation aids used in fabrication and installation. Also refer to Clause 13 and A.13 for pre-service considerations including loadout, transportation, and installation.

The design should be prepared with a clear understanding of the level of in-service inspection and maintenance planned during the topsides structure's life. Where the integrity of the topsides structure during its design life requires in-service inspection, provision for access for such inspection shall be included.

Any design assumptions with respect to in-service inspection shall be clearly recorded and communicated to the fabricator and owner.

The design intent shall be followed during construction, and variances shall be resolved without compromising the design intent.

The designers shall communicate the extent, type, and rejection criteria for all nondestructive inspections. Where performance level (e.g. fatigue performance) depends on the achievement of particular standards in construction, the designer shall ensure that these are communicated.

NOTE Requirements are given elsewhere in this document for materials (see Clause 10), quality control, quality assurance and documentation, welding and fabrication inspection (see Clause 11).

6.12 Design Considerations for Structural Integrity Management

During the design, fabrication, inspection, transportation, and installation of the topsides structure, sufficient data shall be collected and compiled for use in preparing in-service inspection programs (to monitor fatigue, for example), in preparing for possible topsides modifications. Safety-critical elements (SCEs) in the topsides structure shall be identified, and the information shall be used in the preparation of in-service protection programs (see API 2SIM). The aforementioned requirements are driven by the extent to which any in-service inspection programs, future topsides additions or modifications, or related activities are planned during the platform's design life. If none are planned, then the aforementioned requirements are moot.

The design of equipment supports and skids should provide adequate access to the structure to facilitate inspection and maintenance (e.g. painting) of primary and secondary steelwork and of equipment.

6.13 Design for Decommissioning, Removal, and Disposal

6.13.1 General

Decommissioning and removal requirements should be addressed during the topsides structure design phase, particularly for fixed platforms and deep draft floating platforms. Where the preferred removal option requires the use of special features, these should be evaluated for inclusion in the topsides structure during its fabrication. The platform's structural integrity management system should prevent in-service structural modifications that can prejudice later removal (reference API 2SIM for fixed platform facilities).

6.13.2 Structural Releases

Consideration should be given to designing secondary structures between modules and elsewhere that are supported from one side only so as not to depend on temporary supports during dismantling.

The design of module support points, antivibration mountings (AVMs), and equipment supports should consider access requirements for future disconnection.

6.13.3 Lifting Appurtenances

Lifting attachments for installation of the topsides structure should be retained for subsequent use during decommissioning. Where attachments are removed during installation or during the service life of the topsides structure, consideration should be given to facilitating their reattachment or replacement for subsequent removal.

The design should allow for periodic access for inspection.

6.13.4 Heavy Lift and Set-down Operations

Consideration should be given to the dynamic impact factors used in design for allowing for a removal case involving set-down onto a barge that could be more severe than for installation, if such a removal scenario is envisioned.

7 Actions

7.1 General

A topsides structure can be exposed to a number of design situations throughout its design service life. These include the following:

- responses to extreme conditions of wind, waves, and currents;
- responses to normal operating conditions of wind, waves, and currents;
- fabrication;
- transportation;
- installation;
- fatigue: pre-installation and during the design service life;
- accidental situations including fire, explosions, ship impact, and dropped objects;
- abnormal conditions of wind, waves, and currents;
- extreme earthquake conditions;
- abnormal earthquake conditions;
- snow and ice accumulations;
- dismantling/removal.

Each of these design situations comprises several actions such as permanent, variable and environmental actions, deformations, temperature effects, and accidental events, each with appropriate partial action factors.

Both provisions and guidance concerning design situations are given in API 2A-LRFD, API 2FPS, API 2N, API 2T, ISO 19900, ISO 19903, and ISO 19905-1, as appropriate.

7.2 In-place Actions

Each topsides structural component shall be assessed for internal force (action effect), S , resulting from the design action, F_d . The design action shall be derived from the following combinations of actions:

- a) maximum permanent and variable actions, G_1 , G_2 , Q_1 , and Q_2 ;
- b) extreme environmental actions, G_1 , G_2 , Q_1 , E_e , and D_e , together with any actions resulting from associated substructure movements;
- c) operating environmental actions, G_1 , G_2 , Q_1 , Q_2 , E_o , and D_o , together with any actions resulting from associated substructure movements;

where

G_1 is the permanent action imposed on the topsides structure by the self-weight of the topsides structure with associated equipment and other objects (see API 2A-LRFD); in addition, any actions due to the misalignment of structures, such as between the topsides structure and the substructure, are part of G_1 ;

G_2 is the permanent action imposed on the topsides structure by self-weight of equipment and other objects that remain constant for long periods of time, but which can change from one mode of operation to another, or during a mode of operation (see API 2A-LRFD);

Q_1 is the variable action imposed on the topsides structure by the weight of consumable supplies and fluids in pipes, process vessels, tanks, and stores, the weight of transportable tanks and containers used for delivering supplies, the weight of ice accretions, and the weight of personnel and their personal effects (see API 2A-LRFD); in addition, any actions due to the movement of supporting structures not due to environmental effects, such as trim of a floating production storage and off-loading (FPSO) vessel and the effects of cargo loading, including flexure of the substructure due to such effects, are part of Q_1 ;

Q_2 is the short-duration variable action imposed on the topsides structure from operations such as the lifting of drill string, lifting by cranes, liquids in pipes and process vessels for pressure testing, machine operations, mooring of an adjacent ship to the platform, and helicopters (see API 2A-LRFD);

E_e is the extreme quasi-static environmental action on the topsides structure and any environmental action effects transmitted through the substructure (see API 2A-LRFD, API 2FPS, API 2N, API 2T, ISO 19903, and ISO 19905-1, as appropriate); in addition, any actions due to the movement of supporting structures due to extreme environmental effects, such as roll of an FPSO, including any consequent flexure of the substructure due to such effects, are part of E_e ;

D_e is the equivalent quasi-static action on the topsides structure representing dynamic response to the extreme environmental action (see API 2A-LRFD, API 2FPS, API 2N, ISO 19903, and ISO 19905-1, as appropriate);

E_o is the operating environmental action on the topsides structure and any operating environmental action effects transmitted through the substructure for environmental conditions limiting a particular operation (see 7.3.4); in addition, any actions due to the movement of supporting structures due to the operating environmental effects, such as roll of an FPSO, including any consequent flexures of the substructure due to such effects, are part of E_o ;

D_o is the equivalent quasi-static action on the topsides structure representing dynamic response to the operating environmental action, E_o .

The values of G_1 , G_2 , Q_1 , and Q_2 are often not well defined at early stages of the design process, and the potential lack of accuracy should be taken into account (see A.7.2). In a similar manner, potential variation of the center of gravity of the topsides during the design process should be evaluated, particularly with respect to design for loadout, transportation, and installation of the topsides.

7.3 Action Factors

7.3.1 Design Action for In-place Situations with Permanent and Variable Actions Only

The design action, F_d , for the in-place design situation due to maximum permanent and variable actions only shall be calculated using Equation (2).

$$F_d = \gamma_{f,G1}G_1 + \gamma_{f,G2}G_2 + \gamma_{f,Q1}Q_1 + \gamma_{f,Q2}Q_2 \quad (2)$$

The partial action factors, γ_f , shall be the same as those used for the substructure design or assessment. See API 2A-LRFD, API 2FPS, API 2N, API 2T, ISO 19903, or ISO 19905-1, as appropriate.

7.3.2 Design Actions for Equipment Testing

Tanks, pipework, and pressure systems can be subjected to hydrostatic and pressure testing at various stages of a platform's life. The additional actions due to the weight of liquid used for the test should be included in the short-duration variable action, Q_2 , to the extent known in the design stage if such inclusion will have an impact on the member design.

7.3.3 Design Action for In-place Situations due to Extreme Environmental Actions

The design action, F_d , for the in-place design situation due to extreme environmental situation actions for topsides on fixed structures shall be calculated using Equation (3).

$$F_d = \gamma_{f,G1}G_1 + \gamma_{f,G2}G_2 + \gamma_{f,Q1}Q_1 + \gamma_{f,Ee}(E_e + \gamma_{f,D}D_e) \quad (3)$$

Since no short-term duration loads are expected during extreme environmental situations, the Q_2 term has been eliminated from Equation (3). Ensure that G_2 and Q_1 include only those parts of each mode of operation that can reasonably be present during extreme conditions.

The design action for floating structures shall be calculated in a similar manner, which includes allowing for the rotations and accelerations due to the vessel motions.

The partial action factors, γ_f , shall be the same as those used for the substructure design or assessment. See API 2A-LRFD, API 2FPS, API 2N, API 2T, ISO 19903, or ISO 19905-1, as appropriate.

When the internal forces due to permanent and variable actions oppose those due to wind, wave, and current actions in extreme environmental conditions, the design action, F_d , shall be calculated in accordance with Equation (4) using reduced partial action factors for the permanent and variable actions.

$$F_d = \gamma_{f,G1}G_1 + \gamma_{f,G2}G_2 + \gamma_{f,Q1}Q_1 + \gamma_{f,Ee}(E_e + \gamma_{f,D}D_e) \quad (4)$$

For this check, G_2 and Q_1 shall exclude any parts associated with the mode of operation considered that cannot be ensured of being present during the operational conditions.

The partial action factors, γ_f , shall be the same as those used for the substructure design or assessment (see API 2A-LRFD, ISO 19903, API 2FPS, API 2N, API 2T, or ISO 19905-1, as appropriate) for the case when the internal forces due to permanent and variable actions oppose those due to wind, wave, and current actions in extreme environmental conditions.

NOTE 1 The appropriate partial action factor for the environmental action depends on the exposure level, the long-term environment at the offshore location of the platform, and the geometrical and structural properties of the structure considered.

NOTE 2 API 2A-LRFD specifies a value of $\gamma_{f,Ee}$ of 1.35 where no other information is available.

7.3.4 Design Actions for In-place Situations with Operating Environmental Actions

Platform operations are often limited by environmental conditions, and differing limits can be set for different operations. Examples of operations that can be limited by environmental conditions include the following:

- drilling and workover,
- crane transfer to and from supply ships,
- crane operations on deck,

- deck and over-the-side working,
- deck access, and
- helicopter operations.

Each operating situation that is restricted by environmental conditions shall be assessed as demonstrated in Equations (5) and (6), in which E_o and D_o represent the environmental actions limiting the operations.

The design action, F_d , for in-place situations involving platform operations on fixed structures shall be calculated using Equation (5).

$$F_d = \gamma_{f,G1}G_1 + \gamma_{f,G2}G_2 + \gamma_{f,Q1}Q_1 + \gamma_{f,Q2}Q_2 + \gamma_{f,Eo}(E_o + \gamma_{f,D}D_o) \quad (5)$$

For this check, G_2 , Q_1 , and Q_2 shall be the maximum values associated with the particular operating situation being considered.

When the internal forces due to permanent and variable actions oppose those due to wind, wave and current actions in operating environmental conditions, the design action, F_d , shall be calculated in accordance with Equation (6) using reduced partial action factors for the permanent and variable actions.

$$F_d = 0.9G_1 + 0.9G_2 + 0.8Q_1 + \gamma_{f,Eo}(E_o + \gamma_{f,D}D_o) \quad (6)$$

For this check, G_2 and Q_1 shall exclude any parts associated with the mode of operation considered that cannot be ensured of being present during the operational conditions.

The design action for floating structures shall be calculated in a similar manner, which includes allowing for the rotations and accelerations due to the vessel motions.

NOTE API 2A-LRFD allows a value of $\gamma_{f,Eo}$ of $0.9 \times 1.35 \approx 1.20$ where no other information is available.

7.4 Vortex-induced Vibrations

For the fabrication, transportation and in-place phases, an assessment of the possibility of vortex-induced vibrations (VIV) due to wind on exposed structural components shall be undertaken. Vibration due to current-induced VIV of risers and J-tubes has been reported in fixed structures, which, in turn, affected the topsides (see A.7.4).

The possibility of fatigue due to vortex-induced vibrations on lattice structures (e.g. flare booms and drilling derricks) and exposed pipework shall be evaluated.

7.5 Deformations

Internal forces due to imposed deformations can arise from the effects of fabrication tolerance, foundation settlement, and the effects of transportation and lift. Internal forces can also occur from operational or accidental thermal effects.

Where a primary topsides structure is supported by a multicolumn gravity base structure, the movements and deformations of the column tops can result in significant indirect actions applied to the topsides structure. This can also occur with other combinations of topsides and substructures. For this reason, the substructure and the topsides structure should normally be analyzed together, such that an adequate representation of stiffness of one is included in the detail evaluation of the other, for both the serviceability limit states (SLS), ultimate limit states (ULS) and FLS.

All such actions or action effects shall be addressed in combination with appropriate operating and environmental actions to ensure that serviceability and ULS are not exceeded.

The hull of a monohull is often much stiffer than the topsides structure, and, as it sags and hogs, deformations can be introduced at the topsides structure level. It is important that the differences between essentially static behavior due to ballast and cargo loading, and dynamic behavior due to environmental effects are understood. During the sea transportation, it is important that the overall flexibility characteristics of the vessel are captured and that the sagging and hogging effects of the vessel are considered in the topsides structural design and strength verification.

7.6 Wave and Current Actions

Although wave and current actions mainly affect the substructure directly, there are frequently indirect actions on the topsides due to the displacements and deformations of the substructure. Wave and current effects on both the substructure and the topsides shall be included in the calculation of the environmental actions on the topsides, including those listed below.

a) For fixed platforms:

- 1) lateral accelerations of the topsides due to dynamic response of the platform as well as deck acceleration during design hurricane events (see 7.8.2 and 7.10.11);
- 2) framing actions due to horizontal actions on the substructure;
- 3) particular attention shall be given to topsides on multileg concrete platforms in which the wave actions can act in differing directions on different legs, resulting in various forces and moments through the topsides in conditions well below the extreme wave heights.

b) For floating platforms:

- 1) translational accelerations due to sway, surge, and heave of the substructure;
- 2) rotational accelerations due to roll, pitch, and yaw of the substructure;
- 3) rotation of the topsides due to roll and pitch with the consequent effects on the directions of actions;
- 4) particular attention shall be paid to the distortions of the substructure and the consequent effects on the support points of the topsides structure.

Large actions can result when seawater strikes a platform's deck and equipment. Where insufficient air gap exists, when wave run-up against large diameter legs and columns strikes the deck, or when water inundates the deck for floating structures (green water effects), then actions resulting from the water flow including buoyancy, inertia, drag, and slam shall be taken into account. See API 2A-LRFD, API 2FPS, API 2MET, API 2N, API 2T, ISO 19903, or ISO 19905-1, as appropriate.

7.7 Wind Actions

Provisions and guidance on wind speeds, including wind profiles and gust durations, are given in API 2MET. The derivation of the wind action on the topsides should follow the methodology in API 2A-LRFD.

7.8 Seismic Actions

7.8.1 General

The topsides structure shall be evaluated for earthquake conditions, where applicable, as part of the overall platform consisting of the substructure with its foundation. If quasi-static accelerations are determined from the overall platform model, then the topsides may be able to be analyzed separately using those accelerations along with the appropriate boundary conditions. Reference API 2EQ for seismic design requirements and guidance.

Though earthquakes primarily affect fixed platforms, floating facilities shall still be evaluated with respect to the potential applicability of seismic actions. TLPs, for example, could be subject to vertical ground motions.

Topsides structure, equipment piping, and other deck appurtenances shall be designed and supported to satisfy the demand requirements (seismic loading) described in API 2EQ, with a particular focus given to SCEs in this regard. Even in low seismic areas, a minimum level of connectivity and tie-down of topsides components is needed to satisfy the requirement for a minimum lateral design acceleration, as described in 7.8.2.

Design acceleration levels shall include the effects of overall platform dynamic response, and, if appropriate, local dynamic response of the deck and the appurtenance itself. Due to the platform's dynamic response, the design acceleration levels can be greater than the ground motions and hence greater than those commonly associated with the seismic design of similar onshore processing facilities.

7.8.2 Minimum Lateral Acceleration

A minimum lateral design acceleration of 0.05 g shall be applied as an extreme level earthquake (ELE) to the topsides, including equipment and supporting framework, for all fixed structures including those in Seismic Zone 0. This is based on the fact that, even in Seismic Zone 0, ground motions can occur that can generate lateral accelerations in the topsides of fixed facilities on the order of 0.05 g, as described in A.7.8.

Furthermore, 7.10.11 states that a minimum lateral design acceleration of 0.05 g shall be applied to all topsides structures, including those on floating platforms, to ensure a minimum level of connectivity and tie-down of equipment, piping, and other topsides components due to accidental actions or due to deck accelerations generated during storm events. On floating facilities, actual motion analysis will determine the appropriate lateral design accelerations to use, not to be less than the minimum design value of 0.05 g.

7.8.3 Equipment and Appurtenances

In general, most types of properly anchored equipment and appurtenances are sufficiently stiff for their lateral and vertical responses to be calculated directly from maximum computed deck accelerations, since local dynamic amplification of the appurtenances themselves is negligible. However, in some circumstances the flexibility of the topsides can affect the natural frequency of equipment and appurtenances.

For relatively stiff equipment and appurtenances, in which the mass is small compared to that of the topsides structure and which can reasonably be treated as single degree of freedom (SDOF), a simplified uncoupled analysis may be performed using the following steps:

- a) from prior modal analysis of the overall platform (see API 2EQ), extract the accelerations, a_s , at the equipment support location; and
- b) multiply the equipment or appurtenance mass by the resulting acceleration and design its supports for the resulting actions.

A more rigorous analysis shall be undertaken if any of the following apply:

- c) the equipment or appurtenance mass is greater than 5 % of the total platform mass;
- d) the equipment or appurtenance has dynamic characteristics or its supporting structure affects its vibration; or
- e) the SDOF natural period of the equipment or appurtenance exceeds 1.25 times the period of a significant mode of the complete structure.

Where more rigorous analysis is required, it shall be undertaken by:

- f) an uncoupled analysis with deck-level floor response spectra, or
- g) coupled analysis methods.

Equipment and appurtenances that typically require a more rigorous analysis include drilling rigs, flare booms, vent and communications towers, deck cantilevers, tall process vessels, large unbaffled tanks, bridges, and chimneys.

Coupled analyses that properly include the dynamic interactions between the equipment or appurtenance and the topsides structure result in more accurate and often lower design accelerations than those derived using uncoupled floor response spectra.

Drilling and well servicing structures shall be designed for earthquake actions in accordance with an appropriate standard (see A.7.8.2) and shall be tied down or restrained at all times except when being moved.

7.9 Actions during Fabrication and Installation

7.9.1 General

The primary objective of 7.9 is to ensure that a topsides structure begins its design service life with its designed strength and structural integrity intact. Installation encompasses the operations of moving the topsides components from the fabrication site (or prior offshore location) to the substructure and installing them to form the completed platform. Clause 13 contains further details on installation procedures.

7.9.2 Fabrication

The sequence of construction and temporary erection conditions, including jacking and weighing conditions, shall be evaluated to ensure that the ULS requirements are met during all temporary conditions. Individual support reactions during fabrication depend on the stiffness of the topsides structure and of the supporting foundation. Internal forces in the topsides structure due to uneven support points shall be determined.

7.9.3 Loadout, Transportation, and Installation

Specific requirements, recommendations, and guidance for marine operations, including loadout, transportation, and installation are given in API 2MOP. The design actions for loadout, transportation, and installation conditions may exceed those for the in-place conditions and shall be accounted for accordingly. Also reference the *Topsides Installation* clause of API 2A-LRFD for additional guidance on this topic.

7.10 Accidental Situations

7.10.1 General

Prevention, detection, control, and mitigation of accidental situations arising from hazards shall be addressed in the design in order to promote inherently safe topsides. Implementing preventive measures has historically been, and will continue to be, the most effective approach in minimizing the probability of occurrence of an event and the resultant consequences of the event. The owner or operator responsible for the overall safety of the platform shall identify the hazard management issues to be evaluated. Accidental events shall be identified and assessed by means of hazard analysis performed in accordance with ISO 19900. A suitable screening process is shown in Figure 1. (See 7.10.2.)

For topsides structures, the accidental and abnormal environmental situations considered shall include the following where the associated events typically have probabilities of occurrence less than 10^{-3} per annum, i.e. return periods more than 1000 years:

- a) explosion;
- b) fire;
- c) vessel collision;
- d) impact from dropped and swinging objects, from projectiles, and from broken cables and wire;
- e) helicopter impact (emergency landing or crash);
- f) for floating structures, the effects of accidental flooding due to compartment damage, and so forth.

The main load-bearing primary structure, which is one of the SCE and is fundamental to the support of the temporary refuge, the lifeboats, safety-critical piping, equipment, and associated supports and other components

essential to the safety of the personnel, shall be designed to retain sufficient integrity during accidental situations to provide protection to:

- personnel for a duration sufficient to allow their evacuation, and
- the environment for a duration sufficient to effect containment of hydrocarbon spillages from process equipment.

An accidental situation can directly or indirectly impose actions, including drag actions, deflections, strong vibration, impact, and thermal/heat, on structural components and SCE, such as blow-down systems, emergency shut-down systems, deluge systems, processing systems, and piping. Structural discipline engineers shall work closely with engineers of other disciplines (mechanical, electrical, process, etc.), including safety engineers experienced in performing hazard analyses, as part of the owner or operator's safety management system, as described in ISO 13702, to ensure that the likely response of the topsides structure and equipment is suitably assessed.

Interaction between the topsides structure and the substructure shall be assessed. For a floating platform, suitable means of structurally decoupling the topsides structure from the hull should be provided to reduce the internal forces resulting from accidental and abnormal actions to acceptable levels if needed to achieve a workable structural design.

The structural system shall be designed to resist accidental actions to ensure that the main safety functions of the topsides structure are not so impaired as to lead to either unacceptable loss of integrity of the structure or escalation causing its partial collapse. ALS design verification shall be carried out by considering, for each accidental event, a value that reduces risks in accordance with the risk reduction process (RRP) to levels representative of the accidental situations listed in items a)–f) in the second paragraph above. This probability level can be taken as indicative of an order of magnitude since the data basis for accurate determination of this small exceedance probability can be limited and include uncertainties.

Items of equipment and piping essential to the survival of the topsides (i.e. SCE) shall be assessed for structural resistance to accidental actions. The assessment shall include supports to such equipment and associated critical pipework.

Imposed and self-weight actions shall be included in the assessment of the integrity of the structure and its response. The self-weight of the structure shall be combined with a realistic estimate of live or operating actions. Partial action and resistance factors may be set to unity for the ALS. The ALS assessment shall also include appropriate assessment of the integrity of the damaged structure (after-damage design situation) in assessing its capability to resist appropriate environmental actions. An assessment is necessary where the resistance of the structure has been significantly reduced by the structural damage caused by the accident. Criteria for this assessment are given in API 2A-LRFD.

7.10.2 Evaluation of Accidental Situations

7.10.2.1 General

Three risk levels are considered in this document, as described in Table 3.

Table 3—Description of Risk Levels

Risk Level	Description
1—Low risk	Insignificant or minimal risks that can be eliminated from further consideration.
2—Medium risk	Risks shown to be acceptable in accordance with the RRP process.
3—High risk	Risks requiring further mitigation or modification of platform functions or manning philosophy, to reduce the risk level to medium or low.

A risk assessment process shall be undertaken as described in this subclause to:

- a) initially screen the accidental events on the platform to determine if they can be considered low risk in which case no further action is required;
- b) otherwise, study the probabilities, accidental action magnitudes and consequences, and the cost effectiveness of mitigating measures;
- c) determine which mitigation measures are necessary and re-evaluate the risk levels when RRP criteria cannot be met without mitigation.

The assessment process as outlined in Figure 1, comprises a series of tasks to be performed to identify the risk to a platform from fire or explosion actions, from impact loading, or from compartment flooding and to perform a suitable structural assessment.

The assessment tasks listed below should be read in conjunction with Figures 1, 2, and 3 and with Table 4.

- Task 1: For each accidental event in turn, estimate the order of magnitude of the probability of the event. Determining the probability of accidental events can be based on a review of statistics of occurrences at other locations, for example, the occurrence of leaks from particular types of flanges in pipework coupled with the probability of an ignition, but the limitations and inaccuracies in such estimates should be understood.
- Task 2: For the accidental event, estimate the potential for injury from the descriptions in Table 4 and consequently determine the risk level for the event under consideration. In many cases, it can be necessary to undertake a structural assessment of the event to determine the potential consequences (see Figures 2 and 3). For events with low risk, the assessment is complete and the next accidental event shall be addressed.
- Task 3: For medium or high risks, further studies shall be undertaken to better define the risks, consequences, possible mitigation measures, and the costs of those mitigation measures. Mitigation measures can include changes to hardware or to procedures to reduce the likelihood of the event, as well as changes to structure or equipment to reduce the consequences of the event. Having determined costs and possible mitigation measures, the costs shall be compared against the benefit in risk reduction to determine if the RRP process has been satisfied.
- Task 4: Where necessary, mitigation measures shall be undertaken and the risk assessment repeated.

7.10.2.2 Likelihood of Failure and Consequence of Failure due to Accidental Events

The likelihood of failure due to a fire, explosion, impact loading, or flooding event is associated with its origin, point of ignition (fires and explosions), source of impact (other accidental events), location of flooding, and escalation potential. The type and presence of a hydrocarbon source can also be a factor in event initiation or event escalation. The significant events requiring consideration and the associated likelihood of failure levels are normally defined from hazard analysis.

Factors affecting the likelihood of failure and consequence of failure due to an accidental event include the following:

- a) Product type: e.g. gas, condensate, light or heavy crude, should be considered in evaluating the likelihood of failure.
- b) Operation type: The types of operations being conducted on the platform shall be addressed when evaluating the likelihood of failure. Operations to be considered shall include drilling, production, supply boat operations and personnel transfer. Production operations are defined as those activities that take place after the successful completion of the wells; they include separation, treatment, measurement, transportation to shore, operational monitoring, modification of facilities, and maintenance. Simultaneous operations include two or more activities.
- c) Decks, ceiling, and boundary walls: The potential of a platform deck, ceiling, wall, or other physical barrier to confine a vapor cloud is important. Whether a platform configuration is open or closed should be considered when evaluating the probability of an event occurring. Most platforms in mild environments, such as the US Gulf of Mexico, are open allowing natural ventilation. Platform decks in more severe climates (e.g. Alaska or

the North Sea) are frequently enclosed, resulting in increased probability of containing and confining explosive vapors and higher explosion overpressures if ignited.

- d) Equipment type: The complexity, amount, and type of equipment are important. Separation and measurement equipment, pump and compression equipment, heating equipment, generator equipment, safety equipment, and their piping and valves should be considered when evaluating the likelihood of failure due to an accidental event.
- e) Equipment congestion: Turbulence generated by equipment, structure, piping and cable trays, and so forth, can cause high overpressures in the event of an explosion with or without the presence of confining boundaries.
- f) Platform location: The proximity of the platform to shipping lanes can increase the potential for collision with passing vessels.
- g) Compartmentation: For floating structures, the increase in draft and the degree of listing following the accidental flooding of one or more watertight compartments can be influenced by the size of the compartments and any common-mode failures in the pipework or controls to the compartments.
- h) Other factors, such as the frequency of supply boat operations, the type and frequency of personnel training, and so forth, shall be addressed, as necessary.

7.10.2.3 Risk Assessment

7.10.2.3.1 General

Accidental events of fire and explosion are assigned overall risk levels for a particular platform using Table 4. The risk levels are based on probabilities of accidental events and the likely consequences of those events.

Accidental events for platforms with low- and medium-risk levels shall be evaluated as to whether to include them as load cases for structural design.

7.10.2.3.2 Risk Matrix

The risk level matrix in Table 4 provides a means of determining the acceptability of the risks of particular accidental events and is primarily a means of screening low-risk events that do not need further investigation from those that require more detailed investigation and possibly mitigation measures. Documentation of the screening and detailed assessment processes shall be required, particularly with regard to the conservatism of the data used and the sensitivity of the results to changes in assumptions.

Table 4—Indication of Risk Level for Accidental Events

High	Medium risk	High risk	High risk
Medium	Low risk	Medium risk	High risk
Low	Low risk	Low risk	Medium risk
Likelihood of failure Consequence of occurrence	Low	Medium	High

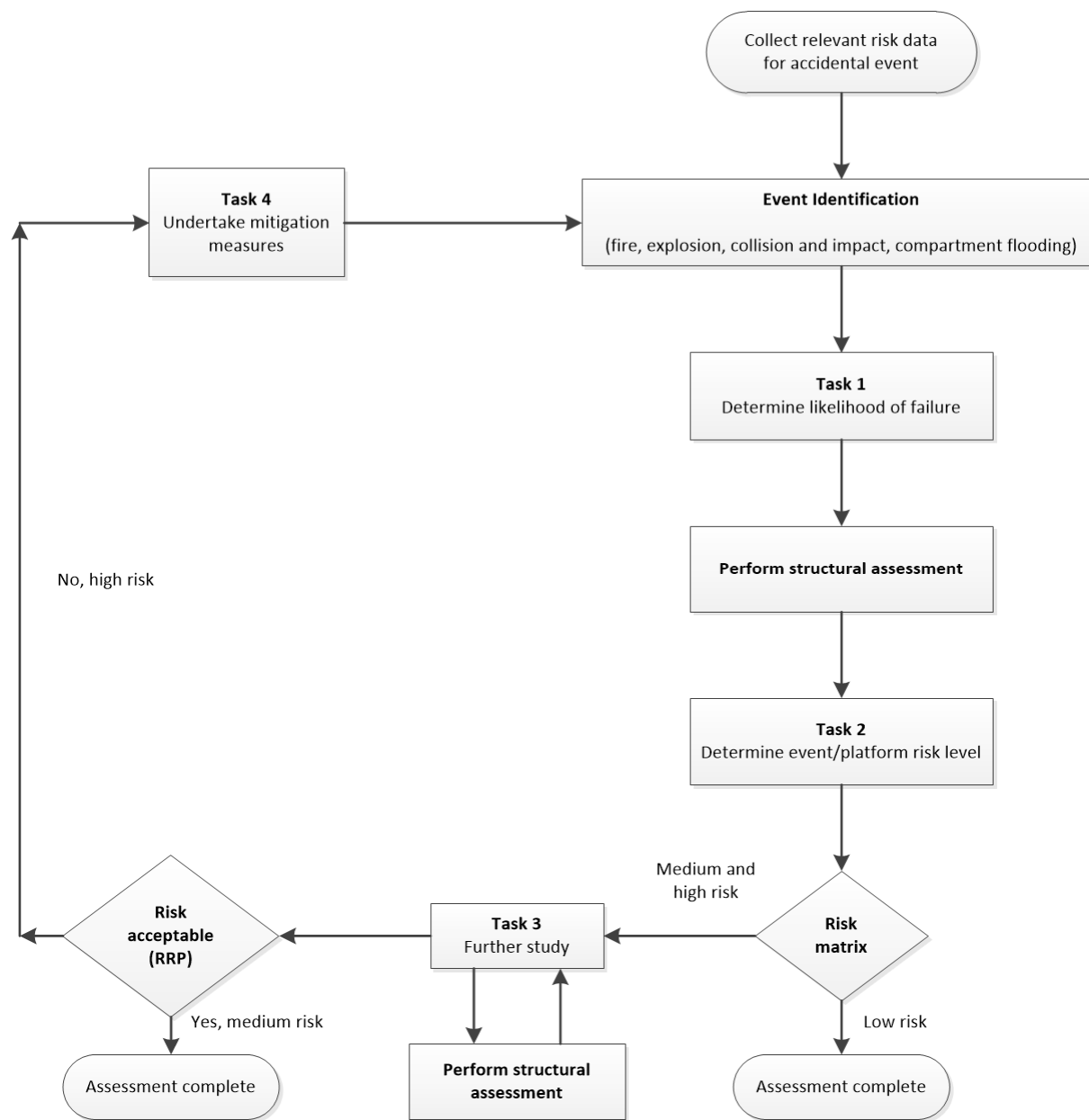
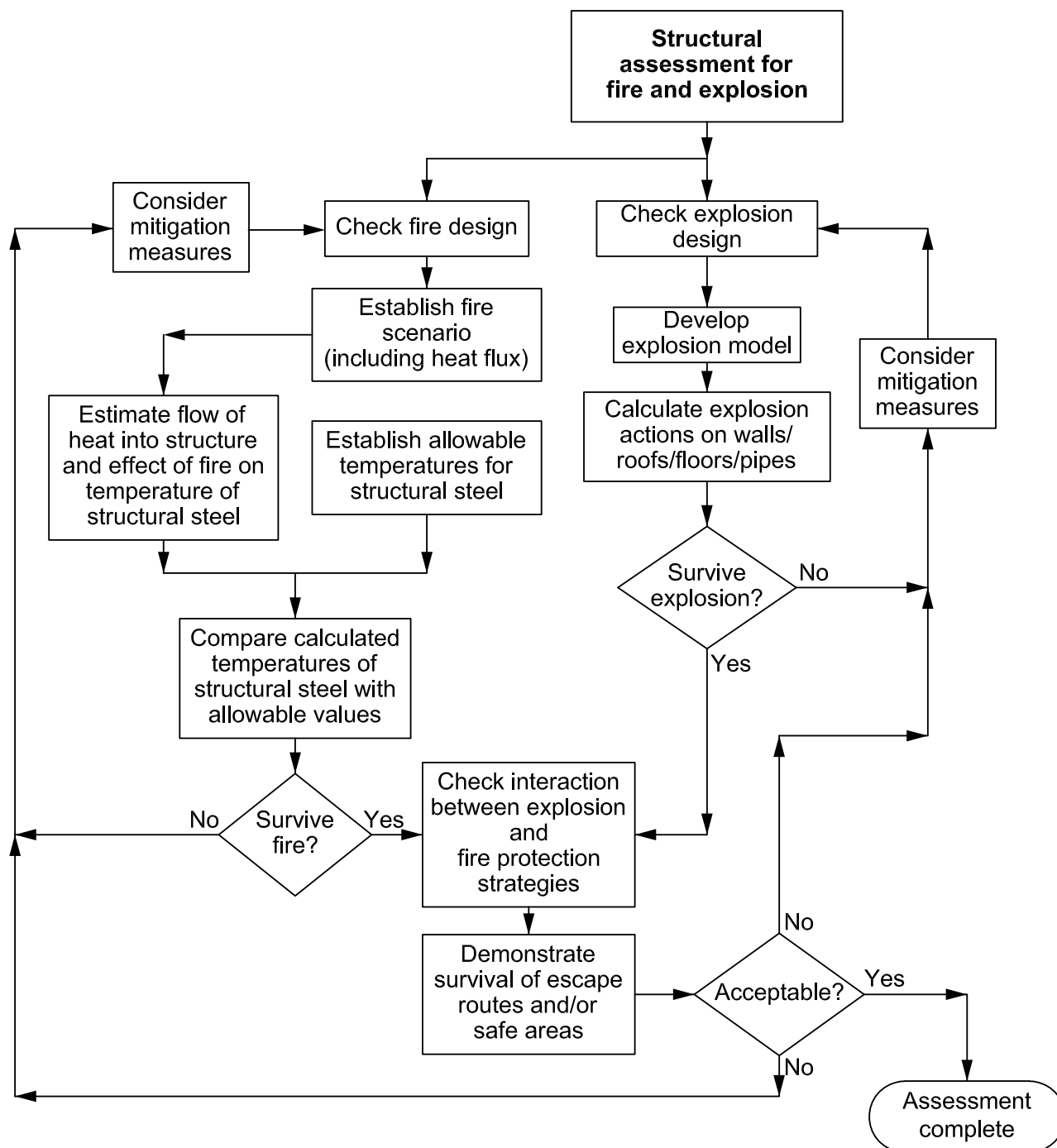
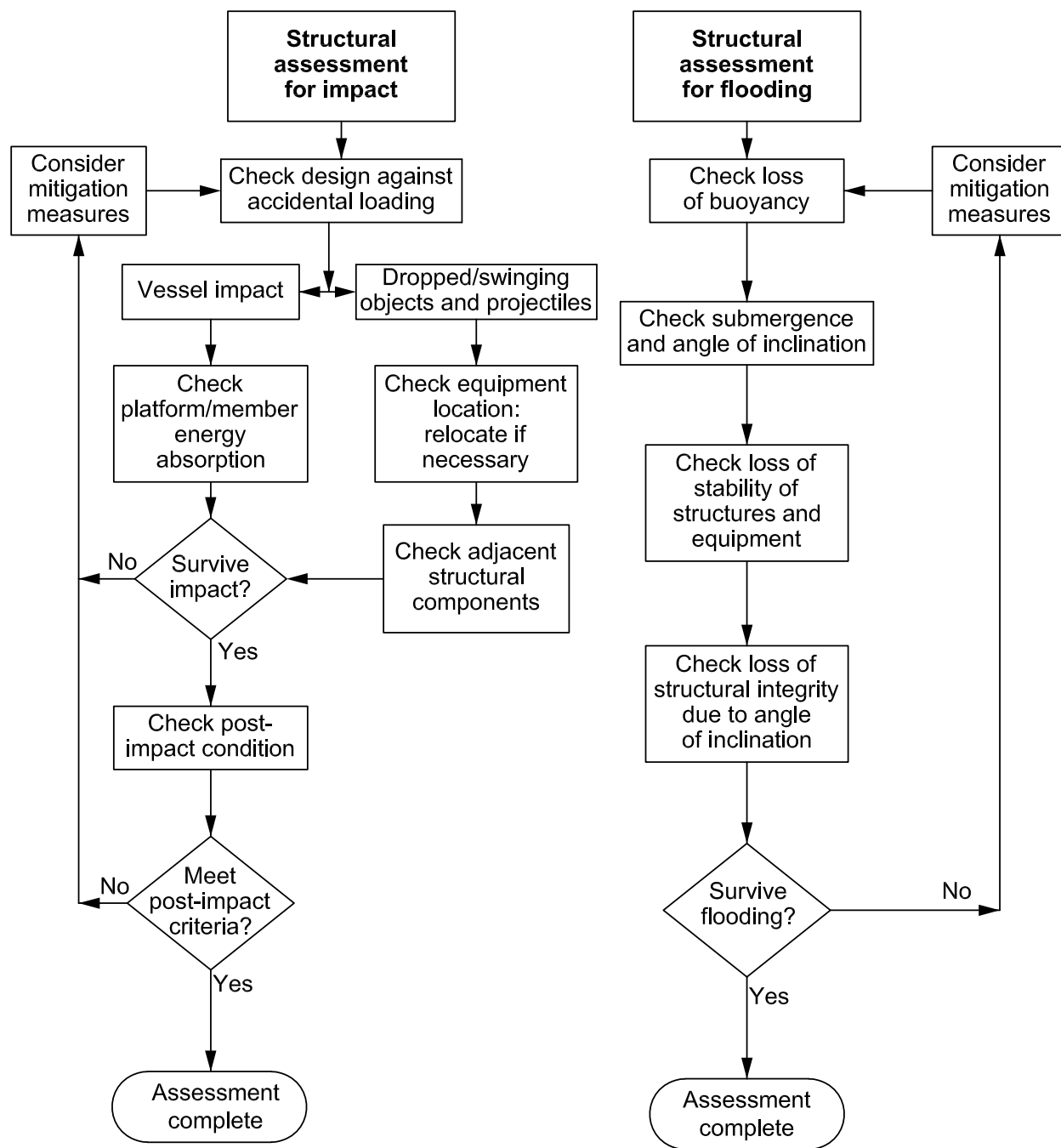


Figure 1—Assessment of Accidental Events



NOTE Survival indicates no loss in serviceability of SCE.

Figure 2—Detailed Structural Assessment for Fires and Explosions



NOTE Survival indicates no loss in serviceability of SCE.

Figure 3—Detailed Structural Assessment for Impact and Accidental Flooding Events

7.10.3 Hydrocarbon Incidents

Explosion and fire events can lead to equipment damage, or to partial or total collapse of topsides and other structures, or to both damage and collapse, resulting in loss of life, or in environmental pollution, or in both loss of life and environmental pollution.