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Petroleum and natural gas industries — Specific requirements for offshore structures —

Part 9:
Structural integrity management

Industries du pétrole et du gaz naturel — Exigences spécifiques relatives aux structures en mer —

Partie 9: Gestion de l'intégrité structurelle

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Contents

Page

Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*, Subcommittee SC 7, *Offshore structures*.

A list of all parts in the ISO 19901 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Structural integrity management (SIM) is the implementation of engineering, inspection, maintenance, monitoring and remediation activities required to demonstrate the fitness-for-service of a structure for its intended application throughout its total service life and prevent/mitigate severe or catastrophic health, safety, environmental, or structural events. The SIM process provides a proactive approach to monitor, evaluate and assess structural condition and establish a procedure to validate the fitness-for-service of an offshore structure.

The purpose of SIM is to provide a process for demonstrating the integrity of the structure throughout its intended total service life. Approaches to dealing with SIM vary depending upon field life, the type of structure and the sophistication of regional infrastructure where the structure is located. In turn, these factors can influence the philosophical approach to the specification of SIM which can vary from one involving emphasis on the use of monitoring equipment to one with a preference for the extensive use of inspections. Additionally, design decisions on safety factors, design margins, corrosion protection, component redundancy and system reliabilities will influence the SIM strategy and program.

SIM process choices are made in the design (e.g. selection of materials, condition monitoring systems, new or proven technology, robustness of design, redundancy, and fabrication/installation methods) that will influence SIM activities during the operations phase. Implementation of a SIM process can benefit significantly from design decisions, such as providing access for inspection and maintenance.

A SIM process is used to develop an inspection scope, program and frequency that, when executed, provides information on the condition of the structure, which can be used to understand present and emerging risk from operating the topsides, and provide information for determining the ongoing strategy for mitigating that risk. A well-implemented SIM process will maintain the structure's fitness-for-service for the operational life of the platform and through the decommissioning process.

Initial SIM development begins early as part of the structure's new design or reuse, ideally during the structure's concept and select stages. Most of the initial SIM data, strategies and program philosophies will be generated during the design by the project team and ultimately handed over to the structure's operating team. Once commissioned, the effective operation of the structure is contingent on the provided SIM philosophy and design documentation from the project team. These deliverables (e.g. design documents, drawings, computer models) are most useful to the operating team when they are complete, up-to-date (i.e. reflect as commissioned installation), organized, in a usable format and readily accessible. To provide sustainable SIM, the project team and operating team work collaboratively during the project in defining the necessary SIM deliverables.

The platform operating team is responsible for validating that the design data are comprehensive and complete. In addition, the operating team is responsible for demonstrating that the SIM strategies conform to the operator's risk criteria, regional regulations and that the SIM strategies are workable based on location infrastructure and capabilities. National and regional regulations can require SIM documentation in a form suitable for verification or for review by a regulator.

ISO 19904-1[5] is applicable to the integrity management (IM) of hull, moorings and marine systems of existing floating offshore structures. However, this document is applicable to the structural integrity management of the topsides structural components of floating facilities.

ISO 19905-1[6] is applicable to the IM of the legs, primary hull structure, spudcans, jacking-systems and marine systems of existing mobile jack-up offshore structures and for setting the limit states. However, this document is applicable to the structural integrity management of permanently located jack-ups.

Petroleum and natural gas industries — Specific requirements for offshore structures —

Part 9: Structural integrity management

1 Scope

This document specifies principles for the structural integrity management (SIM) of offshore structures subjected to known or foreseeable types of actions.

This document specifies requirements and provides recommendations applicable to the following types of fixed steel offshore structures for the petroleum and natural gas industries:

— caissons, free-standing and braced;

— jackets;

— monotowers;

— towers.

This document is applicable to topsides, including but not limited to the main decks, deck legs, topsides modules, crane pedestals, helideck, drilling derrick, skid beams, flare booms, exhaust towers, radio tower, conductor support frames, and lifeboat davits. In addition, it is applicable to compliant bottom founded structures, steel gravity structures, jack-ups, other bottom founded structures and other structures related to offshore structures (e.g. underwater oil storage tanks, bridges and connecting structures), to the extent to which its requirements are relevant.

This document contains requirements for planning and engineering of the following tasks:

a) integrity management data requirements;

b) in-service inspection and integrity management of both new and existing structures;

c) assessment of existing structures;

d) evaluation of structures for reuse at different locations;

e) evaluation of structures for their future removal.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 19900, *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 19901-2, *Petroleum and natural gas industries — Specific requirements for offshore structures — Part 2: Seismic design procedures and criteria*

ISO 19901-4, *Petroleum and natural gas industries — Specific requirements for offshore structures — Part 4: Geotechnical and foundation design considerations*

ISO 19901-5, *Petroleum and natural gas industries — Specific requirements for offshore structures — Part 5: Weight control during engineering and construction*

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

ISO 19906, *Petroleum and natural gas industries — Arctic offshore structures*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 19900, ISO 19901-1, ISO 19901-2, ISO 19901-4, ISO 19901-5, ISO 19902 and ISO 19906 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
anomaly
in-service survey measurement, which is outside the threshold acceptable from the design or most recent fitness-for-service assessment

3.2
assessment
detailed qualitative or quantitative determination of the structural component or system strength

3.3
assurance
process to confirm that *SIM* (3.21) is performed in conformity with the procedures set out in the SIM policy and written description

3.4
collapse
loss of the load-bearing capacity of the platform through failure of one or more structural components

3.5
continual improvement
ongoing implementation of findings of reviews to improve the SIM process

3.6
defect
imperfection, fault, or flaw in a structural component

3.7
emergency response plan
written document associated with an asset, which defines the actions intended to protect people, the environment, and property from adverse consequences associated with emergency situations

3.8
inspection program
scope of work for the offshore execution of the inspection activities to determine the condition of the structure

3.9
inspection strategy
systematic approach to the development of a plan for the in-service inspection of a structure

3.10
mitigation
limitation of negative consequence or reduction in likelihood of a hazardous event or condition

3.11
non-conformance
insufficient strength or inadequate performance of a structure or structural component relative to a limit state or *performance level* (3.13)

3.12
non-redundant
platform for which its global capacity is reached when one of its primary structural elements reaches its maximum capacity

3.13
performance level
required functionality of the structure during and after a hazardous event

3.14
performance standard
statement of the performance required of a system, item of equipment, person or procedure, which is used as the basis for managing the hazard through the lifecycle of the platform

3.15
prior exposure
historical exposure of a structure to significant metocean, seismic or ice events

3.16
redundancy
availability of alternate load paths in a structure following the loss of connection of one or more structural components

3.17
residual strength
maximum strength of a structure in a damaged condition

3.18
risk-based inspection
RBI
inspection strategies developed from an evaluation of the risk associated with a structure with the intention of tailoring inspection scope and frequency to risk magnitude and location

3.19
structural analysis
determination of the effects of actions on structures and their components

3.20
structural assessment
interpretation of available information including available analysis results used to confirm or otherwise the integrity of the structure

3.21
structural integrity management
SIM
systematic multi-step cyclic process intended to assure structural integrity and functionality of a structure throughout its total service life

[SOURCE: ISO 19900:2019, 3.51]

3.22
tolerable risk
level of risk deemed acceptable by society in order that some benefit or functionality can be obtained, but in the knowledge that the risk has been evaluated and is being managed

3.23
weight database
live document containing the present base and factored, dry and operating weight and CoG data for an installation's substructure and topside, broken down by module and by engineering discipline

4 Symbols

The following is a summary of the main symbols that are used throughout this document. Many other symbols are locally defined where they are used. Local use includes main symbols with one or more subscripts when a more specific use and associated definition of the symbol is intended.

A deck area

C_C metocean or seismic hazard curve correction factor

C_d drag coefficient

C_m moment reduction factor

C_r seismic reserve capacity factor

CoV_R resistance coefficient of variance

D diameter

$D1$ existing fatigue damage

$D2$ future fatigue damage

E environmental action

E_{RP} metocean action with return period of RP

E_{100} metocean 100-yr action

F cumulative probability of fatalities

F_int intolerable number of fatalities

F-N frequency-number

G permanent action

Hs significant wave height

L span or length

N number of fatalities

P_f probability of failure

p-y lateral soil resistance versus local pile displacement

Q variable action

Q-z pile end bearing resistance versus pile tip displacement

r resolving vector

RP return period

S internal force

t-z axial soil-pile shear transfer versus local axial pile displacement”

T thickness of a structural element or plate

T_{dom} dominant natural period

U current speed

WiDA wave-in-deck action

WiJA wave-in-jacket action

Γ participation factor

Φ modal displacement

γ partial safety factor

Δ deflection with subscripts for various component effects

φ dynamic coefficient

5 Abbreviated terms

ACFM alternating current field measurement

ADS atmospheric diving suit

ALE abnormal level earthquake

ALS accidental or abnormal limit state

CoG centre of gravity

CoV coefficient of variance

CP cathodic protection

CPT cone penetration test

CS critical structure

CVI close visual inspection

DLM design level method

ELE extreme level earthquake

FMD flooded member detection

GVI general visual inspection

HSE	health, safety and environmental
LQ	living quarters
MOC	management of change
MPI	magnetic particle inspection
NDE	non-destructive examination
ROV	remotely operated vehicle
SMR	strengthening, modification and/or repair
SRA	structural reliability analysis
TR	temporary refuge
ULS	ultimate limit state
UR	utilization ratio
USM	ultimate strength method
WiD	wave in deck

6 SIM fundamentals

6.1 General

SIM is used to manage the effects of deterioration, damage, changes in actions and accidental overloading. In addition, SIM is used to establish the framework for inspection planning, maintenance, and repair of a structure or group of structures.

6.2 Limit states and performance levels

In the design phase, exposure levels and limit states are specified for the structure and/or structural components.

The most severe consequences are categorized through defining exposure levels appropriate for the structure (ISO 19900). ISO 19900 further details the process for specifying appropriate limit states and for verifying that such limits are not exceeded. For fixed steel structures, ISO 19902 details the design/assessment criteria for the highest exposure level, L1, which covers manned and high environmental pollution exposed structures. These criteria are supplemented in ISO 19901-3[2] for topsides and 19906 for structures in arctic and cold climate regions.

Other limit states can be specified by stakeholders, such as those on L1 and L2 structures that cover potential financial and reputational events.

Where several limit states are associated with the same hazardous event, these can be termed performance levels.

6.3 Fitness-for-service assessment

Fitness-for-service assessment leads to an approximate likelihood of exceeding the limit state for a given hazardous event, which combined with a consequence model gives an estimate of risk. This allows the operator to specify risk-based inspection plans.

Motives for performing fitness-for-service assessments should be established prior to selecting the assessment method. Motives can be driven by desire to optimize an inspection program and/or the desire to understand the cost-benefit in determining the effectiveness of a mitigation strategy.

Fitness-for-service evaluation is detailed in Clause 9 while the assessment procedure is detailed in Clause 12.

6.4 Management framework

The operator shall establish and maintain a management framework that provides evidence to the corporate and regulatory stakeholders that the operator has a commitment to a sustainable lifecycle approach to demonstrate the structure is fit-for-service.

The management framework refers to the integrated systems, work processes and documentation, which are used together with the SIM process to deliver structural integrity.

The SIM framework should align with the HSE and business objectives and should have the following interrelated elements:

— policy, which sets out the intention and direction of the operator with respect to SIM;

— written description, which documents the processes and procedures adopted by the operator for the management of the structural integrity;

— organization and personnel, which provides the reporting lines, accountabilities, roles and responsibilities, and competencies required for the personnel;

— SIM process, which is used for demonstrating fit-for-service assets based on asset information/data asset from inception to decommissioning;

— procedures, which are followed for the implementation of the required activities;

— MOC, which is used to identify and monitor changes;

— validation, which is used to measure and verify the implementation against a set of defined metrics;

— continual improvement, which reviews the process periodically and implements required changes.

Core of the management framework is the SIM process (see Clause 7) as illustrated in Figure 1. The other elements mainly support this core process.

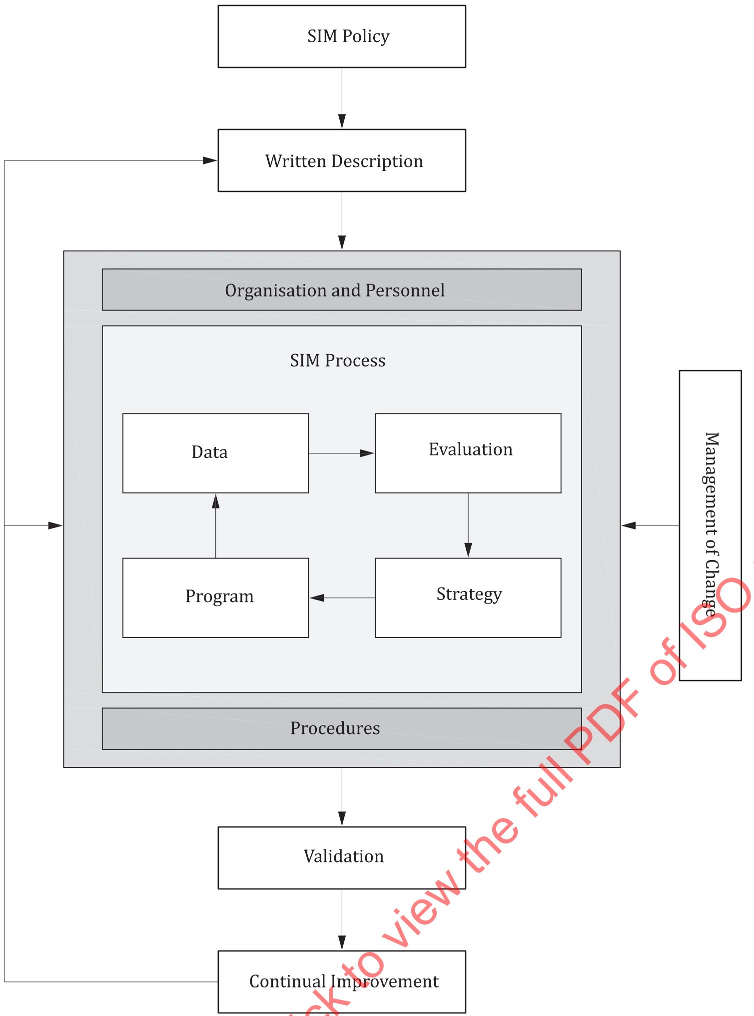


Figure 1 — Management framework

6.5 Design

SIM should be established during the project phase, and should include a systematic and iterative review of risks. Links between design, operations, inspection and maintenance should be addressed during design.

The operator should identify the hazardous events to the structure and structural components and their associated risks, and subsequently develop strategies to manage these risks. This should include identifying the inspection, maintenance and monitoring requirements and possibly adjusting the structural design to accommodate the SIM requirements (see Clause 10).

Before the start of operations of a new or newly acquired facility, the SIM data generated during the project or available from the previous operator should be made available to the operations team responsible for structural integrity. Handover to operations should include:

— transfer of design, fabrication and installation data;

— identification of critical structure for the substructure and topsides;

— initial risk assessment;

— initial long-term plans for inspection, maintenance and monitoring.

Design should incorporate SIM operational learnings and experience into new designs or brownfield modifications, including:

— site-specific criteria;

— damage to existing structures and the causes;

— vessel activity in the region;

— local regulatory requirements;

— decommissioning requirements and regulations;

— general operational experience relating to structural integrity, including appurtenances.

6.6 Topsides

SIM shall include topsides structures with focus on structural components that provide safety to personnel in the event of an incident or accident.

Topsides SIM shall address the interfaces with other discipline-specific integrity programs and the SIM of third-party packages included on the topsides.

SIM of a topsides structure shall be consistent with the SIM process principles used for the supporting structure.

6.7 Continued service

As the structural components age and the structure approaches the end of its service life, the operator shall demonstrate that the structure is fit-for-service during the extended service life.

The operator shall demonstrate that risks are at tolerable levels and the structure can be maintained in a fit-for-service condition through the planned extended total service life.

NOTE To extend the design service life, the assessment initiator occurs at the time the operator proposes to extend the operational service beyond the presently approved design service life. The initiator is not triggered by the age of the structure, but rather when the decision is made to extend the operational service life. This can occur at any time during the structure's service life.

6.8 Structural integrity interfaces

Offshore structures have inspection interfaces, which should be understood and managed within the SIM process. Structural integrity interfaces include:

— topsides / support structure connection;

— boundary between above and below water inspection;

— activities performed by other disciplines (e.g. caisson internal inspection) or equipment vendors.

Inspection interfaces between topsides and support structures for SIM can vary by platform type.

7 SIM process

The SIM process involves the periodic evaluation of data to define mitigation strategies and programs.

The SIM process shall consist of four primary elements, as illustrated in Figure 2:

a) data;

b) evaluation;

c) strategy;

d) program.

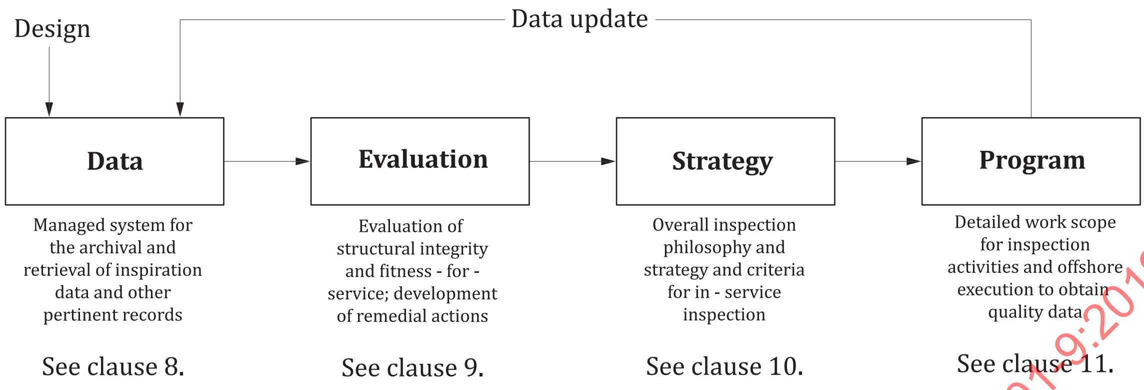


Figure 2 — SIM process

8 SIM data

8.1 General

An in-service data management system containing SIM data shall be established and maintained for the total service life of the structure.

Data shall include information from the original design of the structure, fabrication and installation data, inspection findings, effects of damage and deterioration, structural analyses, overloading, and changes in loading and/or use.

Data should be collated into a data management system at the completion of the design, fabrication and installation phases of a project.

Data for SIM system should include:

a) original design criteria;

b) configuration data (e.g. framing, number of legs, deck elevation);

c) design data (e.g. reserve strength and residual strength);

d) condition data reported from in-service inspection findings (e.g. performance of corrosion protection system, component degradation and/or deterioration);

e) condition data reported from on-line monitoring;

f) operational data (e.g. platform age, weight control data);

g) fabrication data (e.g. fabrication welding quality and occurrence of rework);

h) transportation/installation data (e.g. pile driving records, reported damage);

i) SMR data (e.g. structural modifications and/or structural repairs/strengthening);

j) analytical data (e.g. analysis results and assumptions on condition and criteria used in the original design or previous assessments);

k) structural component capacity data (e.g. published capacity of tubular members or joints from laboratory tests);

l) updated knowledge on geotechnical methods for determining soil capacity;

m) criteria data (e.g. updated knowledge for metocean, seismic, ice and/or collision assessment actions);

n) incident/accident data (e.g. fire, blast, collision, dropped object event or metocean, seismic, ice extreme or abnormal event);

o) learning from similar platforms.

8.2 Missing data

If data is missing, this can force using conservative assumptions during inspection planning or an engineering assessment. This can lead to unnecessary inspections being performed or prevent upgrades being made and hence unjustly prevent potential development.

If the original design data or as-built drawings are not available, assessment data may be obtained by field measurements of dimensions and sizes of structural members and appurtenances.

Weight audits should be performed to monitor and validate the dry and operating loads, equipment layouts, laydown areas and other structures, where there is little or no ongoing weight monitoring and control.

8.3 Data management

The topside weight database should be maintained and kept up-to-date with weight, CoG changes and modifications (i.e. additions, relocations and removals). Proposed weight and CoG changes should be captured and communicated to the structural integrity engineer. Structural models and topside weight database should be kept synchronized.

Data management should be integrated across the stakeholders with differing overlapping structural integrity objectives, including:

— field concept development;

— front end engineering design;

— detail engineering design;

— fabrication;

— installation and hook-up;

— verification/classification;

— periodic inspection and monitoring;

— interventions to mitigate inspection findings that could compromise the structural integrity;

— periodic review of SIM – identifying trends and updating the inspection strategy;

— brownfield development from concept through to commissioning;

— decommissioning.

Data management should be integrated across disciplines, including:

— process equipment, tiebacks – weight control;

— pipeline/riser integrity – structural integrity of appurtenance supports and global loading;

— drilling and work-over campaigns.

9 SIM evaluation

9.1 General

Evaluation shall be performed throughout the total service life of the structure.

Evaluation of the structural integrity data shall be performed as new information/data is collected.

Evaluation shall be used as a basis for establishing or adjusting the inspection, maintenance and monitoring strategies (see Clause 10). The evaluation may address the overall structure or structural components where damage or adverse conditions have arisen or occurred.

Findings from the evaluation shall conclude either:

— that the structure, or critical structural components, is fit-for-service between inspections and requires on-going scheduled maintenance/monitoring/inspection (with a specified scope), or

— that remedial measures (immediate or longer term) are required.

9.2 Data evaluation

Evaluation should account for the SIM data collected in the manner recommended in Clause 8.

In instances where the information/data recommended for inclusion as part of the evaluation is not available, an evaluation may be performed recognizing the inherent uncertainties and assumptions from the missing information. However, missing information/data can affect the evaluation and SIM strategy/program for the structure. Where structural data is not available, or the condition information/data is out-of-date, evaluation can provide a recommendation to survey the structure and facilities to collect the required information.

9.3 Hazards, hazardous events and degradation mechanisms

Evaluation shall include review of hazards, hazardous events and degradation mechanisms in accordance with ISO 19900.

NOTE Corrosion, fatigue, seabed scour and liquefaction are degradation mechanisms rather than hazardous events, and as such can reduce structural resistance.

9.4 Critical structure (CS)

CS is a part of the structure or structural components, loss of which will cause specific life-safety, environmental pollution or financial consequences. CS is typically a structural barrier that has been considered in terms of robustness to prevent an event from causing a major incident or is a structural barrier used to provide mitigation and de-escalation in the event of an incident.

CS identification and categorization should be used by the operator to understand the consequences of CS loss and should form the basis for risk-based SIM strategies recommended in this document.

9.5 Risk

9.5.1 General

The operator should adopt risk-based approaches to manage structural integrity. The structure or structural component risk should be established and used to optimize the inspection, monitoring or maintenance activities required to confirm fitness-for-service.

Risks are evaluated based on the product of the potential consequence (see 9.5.2) and the estimated likelihood (see 9.5.3).

Risks should account for the actions from hazardous events and degradation mechanisms causing reduction in capacity to resist the actions.

Risks evaluated as outside of the tolerable risk limit shall be managed through operational mitigations in conjunction with the inspection, monitoring and maintenance activities.

9.5.2 Consequence

Structure exposure level and limit states shall be reviewed during evaluation and amended to reflect any changes in data, such as change is use (e.g. conversion from manned to normally unmanned platform) or change in perceived risk (e.g. solitons or infragravity waves not considered significant at design phase considered significant in the operational phase following collection and assessment of additional data).

Additional limit states may be specified by the operator, including limit states (performance levels) that cover potential financial and reputational events.

9.5.3 Likelihood

SIM data should be evaluated to determine the likelihood of exceeding a limit state.

The likelihood that a structure will exceed an ALS hazardous event (metocean, ice, seismic, collision or some other foreseeable hazard) may be determined from an assessment of the structure against a range of return period abnormal/accidental actions or action combinations.

Likelihood of exceeding a limit state should be determined by quantitative methods, although qualitative or semi-quantitative methods may be used, see 12.3.

9.5.4 Risk presentation

Risk may be presented in a variety of ways to communicate the results of the analysis to decision-makers and inspection planners.

One goal of the risk determination is to communicate the results in a common format that each stakeholder can understand. This can be achieved by presenting the risk in the form of a matrix. The risk presentation should differentiate between the type of hazardous event and the consequence of exceeding the limit state.

9.6 Demonstrating fitness-for-service

The expectation is that the all criteria applicable in design (e.g. ISO 19902) should also be verified in assessment.

Assessment shall be documented with specific emphasis on assumptions made and calculations performed where the verification process differs from those specified in ISO 19900 and ISO 19902 (or ISO 19901-3[2] or ISO 19906, as relevant), in the manner permitted below.

If one or more assessment criteria cannot be verified as acceptable (i.e. UR >1,0), then site-specific data may be used in assessment verification, e.g. use of measured steel material properties rather than SMYS values, pile driving records from the installation phase, etc.). Linear-elastic and non-linear analysis methods may also be used to verify that the factored resistance exceeds the effects of factored actions or action combinations (as per ISO 19900).

The findings of the structural reliability analyses performed during the calibration of ISO partial safety factors may be used to justify modest reductions in the quoted safety factors for the site-specific design/assessment situation, e.g. the environmental action factor for an L1 exposure level structure specified in ISO 19902:2007, Annex H is a rounded up from the value calibrated and recommended.

Where site-specific data cannot confirm that all assessment criteria are verified, risk assessment may be performed in accordance with the operator's policies and procedures, or as agreed with the regulator, as relevant. In this instance, risk assessment shall include quantative calculation or qualitative estimation of the likelihood and consequence of exceeding the limit state concerned, and the risk mitigation measures to be performed.

Risk mitigation measures can include increased frequency and/or volume, monitoring, strengthening, installation of new safety barriers, unmanning, shut down of hydrocarbon flow and reduction of hydrocarbon inventory, etc. Physical risk mitigation measures should be favoured over analysis-based and procedural measures.

Approval of risk assessment and associated risk mitigation measures can involve disciplines beyond structural engineering and can also involve external organisations such partners and regulators. Consequently, any such requirements are beyond the scope of this document.

Several assessment methods are available for demonstrating that a structure or structural component is fit-for-service. These assessment methods include linear elastic analysis and nonlinear analysis approaches, see A.9.6.

9.7 Assessment

9.7.1 General

The assessment is part of evaluation is illustrated in Figure 3. Recommended methods of fitness-for-service assessment are provided in Clause 12.

If the evaluation determines that the operational risk has become more onerous, some level of engineering assessment analyses shall be performed to determine whether the risks are tolerable or mitigation measures are required.

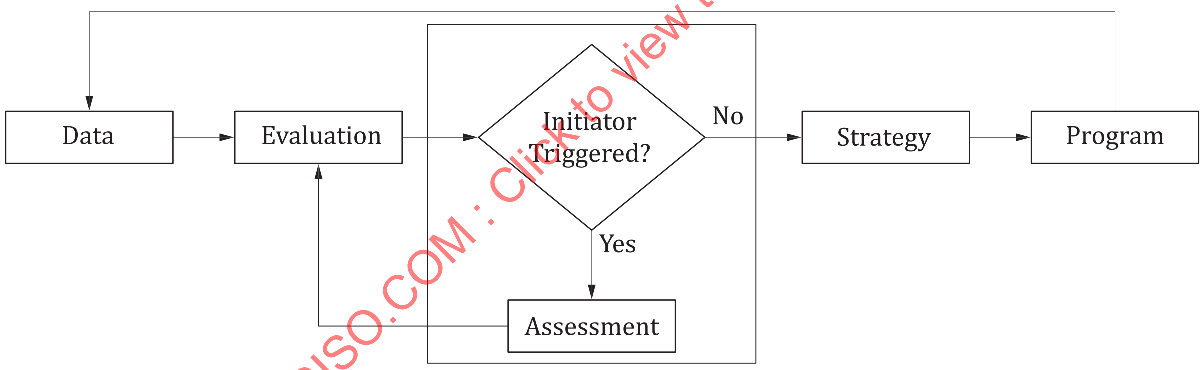


Figure 3 — Assessment within the SIM process

Assessment should use quantitative techniques to demonstrate that, for every hazardous event, the risks are tolerable. Assessment is typically step-wise with increasing complexity and is typically accomplished by performing a structural analysis of the structure or structural component.

If the evaluation indicates that the operational risk has increased, an assessment should be performed to determine whether the risks are tolerable or whether risk reduction or mitigation measures are required.

9.7.2 Assessment motive

Motives for performing a structural assessment vary and should be established prior to performing the assessment. The selection of the assessment method is influenced by the assessment motive, which can include:

a) Supporting an evaluation - for structures where the evaluation has determined that an assessment of the structural strength is required, an assessment should be performed to demonstrate that the structure is fit-for-service.

b) Categorizing the structural likelihood of exceeding the limit state; for risk-based SIM strategies an assessment should be performed to determine likelihood and provide input into categorizing the structural risk.

c) Supporting an inspection program - an assessment should be performed to determine the structural locations required for inspection and for setting inspection anomaly threshold reporting requirements.

d) Supporting a monitoring program - structures that have monitoring as part of their SIM strategies should be assessed to provide information on the threshold that would indicate a change in the structural condition. In situations where monitoring provides a life-safety mitigation measure the actions and triggering thresholds should be determined such that life-safety risk is maintained below the specified limit state.

e) Supporting a mitigation strategy - structures that have included planned mitigation as part of their SIM strategies an assessment should be performed to provide information on the operating limits, which can include:

   — evacuation ahead of predictable events;

   — re-manning after an event;

   — hurricane preparedness;

   — triggering of monitoring action thresholds.

f) Determining the probability of exceeding a limit state.

9.7.3 Assessment initiators

During evaluation, operator shall provide recommendations for changes that can increase the platform operational risk, including:

— changes in condition;

— changes in action;

— changes in criteria;

— changes in consequence;

— changes in use.

9.8 Mitigation measures

9.8.1 General

If it cannot be demonstrated that the risks are tolerable, risk reduction measures shall be implemented.

Procedures and plans shall be established in case of mitigation measures.

Risk reduction should be addressed at each stage of an assessment and may be used in lieu of a more complex assessment.

Mitigation of structural risk should be evaluated even if the life-safety, environmental pollution and financial risks are tolerable. If the risk reduction benefit exceeds the cost of implementing the mitigation the operator should perform the mitigation.

Mitigation measures may include structural modifications or changes in operational procedures that reduce loads, increase capacities or reduce the consequence of failure. Modifications to inspection and monitoring programs may be implemented to identify further deterioration.

Mitigation measures may be implemented in isolation or in conjunction with each other. The choice of measures and their extent depends on the source of risks to structural integrity and their magnitude.

9.8.2 Consequence reduction

9.8.2.1 Life-safety

Life-safety mitigation measures should involve permanently demanning the platform, or temporarily un-manning the platform during a forecasted extreme event.

9.8.2.2 Environmental

Consequence of failure mitigation measures should include one or more of the following:

— installation of subsea safety valves;

— removal or reduction of hydrocarbon storage or inventory volume;

— removal or re-routing of major oil lines;

— removal or re-routing large volume gas flow lines;

— permanently or temporarily abandon non-producing wells;

— isolation of the pipeline to reduce the potential volume of hydrocarbon release.

9.8.2.3 Abnormal storm preparedness

Advanced planning should be used to reduce abnormal storm risks as well as improve post storm response.

Abnormal storm preparedness plans should be developed covering general storm preparedness activities and structure-specific response activities.

Checklists and platform-specific guides can assist during the evacuation process.

9.8.3 Likelihood reduction

Likelihood reduction methods can include:

— increased inspection and/or monitoring;

— removal of a known damaged component;

— load reduction;

— localized strengthening and/or repair;

— global strengthening and/or repair.

10 SIM strategy

10.1 General

The operator shall develop a SIM strategy, which sets out the process for delivering the integrity management of its assets in line with the SIM policy and tolerable risks.

The SIM strategy shall identify the mitigation, monitoring and inspections to be included in the continuous risk reduction requirements for the structure and SC components.

The SIM strategy should be compiled into a document that is periodically reviewed and updated, including the evolving risks in the operation. The strategy should detail the program objectives and the targets that should be met to demonstrate fitness-for-service and continuous risk reduction. The strategy should identify the single points of accountability and responsibility for delivering the steps in the program.

Plans should reflect the overall SIM philosophy, which varies depending upon the design margins, field life, type of structure and sophistication of local infrastructure. These factors can influence the philosophical approach, affecting the extent of future maintenance activities as well as varying the degree of reliance between inspections and monitoring activities to demonstrate fitness-for-service.

For a new platform or platform reuse the overall SIM strategies should be developed during the early concept selection and front-end engineering stages of the design. Inspection, monitoring and maintenance plans should be developed during the later detailed design stages of a platform reuse, ideally performed early enough that potential plan implementation and execution issues can be addressed within the design. Additionally, development of the plans should include full participation of the operating team to confirm that the design, SIM strategy and SIM program are aligned.

SIM strategy should identify the frequency and type of activities required for the structural components. These activities should be based on maintaining the structural integrity of the SC components identified during the data evaluation.

10.2 Inspection strategy

10.2.1 General

An inspection strategy shall cover the total service life of the structure and structural components.

The inspection strategy shall provide the framework for the surveys.

The inspection strategy should account for the interdependence between the SIM process phases (see Figure 2).

The inspection strategy shall be a dynamic or a “living” document, meaning that inspection requirements can change due to inspection results or changes to the structure (e.g. changes in topsides dry and operating weight or CoG, discovery of damage and/or addition of new risers).

The inspection strategy should be periodically reviewed, and as required updated, throughout the total service life based on receipt and evaluation of new data/information (usually through amendments following the receipt of additional inspection reports, results of structure reanalysis or assessments, and other data or information pertinent to structural integrity).

The inspection strategy should be developed from the engineering evaluation (see Clause 9) that, when implemented, can determine within a reasonable level of confidence the existence and extent of deterioration, defects and damage.

The inspection strategy should address the topsides, substructure and splash zone, and should account for:

— inspection motives (see 10.2.2);

— inspection type (see 10.2.3);

— inspection method (see 10.2.4);

— inspection frequency (see 10.2.5);

— inspection scope (see 10.2.6).

Scopes of work may be included in the strategy or may be developed as separate documents in accordance with the operator’s overall management framework.

10.2.2 Inspection motives

Inspection strategies should serve as proactive measures to detect damage and deterioration as well as provide information on the condition of the structure that should be used to confirm that the structural components remain fit-for-service.

10.2.3 Inspection type

10.2.3.1 General

SIM inspection strategy should account for scheduled inspections and unscheduled inspections.

10.2.3.2 Scheduled inspections

Scheduled inspections should include baseline inspections, periodic inspections and special inspections.

10.2.3.3 Unscheduled inspections

Unscheduled inspections should be performed to provide information on the structural condition following a potential overload event or incident. An unscheduled inspection should be performed as soon as practical after the occurrence of:

— a significant environmental event (e.g. storm, earthquake, mudslide);

— a significant accidental action (e.g. vessel impact, dropped object, explosion).

Well intervention or maintenance campaigns can increase the likelihood of accidental damage for the topsides. Therefore, these events should be treated as a potential overload case and a post-event inspection can be planned. Unscheduled post-event inspections should be developed based on an evaluation of the available data, including event/incident reports.

10.2.4 Inspection method

Inspection scope of work may include one or more of the following inspection methods to understand the condition of the structure:

— a general visual inspection (GVI);

— a close visual inspection (CVI);

— flooded member detection (FMD) complementing GVI and CVI;

— a non-destructive examination (NDE).

Selection of appropriate inspection method(s) for a given task shall be determined by qualified personnel based on the goals/objectives of the inspection and the sensitivity, effectiveness, reliability, cost, and availability of the various tools and techniques.

10.2.5 Inspection interval

10.2.5.1 General

SIM inspection strategy shall specify inspection intervals for:

— periodic above water inspection (see 10.2.5.2);

— periodic underwater inspection (see 10.2.5.3);

Periodic above water and underwater inspections should be performed at an interval consistent with the structural integrity strategy adopted by the operator. Underwater inspection intervals should be developed using a risk-based approach. However, the consequence-based (default) inspection program based on worldwide experience provides a predefined in-service inspection program that may be used if operators choose not to implement a risk-based inspection strategy.

10.2.5.2 Periodic above water inspection

10.2.5.2.1 General

Above water inspection shall include the topsides structure and jacket structure above the waterline.

10.2.5.2.2 Consequence-based inspection interval

In the absence of a risk-based in-service inspection strategy, the topsides structure and jacket structure above the waterline shall be inspected annually using GVI.

Use of other inspection techniques (i.e. CVI and/or NDE) may be included with the annual GVI and should be selected based on the type of expected deterioration/degradation and the present known condition of the topsides CS. A CVI and/or NDE inspection should be performed when the GVI discovers deterioration/degradation and/or damage that require more detailed inspection to determine the extent and possible cause.

10.2.5.2.3 Risk-based inspection interval

Where the operator has adopted a risk-based structural integrity strategy, the topsides CS inspection intervals may be set that account for the risk associated with possible failure of the CS. The CS may be divided into system, sub-system or component level as required. Timing for the first risk-based topsides inspection should be determined from the completion date of the baseline inspection.

Risk-based intervals should account for the possible CS failure mechanisms and the associated deterioration/degradation mechanisms in the risk evaluation. The risk-based intervals should account for the following possible deterioration/degradation mechanisms:

— coating breakdown;

— corrosion;

— fatigue;

— fretting;

— erosion;

— passive fire protection (PFP) degradation;

— physical damage (e.g. vessel impact, dropped object);

— bolt loosening/failure;

— other material degradation.

10.2.5.3 Periodic underwater inspection

10.2.5.3.1 Consequence-based inspection interval

In the absence of a risk-based in-service inspection strategy, periodic underwater inspections shall be performed at intervals in conformance to Table 1. The consequence-based inspection interval requirements only address the concerns of safeguarding human life and protecting the environment.

Table 1 — Underwater consequence-based inspection program intervals

Exposure level	GVI	CVI	NDE
L1 structures	Every 3 years	Every 6 years Or as determined from GVI findings	Determined from CVI inspection findings
L3 structures	Every 5 years	Every 10 years Or as determined from GVI findings	Determined from CVI inspection findings

10.2.5.3.2 Risk-based inspection interval

Timing for the first risk-based underwater inspection shall be determined from the completion date of the baseline inspection.

Platforms with higher consequence appurtenances can require more frequent inspection than that based on the structure's risk-based interval. In addition, the risk-based interval can require adjustment to account for the service life or present condition of the cathodic protection system.

Setting of intervals between inspections greater than 10 years requires the operator to demonstrate that:

— exposure level is L3;

— risk of exceeding all ULS and ALS have been quantified through a USM;

— inspection trends are understood;

— annual drop cell CP readings are performed and are acceptable.

Risk-based inspection intervals can be optimized through the use of a quantitative risk analysis that accounts for the annual risk of platform collapse from metocean or seismic hazards and the increase of this risk due to time-dependent degradation.

10.2.6 Inspection scope

Inspection strategy should develop scopes of work for each of the surveys specified as part of the inspection. The strategy should address the different inspection motives and should include scopes of work for:

— baseline inspection;

— above water periodic inspection;

— underwater periodic inspection;

— special inspection;

— unscheduled inspection.

For each survey identified as part of the inspection, a work scope should be developed which specifies the data recording and defect/anomaly reporting requirements. A system for reporting and documenting anomalies and defects should be in place so that data can be collected for an engineering evaluation.

10.2.7 Pre-selected inspection areas

Where the structural integrity strategy determines that CVI or NDE is required, the selection of the welded joints to be surveyed should include an evaluation of:

— data collected from the baseline survey;

— general inspection findings in the offshore industry;

— the significance of members and joints to the platform system capacity;

— the platform robustness and damage tolerance;

— joint and member stresses and stress concentrations;

— joint fatigue lives.

During design and subsequent assessment, member and joint action effects should be recorded and used to define requirements for future surveys.

10.3 Maintenance strategy

A structural maintenance program is a component of the overall SIM strategy, complementing the inspection and monitoring plans. Maintenance programs for structures should cover the corrosion control systems such as coatings and impressed current systems. The maintenance tasks and schedules should be developed based on good practices, equipment vendor guidelines and operator risk tolerance criteria.

Topsides structure is protected from atmospheric corrosion by the coating system which is applied during fabrication or commissioning. If the coating system is maintained during the total service life, a significant degradation mode that can reduce the load carrying ability of the structure will have been mitigated. A risk-based coating maintenance program will require that higher risk areas be painted first.

Maintenance strategy should account for:

— coating/fabric maintenance program;

— grating replacement schedule.

Maintenance should be specified accounting for the importance and use, knowledge of the durability of the components, environmental conditions and the protection against external actions. Structural components that are essential to the stability and resistance of a structure should, as far as possible, be accessible for inspection.

10.4 Monitoring strategy

10.4.1 General

Monitoring may be used in combination with an inspection plan to enhance the level and quality of condition and operation data used to confirm fitness.

If monitoring is used in lieu of scheduled inspections, the monitoring program shall be documented within the inspection plan to confirm monitoring program execution (i.e. occurring as planned, timely data evaluation and personnel competencies).

Different types of monitoring strategies can be implemented to address expected degradation due to defined mechanisms. Monitoring strategies should produce monitoring data regarding degradation rates or indicators for risk change, including:

— weight and CoG monitoring (see 10.4.2);

— deck elevation monitoring (see 10.4.3);

— natural frequency monitoring (see 10.4.4);

— corrosion protection monitoring (see 10.4.5);

— metocean monitoring (see 10.4.6).

Monitoring programs often require specialty equipment, continuous data recording, periodic calibrations, plus specialty software and personnel to evaluate the data.

The project team and operating team shall confirm that adequate infrastructure and support can be provided to maintain the monitoring program in the long term.

Guidance should be provided on the specific activities that should be performed, when they should be performed, what should be measured, who is responsible for recording the data and maintaining it, and who should review, evaluate and communicate the results. Additionally, threshold criteria should be defined such that they indicate an anomalous condition that would trigger an evaluation.

10.4.2 Weight and centre of gravity (CoG) monitoring

Operational topsides weight should be managed by an operational weight management procedure that provides a basis for monitoring and assessing the magnitude and locations of loads.

Weight of topsides is likely to change during operational life due to modifications and upgrades. This should be monitored and managed through the introduction of periodic weight audits and following the weight control procedure.

Laydown areas should be monitored to confirm that the weight limits specified in the original design or assessments are not exceeded. Laydown areas are sometimes not included in an operational weight management procedure.

ISO 19901-5 provides recommendations that should be followed for typical procedures, common topside operating philosophy, drilling matrix, and list of coincident operating loads.

10.4.3 Deck elevation monitoring

Continuous monitoring of the deck elevation above a reference water level may be used as part of the structural integrity strategy. This may include GPS, differential tilt surveys, radar or other reflective signal technology.

10.4.4 Natural frequency monitoring

Continuous monitoring of the platform natural frequency may be used as part of the structural integrity strategy. Response characteristics should be compared over time to determine if the natural frequencies have decreased or if the mode shapes have changed. Changes in mass and the distribution of mass on the deck are a normal part of operations. These (and other effects) provide a background variation in response characteristics. If the response characteristics have changed, this can be attributed to some form of structural failure.

10.4.5 Corrosion protection monitoring

Results from CP and anode surveys should be monitored to determine if the corrosion protection system is working in line with design expectations. Monitoring and trending of corrosion protection can assist with early identification of issues by highlighting abnormal CP readings or increased anode usage.

10.4.6 Metocean monitoring

Metocean data may be monitored to confirm the actual environment a platform encounters (which may be used in subsequent fatigue assessments) and may help validate certain aspects of the original metocean basis of design.

10.5 Evacuation strategy

A personnel evacuation strategy should be developed if a performance standard is dependent on the personnel being relocated prior to the occurrence of a foreseeable event. The evacuation strategy should account for the duration, the speed of development, the speed of movement and the extent of event conditions.

Advanced planning can reduce risks as well as improve post-event response. Written evacuation preparedness plans should be developed covering both general preparedness activities and structure-specific response activities. Checklists and platform-specific guides can assist during the evacuation process.

10.6 Marine site investigations

Marine site investigations should be available in conformance to ISO 19901-2, ISO 19901-4 and ISO 19901-8[4]. Prior to performing an assessment, the marine site investigation engineering parameters should be reviewed and a new site investigation/analysis should be performed if the parameters are no longer valid or if data are missing (see 8.2).

11 SIM Program

11.1 General

The SIM program represents the execution of the detailed work scope and should be performed to complete the activities specified in the SIM strategy.

The SIM program shall include the activities defined within the SIM strategy over the total service life and include:

— an inspection program (see 11.2);

— a maintenance program (see 11.3);

— a monitoring program (see 11.4);

— a reuse program (see 13);

— a decommissioning and removal program (see 14).

To complete the SIM process, data collected during the SIM program should be incorporated back into the SIM data management system. Consistency, accuracy, and completeness of inspection, maintenance and monitoring records are important, since the data form an integral part of the SIM process. Specific requirements for the execution of the work scope, including data recording and reporting requirements, should be defined within the inspection, monitoring and maintenance plans.

11.2 Inspection program

11.2.1 General

If anomalies are discovered that can potentially affect structural integrity, conductors, risers and J-tubes or appurtenances, personnel should perform an evaluation to determine if additional inspection and/or remedial measures should be performed. Additional inspection can require use of more detailed survey techniques.

If above water damage is detected, NDE should be used when visual inspection cannot determine the extent of damage. If the above water inspection indicates that underwater damage is possible, an underwater inspection should be performed as soon as conditions permit.

11.2.2 Specifications

Inspection program should establish specifications for inspection activities and establish procedures for quality assurance, quality control, and data validation.

Inspection specification should, as a minimum, include:

- anomaly reporting requirements;
- diver and ROV operator qualifications;
- NDE technician qualifications;
- notification requirements following discovery of an anomaly (e.g. flooded member);
- measurement procedures (e.g. dents, bows, holes);
- sensors and instrumentation;
- reporting formats and procedures;
- photography and video recording procedures.

11.2.3 Inspection method

11.2.3.1 General

Selection of an inspection method(s) for a given task shall be determined by qualified personnel based on the goals/objectives of the inspection and the sensitivity, effectiveness, reliability, cost, and availability of the various tools and techniques.

11.2.3.2 General visual inspection (GVI)

GVI shall be performed to determine the condition of the members, joints, or components selected for inspection.

If above water damage is detected, a record of the damage should be made to allow engineering personnel to determine if repairs or further inspection (e.g. NDE) are required.

Damage records should include measurements, photographic documentation, and drawings. If the above water survey indicates that underwater damage could have occurred (e.g. a missing boat landing or unrecorded damage exists), an underwater inspection should be performed as soon as conditions permit.

11.2.3.3 Coating survey (including passive fire protection)

Coating survey shall be performed to detect deteriorating coating systems and corrosion.

The survey should report the type of coating systems for the components inspected (i.e. Monel cladding or elastomers on the splash zone members and jacket legs, paint on the conductors) and record the locations and extent of coating deterioration. ISO 4628[1] may be used for specifying the degree of rusting of coatings by comparison with pictorial standards.

11.2.3.4 Survey of underwater cathodic protection

Survey of the underwater cathodic protection shall include a below water measurement over the water depth of the cathodic protection system by silver/silver chloride drop cells or other approved drop 057 accepted cells.

The reference cell should be within 1,0 m of the structural component being inspected.

11.2.3.5 Appurtenance and personnel safety devices surveys

Appurtenances and personnel safety devices include handrails, grating, stairs, swing ropes, boat landings, helideck, bridges, supports to risers, survival craft supports, crane pedestals, communications tower deck connections, and structural elements supporting evacuation routes and TR.

11.2.3.6 Air gap survey

In operational areas of known or suspected subsidence, the above water inspection shall include a survey of the gap between the cellar deck bottom of steel and the water level. For other areas, the deck elevation should be measured on a periodic basis to provide up-to-date information.

For accurate air gap measurements, wave radars should be used. Alternatively, measurements may be made with a plumb line and recorded against the time of measurement to allow later agreement with tidal information or changes. Suspected subsidence or differential settlement of the structure should be recorded.

11.2.3.7 Close visual weld/joint survey

The close visual weld/joint survey should be used to detect and size visual cracks in or adjacent to the weld and confirm the extent of corrosion of the steel surface and areas adjacent to the weld.

11.2.3.8 Damage survey

If damage is found during the visual survey, a follow-up survey should be performed to obtain data for the damage evaluation. The survey should identify the location and should include dimensional measurements to measure such quantities as damage size and geometry, member out-of-straightness, crack length and depth, corrosion pit size, etc. The survey should be extended to inspection for collateral damage (e.g. a heavily dent-bowed member, bulging or buckled could have cracks at the member ends).

11.2.3.9 Supplemental surveys

Above water inspection may include supplemental surveys to characterize damage as specified in the scope of work (e.g. NDE, material sampling, wall thickness measurements).

Bolt tightness checks should be performed to confirm that the bolt nuts used for connecting and attaching topsides components are not loose.

A settlement and tilt survey should be performed during the scheduled above water inspection. Settlement can induce stresses in the platform members and at the deck structure, and can be precipitated by seabed subsidence. Differential settlement in case of fixed platform can induce stresses at the deck structure.

Unmanned aerial vehicles (UAVs) may be used for high-altitude inspections on structures (e.g. flare booms and drilling towers). However, such surveys should be verified and certified for reliability and fit-for-service.

11.3 Maintenance program

Maintenance activities should follow the program specified in the maintenance strategy. The most important facet of a maintenance program is being proactive and preventative. Not completing maintenance tasks or associated repairs can result in a “reactive” program, increasing the risk of failures and diminishing the fitness-for-service of the structure.

As part of the inspection plan work scope and structural integrity program reviews, checks should be made to confirm that critical maintenance has taken place. If the maintenance has not taken place the affected CS should be treated as in an anomalous condition. Actions should be taken to work off the maintenance backlog and confirm execution of future tasks.

11.4 Monitoring program

As the monitoring data are collected, the information should be reviewed to determine whether anomalous conditions exist that would warrant further evaluation. The data review should be performed periodically based on the monitoring plan.

As part of the inspection plan work scope and structural integrity program reviews, checks should be made to confirm that the essential elements of the monitoring plan (e.g. data collected, post-processed) are taking place. If the maintenance has not taken place, the affected CS should be treated as in an anomalous condition. Similarly, if the monitoring device is damaged or not functioning, the affected CS should be treated as an anomalous condition. In either instance, actions should be taken to reinstate the monitoring plan and the anomalous condition evaluated based on the SIM processes recommended in this document.

12 Assessment

12.1 General

Assessment should use quantitative or semi-quantitative techniques to demonstrate that, for every hazardous event specified, the structure and structural components, including the jacket primary structure and foundations, does not exceed the specified limit states.

An assessment should include the following:

— establish motive for assessment (see 9.7.2);

— gather assessment information (see 12.2);

— select assessment method (see 12.3);

— generate assessment model (see 12.4);

— perform assessment (see 12.5, 12.6, 12.7, 12.8, 12.9, 12.10 and/or 12.11);

— determine if the assessment verifies the limit state assessment criteria.

Assessment is typically step-wise from qualitative methods, if applicable, to quantitative analysis methods with increasing complexity but reducing conservatism. If verification of all the limit state criteria is not achieved, then the assessment may be re-performed with a more complex, but less conservative analysis method.

An assessment should demonstrate that the structure achieves the limit state verification.

For structures that do not achieve the limit state verification, risk reduction options shall be initiated that either reduce the likelihood (prevention) and/or reduce the consequence (mitigation).

12.2 Assessment information

Structure should be assessed based on its present condition, accounting for damage, repair, scour, seabed subsidence, or other parameters potentially affecting its fitness-for-service. The operator should verify that assumptions made are reasonable and that the data is accurate and representative of actual conditions at the time of the assessment, or for future modifications.

Data should be up-to-date and reflect the condition at the time of the assessment. This information should be available from the SIM data management system (see Clause 8).

12.3 Assessment method

12.3.1 General

Assessments may use semi-quantitative or quantitative methods that can include using:

— simplified procedure;

— platform similarity;

- previous assessment;
- prior exposure;
- design level methods;
- ultimate strength methods;
- structural reliability methods.

Structural reliability methods are not a requirement of this document. However, for structures requiring a more complete assessment structural reliability can be used.

Selection of the assessment method should be based on Table 2.

12.3.2 Qualitative method

Likelihood of exceeding a limit state may be established using a qualitative method that uses judgment, experience and knowledge on the structural aspects to categorize the structure or structural component.

Table 2 — Assessment method selection

	Method								
	Semi-quantitative				Quantitative				
					Design level		Ultimate strength		
	Simplified procedure	Similarity	Previous assessment	Prior exposure	Linear-elastic analysis[a,c]	Linear-elastic redundancy	Static nonlinear analysis	Dynamic nonlinear analysis[d]	Structural reliability analysis[e]
	Increasing complexity → Reducing conservatism								
Assessment trigger									
Change in platform condition					Yes	Yes	Yes	Yes	Yes
Change in estimated actions [b]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Change in assessment criteria	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Change in consequence					Yes	Yes	Yes	Yes	Yes
Change in use					Yes	Yes	Yes	Yes	Yes
Assessment motive									
Support evaluation	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Categorize likelihood	Yes		Yes	Yes			Yes	Yes	Yes
Support inspection program							Yes	Yes	Yes
Support mitigation strategy							Yes	Yes	Yes
Determine probability									Yes

[a] Linear-elastic analysis with nonlinear foundations.

[b] Change in actions due to WiDA can require the use of a nonlinear assessment method.

[c] Includes seismic response spectra analysis.

[d] Includes seismic time-history analysis.

[e] Not a requirement of this document.

12.3.3 Semi-quantitative method

12.3.3.1 General

Likelihood of exceeding a limit state may be established using a semi-quantitative method that categorizes a structure based on a set of rules relative to other similar structures. The ranking system should determine a likelihood based upon key information that accounts for the strength, and the extreme, abnormal or accidental action.

Likelihood categorization system should identify the parameters affecting structural strength and actions (e.g. platform type (drilling, production, wellhead), year designed, number of legs, bracing scheme, water depth). Parameters that indicate the strength has deteriorated or is not up to present standards increase the likelihood of exceedance. In addition, parameters that indicate that extreme, abnormal and accidental actions can increase in frequency or severity increase the likelihood.

12.3.3.2 Simplified procedures

Simplified procedures exist for the fitness-for-service evaluation of existing structures. The use of these procedures requires knowledge of the assumptions upon which they were based, as well as an understanding of their application and limitations. The loadings used in a simplified procedure should be validated as being conservative compared to the quantitative methods recommended in 12.3.4.

12.3.3.3 Previous assessment

A previous assessment of a structure may be used if the analysis represents the present configuration and condition of the structure, and represents the applied actions to verify the limit state.

If a USM is required by the assessment initiator, a previous DLM shall not be used.

12.3.3.4 Prior exposure

An alternative to a quantitative assessment is to use prior event exposure, provided the structure has survived with no significant damage. Prior exposure uses the survival of an event that is known with confidence to have been as severe as, or more severe than, the event required to demonstrate limit state verification.

For metocean or seismic events, prior exposure should be performed by comparing the expected maximum base shear to which the platform has been exposed, from measurements or calibrated hindcasts, with the base shear required for the limit state verification.

Prior exposure comparison should account for:

— uncertainty of the prior exposure event actions;

— uncertainty in the platform ultimate strength;

— degree to which the platform’s weakest direction was tested by the prior exposure actions;

— possible changes in condition and/or topsides weight or CoG since the prior exposure.

12.3.3.5 Similarity

Assessment results for one structure may be used for another structure if the structures are similar with respect to jacket framing, steel material, soil properties and pile geometry, structural condition, topside mass and geometry, water depth and actions.

An assessment based on similarity shall not use a structure which itself has been demonstrated as fit-for-service based on an assessment by similarity.

12.3.4 Quantitative methods

12.3.4.1 General

Likelihood of exceeding a limit state may be established using a quantitative method that uses explicit probabilities, or implied probabilities based on a DLM to categorize the structure or structural component.

12.3.4.2 Design level method (DLM)

DLM is the method used for designing new platforms, as recommended in ISO 19902, where a structure is designed on a component-by-component basis.

DLM should be performed using linear analysis with nonlinear soil springs. DLM may be performed for the ULS and/or the ALS. The ISO 19902 ALS includes WiD action effects. Therefore, if the ALS is used to demonstrate that the structure achieves the limit states it is not necessary to undertake a USM (nonlinear) assessment. Also, the ALS may be used in-lieu of a ULS.

A reference action vector with partial action factors should be used together with a characteristic capacity and partial resistance factors to give a design action and a design capacity. If the design capacity exceeds the design action effect, the component has achieved the limit state.

12.3.4.3 Ultimate strength method (USM)

12.3.4.3.1 General

USM should be performed using static or dynamic nonlinear analysis techniques that include material nonlinearity and geometric nonlinearity by finite displacement or finite strain theory to determine the maximum actions that the structure can sustain with in the relevant limit state.

USM involves performing an assessment of the structure's capacity, as opposed to the component assessment used in a DLM. Local failure of structural members, joints or foundations is inconsequential if the structure's capacity achieves or exceeds the required limit state.

Provisions in this document for the ultimate strength method generally apply to structures where a static analysis adequately represents structural response. For dynamically sensitive structures, a dynamic, time domain, nonlinear pushover analysis may be utilized.

Cyclic degradation of the member capacity, joint capacity and soil capacity should be represented by an evolving force-deformation relationship.

12.3.4.3.2 Static nonlinear analysis

Nonlinear methods are intended to demonstrate that a structure has adequate strength and stability to withstand the ultimate strength loading. Local overstress, and member or joint failure may be predicted, without global collapse. At this level of analysis, stresses have exceeded linear levels and modelling of overstressed members, joints, and foundations should adequately recognize ultimate capacity as well as post-buckling behaviour, rather than linear action limits.

Ultimate strength is typically determined using nonlinear structural analysis software, which applies an incrementally increasing lateral action to the structural model until limit state is met. The lateral action should be representative of the actions acting on the structure at the limit state.

12.3.4.3.3 Dynamic nonlinear analysis

A dynamic nonlinear analysis may be performed as a more accurate assessment option to a static nonlinear analysis when dynamic response is significant or when damage is predicted to occur during the duration of the hazardous event (e.g. to confirm no collapse occurs during the highest and subsequent waves in the abnormal storm or the highest and subsequent accelerations in an abnormal earthquake).

Dynamic nonlinear analysis involves performing an analysis in the time-domain using the time-history action vector for a given return period of the hazard. Member or joint fracture due to low cycle fatigue should be included in the evolving the force-deformation relationship.

12.3.4.3.4 Structural reliability analysis (SRA)

SRA may be used to assess the limit states of a structure including the effects of uncertainties in the actions, resistances and modelling. The inherent or physical randomness in the basic variables (known as aleatory randomness) should be represented together with epistemic uncertainties originating from lack of sufficient data and shortcomings in the model's representation of reality. Epistemic uncertainties can be reduced by collection of more data or by further investigation regarding the modelling of actions or the modelling of resistance.

12.3.5 Fatigue analysis

Dynamic spectral fatigue analysis (ISO 19902) is typically used to determine the fatigue lives at tubular joint welds and circumferential welds on tubular members. Deterministic fatigue analysis or time-history fatigue may be used.

In addition, the following should be used to avoid the calculated fatigue lives being overly conservative:

— local joint flexibility;

— realistic rather than conservative loading of members' subject to intermittent wetting near the water surface;

— application of the hydrodynamic load on members near the water surface by multiple vertical diagonal segments to accurately model the rapid attenuation of hydrodynamic load with depth;

— use of MacCamy-Fuchs[34] method to determine the C_m as a function of wave frequency for large diameter legs.

Actions should be based on the actual structural configuration over the period being assessed (e.g. actual number of conductors or risers, drill rig and position). Future planned or temporary actions should be assessed.

As part of the evaluation/assessment process for future total service life, accumulated fatigue degradation effects may be calculated.

Where CVI and/or NDE underwater inspections are made and known damage is assessed and/or repaired, fatigue analyses may not be required before the next inspection interval.

Underwater non-destructive inspection of a welded joint may be used to reduce estimated accumulated fatigue degradation if there is no evidence of surface cracking. This information may be used to establish an acceptable RBI interval that accounts for the inspection method and length of in-service exposure of the weld to fatigue. Monitoring fatigue-sensitive joints, and/or reported crack-like indications, is an acceptable alternative to analytical verification.

12.4 Assessment model

12.4.1 General

The assessment model should accurately represent the structural configuration and should account for the present condition as reported from the condition assessment (see 12.2).

12.4.2 Tubular members

Assessment of the resistance of structural tubular members shall be performed in conformance to ISO 19902.

In addition:

a) Tubular members should be modelled using local joint flexibility (see UK HSE report 2001/056[46]).

b) For structures in regions subjected to low temperatures, the fracture resistance of exposed connections made of steel not originally specified for low temperature service should be included in the resistance model.

c) Approach to member and joint resistance should be adopted for nonlinear analysis methods and:

— computed peak axial load of critical compression members should be calibrated, by adjusting the initial lateral imperfection, to match the mean of test data for capacity of tubular columns, in conformance to ISO 19902;

— post-peak axial load versus end shortening of tubular compression members should include the effects of local plastic buckling.

12.4.3 Connections

Strength of connections should be represented in the analysis model in conformance to ISO 19902. For tubular joints in tension, first cracking capacity should be used. Nonlinear shell element models, embedded into the beam element model of the platform, may be used.

12.4.4 Conductors

Conductors (drilled and grouted or driven) should be modelled with p-y springs and should be included in the assessment model. The conductors provide additional lateral foundation support to the platform system and the conductor guide framing should be modelled to account for conductor loading to the jacket.

12.4.5 Damage

12.4.5.1 General

Residual capacity of a damaged component may be determined through simplified methods or detailed analytical techniques. The residual capacity of the component may be used in the evaluation of the system capacity.

12.4.5.2 Dented tubular members

Axial capacity of a transversely loaded brace can be reduced due to the presence of a dent. In offshore structures, braces are susceptible to wave loadings, particularly near the water surface, where wave slamming during storms can impose lateral loading on these members. Tubular members under an impact event can suffer denting and bowing of the member. The most significant geometrical parameter affecting residual strength is the dent depth.

Effects of member bowing on the capacity of the member may be incorporated by using the out-of-straightness of the damaged member. For an initial assessment, the dented member should be treated as unable to carry the load.

Dented tubulars may be modelled explicitly using nonlinear software by simulating a collision using a shell element model or a beam element model (if the software has the capability to represent dents in beam elements).

12.4.5.3 Uniformly corroded tubular members

A reduction in the thickness of a member may be used to model the reduction in strength for uniform corrosion. Thickness reduction should be consistent with the quantity of material removed due to corrosion. Member should be evaluated as an undamaged member with reduced wall thickness. Using minimum local thickness (i.e. averaged over the worst 60$^{\text{-degree}}$ arc) is conservative even though the reduction in thickness is not constant throughout the member length.

12.4.5.4 Locally corroded tubular members

Localized corrosion (i.e. pitting and/or holes) can reduce the member capacity. In lieu of a refined analysis, the strength of members with severe localized corrosion should be assessed by treating the corroded part of the cross-section as non-effective and using methods like those provided in 12.4.5.2 for dented members.

12.4.5.5 Cracked tubular members

Static tensile strength of a partially cracked tubular joint may be estimated by reducing the affected joint strength by some fraction, or by removing the member/joint weld connection from the structural model.

Provided the material is ductile under service conditions, the reduced joint strength may be estimated from simple methods, based on the use of reduced area or section modulus in proportion to the lost area on the failure surface, or based on more extensive numerical analysis using finite element analysis models or experimental evidence.

Partially cracked tubular members can reduce member capacity. In lieu of a refined analysis, a partially cracked member with the cracked area loaded in compression can be treated in a similar manner to that of a dented member (i.e. using a reduced capacity). For tensile loads or tensile bending moments, an engineering fracture mechanics assessment may be used as part of the assessment.

If a cracked joint or member is in tension for the pushover event, it should be demonstrated that its capacity will not be degraded by low cycle fatigue during the RP storm, unless such degradation is represented in the structural analysis.

12.4.6 Repaired and strengthened elements

Members and joints element properties should be modified to account for the local or global effects of repair/strengthening.

12.4.7 Foundation model

12.4.7.1 General

The soil resistance model for piled (drilled and grouted or driven) foundations shall be in conformance to ISO 19901-4.

12.4.7.2 Pile capacity

Analyses shall be performed using the following:

a) DLM - characteristic soil parameters;

b) USM - best estimate (mean) or characteristic soil parameters in in conformance to ISO 19901-4.

The ultimate capacity of the pile shall be the cumulate of the t-z springs at compatible z displacements down the pile length plus the end bearing (q) for the compatible z at the pile tip.

The sum of the peak t and the peak q overestimates the soil capacity, if they do not occur at the same pile head displacement. Static p-y curves for lateral soil response should be used for ultimate strength assessments.

12.4.7.3 Available soil data

A soil boring that was not drilled at the location of the platform or was not drilled using modern methods of sampling and testing may be used. However, the validity of the sampling techniques should be determined, and if a nearby boring is appropriate for the platform location, otherwise a site-specific boring should be used.

12.4.7.4 Pile driving records

Pile driving records as well as soil boring logs may be used to provide additional insight on the soil profiles at each pile location, and to infer the elevations of pile end bearing strata. The records can assist in re-estimating the axial pile capacities. Although not always available, these records are useful for verifying the soil stratigraphy or the final pile penetration. If pile driving records are used the pile hammer performance should be reviewed (see ISO 19901-4).

12.4.7.5 Piles

Piles shall be included in the assessment model using an approach that represents the soils using nonlinear springs (*p-y*, *t-z* and *Q-z*).

The assessment model may account for a conservative (i.e. lower bound) effect of ageing on pile capacity (see A.12.4.7.2) and a continuum model for the soil may be used.

To represent the vertical soil displacements down the pile length, the pile axial flexibility shall be modelled (rather than rigid piles), see ISO 19901-4.

Piles should be modelled to include the structural effects of jacket leg extensions below the seafloor.

For linear-elastic analysis with nonlinear foundations and for static nonlinear analysis, the analysis shall include cyclic degradation at the event RP and loading rate enhancement.

For a dynamic nonlinear analysis, the soils should be represented:

— using elasto-plastic springs (*p-y*, *t-z* and *Q-z*) with hysteretic damping and post-holing (i.e. formation of a gap around the pile, if any);

— with radiation soil damping when a seismic analysis is performed;

— with cyclic softening of the soil in the evolution of the elasto-plastic soil springs (*p-y*, *t-z* and *Q-z*) in time.

12.4.7.6 Pile groups

Representing pile groups shall account for vertical and lateral pile group efficiency at the ultimate capacity of the pile group.

Soil springs (*p-y*, *t-z* and *Q-z*) shall be defined for the displacement magnitudes that can be realized in the analysis as the piles plunge or pull-out.

12.4.7.7 Mudmats

Additional contribution to pile capacity from mudmats may be included, but should be limited to the total soil capacity due to pile loading combined with mudmat loading. Mudmats should not be included in areas where the soils are granular and are liable to scouring.

12.4.8 Material strength

If data is available, the actual (coupon test or mill certification) or mean yield strength may be used instead of specified minimum yield strength (SMYS).

12.5 Assessment for gravity hazard

12.5.1 General

If weighing records of the topsides are not available, then the calculated topsides permanent action should be used. The mean permanent and mean variable topsides action should be used. Coincident operational actions, including drilling actions, should be applied in conformance to ISO 19901-5.

12.5.2 Design level method (DLM)

Permanent and variable actions for assessment should be determined in conformance with ISO 19901-5.

12.5.3 Ultimate strength method (USM)

A static nonlinear analysis may be used to verify the limit state against the gravity load hazard for soil and structure in stillwater conditions at a system level rather than at the component level as in the stillwater DLM. In a static nonlinear analysis for the stillwater the permanent dead actions, variable actions and stillwater buoyancy should be initially applied followed by incrementing the permanent dead actions and variable actions until the platform collapses.

A static nonlinear analysis should be performed where critical components of the structure have a dead action (permanent and variable) to metocean action ratio of 80 % or more and these components have URs exceeding unity in a stillwater linear-elastic analysis. The static nonlinear analysis for the stillwater should be used to verify the limit state (as a system) for the gravity load hazard in stillwater conditions can be achieved by local yielding and redistribution with strains limited to the tearing limits recommended in ISO 19900.

12.6 Assessment for metocean hazard

12.6.1 General

Prior to performing an assessment of the structure, and prior to performing complex analyses, such as a static or dynamic nonlinear analysis, the quality, methodology and accuracy of the metocean analysis (including the amount and quality of raw metocean data) should be evaluated.

In some shallow water locations, the system strength of platforms with large decks can be governed by wind actions, rather than wave and/or current actions. In such cases, the platform system capacity should be assessed against the maximum wind criteria in combination with the associated waves, currents and surge.

12.6.2 Metocean criteria

Metocean analysis should account for the following:

— independent extremes of the metocean variables (e.g. wave, winds, currents and crest elevations);

— long-term distribution of metocean processes (i.e. annual distribution of storm peaks sea states);

— short-term distribution of metocean processes (i.e. distribution of crests in a sea state);

— relevant parameters associated with extremes (i.e., wind speed, current speed and depth, wave heights, wave periods, kinematics factors).

Independent extremes should be determined in conformance to the approaches recommended in ISO 19901-1.

12.6.3 Crest elevation

When assessing air gap, the annual probability of exceedance of the total water surface elevation shall be determined by an approach that includes the combined probabilities of:

— exceedance of the stillwater-level (including storm surges, astronomical tides);

— settlement and subsidence of seabed;

— wave crest height including spatial statistics to account for finite deck area (different from point statistics);

— change in water-level.

Wave crest height distribution shall be determined in conformance to ISO 19901-1.

12.6.4 Metocean action combinations — Jacket

Metocean action combinations shall be calculated in conformance to ISO 19902 accounting for variations in magnitude and direction.

To avoid excessive conservatism, the wave, current and wind parameters may be determined from a response based metocean analysis as recommended in ISO 19902.

A response-based metocean analysis determines the coexisting wave, current and wind parameters that, when input to a metocean action calculation, will produce the most realistic exceedance estimate of action with the required return period. Other forms of metocean analysis involving inputting wave, current and wind parameters, with defined return periods, will typically result in a larger metocean action than that determined by the response based analysis.

Wave actions on a platform are dynamic in nature. For most design water depths, these actions may be adequately represented by their static equivalents. For deeper waters (i.e. greater than 122 m), or where platforms are more flexible (i.e. natural period greater than 3 s), or the platform is damaged, an inertial action should be applied or a dynamic analysis performed. The inertial action should be determined in conformance to ISO 19902.

12.6.5 Metocean action combinations — Deck

Unless it is demonstrated that the air gap is sufficient to avoid wave-in-deck impact, the assessment shall include metocean action combinations for the deck.

WiD load effect shall be added to the maximum jacket load effect unless it can be demonstrated that these effects should be separated in time, based on an appraisal of the time history results.

WiDA shall be based on analysis of the interaction between wave event and deck structure (e.g. geometric modelling of the underside of the deck, including girders that affect the WiDA) by using either:

— model test results;

— momentum flux that accounts for the spatial and temporal convergence; or

— computational fluid dynamics (CFD) that accounts for the spatial and temporal convergence, and possible effects of compressed air;

— silhouette method.

For L1 structures, the primary mitigation strategy for the wave-in-deck actions should be raising the deck. Other mitigation strategies may be deployed that either reduce the likelihood or reduce the consequence (see 9.10).

12.6.6 Directionality of metocean hazards

In some locations, representative storm tracks and topographic features can provide fetch limitations on wave heights from specific directions, or tidal or general circulation currents can be in a predominant direction. For assessment in such situations, different wave, wind, and/or current magnitudes may be used for different approach directions, provided data are available to derive them.

However, the operator shall confirm that the overall reliability of the structure is not compromised by using lower directional environmental conditions.

12.6.7 Design level method (DLM)

12.6.7.1 Ultimate limit state (ULS)

ULS should use E_{100} to determine the URs, with characteristic capacities for structural components and characteristic soil parameters (see ISO 19901-4), together with partial action factors and resistance factors in conformance to ISO 19902.

To achieve the limit state, URs of members and joints shall not exceed unity.

Axial capacity of a pile is acceptable if the capacity of the foundation system, with partial resistance factors in conformance to ISO 19902, can resist the applied actions. In addition, the deck elevation is required to exceed the elevation of the wave crest for the wave with return period of RP years.

12.6.7.2 Abnormal limit state (ALS)

ALS should use E_{RP} to determine the URs, with characteristic capacities for structural components and soil, together with partial resistance factors of unity and partial action factors of unity. Deck elevation is not required to exceed the elevation of the wave crest for the wave with return period of RP years.

URs of members and joints shall not exceed unity.

Axial capacity of a pile is acceptable if the capacity of the foundation system can resist the applied actions.

12.6.8 Linear-elastic redundancy method

Linear-elastic redundancy method is similar to the ALS option of the DLM, but is performed by removing members or joints with a UR > 1,0, until the URs of remaining members and joints are less than unity.

Other equivalent linear methods can be used, if they can be justified to provide conservative or similar results as nonlinear methods.

12.6.9 Ultimate strength method (USM)

12.6.9.1 General

USM shall:

a) include an inertial dynamic amplification factor (DAF) in accordance with ISO 19902;

b) use mean (best estimate) values for structural component resistance parameters;

c) use mean (best estimate) values for soil strength parameters.

12.6.9.2 Static nonlinear analysis

A metocean static nonlinear analysis should be initiated by incrementally applying the metocean action E_{RP}, where E_{RP} is the metocean action combination having the required return period. The static nonlinear analysis requires the structure not to collapse when E_{RP} is applied and the strains are within the tearing limits recommended in ISO 19900.

A static nonlinear analysis should be performed for each wave direction or by use of the omni-directional metocean action E_{RP}.

12.6.9.3 Dynamic nonlinear analysis

A metocean dynamic nonlinear analysis (or time-history analysis) may be performed for the critical wave sector directions. The annual probability of platform collapse is the sum of the directional probabilities of platform collapse.

Dynamic nonlinear analysis (or time-history analysis) should use the following manual iterative approach:

— select a trial RP;

— determine the time varying WiJA for the selected RP;

— determine the corresponding WiDA time history, and factor to account for uncertainty;

— apply the time varying WiJA together with the WiDA time history.

Demonstrating that the platform has a return period to collapse of RP years requires the platform not to collapse during the dynamic nonlinear analysis. Component and joint strains should remain within the tearing limits recommended in ISO 19900.

12.7 Assessment for seismic hazard

12.7.1 General

Prior to performing an assessment of the structure, and prior to performing complex analyses, such as dynamic nonlinear analysis (or time-domain), the quality, methodology and accuracy of the seismic probabilistic seismic hazard analysis should be evaluated.

Seismic hazard curves should be developed by a probabilistic seismic hazard analysis in accordance with ISO 19901-2 that give the magnitude of the spectral acceleration as a function of return period of the hazard.

12.7.2 Seismic criteria

Accelerations should be calculated and applied down the full length of the pile. If non-depth varying accelerations are used, then the seafloor time-history should be applied uniformly down the full length of the pile. Depth varying response spectra at the natural period of interest should be compared to verify that the seafloor time-history provides the highest accelerations.

Gravity actions due to normal operational conditions, including 75 % of the variable actions *Q1*, shall be applied in conjunction with the seismic actions.

Topside mass should be represented, with the correct vertical and horizontal CoG. Jacket mass should be represented, with the mass of entrapped water and the added hydrodynamic mass included (i.e. marine growth).

12.7.3 Seismic action combinations

Seismic action vector should be calculated using the procedures recommended in ISO 19902 and ISO 19901-2. The seismic hazard curve (for the dominant natural period of the platform) should be determined from a site-specific probabilistic seismic hazard analysis as recommended in ISO 19901-2.

Selection and scaling of the acceleration time-history should be based on ISO 19901-2, including:

— use of linear scaling, spectral matching or a conditional mean spectrum (see Reference [33]);

— period range of interest;

— orientation of ground motion components;

— sites close to controlling active faults.

Spectral acceleration, which is used as the basis of the action vector for seismic analysis, should be derived in conformance to ISO 19901-2, which gives Formula (1):

$$\bar{S}_{a,ALE}\left(T_{\mathrm{dom}}\right)=C_C\times\bar{S}_{a,Pf}\left(T_{\mathrm{dom}}\right) \tag{1}$$

where

Pf = $1/RP$;

RP is the return period for collapse of the platform rather than return period of the hazardous event.

For structural models with a coarse representation of the topsides, the acceleration time-history from the ELE_{RP} or ALE_{RP} at the topside support points may be used to create response spectra for input to a response spectra analysis of a detailed topside model.

12.7.4 Directionality of seismic hazards

Directionality of the horizontal motions in relation to platform axes should be based on ISO 19901-2. The requirement of ISO 19901-2 that the structure does not collapse in 4 out of 7 time-history analysis allows for record to record variability in the accelerograms and for the variability in the component accelerograms relative to the platform axes.

12.7.5 Design level method (DLM)

Limit states for life-safety and environmental pollution due to seismic hazards are provided in ISO 19901-2 where ALE_{RP} is the RP associated with the abnormal/accidental limit state. Limit states for financial risk due to seismic hazards are also provided in ISO 19901-2 where ELE_{RP} is the RP for the associated ultimate limit state.

ISO 19902 denotes the inherent ductility by the seismic reserve capacity factor $C_{\mathrm{r}} = \Delta_{\mathrm{collapse}}/\Delta_{ELE}$ Ductility designed jackets are such that if the ELE performance level is achieved for actions having return periods of the order of 200 years, the ALE performance level will be achieved for actions having return periods of the order of 3 000 years. However, existing platforms are required to achieve the governing limit states for life-safety, environmental pollution or financial.

A response spectra analysis may be used for assessment of the platform for the ELE seismic hazard.

Characteristic capacities for structural components and soil, together with partial resistance factors in conformance to ISO 19902, shall be used to determine the URs.

URs of members and joints shall not exceed unity.

The axial capacity of a pile is acceptable if the capacity of the foundation system, with partial resistance factors in conformance to ISO 19902, can resist the applied actions.

Seismic action vector for a response spectra analysis should be determined directly from the spectral acceleration $S_{a,ALE}\,(T_n)$ and the modal participation factor for the n^{th} mode, $L_n=\varphi_n^T Mr$, where r is a resolving vector of cosines of the angle between the direction of the ground acceleration and the direction of the structural degrees of freedom.

12.7.6 Ultimate strength method (USM)

12.7.6.1 General

For structures subjected to base excitations from seismic events, either of the following two methods of analysis may be used to verify the required limit state:

a) static nonlinear analysis or extreme displacement method, or

b) dynamic nonlinear analysis.

12.7.6.2 Static nonlinear analysis

Seismic assessment using a static nonlinear analysis shall be performed in conformance with ISO 19901-2.

12.7.6.3 Dynamic nonlinear analysis

Seismic action vector for a seismic dynamic nonlinear analysis (or time-history analysis) should be determined by scaling the accelerograms from 7 recorded earthquakes to match their spectral accelerations with $S_{a,ALE}$ (T_n).

Seismic assessment using a dynamic nonlinear analysis (or time-history analysis) shall be performed in conformance with ISO 19901-2.

12.8 Assessment for collision hazard

12.8.1 General

Kinetic energies for the abnormal and operational collision events should be determined from a hazard curve for a given annual probability of exceedance. Collision actions, for abnormal and operational collision events, should be evaluated at the following locations:

— boat-landing impacts;

— protective guard impacts;

— brace impacts;

— leg impacts;

— riser impacts;

— conductor impacts;

— impacts on struts or cantilever supporting the TR (or LQ).

Collision assessment should be performed using the following steps:

— define the collision scenarios and collision energy (mass and speed);

— define a deformation mechanism and calculate the energy absorbed by elastic and plastic deformation of the actual structural element(s), by denting and bowing of the impacted member together with elastic and plastic deformation of the remainder of structure and by deformation of the vessel by use of action-deformation curves;

— define the element fracture capacity and check potential collision of the vessel with critical structural or hydrocarbon risers or conductors following the initial jacket brace fracture using the residual kinetic energy of the vessel;

— check that the element joint capacity can transfer the impact forces;

— check that the surrounding elements have the capacity to sustain the redistributed forces from the impacted member together with the permanent actions.

— check that the global structural integrity is not impaired during a collision;

— check if the damaged structure can resist the gravity metocean and seismic actions within a specified return period.

Methodology relies on an examination of each of these energy absorbing mechanisms to establish their maximum potential absorption capacity and the associated impact force and to identify intervening factors that can limit the maximum energy capacity from being fully realized.

12.8.2 Collision zone

The vertical extent of the collision zone is assessed based on:

— vessel draft;

— maximum operational wave height;

— maximum and minimum tidal elevation.

The upper elevation of the collision zone is defined as the maximum still water elevation plus the most probable maximum wave crest (for the limiting sea state for supply vessel operations) plus the maximum freeboard of the supply vessel.

The lower elevation of the collision zone is defined as the minimum still water elevation minus the most probable maximum wave trough (for the limiting sea state for supply vessel operations) minus the maximum draft of the supply vessel.

12.8.3 Collision criteria

Collision hazard curves should be developed to give the magnitude of the vessel kinetic energy as a function of return period of the hazard.

Collision hazard curves should be developed for platform supply vessels, diving support vessels, emergency response and rescue vessels, fishing vessels, and passing vessels (powered and drifting). If passing vessels have a low probability of collision, their collision hazard does not require assessment.

12.8.4 Directionality of collision hazards

Directional collision data may be used in collision linear or nonlinear analyses. Use of omni-directional collision data is conservative in linear or nonlinear analyses.

12.8.5 Collision assessment method

Collision should be performed using a USM (i.e. using static or dynamic nonlinear analysis techniques). Analysis should be performed using a model that represents the as-is condition of the platform and should be performed in the following stages:

— apply in-place actions (topside weight and gravity – stillwater conditions);

— increase the impact action to the required energy;

— perform a post-impact analysis.

12.9 Assessment for ice hazard

Ice hazard curve and action vector should be determined in accordance with ISO 19906.

12.10 Assessment for explosion hazard

Blast hazard curve and action vector should be determined in accordance with FABIG Technical note 14[25].

12.11 Assessment for fire hazard

Fire scenario events and heat dose hazard curve should be determined in accordance with FABIG Technical note 13[24]. The material properties in a static or dynamic nonlinear analysis should be degraded in accordance with FABIG Technical note 13[24].

13 Reuse

13.1 General

If the operator requires relocating and reusing the platform, the SIM process should be used to demonstrate that the platform structural aspects are fit-for-service at the new location.

Platform reuse should address:

— fatigue (see 13.2);

— materials (see 13.3);

— inspection (see 13.4);

— removal and reinstallation (see 13.5).

Structures that are reused shall conform to ISO 19902 design requirements.

Design criteria for reuse shall be in conformance to ISO 19902 rather than the assessment criteria of this document. However, once a reuse platform is installed, this document may be used.

13.2 Fatigue in reused structures

Fatigue sensitive locations in reused structures (e.g. tubular joints) shall be inspected in conformance to 10.2.6.

The calculation of fatigue damage shall include allowances for fatigue damage accumulated during the prior in-service period(s) and transportation phases, in addition to the design service life at the new location.

The sum of the existing accumulated fatigue damage, *D1*, and the future fatigue damage, *D2*, for the intended reuse period shall not exceed a value of 1,0, including the fatigue damage design factors for both periods (see ISO 19902).

13.3 Steel in reused structures

Type and grade of steel used in primary structural members of platforms removed and reinstalled at new sites shall be determined from the original records.

If information on the type and grade of steel used is unavailable, 225 MPa minimum yield strength and NT toughness class should be used for the design analysis at the new location. In addition, tubular sections of unknown steel type and grade with outside diameters typical of drilling tubulars (e.g. 5 1/2 in, 9 5/8 in, 13 3/8 in should be avoided or removed from existing structures. Reused platforms having tubular connections in which the heavy wall joint-cans were fabricated from other than Class CV1 (or better) steel should be inspected, including UT inspection to detect the occurrence of unacceptable defects.

Chemical composition and mechanical properties of materials should be verified for consistency with the assumptions made for the design analysis at the new location. Properties of steel of Group II or higher should be confirmed.

Mill certificates or other documentation from the original fabrication with the material traceability may be used. If material certificates are unavailable, or if there is doubt about the correlation of certificates with the locations of steel within the structure, specimens should be taken from the structure and tested by a laboratory to confirm chemical and mechanical properties.

13.4 Inspection of reused structures

13.4.1 General

When structures are evaluated for reuse, inspection and testing should be performed to confirm suitability for the intended application. In-situ inspection should take into account its ability to provide a thorough inspection and the possibility of further damage during removal and transportation.

Inspection programs prepared for evaluating reuse candidates shall conform to the inspection scopes of work recommended in 10.2.6.

Additionally, inspection should be performed to verify the absence of damage which can impair the structure's ability to withstand actions imposed during each phase of removal operations from the prior location.

Design assumptions should be verified by inspection, including material composition and properties, connection condition and extent of corrosion or other degradation due to prior service.

Assessment of the condition of used structures should begin with a review of existing documentation from the original construction of the structure, together with results of in-service surveys. Evidence of damage or repairs, for which investigation and assessment has not been performed, should be reviewed and assessed in conformance to the assessment requirements in Clause 12. Such damage can occur from environmental overload, ship collisions and operational activities. Validation of repair systems and their condition should be performed.

13.4.2 Initial condition assessment of structural members and connections

Structural members and connections having in-service damage shall be 100 % inspected, using NDE techniques.

Extent, quality, timing and findings of NDE performed during the original fabrication and during periodic in-service inspections of the structure should be reviewed. Where documentation exists, and the extent of inspection and weld qualities are consistent with present criteria, inspection may be limited to an investigation of in-service damage due to overload and fatigue.

Where NDE documentation is not available, an initial spot survey of the structure should be made to provide information for the assessment and to assist in the formulation of an inspection plan. The spot survey should include a general visual inspection of the whole structure to detect structural damage (e.g. parted connections, missing members, dented or buckled members, corrosion damage).

13.4.3 Extent of weld inspection

Extent of weld inspection performed on a reused structure should be determined from assessments of the utilizations of members and joints in the structure in prior service and future reuse. The inspection of welds at joints, where they are fatigue-sensitive, should be directed to the higher stressed areas where fatigue cracks are more likely to initiate.

Weld inspection may take place with the structure still at the previous location, or with the structure removed from the water.

However, the requirements for the extent of the inspection shall be the same.

13.4.4 Corrosion protection systems

Integrity of corrosion protection systems should be verified in accordance with ISO 19902 and the cathodic protection verification provisions recommended in Clause 10.2. Verification should include assessment of remaining anode materials, anode connections, impressed current functionality and the condition of protective coatings (e.g. splash zone coatings and wraps), and possible hidden damage under coatings.

13.5 Removal and reinstallation

Removal should follow the provisions of ISO 19901-6[3].

14 Decommissioning and removal

14.1 General

At the end of field life, the operator shall implement a decommissioning plan.

During the total service life, the SIM process should be used to demonstrate that the structural aspects remain fit for decommissioning and removal.

The decommissioning process should be followed to plan, and implement the removal, disposal or reuse of the structure, equipment and associated pipelines and wells.

14.2 Decommissioning process

The decommissioning process involves ceasing operations at the end of field life including permanently abandoning wells, disposing of hydrocarbons and chemicals, making the structure safe, and removing the facilities for reuse or disposal.

14.3 Pre-decommissioning data gathering

Pre-decommissioning data gathering should be performed to gain knowledge of the structure and associated facilities. The SIM strategy should integrate with the decommissioning planning process to align late total service life structural inspections to collect the condition data.

14.4 Planning and engineering

Data collected from the pre-decommissioning activities should be used to develop the decommissioning plan. Engineering should be performed to allow selection of the preferred execution plan to verify that environmental and life-safety risk has been addressed. Structure removal plan should identify the primary components that are to be removed and reused.

Removal should include site clearance procedures that take account of applicable specifications, industry standards, statutory and regulatory requirements. Typically, these regulations require removal of the components above the seabed and piling removal to at least five meters below the seafloor.

Structural components left above the seafloor (e.g. bottom sections of jackets, suction piles with appurtenances, pipeline exchange manifolds and subsea wellhead that have been permanently abandoned) can require placement of navigational aids for shipping. This should be part of the removal plan.

Structural components can be transported to shore by lifting onto material barges for transport to shore. A wet tow can be used to transport jackets to shallow water and then set horizontally and lift onto a material barge.

Analysis for the removal plan should include actions during the removal process and the analysis should be performed using linear-elastic techniques. ISO 19902 should be followed for structural modelling, strength of tubular member and strength of tubular joints.

14.5 Well decommissioning

Well decommissioning involves the permanently abandonment of the well bores and eventual removal of the conductor. In many cases, it can be advantageous to permanently abandon wells as they become non-productive or uneconomic to reduce the potential environmental, life-safety or financial consequence of platform failure.

14.6 Facilities decommissioning

Facilities decommissioning involves the flushing, cleaning and removal of process equipment and facilities as well as the removal and environmentally sound disposal of waste streams.

14.7 Pipeline decommissioning

The pipeline decommissioning plan depends on geographic location and/or national or regional regulations. Pipelines can be decommissioned in-situ or completely removed. For in-situ decommissioning, the pipeline can be disconnected from the platform and left in place following cleaning, plugging and burying at the ends.

14.8 Conductor removal

Conductors from the well tree to below the seafloor are usually severed at a suitable distance below the seafloor and the upper portion removed prior to the substructure (jacket) decommissioning. Planning for conductor removal should be integrated with the overall SIM strategy as complete or partial removal of conductors can be effective in reducing the likelihood of platform failure (see 9.5.3).

14.9 Structure removal

Before removal of the substructure (jacket), the foundation piles should be severed at a suitable distance below the seafloor. The substructure and topsides may be removed in one or more lifting operations and recovered to shore for disposal or reuse.

Subject to national and regional regulations, the structure may be toppled in place to form an artificial reef or transported and placed at a designated reef site. Leaving the lower part of the jacket in place as a reef can be an acceptable alternative.

Structural removal activities should be integrated with the late life SIM strategy for the platform to verify that the structural integrity of the platform is consistent with safe access for decommissioning operations.

14.10 Site clearance

After the platform is removed, the area should be cleared of debris in accordance with the execution plan. The execution plan should take account of applicable specifications, industry standards, statutory and regulatory requirements.

Annex A
(informative)

Additional information and guidance

NOTE Clauses in this annex provide additional information and guidance on clauses in the body of this document. The same numbering and heading titles have been used for the ease in identifying the subclause in the body of this document to which it relates.

A.1 Scope

This document is applicable to fixed steel offshore structures and the topsides of all structures, including floating structures and jack-up structures:

— located anywhere in the world;

— built to any design code;

— analyzed to any degree of engineering sophistication;

— fabricated with any welding procedure/specification;

— installed in any year;

— subject to any operational history;

— possibly containing design deficiencies or fabrication defects;

— possibly experiencing degradation or damage from a variety of sources.

Evolution of the design process has resulted in a varied assortment of structures since platforms were first installed offshore in the late 1940's. Platforms built prior to the late 1970's exhibit a wide diversity in design criteria and fabrication techniques. Assessment effort of the offshore industry has been focused on the historical response of these structures to the environment and their structural fitness-for-service as they have aged. Platforms installed since the late 1970's provide a more uniform design basis and have incorporated many of the lessons learned during the design, installation and operation of earlier generation platforms.

As the offshore industry has matured, the implicit levels of risk has changed. In addition, as structures age, the original safety margins can have been altered due to damage, deterioration or changes in use from the original design.

A.2 Normative references

No guidance is offered.

A.3 Terms and definitions

No guidance is offered.

A.4 Symbols

No guidance is offered.

A.5 Abbreviated terms

No guidance is offered.

A.6 SIM fundamentals

A.6.1 General

The SIM fundamentals apply to any structure, and SIM for floating structures or jack-ups is not conceptually different from that for fixed structures. Many of the SIM processes, requirements and recommendations in this document are equally applicable to floating structures and jack-ups. The only exception to the applicability relates to the fitness-for-service assessment, which is not applicable to hulls, moorings and marine systems.

A.6.2 Limit states and performance levels

Future structural integrity strategies can be influenced by the margin that the structure or structural component is below the limit state / performance level, e.g. a structure that is close to the limit state can require more inspection and repair if degradation mechanisms are likely to further reduce its capacity.

Limit states include specification of criteria for strength, stiffness, and stability. However, the provision of adequate strength is not always sufficient to meet the limit states; serviceability and business continuity after a hazardous event are also important.

Example performance level are provided in Table A.1.

Table A.1 — Performance level

Performance level	Description of performance level
Operational	Occurs when the hazard causes vibration, displacements or motions that exceed the limits acceptable for personnel health and safety or exceed the limits for operability of production and or life-safety equipment.
Temporary loss of production	Occurs when the hazard causes a limited interruption to production for post-event inspection and repair (damage is mostly to secondary structures).
Prolonged loss of production	Occurs when the hazard causes a major interruption to production for significant subsea and topside repairs to the primary structure. Although repairs are required, they are cost effective and the platform is not condemned. Possible permanent tilt of the platform after the event does not affect future operations including access to the wells. Typical damage includes severed brace members, cracked welds at joints or punching shear “tear out” of the chord wall.
Asset loss without fatalities	Occurs when the hazard causes damage that cannot be repaired cost effectively and decommissioning of the platform is required. However, as the platform does not collapse the structure performs its function to prevent fatalities. Damage is not repairable and decommissioning of the platform is required. Typical damage includes multiple severed brace members, tearing of a leg due to local plastic buckling, multiple cracked welds at joints or punching shear “tear out” of the chord wall and/or a permanent tilt of the platform that the prevents future operations including access to the wells.
Asset collapse with fatalities	Occurs when the hazard causes collapse of the platform during the hazardous event with a proportion of the PoB becoming fatalities.

An example of the possible performance levels that can be established for a fixed offshore structure jacket system is provided in Figure A.1 in the form of a load/displacement curve for a typical hazardous event. The figure illustrates five possible performance levels:

1) platform remains operational;

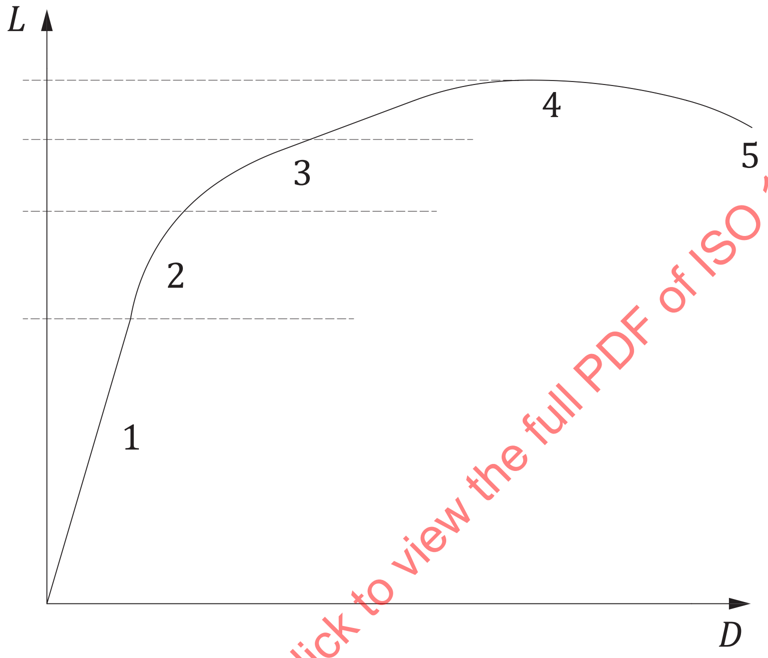
2) business is disrupted, due to post-event inspection and minor repairs, with temporary loss of production;

3) business is disrupted, due to post-event inspection and major repairs, with prolonged production loss;

4) platform remains upright, but is condemned, and crew can be safely evacuated; personnel fatalities are unlikely (ALS);

5) platform collapses and fatalities occur

NOTE It is rare to specify a limit state / performance level beyond ALS.



Key

1 operational

2 temporary production loss

3 prolonged production loss

4 asset loss without fatalities

5 asset collapse with fatalities

D displacement

L load

Figure A.1 — Example performance levels

A.6.3 Fitness-for-service assessment

No guidance is offered.

A.6.4 Management framework

A.6.4.1 General

SIM requires the setting of clear objectives/targets and regular review, with deviations from the expected outcomes being addressed through corrective action.

Management framework is the means of demonstrating that the personnel (competencies and job descriptions), policies and procedures, systems, processes and resources that deliver structural integrity are in place, in use and are performed when required over the whole lifecycle of the asset.

SIM aligns with the HSE and business objectives of the operator through a management system with three interrelated elements:

— Managing elements, which define a consistent set of policies and business principles which create the requirements that the structural integrity aims to achieve. These requirements are non-negotiable.

— Functional elements, which define the integral, critical functions of SIM. Each of these functional elements is found to varying degrees for each stage of the asset lifecycle, from conceptual design through to decommissioning.

— Supporting elements, which provide critical system support to the structural integrity function in achieving its objectives. This support is provided by persons and organizations not directly managed by other business processes that influence structural integrity results.

A.6.4.2 Policy

Legislation in most countries requires a policy on the prevention of major accidents and environmental damage for hydrocarbon production, processing, storage and export facilities. In some instances, the regulations are prescriptive and dictate specific activities and schedules. The operator's SIM policy is intended to complement regulations.

The SIM policy sets out the intention and direction with respect to the structural integrity related processes and activities. These are aligned with the operator strategic plan and other corporate policies and typically include:

— defining the intentions and direction of the organization with respect to SIM;

— integrating and align SIM with the corporate business plan and other policies;

— being reviewed periodically and be committed to continual improvement of the SIM process;

— being documented and communicated to parties involved in SIM;

— being matched by a commitment to make resources available for the implementation of the policy.

A.6.4.3 Written description

For ease of reference, a written description is typically brought together into a single document that identifies technical and budgetary responsibilities and cover the role and management of external suppliers. The written description is reviewed periodically and updated to reflect changes in monitoring requirements, processes, personnel and documentation as required throughout the life of a platform or group of platforms. The written description is usually reviewed following mergers and acquisition of additional assets to confirm its continued suitability.

Written description provides the operator with an auditable mechanism of the approach for the management of structural integrity and typically includes:

— description of the assets included in the framework, including their function(s) and performance and condition requirements;

— organizational structure and the roles and responsibilities, and reporting lines of personnel, by which the operator delivers the SIM strategies;

— definition of the process and rationale involved in the inspection, testing, and preventative maintenance activities by which the operator delivers and assures the structural integrity;

— SIM related procedures and reporting formats by which the operator validates that the structural integrity processes are followed;

— Identification of the procedure for risk assessment and risk management;

— reference to the emergency response plan;

— documentation of the structural incidents that can lead to an emergency response;

— process by which the operator performs periodic review and continual improvement of the SIM strategies;

— arrangements to capture lessons from in-service performance of structures and feed this back into the management arrangements to seek continual improvement;

— limits and interfaces against a specific responsibility for the structural components and the structural system;

— codes and/or standards required by local regulations or the codes and/or standards in which the SIM process is based;

— details of the computerized information systems that will be used to support these activities.

A.6.4.4 Management of change

The operator should maintain an MOC system for temporary and permanent changes to process, equipment, operations and organizations.

Weight change should be recorded in a weight database system. ISO 19901-5 contains recommendations on operational weight databases, their custodianship and SIM interfaces.

The operator should use the MOC to identify and monitor SIM-related changes. Additionally, SIM practitioners should participate in the MOC process by supporting the associated risk assessments and approvals for a SIM-related change.

MOC should be used for structural integrity related changes, including:

— overdue activities;

— managing deficiencies;

— temporary changes;

— permanent changes;

— changes to the hazards;

— changes to regulations, standards and specifications.

MOC item for temporary non-conforming condition repair should be closed once permanent actions are completed. The process should track modifications throughout the asset lifecycle to confirm that input data reflects operations at each stage.

A.6.4.5 Procedures

Procedures provide criteria that can be measured, so that the effectiveness of the procedures can be monitored, including:

— Procedures for investigating to determine the root cause(s) following a structural integrity incident. Findings and recommendations from incident investigations that affect the platform structural components are captured during periodic review/updating of assets risk assessment and fed back into the SIM process. To assist in the reduction of possible future incidents, the findings from incident investigations are shared.

— Procedures for emergency response and control preparedness that interfaces with the platform evacuation, escape and rescue (EER) plan. The emergency response plan set out the means in which parties are alerted in the case of an emergency.

— Procedures for competency management that can be aided by putting in place a policy for recruitment, retention and succession planning of the operator staff and contractor staff to provide continuity of personnel. In many instances, competency management extends to external suppliers.

— Procedures for non-conformance management that put in-place a reporting process to document that the recommended actions to resolve non-conformance are approved.

Processes and documentation that typically constitute the procedures include:

— regulatory and operator reporting requirements;

— SIM policy;

— risk management;

— protective systems documentation;

— project and operating procedures;

— competency management;

— non-conformance management;

— management of change;

— emergency response related to structural integrity;

— intervention and repair;

— incident reporting and investigation;

— performance management;

— documentation and control;

— project data handover;

— information and data management;

— data evaluation;

— fitness-for-service assessments;

— anomaly management;

— inspection strategy;

— inspection program;

— key performance indicators;

— integrity statements;

— performance standards;

— operational weight control procedure, including the topside operating philosophy;

— weight control database;

— annual weight report summaries;

— integrity summary reports;

— structural assessment models;

— performance monitoring reports.

A.6.4.6 Investigation of incidents

A structural integrity-related incident or near miss can be an indication that the framework for structural integrity is incomplete. Every instance of unexpected failure, damage or operational upsets and excursions beyond design limits represents an opportunity to learn about the structural integrity of the assets.

A.6.4.7 Emergency response and control

Developing emergency response plans for each structural failure mode is a proactive means for providing the operator with a rapid response in the event of an emergency. The response plans can be assembled to reflect the identified hazards with a process put in-place for periodic review to confirm that the plans capture changes in risk and/or address new hazards that are created during the total service life.

A.6.4.8 Validation

Periodic validation is used to confirm that the SIM process is being performed in conformity with the procedures set out in the SIM policy and written description, and that the SIM process complies with regulatory requirements.

Validation includes a periodic review to identify gaps between actual performance and the plan, and develop agreed corrective actions. The review consists largely of interviewing personnel and reviewing structural integrity related records. The results of the review are documented and communicated as part of a summary report.

Periodic review determines whether the SIM processes:

— are meeting the SIM policy and strategy objectives;

— are meeting the operator legal obligations with respect to SIM;

— are managing structural integrity risks;

— have been implemented, maintained and recorded;

— review the results of previous reviews and the action taken to rectify non-conformance;

— provide information on the results of the reviews to senior management.

Prior to acquisition of a structure, a due diligence exercise is performed to ascertain the structural condition and status of operating and maintenance records. On divestment of a structure, a record of the structural integrity data transferred to the new operator is retained.

The operator periodically performs a gap analysis of its structural integrity process against the written description. The objective of this gap analysis is to identify gaps in the present structural integrity processes employed by the operator. The gap assessment compares the present processes against the future requirements for structural integrity and provides recommendations for closing gaps.

Review is based on the results of risk assessments of the structural integrity process, in-service incidents or unexpected performance, as well as the findings from previous findings. Reviews can be applied (or required) following incidents or failures. Where possible, reviews are performed by personnel (internal or external) who are independent from those having direct responsibility for the activity being examined.

The operator typically reviews the structural integrity policy and the objectives of its structural integrity processes to decide whether the process warrants inclusion of a verification approach. Structural integrity processes usually involve independent validation to confirm that the quality of the work is controlled and the accuracy of the data and robustness of the decision making is validated.

A.6.4.9 Continual improvement

Maintaining structural integrity is a continuous process through the total service life of the asset. Processes degrade with time, and management processes are no exception to this. Structural integrity processes can provide opportunities for the operator to adopt risk-based approaches, eliminate low-value work, minimize failures and continuously improve.

Continuous monitoring and review is performed to confirm that structural integrity framework remains fit-for-service. Changes will inevitably occur over time in personnel, corporate structures, management systems, and operatorship of assets. These changes can affect an organization's ability to maintain structural integrity to required levels.

Continual improvement requires the measurement and gathering of data for the performance metrics for the adopted structural integrity processes. Performance data are analyzed and trended over time to provide point-in-time evaluation and performance trends. The structural integrity performance is reported and reviewed on a regular basis.

Findings from the structural integrity process validation are used to improve their approach to structural integrity. This includes assessing the performance against defined leading and lagging performance indicators. The leading indicators focus on management of the work process elements and the lagging indicators focus on the results of the processes. The combination drives efficiency and effectiveness.

Opportunities for improvement are captured by proactively seeking, applying and sharing sound practice, behaviours and systems. Structural integrity practitioners share lessons learned in relation to structural integrity across their organization.

A.6.4.10 Organization

Objective of defining the structural integrity organizational structures is to provide the accountabilities of individuals and to set out their activities, interactions, lines of communication and interfaces. The organizational structure covers each aspect of the structural integrity process and represents the accountability flow and reporting relationships. The organizational arrangements are combined with defined roles and responsibilities and the competency requirements for those involved in the structural integrity process. The organizational arrangements are communicated so that personnel are aware of, and accept their responsibilities and the reporting relationships.

A.6.4.11 Roles and responsibilities

The operator typically provides structural integrity engineers and practitioners with job descriptions and competency profiles. Job descriptions define the responsibilities and activities of structural integrity related activities, together with the required attributes, competencies, qualifications, experience, training and certification (where required by regulators). Auditable self-assessments can be made against the job description profiles as part of periodic performance appraisals.

Roles and responsibilities can vary depending on the organizational set-up, complexity, number of platforms and regulatory requirements. The custodian of structural integrity is identified with job description and authority and the roles and responsibilities of other support staff, contractors, specialists, etc., is defined.

The operator typically verifies that personnel whose work affects the structural integrity have defined roles and are assessed as competent for the tasks required of them. Roles and responsibilities of personnel between the operations, maintenance and technical integrity groups are typically documented in writing and communicated.

A.6.4.12 Capabilities and resources

Throughout the total service life, the operator can require access on an as-needed basis of a range of skills to complete the structural integrity activities, which can include:

— structural engineering;

— weight engineering;

— geotechnical engineering;

— metocean specialists;

— marine operations;

— risk champions;

— inspection coordinators.

The operator is responsible for structural integrity, which includes competency of its personnel, and a responsibility with respect to the competency of external contractors. The operator should act as an intelligent customer when purchasing services from external contractors. Competency management extends to the assurance of competence within the internal organization and to external contractors involved in the structural integrity process. Their understanding of the training received is verified, and their competence assessed, at regular intervals.

Structural integrity can often be one skill in an individual's overall skill set and can be of greater or lesser importance as defined by the job requirements. For those individuals involved continuously with structural integrity, the "structural integrity practitioners", their skill level is typically greater and reflect the breadth of the structural integrity process.

Engineers or group of engineers involved with the structural integrity process are typically:

— familiar with the SIM information on the platform being addressed;

— knowledgeable about degradation processes and remedial measures;

— experienced in offshore structural engineering;

— aware of the difference between design and assessment engineering;

— conversant with risk-based engineering decision making;

— experienced in inspection planning;

— knowledgeable and certified in the use of inspection tools and techniques;

— aware of general inspection issues in the offshore industry.

A.6.5 Design

No guidance is offered.

A.6.6 Topsides

The differences between the topsides and supporting structure are how they change over time, and what activities are performed to maintain the various components for the total service life. Topsides are more likely affected by corrosion due to coating failure, increase in member loads due to additions to the topsides and wear and tear / damage caused by daily operations.

A.6.7 Continued service

Concept of 'life extension' is that there is a time or amount of 'service' when the structure would be considered for retirement, but where, with certain processes and criteria, service life can be extended for a further period.

Over time the structure, process plant, safety systems and other facilities comprising the platform are subject to ageing mechanisms that can lead to deterioration in their condition and degradation of their capacity, with a potential effect on the safety, functionality and fitness-for-service in the longer term. Many structures are designed for a design service life of 20 years to 25 years, which were set for investment appraisal purposes. Where the effects of ageing are slow, or can be mitigated and managed through inspection, maintenance and replacement, there is clearly potential for extending the service life.

A.6.8 Structural integrity interfaces

The following interfaces are commonly encountered in topsides structural inspection, noting that several of the activities listed require isolation and/or shutdown:

— crane pedestal and boom rest / crane slew ring, crane cab and boom;

— lifting equipment supports/ runway beams and gantry cranes;

— riser supports / risers;

— drilling derrick / rig skidding system / rig recertification;

— flare tower / flare tip and pipelines;

— lifeboat davits / lifeboat and lifeboat lifting equipment;

— helideck and supporting structure / helideck certification;

— integrated storage tanks / pressure systems;

— major pipe supports / pipelines;

— major equipment supports / equipment;

— internal caisson inspection / pump maintenance;

— coating inspection / passive fire protection (PFP).

In addition to the inspection structural integrity interfaces, the SIM process can require interfacing with:

— geotechnical engineers;

— metocean engineers;

— earthquake engineers;

— risk engineers;

— well engineers;

— operational personnel;

— inspection personnel;

— service providers;

— document controllers.

A.7 SIM process

A.7.1 General

The SIM process provides a means for the operator to predict how a structure performs when damaged and/or overloaded by application of techniques including analysis, testing, monitoring, etc. Once this structural behaviour is known and understood, an inspection program tailored to the lifecycle can be designed and implemented.

Further to maintaining as fit-for-service, SIM provides insight into how structural integrity affects decision making regarding adding personnel, equipment, wells, and/or risers. SIM provides insight into when an operator is required to reduce personnel, permanently or temporarily abandon wells, remove equipment, risers and other appurtenances to reduce risk and/or the consequence associated with damaged platforms and wells.

The SIM process is continuous and is used as a means of determining whether an existing platform can fulfil its required function, based upon a fitness-for-service philosophy. The essence of the approach is based upon an appraisal of the structure in conjunction with a topside and underwater survey and planned maintenance program.

When implemented, the SIM process can be used to demonstrate that the technical integrity of offshore assets is maintained for their intended total service life. In summary, SIM can be used by individuals or groups of individuals who contribute to the structural integrity over the lifecycle from the design/project phase, through construction and operations, to decommissioning and removal.

SIM improves operational effectiveness by enhanced HSE performance, and improved business returns through increased availability of the facility. SIM uses the identification of hazards to communicate and manage the structural risk in a cost effective and consistent manner.

SIM provides the opportunity for the operator and engineers to adopt risk principles for developing SIM strategies.

A.7.2 Benefits

Potential benefits of SIM include:

— Prioritization of inspection resources – structures and components can be prioritized on a consequence, risk or reliability basis.

— Increased knowledge of assets – SIM requires evaluation of available data and assessments, which provides knowledge on the structure’s condition, strength and fatigue resistance.

— More effective MOC – records can be reviewed and maintained, thereby allowing transfer of knowledge and learning for the operator and improving decisions.

— Planned maintenance in lieu of on-the-spot repairs or modifications.

— Increased knowledge of a structure’s condition, strength and fatigue resistance can allow increased time to engineer a repair. Review of assessment can result in delayed or no repair.

The following principles apply to SIM:

a) hazardous event control;

b) component structural integrity;

c) redundancy and alternative load paths;

d) consequence reduction;

e) emergency response;

f) rationalization.

A.8 SIM Data

A.8.1 General

A.8.1.1 General

Evaluations and assessments are only as accurate as the engineering methodology and the data used. Missing or incorrectly measured data can force conservative engineering assessment assumptions, which can prevent upgrades and hence unjustly prevent potential development. An example is when a dent location is not correctly measured. In this case, the engineer should assume that the dent is located where it will cause the highest strength reduction. In some instances, this error can prevent modification to the structure or erroneously trigger a more detailed assessment. To improve data quality, the operator can develop specifications which detail underwater measurement techniques, personnel qualifications, survey limits, anomaly criteria, etc.

Essential aspects of SIM are the validity, extent and accuracy of the structure's data and inspection history. Accordingly, records of original design analyses, fabrication, transportation, installation (including piling) and in-service inspections, engineering evaluations, repairs, and incidents should be retained by the operator for the life of the structure and transferred to new operators' as necessary.

Up-to-date information is required for the SIM process. Information on the original design, fabrication and installation (including results of structural analyses), in-service inspections, engineering evaluations, structural assessments, modifications, strengthening, repairs, and operational incidents, all constitute parts of the SIM knowledge base.

A.8.1.2 Design data

Design data should be collected and retained by the operator over the total service life of the structure.

Design data should be collected during the project design phase.

Design data is the baseline data that represents the structure at installation and includes a broad spectrum of information.

Other design data the operator should obtain from the project and maintain over the total service life are design computer models. Models can be used to assess future changes over the total service life or be incorporated into an emergency response plan to assess major damage resulting from accidents, storms, or deterioration.

Typical examples of design data include:

— original and present operator;

— original and present function and use of the structure;

— location, water depth and orientation;

— structure type - caisson, tripod, 4/6/8-leg, etc.;

— number of wells, risers and production rate;

— other site-specific information, manning level, etc.

— design contractor and date of design;

— design drawings and material specifications;

— design codes;

— basis of design;
— design criteria (e.g. metocean, seismic, collision, ice, fire and blast);
— deck clearance elevation (underside of cellar deck steel);
— operational criteria - deck loading and equipment arrangement;
— soil data and pile capacity data with geotechnical design method, including geohazard data (if applicable);
— piles and conductors - number, size, and design penetration;
— appurtenances - number, size list and location as designed.

A.8.1.3 Fabrication and installation data

Fabrication processes can produce a vast quantity of information regarding the construction of a structure and its predicted response to actions. Fabrication and installation inspection data provides information about the initial structure condition and have a direct bearing on the in-service inspection strategy.

Typical examples of fabrication data include:

— fabrication contractors' details;
— approved for construction drawings or as-built drawings;
— inspection results following fabrication/construction;
— fabrication, welding, and construction specifications;
— mill certificates and material traceability documentation;
— construction tolerances and compliance/deviation records;
— weld inspection records;
— anomaly, defect, repair and remedial action records;
— quality assurance records;
— material datasheets;
— weighing reports with weighing certificates.

Typical examples of installation data include:

— installation contractor details and date of installation;
— pile driving records;
— conductor driving records;
— conductor installation and well top hole construction records;
— pile grouting records (if applicable);
— records of field modifications, damage or repairs;
— transportation records (severe weather / motions).

A.8.1.4 Condition data

Platform condition data should include the changes to the data that can occur during the total service life of the structure and represents the present as-is and possible future condition of the structure.

Condition data should be divided into two categories:

— historical condition data, relating to changes made to the structure;

— present condition data, relating to the surveyed condition of the structure.

Typical examples of historical condition data include:

— post-installation / baseline inspection records;

— in-service inspection records - subsea and topsides;

— in-service structural maintenance records - subsea (if any) and topsides;

— corrosion protection records - CP potentials, anode grades and details of anode retrofits;

— strengthening/modification/repair (SMR) data - descriptions, analyses, drawings, and dates;

— seafloor profile data with scouring around structure legs;

— condition monitoring data;

— settlement / subsidence records (if applicable).

Typical examples of as-is condition data include:

— all decks - actual size, location and elevation;

— all decks - existing loading and equipment arrangement;

— field measured deck clearance elevation (bottom of steel);

— production and storage inventory;

— appurtenances (i.e. list, sizes, and locations);

— wells - number, size, and location of existing conductors;

— above water survey results;

— underwater survey results;

— structural MOCs;

— mitigation plans;

— maintenance records;

— inspection scopes of work.

A.8.1.5 Operational data

Operational data should include knowledge on the actual structural performance and provide a benchmark for understanding some of the assumptions and uncertainties used in the structural design.

Operational data should include information on:

— changes in topsides deck weights and CoGs;

— platform exposure to storms, earthquakes and other environmental events;

— platform exposure to accidental events;

— envelopes used in operating platform equipment.

Typical examples of operational data include:

— operational loading history - records of weight additions, relocations and removals;

— metocean loading history - extreme events including descriptions dates and platform performance during event;

— seismic loading history (if applicable) - descriptions, dates and platform performance during event;

— accidental loading history – collisions, dropped objects and other accidental loads;

— loading and offloading operations (e.g. crane reach, faces of platform used);

— drilling structures and future drilling campaigns;

— access limitations (e.g. exhausts, flares, underdeck areas);

— vessel operations;

— helicopter operations;

— walk-to-work or bridge landing structures and their use;

— caisson pump retrieval and maintenance operations;

— wells/conductors in use on the platform;

— well intervention philosophy/strategy;

— additional modules, caissons, conductors;

— expanding or over utilized laydown areas;

— crane replacements;

— tie-backs from other platforms or fields;

— operational incident data;

— equipment layout;

— management of change documentation.

SIM engineers are tasked with interpreting the variable operating load combinations that occur from movable loads, (e.g. drilling equipment set, setback drillstring, hookload, piperack casing loads, laydown loads, BOPs). In conjunction, weight control information can be usefully collated into a sketch showing topside module designations, geometry, weight report location of reported drilling derrick and other movables, grid lines, eastings and northings, elevations, and the CoG origin point.

A.8.1.6 Engineering data

Engineering data should include information on the methods, decisions and data used to demonstrate that the platform structural aspects are fit-for-service.

Engineering data should include documentation on work performed to confirm fitness-for-service and can include hazard studies, risk assessments, calculations, analysis, structural analysis and/or structural models.

Typical examples of engineering data include:

— damage evaluation data - descriptions, analyses and dates;

— hazard analysis;

— hazard curves;

— engineering evaluation screening records;

— anomaly register;

— assessment basis;

— assessment models;

— risk registers;

— cost-benefit analyses;

— incident root-cause analyses;

— performance levels;

— structural models.

A.8.2 Missing data

Maintaining structure and inspection data cannot be overemphasized. Evaluations and assessments are only as accurate as the engineering methodology and the data used therein. Missing or incorrectly measured data can force the making of conservative assumptions during an engineering assessment. Examples of insufficient data affecting the potential or perceived structural integrity include:

— lack of knowledge of the structure that can prevent the addition of additional facilities if spare capacity cannot be exploited;

— lack of information on a dent depth and location that requires the assumption that the dent is located where it will cause the highest strength reduction.

A.8.3 Data management

Historical data is the cornerstone of informed structural integrity assurance and a system for referencing and archiving documents relating to the SIM process provides a means to connect the various stakeholders.

A.9 SIM Evaluation

A.9.1 General

As new data is collected (e.g. through periodic inspections, because of accidental events, from planned modifications, or from additions to the platform) an engineering evaluation of data should be performed.

If the evaluation determines that the structure operating risk has increased, some level of engineering assessment should be performed to determine whether the structure is fit-for-service or whether risk reduction or mitigation measures are required.

Evaluation can incorporate engineering judgement, operational experience, research data, qualitative screening analysis and predictive techniques to assess the effect that new data has on the SIM strategy. Evaluation should be based on a qualitative analysis of the structure and can include a review of results from a previous design or assessment structural analysis, without performing a detailed assessment.

The results from the evaluation are used to develop and implement an inspection strategy. The program is the implementation of the inspection, maintenance and repair work scopes, as defined from the SIM strategy.

An assessment typically involves an analysis of the structural system that minimizes the inherent conservatism used in the design or most recent assessment. Conservatisms can be a result of the uncertainty used to establish design parameters that, from knowledge gained in operating or advances in technology, can justifiably be removed.

Evaluation is the ongoing process that reviews the present condition of the structure compared to that when it was last assessed and other parameters that affect the structural integrity and risk levels to confirm or otherwise that the limit states are verified. This process identifies repair or maintenance requirements to achieve the limit states. Evaluation should identify the risk associated with operating the assets and differentiate between those hazardous events that can result in global or local damage.

SIM evaluation is the application of engineering to evaluate the effect that new information/data has on the fitness-for-service. Risk-based approaches can be beneficial in the evaluation that enables risks to be calculated and related back to tolerable values. This can provide justification for future activities, priorities and implementation timing.

The following distinguishes evaluation from assessment:

a) Evaluation is an ongoing process, whereas assessment is triggered by certain initiators.

b) Evaluation is typically qualitative, based on engineering judgment, and is sometimes supported by simple or approximate calculations.

c) Evaluation can incorporate operational experience, and reference to research data, qualitative screening analysis and predictive techniques to assess the effect that new data has on the structural integrity strategy.

d) Upon receipt of inspection data, an evaluation is performed, even if no defects are found (e.g. an inspection strategy can be modified based on trends in cathodic potential readings).

e) When damage, defects or deterioration are found, an evaluation is performed to determine if more inspection is required on an urgent basis to further define the extent of the damage (e.g. whether a primary component is affected, in which case an assessment can be required).

f) Potential benefits of remedial measures can be qualitatively determined by an evaluation or, if required, can be quantitatively determined by an assessment using one of the analysis methods.

g) Assessment allows for the use of remedial measures in lieu of the pursuit of further, more detailed, analysis.

Evaluation is performed throughout the total service life and used to confirm that the structural integrity, mitigation strategies and established risk levels are still valid to achieve the limit states. The evaluation addresses the overall structure or structural components where damage or adverse conditions have arisen or occurred.

Findings from the evaluation are used as a basis for supporting or adjusting the integrity strategy and integrity program, and can conclude either:

— that the structure or structural component is fit-for-service between inspections and requires on-going scheduled maintenance/monitoring/inspection (with a specified scope), or

— that remedial measures (immediate or longer term) are required.

A.9.2 Data evaluation

Some of the data that should be evaluated to determine the strength and fatigue performance of fixed steel offshore structures are provided in Table A.2.

Table A.2 — Evaluation factors

Data	Evaluation
Structure age, condition, original design situations and criteria and comparison with present design situations and criteria	Remaining total service life, desire to extend service life Consult with operating and maintenance personnel to see if they have observed conditions (e.g. corrosion evidence, movement in conductor guides or riser/J-tube/caisson supports, deformations or deflections, unusual vibrations, change in platform sway response to waves) that require evaluation
Analysis results and assumptions for original design or previous assessments	Computed utilizations and fatigue lives Original design code and version Original soil data and geotechnical design Degree of sophistication and conservatism in the design/assessment analyses Amount of conservatism used in design against the required limit states. Intentional overdesign for fatigue to reduce periodic inspection requirements Material specification
Structure reserve strength and structural redundancy	
Fatigue life	Sensitivity to metocean criteria Amount of conservatism present in the SN curve Amount of conservatism present in the SCFs Method used to establish the nominal stresses
Degree of conservatism or uncertainty in specified abnormal hazards	Data source Degree of certainty or conservatism in abnormal hazard conditions (wave, current, wind) and design assumptions (marine growth, earthquake spectra) Sensitivity of storm actions to RP. For example, difference in magnitude of actions is there between the 10 year, 100 year, and 1 000 year events? Relative severity of sea states for fatigue and extreme/abnormal conditions, since fatigue can be important in instances where operational sea states are not far below extreme/abnormal conditions Marine growth type (hard, soft), percent coverage, thickness, variation with depth, roughness
Extent of inspection during fabrication and after transportation and installation	
Fabrication quality and occurrences of rework or rewelding	Unusual or special circumstances, rework/rewelding, wind induced vibrations/fatigue Extent of inspection during fabrication Fabrication quality Welding procedures and specifications
Damage (including fatigue damage) during transportation or installation	Extent of inspection after transportation Severity of transport conditions and actual exposure (e.g. transocean versus local tow) Occurrence of damage during installation Extent of inspection after installation Extent of deviations from design assumptions (e.g. air gap between deck and mean sea level)

Table A.2 *(continued)*

Data	Evaluation
Operational experience, including previous in-service inspection results and lessons from performance of other structures	Degree of vigilance in reporting/evaluating accidental events. Extent of deviations from design assumptions (e.g. sea states, marine growth, platform purpose) Modifications and additions of risers, service caissons, topsides, etc. Occurrence of damage Absolute years of service Years of service relative to design service life Subsidence Scope of prior inspections Tools and techniques used Anomalies discovered Trends identified Failures or problems encountered with certain components under certain conditions Success of similar structures in same area/region
Modifications, additions and repairs or strengthening	Underlying causes necessitating repair or strengthening In-service performance of repairs or strengthening
Occurrence of accidental, extreme and abnormal events	
Criticality of structure to other operations	
Structure location (geographical area, water depth)	Regional experience
Structural monitoring data, if available	
Potential reuse or removal intents	

For older structures, the age of the design provides a clue to possible deficiencies or conservatisms in the design that assist in developing an inspection program. As offshore technology has evolved, lessons learned from in-service problems, as well as new experimental data and analytical capabilities have been incorporated in updated versions of various design codes. For example, improvements have been made in areas including:

— design requirements for joint cans;

— foundation design;

— material selection;

— calculation procedure for metocean actions;

— S–N curves.

If cracks occur, they are most likely found at:

— joints in the first horizontal conductor framing below the water surface (normally resulting from fatigue);

— the main brace to leg joints in the vertical framing at the first bay above the seafloor (normally due to extreme or abnormal metocean/seismic events);

— the perimeter members in the vertical framing at the first level below water (normally because of collision);

— poorly designed connections in which the arrangement of components, accessibility and quantity of weld metal required make weld quality difficult to achieve.

Extent of knowledge about metocean, seismic or ice conditions varies for different regions of the world. The degree of certainty in establishing design data for sea states, current, wind, marine growth, seismicity and corrosion rates is not uniform. The amount of conservatism used to account for the possible lack of knowledge can vary for different regions, even among different operators within a given region. Inspection planners require an understanding of these uncertainties and conservatisms.

Some North Sea operators have adopted a strategy of intentionally overdesigning components of a structure for fatigue (such that the computed fatigue lives are 10 times higher than the design service life) with the goal of reducing/eliminating the requirement for an underwater CVI and or NDE survey. Such strategies are legitimate ways of trying to minimize the lifecycle cost of inspection. However, CVI and/or NDE surveys should be performed for new structural concepts - at least until experience of the performance has been gained. The strategy of overdesigning for fatigue does not preclude the requirement for periodic above water and underwater GVI.

Quality of structure fabrication and extent of inspection during fabrication and installation has a direct bearing on the strategy for in-service inspection. One of the main motives for in-service inspection is detection of unknown fabrication defects (usually in weldments) or installation damage. If the incidence of these defects can be reduced through increased fabrication/installation inspection, better quality materials and improved welding procedures, in-service inspection requirements can be decreased. The operator has the flexibility to adopt stricter practices in these areas to reduce in-service inspection requirements.

Inspections can be more efficient and cost-effective when planned with knowledge of the operational history and design/fabrication peculiarities of the structure.

In-service inspection requirements can be positively or negatively affected by lessons learned from the performance of other structures. Such knowledge provides an incentive for the operator to cooperate and share technical lessons from inspections to benefit the industry.

A.9.3 Hazard, hazardous events and degradation mechanisms

No guidance is offered.

A.9.4 Critical structure (CS)

A.9.4.1 General

Some regional regulators require CS to be identified for major accident hazardous events, where a major accident is defined as an event involving major damage to the structure with the potential to cause five or more fatalities or an incident which results, or is likely to result, in significant adverse effects on the environment.

Part of the structure whose failure can cause or contribute substantially to a major accident is safety and environmentally critical, as is a part which is intended to prevent or limit the effect of a major accident. Some regional regulators define these as one of the safety and environmental critical elements (SECEs). A verification scheme for the inspection, maintenance and repair of each safety and environmental critical elements is typically required by the regional regulator.

A.9.4.2 Major accident

Examples of CS whose loss can result in a major accident (five or more fatalities) include:

— jacket and pile system (individual members or joints in a jacket are not CS);

- topsides primary steel that provides direct support and stability of the LQ or TR (individual members or joints in a topside are not CS);
- temporary refuge;
- helideck and helideck support structure;
- bridges and bridge support structure;
- TEMPSC (totally enclosed motor propelled survival craft) davits and support structure;
- muster area walkways and support structure.

A.9.4.3 Major environmental event

Examples of CS whose loss can result in a major environmental event include:

- conductors;
- conductor centralizers;
- conductor guide framing.

A.9.4.4 Major accident prevention or mitigation

Examples of CS that are intended to prevent or limit the effect of a major accident, directly or by loss of a prevention or mitigation barrier:

Direct escalation:

- risers or pipelines, riser clamps, riser guides and emergency shutdown valve supports;
- hydrocarbon pipework supports;
- process equipment tie-downs.

Escalation due to loss of a mitigation barrier:

- riser and conductor protection frames;
- fire wall and fire wall supports;
- blast wall and blast wall supports;
- fire pump enclosures;
- fire pump caissons and supports or guides;
- dropped object protection.

A.9.4.5 Personnel safety

Examples of CS whose loss can result in one or more fatalities include:

- walkways (including their supporting structure), handrails and stair treads;
- drilling rigs (and masts), substructure, tie-downs and skid beams;
- communication towers and support structure;
- crane pedestals and support structure;
- exhaust stack support structure;

— runway beams and their connections.

A.9.4.6 Financial loss

Examples of CS whose loss can result in significant financial loss to the operator:

— flare boom and support structure;

— caissons and supports (other than fire pump caisson);

— primary topside structure (other than that providing direct TR support).

A.9.5 Risk

A.9.5.1 General

In developing an inspection strategy for a fleet of platforms, one approach is to categorize the platforms based on the risk posed to the operator by each platform.

In a qualitative approach the determination of the likelihood of exceeding a limit state is based upon information on structural configuration to determine its "baseline" susceptibility (e.g. tripod, versus 4 leg, versus 8 leg), as well as its present condition, based on inspection that can influence the baseline likelihood (e.g. damaged members). As an example, and although deck level is the most important parameter for metocean hazards, a 1960's vintage 6 leg, K-braced platform has a higher likelihood of exceedance than a 1980's vintage 8 leg, X-braced platform. The newer platform is designed to better standards, (e.g. incorporating joint cans), and has an inherently more redundant structural configuration since it has 8 legs and is X-braced.

A.9.5.2 Consequence

A.9.5.2.1 General

Consequence is governed by the most critical of the life-safety consequence, environmental consequence or financial consequence categories.

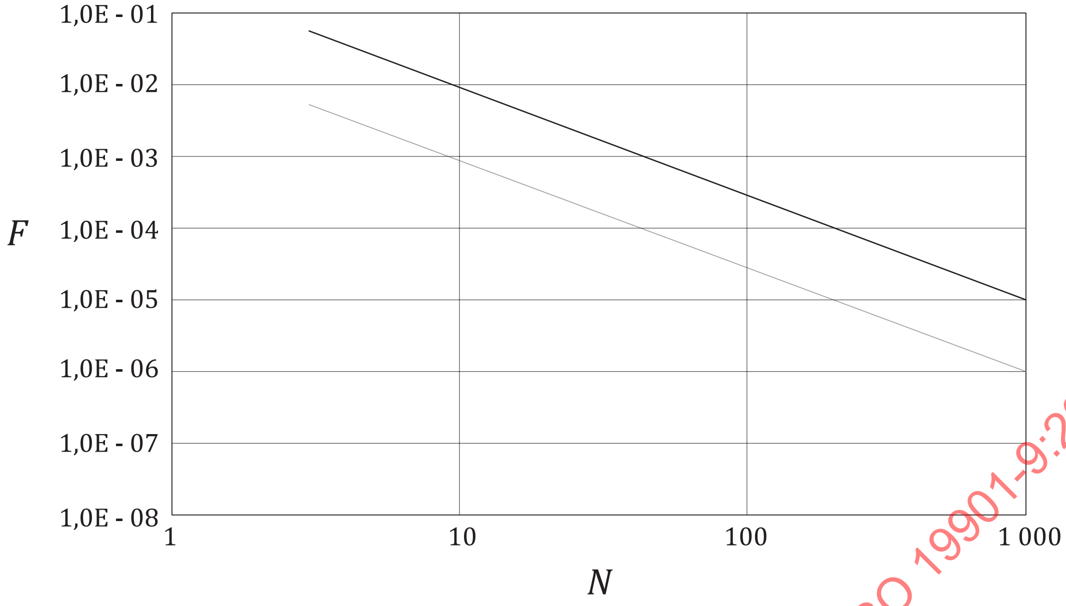
Life-safety consequence in ISO 19900 and in this document is not a function of the number of potential fatalities. However, the operator or regional regulator can require an F-N approach where life-safety consequence is a function of the number of potential fatalities.

Financial consequence should account for the anticipated losses to the operator, other operators, and industry. Financial consequence should include possible repair costs, lost production revenues, and clean-up costs. A driver for the financial categorization can be the possible damage to society (e.g. the situation where a community/state/country will suffer significant financial losses because of the interruption of production). Financial consequence categorization assumes that the operator determines the financial loss category to suit its tolerance of risk, with the agreement of the regulator where applicable.

A.9.5.2.2 F-N Curve

An *F-N* curve (see Figure A.2) specifies the intolerable cumulative probability of fatalities (F) as a function of the number of fatalities (N). The *F-N* curve for fatalities due to non-structural hazards is summed with the *F-N* curve for hazards for fatalities from a hazardous event, and then compared against the operator's and/or regulator's *F-N* requirements.

The intolerable F, F_{int}, is specified as $F_{int} \times N^m$ = constant, where, if risk aversion is included, m is greater than 1,0 (typically m = 1,5) as illustrated in Figure A.2 from CCPS[13]. If a platform collapses in an abnormal storm, then the number of fatalities (N) is likely to equal the PoB as rescue of personnel in the water would be unlikely.



Key

——— (thick line)	boundary of intolerable societal risk for workers
——— (thin line)	boundary of intolerable societal risk for public
N	fatalities
F	cumulative frequency of *N* or more fatalities (1/yr)

Figure A.2 — Life-safety F-N curve (including risk aversion)

A.9.5.2.3 Life-safety risk

Life-safety risk can be measured by the individual risk and the group (or societal) risk. Individual risk per annum (IRPA) includes hazards that offshore personnel can be exposed to, and includes a summation of the operational risks (e.g. helicopter transfers and hydrocarbon blast and fire risks) along with the structural failure risks in determining the tolerable risk.

In some regions, operators and regulators have a structural integrity strategy to unman specific platforms on forecast of the sea state exceeding a predetermined magnitude. In these situations, the operator demonstrates that the annual life-safety risk while the platform is manned is smaller than the limit state criteria.

Risk per annum can be measured by temporary refuge impairment frequency (TRIF) and includes hazards that personnel can be exposed to in the TR (or LQ), including smoke and gas ingress, heat stress and submergence of the TR (or LQ) by global or local collapse of the platform.

In the US Gulf of Mexico, platforms are unmanned (evacuated) for full-population hurricanes and the operator demonstrates that the minimum life-safety limit state is achieved for the winter storm and sudden hurricane metocean hazards.

Scenarios that can result in fatalities are:

— fatalities from loss of TR (or LQ) integrity by sudden platform collapse (topsides, substructure or foundations) during a hazardous event;

— fatalities from loss of TR (or LQ) integrity by platform collapse (topsides, substructure or foundations) because of sustaining severe damage during a hazardous event followed by progressive component failures during the same hazardous event;

— fatalities from loss of TR (or LQ) integrity by sliding or toppling because of local topside collapse during a hazardous event;

— fatalities from loss of TR (or LQ) integrity due to escalation of a hydrocarbon release because of structural failure of risers, pipework or conductors or their supports from the substructure, underdeck or topsides;

— fatalities from escalation due to loss of protective barrier for fire and/or blast;

— fatalities from escalation due to loss of protective barriers for vessel collision or dropped/swinging objects;

— fatalities due to loss of supports for evacuation, escape and rescue.

A.9.5.2.4 Regulators

Presently, regional regulators can require different limit state verification criteria for life-safety. However, all are consistent in recommending that risk reduction measures should be assessed. For example:

a) US regulator, using API RP 2SIM[11] for metocean hazards, specifies the required minimum return period of the action, RP_A, having an annual probability of exceedance of $1/RP_A$, that causes collapse of the platform based on mean values of resistance parameters.

b) US regulator, using API RP 2EQ[10] for seismic hazards, specifies the required minimum return period to collapse of the platform, RP_c. The calculation of RP_c accounts for the uncertainty in the resistance parameters by convolution of the hazard curve with the slope of the fragility curve. If $E_{2\,500}$ is the action having an annual probability of exceedance of 1 in 2 500 years, then the minimum required capacity is $C_c \times E_{2\,500}$ based on mean values of resistance parameters.

c) Norwegian regulator, using NORSOK N-006[40], specifies the required minimum return period of the action, RP_A, having an annual probability of exceedance of $1/RP_A$, that causes collapse of the platform based on characteristic values of resistance parameters.

   If the platform does not collapse, but sustains damage, when resisting the action with return period RP_A, then a further performance level is required to demonstrate that the platform does not collapse during the remainder of the hazardous event in which the action with return period RP_A occurred. This includes demonstration that the damaged platform does not collapse in the 2nd, 3rd etc., largest actions during the remainder of the hazardous event (e.g. metocean or seismic event) and includes the requirement that further damage from component failures during the 2nd, 3rd etc., largest actions and due to low-cycle fatigue in the remainder of the hazardous event is accounted for. The minimum capacity requirement of $C_c \times E_{RP}$ based on mean values of resistance parameters is approximately equal to the capacity requirement of E_{RP} based on characteristic values of resistance parameters. NORSOK N-006[40] methodology is therefore compatible with the ISO 19901-2 and API RP 2EQ[10] methodology.

d) Norwegian regulator, using NORSOK N-006[40], requires that shutdown and unmanning procedure is determined in a way that verifies that the structural reliability of the facility with personnel on-board is not less than for manned platforms (NORSOK N-006[40]) and is assumed to give a life-safety limit state objective in accordance with the ALS requirement of NORSOK N-001[38].

e) UK regulator requires the life-safety risks for individuals and groups on the platform to be less than 1/1 000 per annum.

   IRPA (see UK HSE[47]) is an individual's probability of fatality per annum and accounts for the sum of the probability of fatality due to the following hazards:

   — collapse of the platform or local structural collapse leading to toppling of the TR (or LQ) while the individual is on the platform;

   — hydrocarbon explosion while the individual is on the platform;

   — helicopter travel by the individual to and from the platform while individual is performing his role on the platform (occupational risk).

TRIF (temporary refuge impairment frequency, see UK HSE[49]) is the probability of fatality per annum of the group of individuals on the platform and accounts for the sum of the probability of fatalities due to the following hazards:

— collapse of the platform leading to submergence of the TR (or LQ) or local structural collapse leading to toppling and submergence of the TR (or LQ);

— smoke or gas ingress to the TR (or LQ);

— heat stress to personnel in the TR (or LQ);

— crushing due to collision with the TR (or LQ) from vessels, dropped objects or toppling of the drilling derrick or flare tower.

A.9.5.3 Likelihood

Perceived likelihood accounts for:

a) characteristics of actions or action combinations;

b) vulnerability to accidental loading (e.g. proximity to shipping lanes);

c) present structural condition;

d) degradation mechanisms;

e) service history;

f) reserve strength;

g) structural redundancy and alternative load paths;

h) fatigue sensitivity.

Structural configuration is a function of the ability of a structure to sustain component damage without loss of system structural capacity. Tolerance to damage is a parameter in developing a SIM inspection/monitoring strategy and the associated SIM programs.

An X or XH type of framing configuration typically provides robustness to component damage when subjected to abnormal actions through many alternate paths to transmit loading to the foundation. In the absence of accidental actions, this configuration can often allow the operator more flexibility in developing and implementing an inspection program due to the significant tolerability to component damage and/or overload.

Conversely, a D or K framing pattern does not provide alternate load paths and is less ductile when subjected to abnormal actions. As such, this framing does not provide as much flexibility in developing and implementing an inspection program.

A.9.5.4 Risk presentation

Typical matrices for the life-safety consequence and environmental/financial consequence are provided in Figure A.3 and Figure A.4, respectively. In these figures, the consequence category and likelihood category are arranged such that the highest risk ranking is toward the upper right-hand corner. The operator can adopt more detailed risk assessment techniques or more complex matrices to further subdivide the consequence category and/or likelihood. Risk categories are typically assigned to the boxes on the risk matrix as illustrated in Figure A.3 and Figure A.4.

Risk matrices and consequence categories in Figure A.3 and Figure A.4 provide a useful basis for presenting risk. However, the risk determination should be supplemented with additional evaluation, if the risk level is:

— too coarse;

— too general to address:
  — specific concerns;
  — aspects of performance;
  — individual components.

Risk matrices can be presented as symmetrical or asymmetrical (i.e. the consequence of loss of structure or structural components is given a higher weighting than the likelihood category).

Consequence of failure	Manned	Risk level 3	Risk level 2	Risk level 1
	Unmanned	N / A	N / A	N / A
		Low	Medium	High
		Likelihood of failure		

Figure A.3 — Example life-safety risk matrix

Consequence of failure	High	Risk level 3	Risk level 2	Risk level 1
	Low	Risk level 4	Risk level 3	Risk level 2
		Low ≤ 10^{-3}	Medium > 10^{-3} and ≤ 10^{-2}	High > 10^{-2}
		Likelihood of failure		

Figure A.4 — Example environmental pollution risk matrix

A.9.6 Demonstrating fitness-for-service

A.9.6.1 General

Limit states to limit life-safety risk and environmental pollution risk are independent of remaining service life (i.e. these risks are measured as risk per annum). Financial risk can be measured per annum or over the remaining total service life.

In engineering practice, it is widely recognized that although an existing structure does not always meet present-day design standards, the structure can still be adequate or serviceable. Examples of this do not only include fixed offshore structures, but also buildings, bridges, dams, and onshore processing plants.

ISO 19900 recognizes that the partial factor design approach inherent to limit states design has not been developed for each aspect of offshore structures and consequently other methods can be used. ISO 19900 states that a reliability-based approach can be used for the following:

— determination of partial action factors and resistance factors in the process identified as calibration;

— for design, provided the consistency of SRA with acceptable design practice has been demonstrated.

A.9.6.2 Linear-elastic analysis

Linear-analysis methods (or design level methods) that check the component ULS may be used to demonstrate fitness-for-service.

Recommendations on performing linear-elastic analysis for the possible hazardous events are provided in companion design standards (e.g. ISO 19902, ISO 19901-2, ISO 19906) that provide calibrated action and resistance factors. In lieu of calibrating for different action return periods these standards may be used to demonstrate that the platform is fit-for-service.

For structures that are likely to have decks inundated with waves, ISO 19902 ALS linear-elastic analysis approach may be used to demonstrate that a structure achieves fitness-for-service. However, to investigate the potential for structural collapse induced by a metocean hazardous event with wave-in-deck, nonlinear analysis methods should be used.

A.9.6.3 Nonlinear analysis

Static or dynamic nonlinear analysis methods may be used to demonstrate that a structure is fit-for-service. A nonlinear analysis may use representative values or mean values for resistance.

If mean values are used, the variability of a parameter's value about its mean value should be included.

To verify that the collapse prevention limit state has been met, nonlinear analysis methods should use either of the analysis options provided in Table A.3. Two nonlinear analysis options are provided which differentiate between using representative or mean resistance parameters. Either analysis option, when used, will implicitly demonstrate that the structure is fit-for-service against the collapse prevention limit state. The provision of two nonlinear analysis options allows for situations where information on the actual resistance parameters (e.g. yield strength from mill certificates) is available. However, the use of mean parameters without an adjustment of the characteristic RP load will invalidate the analysis recipe.

Table A.3 — Nonlinear analysis recipe for collapse prevention performance level conformance

Analysis recipe		Conformance
Resistance	**Action**	
Representative	Characteristic action at RP in ISO 19902	Structure does not exceed the limit state at or before the applied action.
Mean	Characteristic action at RP in ISO 19902 increased by a correction factor (Cc) that accounts for the uncertainties in using mean resistance parameters[a,b]	

[a] Seismic nonlinear analyses performed in accordance with the recommendations in ISO 19901-2 include a correction factor.

[b] A 1,15 correction factor can be used for a nonlinear analysis of a metocean event in lieu of establishing a more representative value. Guidance on deriving a correction factor for analyses of metocean events is provided in Reference [35].

A.9.7 Assessment

A.9.7.1 General

A fitness-for-service assessment determines the design action effect combination and design resistance of a structure or structural component, and verifies this against the required limit state.

An assessment may consist of comparing the platform response to an actual proof or extreme/abnormal action against the limit state. However, this is typically only possible when financial risk governs (e.g. evacuated, low consequence platforms in the US Gulf of Mexico) and the return period for the collapse performance level is of the order of 100 years. Platforms with a return period requirement of several thousands of years for the collapse performance level are unlikely to have experienced the required proof load since their installation.

There are numerous methods that have evolved that can be used for performing DLM and USM assessments that are simple to use. However, care should be taken when using such methods, including prior testing and verification of the method to confirm the approach and the applicability of the method to the assessment case.

A.9.7.2 Assessment motive

No guidance is offered.

A.9.7.3 Assessment initiators

A.9.7.3.1 General

No guidance is offered.

A.9.7.3.2 Changes in condition

Evaluation should periodically review the condition of the structural components to determine if the structural capacity has reduced below that used to demonstrate that the structure is fit-for-service. The evaluation should review the condition used in the design or most recent assessment against the new condition.

Evaluation should account for credible degradation and deterioration mechanisms. The mechanisms should be divided into the following categories:

— time dependent where the deterioration can be observed and measured through inspection (e.g. corrosion);

— non-time dependent where deterioration develops quickly after an unknown incubation period and inspection is ineffective (e.g. mechanical damage).

An assessment of the structure or structural component strength against the limit states should be performed if the evaluation indicates that the condition of the structure has resulted in a reduction of the structural capacity. The assessment should be made for the present degraded condition and the anticipated additional degradation by the planned end of total service life.

A.9.7.3.3 Changes in action

Evaluation should periodically review the actions (metocean, gravitational, seismic, etc.) used to demonstrate that the structure is fit-for-service. The evaluation should review the actions used in the design or most recent assessment against the estimated new actions.

An assessment of the structure or structural component strength should be performed if the evaluation indicates that the actions on the structure have increased. An increase in action could occur from the addition of conductors not accounted for in design or the findings from an underwater inspection that indicate that the marine growth exceeds the thicknesses assumed in design.

One of the most notable factors leading to changes in actions is the potential addition of wave-in-deck actions due to subsidence or revised metocean conditions. Other changes in action can include adding a new appurtenance that attracts increased metocean action or a brownfield modification that adds additional equipment and/or structure to the topsides.

Many historical platform failures in the US Gulf of Mexico have been attributed to waves impacting the cellar deck, resulting in a large step-wise increase in loading. In several of these cases, this conclusion is based on hurricane wave and storm surge hindcast results, which indicate conditions at the platform location that include estimated wave crest elevations being higher than the underside (bottom elevation) of the cellar deck main beams.

Inadequate cellar deck height can result from one or more of the following circumstances:

— cellar deck elevation set to only clear a lower design wave height;

— platform installed in deeper water than its original design specified;

— subsidence of the seabed formations.

In some cases, the cellar deck elevation can be greater than the crest elevation for the E_{RP} action, but the sub-cellar deck, such as a scaffold or sump deck, can be impacted by waves causing the E_{RP} action. The sub-cellar deck typically has a small profile and the anticipated wave loading is not expected to be sufficient to cause collapse. However, the assessment should account for the hydrodynamic loads on these decks and associated equipment, for either a DLM assessment or a USM assessment.

A.9.7.3.4 Changes in criteria

Evaluation should periodically review the design/assessment structural or soil data criteria used to demonstrate that the risks are tolerable. Design/assessment criteria can change as industry knowledge and capability to improve the accuracy of hazard curves increases.

Evaluation should review the following criteria used in the design or most recent assessment against the new criteria, as a minimum:

— metocean;

— seismic;

— ice;

— collision;

— geotechnical.

An assessment of the structure or structural component strength level should be performed if the evaluation indicates that the new assessment criterion is more onerous.

A.9.7.3.5 Changes in consequence

Evaluation should periodically review the consequence. If the evaluation indicates that the consequence of exceeding a limit state is more restrictive than that used in the design or most recent assessment, an assessment of the structure or structural component strength should be performed.

Evaluation should, as a minimum, review the following consequence:

— addition of accommodation facilities;

— addition of facilities (e.g. additional pipelines, additional wells, or an increase in topside hydrocarbon inventory capacity).

A.9.7.3.6 Changes in use

If there are plans to change a platform's use, an evaluation should be performed to demonstrate that the risks are tolerable. For L3 structures that are unmanned and that have a low environmental consequence, the change-of-use suitability should be based on an evaluation of the financial risk.

An assessment of the structure or structural component strength against the limit states should be performed.

Examples of platform change-in-use include the addition of a pipeline crossing to an existing platform, the use of an existing platform as a tie-back for a deepwater facility, and the conversion of an existing platform into a receiving terminal for liquid natural gas or other non-exploration and production activity. In these cases, the use of the structure has changed since the platform can now have a different function, expected life and consequence.

For example, fatigue should be re-evaluated since the structure now has a longer-term use under perhaps different actions compared to its original design.

A.9.8 Mitigation measures

A.9.8.1 General

Mitigation can help extend the life of a structure or improve its chances of survival in an abnormal or accidental event if employed early. Mitigation typically involves reducing actions on the structure such as removing unused risers, plugged and abandoned conductors, appurtenances such as boat landings and barge bumpers and increase deck height elevation (deck inundation reduction) or increasing the structure's strength.

Consequence mitigation and likelihood reduction can be addressed at any stage of the assessment process.

Mitigation can include active programs to minimize consequence, such as plugging and abandoning unused wells, removing inactive process equipment, relocating critical equipment., or modifications or operational procedures that reduce actions, increase capacities.

Mitigation measures can include:

— change to operational procedures (e.g. supply vessel operating procedures);

— unmanning criteria;

— inspection of other components, or similar structures;

— more detailed or frequent inspection of defects or damage;

— remedial grinding of crack-like indications;

— repair of identified damage or defects;

— loading reductions (e.g. marine growth removal);

— strengthening.

A.9.8.2 Consequence reduction

A.9.8.2.1 Life-safety

If the structural integrity strategy includes unmanning on a forecast, then the influence of uncertainty in weather forecasting is accounted for in setting the wave height threshold that initiates unmanning. The wave height threshold that initiates unmanning is determined by accounting for the financial costs of shutdown, demanning, re-manning and re-starting in addition to the requirement of meeting at least the minimum life-safety limit state.

A.9.8.2.2 Environmental

When a platform is known to have storage for oil that can be released during a hazardous event, the operator should demonstrate that the CS supporting oil containing pipes (e.g. risers supported from the underdeck or substructure, emergency shutdown valves supported from the underdeck, pipework supported from the deck or conductors) achieve the relevant environmental limit state.

Rupture of oil containing pipes can be caused by the action from the hazardous event being applied directly to the pipe or can be due to large deformations of their supports or due to platform collapse.

A.9.8.2.3 Abnormal storm preparedness

Examples of abnormal storm preparedness are:

a) Evacuation planning, including priority evacuation of platforms that are at greater risk of failure and those that are furthest from shore. Initial evacuation of non-essential personnel should begin early.

b) Evacuation planning for extreme storms that occur with short notice can include evacuation to a more robust platform.

c) Development of advance plans for accessing the structure post storm, if normal access and safety systems are not available due to damage.

d) Establishing of evaluation guidelines and procedures for the eventual safe re-boarding of a damaged structure in terms of whom, how, and when.

e) Identification of critical members and joints for structural integrity for post storm inspections.

A.9.8.3 Likelihood reduction

A.9.8.3.1 General

Strengthening of the jacket structure can be an effective means of reducing the likelihood of damage. Strengthening scheme should be designed to increase the system capacity to the level required to demonstrated that the risks are tolerable. Alternatively, it may be possible to modify the structure to reduce the action effects.

A.9.8.3.2 Increased inspection and/or monitoring

Revisions or additions to the inspection and monitoring plan to detect anomalies may be used to reduce the risk. More frequent inspection of an area known to have damage or where damage is more likely to occur will identify damage, enabling mitigation to be implemented before loss occurs. Similarly, an increased level of inspection may be used (e.g. CVI instead of GVI or NDE instead of CVI) to provide a better level of clarity on the true condition of a CS and detection of anomalies.

Monitoring may be used to help maintain a level of understanding about the condition of a CS between inspections. Monitoring can identify anomalous conditions that could increase the likelihood of damage such that a response (e.g. additional inspection, repair) can be implemented.

A.9.8.3.3 Strengthening, modification and/or repair (SMR) techniques

A.9.8.3.3.1 General

Design practices for SMR should take account of applicable specifications, industry standards, statutory and regulatory requirements.

A selection of SMR techniques available for likelihood reduction is provided in Figure A.5.

The assessment methods (see Clause 12) should determine whether strengthening or repair is required to demonstrate that the risks are tolerable. If the structure requires strengthening and/or repair, the assessment model should be used to develop strengthening options. Once a decision has been made in favour of SMR, an appraisal should be performed of available SMR techniques.

Selecting and designing an SMR technique should account for:

a) safety of diving, diving support, construction and operations personnel;

b) potential for use of diverless techniques;

c) difficulty of fabrication, handling, and installation;

d) rigging complexity and layout;

e) list support vessel type, availability, and access;

f) fit-up tolerance (clamps and members);

g) interference with conductors, jacket members, and appurtenances (e.g. sumps, caissons, anodes);

h) potential for collision with existing risers and control bundles;

i) requirements for pre-design inspection, field measurements, and materials samples;

j) outfitting with well-designed installation aids;

k) required weather windows.

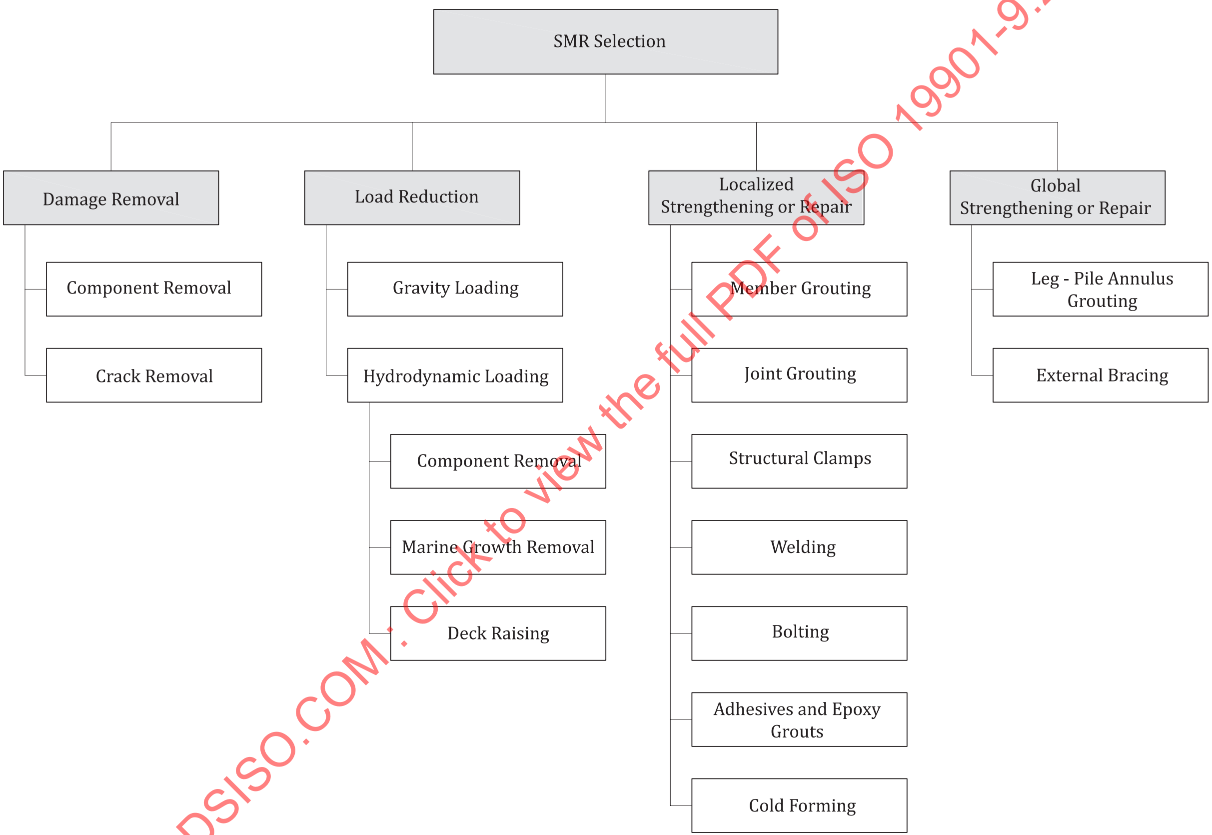


Figure A.5 — SMR techniques

Action effect reduction may be achieved by removing items that contribute to the gravitational loading. Alternatively, or in conjunction, action effect reduction may be achieved by removing items that attract metocean loading. This will be most beneficial in the upper water column where wave kinematics is highest.

Localized strengthening or repair can be used to directly strengthen or repair a component without altering load paths within the structure. For damaged structures, the damage will normally be left in-place. The designer should recognize that additional actions can be attracted to the component due to its increased stiffness following SMR or due to increased hydrodynamic loads.

Localized strengthening or repair options include:

— grout filling – members and joints;

— clamps – unstressed grouted, stress grouted, mechanical and elastomer-lined;

— welding, one atmosphere, wet welding and hyperbaric techniques;

— weld improvement, grinding, shot peening, and toe dressing;

— member removal as a standalone repair technique;

— mechanical repair system (e.g. bolting or swaging);

— composite materials.

Design of a global strengthening or repair scheme should confirm that load is diverted away from the damaged or under-strength component. To achieve this, the strengthening or repair scheme should be designed to attract a portion of the load which would otherwise have been applied to the defective part of the structure.

Type of repairs usually used range from wet or hyperbaric welding, grouting, and clamps to grinding and relief of hydrostatic pressure. Grouting is used to stiffen members and joints, and to preclude local buckling due to dents and holes. Grinding is commonly used to improve fatigue life and to remove cracks. Several types of clamps have been successfully used, such as friction, grouted, and long-bolted clamps. Strengthening can be accomplished by adding lateral struts to improve the buckling capacity of primary members, and by adding insert or outrigger piles to improve foundation capacity.

A.9.8.3.3.2 Damage removal

— Member removal

  Removal of damage by cutting-out the affected member is performed, if it can be demonstrated during the assessment phase that the member is no longer required for the structure's in-place condition.

— Crack removal

  Removal of cracks can be achieved by remedial grinding. In the case of cracks caused solely by fatigue loads (i.e. not in combination with a fabrication defect), other SMR techniques are included in addition to grinding.

A.9.8.3.3.3 Gravity action effect reduction

During operation, the actual topsides actions can be lower than those used in the design. Operational procedures can be implemented to reduce and control topsides actions, for example by:

— removal of unnecessary equipment and/or structures;

— weight management procedures (see ISO 19901-5) with defined weight limits;

— use of lightweight drilling rigs or rig-less operations;

— use of cantilever jack-up drilling operations.

The effect of action reduction will be to reduce leg and pile stresses and pile reactions. Reduced mass typically has a beneficial effect on structural dynamics (although not necessarily for earthquake response), although in most instances this effect is likely to be small. One potential benefit of removing equipment is a possible associated reduction of wind area.

A.9.8.3.3.4 Hydrodynamic action effect reduction

— Component removal

  Action reduction can be achieved by removing items that attract metocean actions. This load reduction will be most beneficial in the upper water column where wave kinematics is highest.

Removal of non-essential or out-of-service components (e.g. barge bumpers, boat landings, walkways, stairs, or risers) can reduce load. Boat landings, walkways, stairs and ladders can be removed only after verifying that they are no longer part of the escape routes.

Removal of conductors can reduce action effects. However, conductors can contribute to the capacity of the foundation. This is confirmed during the assessment process. If the conductors increase the foundation capacity, removal of the upper portion to reduce the hydrodynamic action effects can be an option. However, the upper portion of the conductors can also contribute to the lateral resistance of the structure under wave loading which should be accounted for.

Removal, or relocation, of equipment on lower deck elevations can reduce action effects in the event of wave inundation of the deck.

— Marine growth removal

Action effect reduction can be achieved by the removal of areas of anomalous marine growth. However, the amount of reduction required is evaluated prior to implementation. The reduction can be sufficient (in combination with other action effect reduction measures) to verify the limit state.

Measures are taken to confirm that returning marine growth does not cause the hydrodynamic loading to exceed the required limit state. Such measures can include installation of sliding marine growth preventers and/or adding periodic removal to the SIM program for the platform.

— Raise deck

For platforms where the wave crest is expected to inundate the deck, raising the deck out of the wave crest can reduce global hydrodynamic loading. However, the structural stability of increased deck legs lengths is evaluated.

Due to the cost and operational effect of raising the deck, the cost-benefit is addressed on a case-by-case basis. An alternative to raising the deck is to remove or re-locate equipment and non-essential structures from the lower deck elevations. This results in lower hydrodynamic forces and can reduce equipment damage from direct wave loads.

Deck grating instead of plating can be beneficial in reducing vertical actions on the underside of the deck by allowing encroaching water and trapped air to dissipate.

In some locations, field subsidence has caused a general settling of the seafloor. Mitigation alternatives for this case often rely on reservoir pressure techniques (e.g. water or gas injection). However, this approach does not recover lost height, but can be used to slow future subsidence.

Some platforms with low decks have been strengthened by direct bracing to a modern structure. This allows for the placement of the process and control equipment on the new higher deck.

— Hydrodynamic blockage and shielding

For structures having dense framing, hydrodynamic studies can be used to justify lower hydrodynamic forces than used in the original design. Dense framing has the effect of developing internal shielding of the members and can result in lower global action effects.

A.9.8.3.3.5 Localized strengthening or repair

— Member grouting

Member grouting, which involves filling the tubular member with grout, can be used to enhance its axial compressive capacity. This procedure is not reliable, unless grouting along the member length can be assured (i.e. avoiding voids at the member end). For bending strength increases near mid-span, the presence of small voids at member ends is less critical.

Additionally, tests have shown that capacity up to the original capacity can be obtained by grouting the dented portion or the whole length of a dented member. However, effect of the increased gravity loads and dynamic mass as well as possible decommissioning implications is evaluated before grouting.

— Joint grouting

Grout filling of tubular chord elements can be used to improve the static strength of the joint and, if required, increase the fatigue life of the connections at the joint. The repair method has the advantage of introducing no additional metocean action effects on the structure. However, the increased chord rigidity restricts joint ovalization thereby increasing joint capacity for compression and tension loads. In some cases, grouting can increase the moment at the joints and this is evaluated.

Grouting can be counterproductive for seismically loaded structures, where the grouting leads to an increase in joint stiffness and a reduction in joint ductility. However, the effect of the increased gravity loads and dynamic mass as well as possible decommissioning implications is evaluated before grouting.

— Structural clamps

Structural clamps can be used to:

— repair brace members or joints of jacket structures;

— connect external bracing to additional piles in a global strengthening scheme;

— add new members into a structure to increase redundancy;

— increase the capacity of existing members or joints;

— reinstate the capacity of damaged members of joints.

Stressed clamps rely on bolt tension to induce hoop stress around the member or joint to resist axial and bending loads in the structure. In many cases the clamp is made oversized to accommodate lack-of-fit tolerances and the annulus between the clamp and the structure is grout filled prior to bolt tensioning – the grout acts a load transfer medium. Unstressed grouted clamps can be applied to intact or damaged brace members to increase the axial and bending capacity of the member.

Structural clamp design requires control of bolt strength, bolt length, fatigue design, and detailing to avoid loss of pre-stress over the life of the repair. Tight fabrication tolerances are required to avoid fit-up problems during fabrication and installation procedures are essential to long-term performance.

— Underwater welding

Welding is often regarded as the best strengthening or repair technique and would be used even more often if it was not for certain operational difficulties in its execution. There are several underwater welding techniques that can be used:

— dry welding at or below sea surface at one atmosphere using a cofferdam or pressure-resisting chamber;

— hyperbaric welding using habitats;

— underwater wet welding.

Repairs by cofferdam and hyperbaric habitat welding techniques have proven track records and can produce high quality welded connections. The disadvantages to both are the high cost and extended schedules associated with cofferdam or habitat design, fabrication and deployment and the associated hazardous diving operations.

Wet welding is underwater welding, when the arc is operated in direct contact with the water. The principal advantage over conventional welding is the ability to weld below the water surface without the use of a welding habitat or chamber. Provided the weld is designed for low stress, fit-up can be assured, and the parent material is tested to confirm compatibility, wet welding can be a viable solution.

— Bolting

Bolts are an integral part of steel repair clamps, and are found in riser and other pipe supports throughout a platform. They are used for topsides repair where a bolted joint can be made in a hazardous area without having to shut down the platform operations.

Maintaining the long-term bolt tension is critical to a safe bolt design. Proof of the applied tension at the time of bolt installation is the normal standard for acceptance and is indicated by the pressure applied through hydraulic equipment. Sound engineering practice demands that the loss of bolt tension through load transfer and elastic relaxation is calculated. Additional long-term bolt tension losses can occur by creep in stressed grouted and elastomer-lined clamps.

There are physical limits placed on bolt sizing, spacing and group number when tensioning devices are used. In addition, corrosion of bolting materials has been a problem and material selection of bolts is evaluated.

— Member removal

Structural member removal can be a staged development in a larger repair scheme or can constitute a repair. In either event, the structural framework is assessed to confirm fitness-for-service under the proposed loading and revised framing configuration.

— Member flooding

Intentional flooding of structural members that are subjected to a combination of structural and hydrostatic loading can be used as a method for increasing the load carrying capacity of the member. However, the effect of the increased gravity actions and dynamic mass as well as possible decommissioning implications are evaluated before flooding members.

— Adhesives and epoxy grouts

Resins can be used as:

— adhesives;

— grout;

— matrix in composite materials.

— Cold forming

Two broad categories of cold forming techniques are available: mechanical connectors and swaging.

A swaged connection between two concentric tubular members is formed when the inner one is expanded (by internal pressure) and is plastically deformed into grooves machined in the other member. The technique has been used to make pile-sleeve connections.

Advantages of swaged or mechanical connectors, which can potentially be exploited in SMR applications, are that:

— connection can be made quickly;

— full strength is obtained immediately on installation;

— they are suitable for permanent or temporary SMR (some connectors are reusable);

— they can be installed by ROV.

A.9.8.3.3.6 Global strengthening or repair

— Leg-pile annulus grouting

Grouting of the annulus between the jacket legs and piles is a method used for increasing the global capacity of the structure. The grout causes the pile and jacket leg to act compositely. The effect can be pronounced on jackets that have skirt piles, as the increased leg stiffness will tend to take load from the skirt piles and move it to the jacket main piles.

Grouting of the annulus between the jacket legs and piles has the added benefit of locally strengthening the jacket joints for bracing loads. The grout, in effect, mobilizes the pile cross-section and forces the jacket leg and pile to act in composite behaviour against joint ovalization, thereby increasing joint capacity for compression and tension loads.

Installation can be difficult, if the area between the jacket leg and pile is not sealed. Additionally, grout nipples can be sealed to prevent leakage. However, effect of the increased gravity loads and dynamic mass as well as possible decommissioning implications are evaluated before grouting main piles.

— External bracing

Small platforms, particularly cantilevered wellhead caissons, may be globally strengthened by the addition of external bracing to additional piles. External braces may be attached to the structure using welded or clamped connections. This method can be extended for larger structures using additional external braces and piles, or sometimes by the installation of a new adjacent structure with its own piled foundation to brace the existing structure.

A.10 SIM Strategy

A.10.1 General

Two contrasting structural integrity strategies can be used as part of the SIM process:

— prescriptive approach based on consequences;

— risk-based approach based on likelihood of exceeding a limit state and associated consequences.

Each approach is valid under different circumstances, and the choice of strategy depends on:

a) statutory requirements;

b) operator's corporate policy;

c) characteristics of the operator's structures inventory;

d) engineering judgment;

e) scheduling flexibility, including:

   — intervals between periodic inspections;

   — promptness of post-event and post-incident inspections;

   — opportunities to align inspections on clustered platforms.

f) cost, capability and availability of equipment and services, including:

   — tools and specialized equipment;

   — personnel;

   — deployment of support vessels and equipment;

— seasonal weather windows.

g) regional differences, including:

— severity and frequency of storms;

— conditions for fatigue;

— seismicity levels;

— wind speeds and/or the presence of sea ice and icebergs.

h) reliability and applicability of inspection technique(s) (e.g. probability of detection and accuracy of sizing).

A.10.2 Inspection strategy

A.10.2.1 General

A.10.2.1.1 General

Development of an inspection strategy provides a basis for flexibility in extent and scheduling of periodic inspection program for a given structure. Standardization of work scopes, tools and techniques, and execution procedures can promote consistent quality and reporting and lead to efficiencies.

An inspection strategy accounts for the condition of the structure through evaluation of existing inspection data and trend analyses, together with strength and fatigue analysis results. The strategy is typically broad enough in scope to capture unpredictable anomalies (e.g. damage from dropped objects).

Purpose of in-service structural inspection is to determine, with a reasonable level of confidence, the existence and extent of deterioration, defects or damage. Data collected during an inspection is required to verify the structural integrity of the structure.

Two contrasting inspection strategies can be used as part of the structural integrity strategy, with approach being valid under the following different circumstances:

— A commitment to ongoing in-service inspection with the goal of reducing the possibility of major repairs (clamps, member replacements) in the future. This approach relies on early detection of damage and defects with prompt implementation of relatively inexpensive repairs and preventive measures. Early detection of defects typically requires greater use of NDE techniques.

— Minimization of in-service inspection scope where measures have been taken to reduce the risk of damage, defects or deterioration that would require major repair efforts in the future. This approach assumes that in-service inspection without the use of NDE techniques will be able to detect damage, defects or deterioration before structural integrity is threatened. This approach can be used for robust structures that are tolerant to damage and overload.

A.10.2.1.2 Damage tolerance

Each structure has an inherent reserve and/or residual strength, which is directly related to the ability of the structure to provide alternate load paths after failure of a member. This redundancy in the structural system (or robustness) is primarily associated with the arrangement of the braces within the system. A reduction of component capacity does not necessarily imply that the system strength cannot meet the assessment verification of limit state. This depends on whether the component is participating in the failure sequence that produces the system collapse mechanism, or whether the members' structural integrity is required to release the failure mechanism.

For a robust structure, damage can result in little immediate risk to the facility. For other less robust structures, even a small damage event can significantly degrade the global structural capacity resulting in a high-risk situation, justifying immediate response (e.g. demanning, shutdown, or emergency repair). Robustness is useful for inspection planning. Robust structures typically do not require as much inspection as other structures, since they are more damage tolerant. Information on platform robustness can be used to identify areas of a structure that are crucial in terms of secondary load paths. These regions should be the focus of inspections.

During the lifecycle of the structure, the operational costs and risk levels can be significantly influenced by the framing configuration adopted at the outset. For example, a minimally braced structure typically does not have alternative load paths to redistribute forces if a component is damaged or if applied loads are higher than initially anticipated. Consequently, loss of a single component can be critical to overall structural integrity – relatively intense inspection activity can be required to monitor the structural condition of critical load paths and there can be little scope to modify the platform for enhanced facilities at a later stage without adversely affecting safety levels. Conversely, a robust structure with alternative load paths can be more tolerant of damage or increased action effects, offering greater operational flexibility and reduced inspection activity to provide the same assurance of safety. Framing arrangements therefore directly affect the safety and economic performance through the lifecycle of jacket structures.

A.10.2.1.3 Appurtenances

Appurtenances include such items as the corrosion protection system, firewater caissons, export risers and conductors. Evidence from surveys or analytical studies on these components can suggest a different SIM strategy for the structure For example, in-service performance of a firewater caisson can reveal a fatigue weakness in the component that requires more frequent monitoring and necessitate a change in the SIM strategy for the structure(s).

A.10.2.1.4 Surveys

An effective SIM strategy makes use of the above water and below water survey findings. Damage to above water components can be an indicator of structural damage below water. In addition, the above water survey can be used to determine the effectiveness of the below water corrosion protection system.

A.10.2.1.5 Fatigue issues

With the growth of operating experience with time, it has become clear that the number of occurrences of fatigue cracks discovered in offshore structures is not as high as would be expected based upon analysis results. Projects looking at North Sea and US Gulf of Mexico experience have documented the results of over 3 200 underwater inspections. Results show that fatigue damage that exists is isolated to known susceptible details. The reason for the lack of correlation between the predicted and observed fatigue performance of offshore structures is the degree of conservatism in the conventional fatigue design procedure. This conservatism has served the industry well, allowing many structures to continue to operate safely well past their initial design service life.

Conventional fatigue design methods can under-predict the life of structures in comparison to the experience gained from inspections. Historically, this has meant that structures are more tolerant to damage, life extension and changes of use or reuse than could have been expected at the outset.

Fatigue damage results primarily from the oscillatory metocean loads due to waves that impact the platform and secondarily from crane and rotating equipment loads. Stresses resulting from wave loading and corresponding structural dynamic response are typically random and the metal fatigue strength in the structural members have random characteristics. Therefore, fatigue prediction in structures is a very complex task involving many factors:

- uncertainties associated with the statistical scatter in the metocean data (sea state description);
- uncertainties associated with the wave load prediction (wave theory, Morison's formulae);
- uncertainties associated with the nominal member load stress response prediction in the structural elements (finite element model description);

— uncertainties associated with the estimation of the hot spot stress concentration factors in the welded connections;

— uncertainties associated with the fabrication and assembly operations;

— uncertainties associated with the fatigue damage and crack growth models (i.e. Miner-Palmgren rule, Paris' law and *S-N* fatigue curves).

Therefore, during the design stage, to account for the uncertainties, some conservative choices are customarily made. The 'nominal' fatigue life is computed based on the 'design' *S-N* fatigue curves, which predict on the safe side the characteristic fatigue strength that are evaluated as the 'mean' strength based on laboratory tests minus 2 standard deviations.

Use of theoretical fatigue life in establishing the extent and frequency of joint inspection should account for the actual in-service performance of the surveyed member/joint connections, the effects of joint flexibility on fatigue life, and the influence of each connection on the overall platform safety. Historical inspection data indicates that joint fatigue is not a common occurrence in complex multi-planar connections of older platforms. However, fatigue can be more common in fixed platforms having stiffer joint connections.

A.10.2.2 Inspection motives

General motives of the inspection plan(s) include:

— identifying mechanical damage;

— identifying degradation or deterioration of the structure;

— identifying design uncertainties or errors;

— identifying areas of potential environmental or weight overload or CoG shift;

— identifying accidental events damage;

— monitoring of known defects or repair effectiveness;

— performing due diligence prior to change of ownership or operatorship;

— addressing statutory requirements;

— confirming platform condition prior to changing its use or reuse;

— confirming platform condition prior to decommissioning;

— operator's corporate policy;

— other industry or national standards and practices.

Table A.4 provides examples of inspection motives (root causes of the requirement for inspection).

Table A.4 — Examples of inspection motives

Motive	Description of limit state
Fabrication defects or installation damage	Weld defects (major and minor), material imperfections, dents, deformations
Degradation or deterioration	Corrosion, fatigue, scour, subsidence, seafloor instability
Design uncertainties or errors	Approximations (e.g. oceanographic and seismic data), analysis uncertainties (e.g. fatigue), under-design, marine growth build-up
Environmental overload	Storm, earthquake, mud slide, tsunami, ice
Accidental events	Vessel impact, dropped objects, explosion, abrasion, floating debris, riser damage from anchor drag on pipeline

Table A.4 *(continued)*

Motive	Description of limit state
Modifications from original purpose	Addition of personnel, topsides equipment, support framing, risers or conductors, structure life extension
Repairs	Clamps, wet welds, bolting, adhesives

A.10.2.3 Inspection type

A.10.2.3.1 General

Scheduled inspections are used to address the inspection motivations but allow for flexibility to modify the scope of work if unexpected damage or deterioration is detected. Unscheduled inspections are performed as soon as practicable following an incident or event. Table A.5 illustrates how the different inspection types address the various inspection motives.

Inspection strategy recognizes that the appearance of defects tends to follow a classic "bathtub" curve (i.e. clustered early in the service life, then a lull, followed by gradually increasing effects of deterioration). However, it can be difficult to determine where on the bathtub curve a structure is and how regional differences affect the curve.

Table A.5 — Function of inspection types

Inspection motive	Inspection type				
	Baseline	Periodic	Special	Post-event	Post-incident
Detection of degradation or deterioration	S	P			
Detection of fabrication defects or installation damage	P	S	S	S	
Detection of damage due to design uncertainties or errors	P	S	S	S	
Detection of damage due to environmental overload		S		P	
Detection of damage due to accidental event		S			P
Changes in function or in permanent actions due to modifications		P			
Monitoring of known defects or repair effectiveness		P			
Change of operatorship			P		
Reuse			P		
Decommissioning		P	P		
National or regional regulations	As required				
Key P: Primary purpose of inspection. S: Secondary purpose of inspection.					

A.10.2.3.2 Scheduled inspections

A.10.2.3.2.1 General

No guidance is offered.

A.10.2.3.2.2 Baseline inspection

Baseline inspections should be performed to determine the initial condition of the structure for use as a benchmark for items not included in fabrication and installation inspections, and to detect transportation or installation damage and early appearance of defects or deterioration.

A baseline inspection should be performed within one year of installation.

Where baseline inspection data is unavailable for development of the long-term inspection strategy, penalties (e.g. unnecessary scour protection or mitigation for a structure initially installed high) can occur. Consequently, the review, retention and transfer of baseline inspection and fabrication data should be performed.

To facilitate monitoring of structural condition trends, the baseline inspection establishes the following for subsequent periodic inspections:

— cathodic potential measurement stations;

— scour measurement stations;

— marine growth measurement stations.

A.10.2.3.2.3 Periodic inspection

Periodic inspections should be performed to provide information/data on the present condition by executing surveys with the objective of detecting deterioration, defects and degradation to the structural components. The inspection strategy should define the inspection interval and the inspection scope of work for periodic inspections, which can vary depending on the results of periodic evaluations.

Main mechanisms for degradation and deterioration are corrosion and fatigue. Corrosion is typically not a problem, provided the cathodic protection system is designed and maintained. Fatigue cracks can occur under cyclic actions (e.g. at points of stress concentration). Such cracks can be found using NDE methods or by using FMD (when cracks become through thickness and open for flooding to occur).

Improvements in quality through familiarity and efficiencies can be achieved when the periodic inspection strategy is developed for a group of structures together. When the group of structures has similar characteristics and inspection history, reduced scopes of work can be justified (compared to those required if the structures were addressed individually). The greatest benefit is realized when the inspection intervals and scopes of work are periodically reviewed and adjusted, based on the latest inspection findings for the group of structures, as well as general industry experience.

Periodic underwater inspections should be performed to detect, measure and record defects, deterioration or anomalies that affect the structural integrity. Deterioration can include corrosion to welds and members, weld/joint damage (including deformation due to overload and cracking due to fatigue damage), flooded members and mechanical damage in the form of dents, holes, bows and gouges. Anomalies can include non-operating or ineffective corrosion protection system, scour, seafloor instability, hazardous or detrimental debris, and marine growth.

Primary objectives of this document are to safeguard life and to protect the environment. The default inspection requirements are based on addressing these two objectives. However, the operator has the responsibility and prerogative to address economic and property interests in deciding whether additional inspection is required to achieve a desired level of structural reliability and risk management objectives. Such economic interests can include prevention of lost hydrocarbon production resulting from shutdown.

National standards and/or statutory requirements can specify more onerous inspection requirements, reflecting special national or regional interests or priorities for protecting human life and the environment, minimizing waste of natural resources, preventing general economic disruption, etc.

A.10.2.3.2.4 Special inspections

Special inspections may include performing the following:

— Monitoring inspections to verify the condition of known anomalies or damage (e.g. monitor growth of known cracks at primary or safety-critical secondary member end connections or confirming that damage that has been evaluated through the assessment process as not requiring a repair has not become more extensive through fatigue, corrosion, or another mechanism).

— SMR monitoring inspections to verify the condition of repairs to structural components and appurtenances (e.g. NDE of underwater wet welds, confirming the tightness of bolts in stressed ungrouted clamps, or inspection of swaging or mechanical connectors).

— Pre-engineering assessment inspections to provide condition/configuration information of the structure or critical structure prior to performing an engineering assessment.

— Pre-decommissioning inspections to provide condition/configuration information of the structure or critical structure prior to the structure decommissioning and assist in demonstrating that the structure is robust enough to sustain the loads imposed during removal.

— Pre-reuse inspections to provide condition/configuration information of the structure or critical structure prior to the structure reuse and assist in demonstrating that the structure is robust enough to sustain the loads imposed during removal and reinstallation.

Timing of special inspections can, subject to evaluation, be advanced or delayed to coincide with periodic inspection. A separate inspection program could be required to provide condition data on the platform structure or to allow designing and planning of repair/strengthening work to fit seasonal weather windows.

SMR monitoring inspections should be performed within one year of the repair, but may be performed during the next periodic inspection if the repairs are not critical for the structure's fitness-for-service.

Decommissioning and reuse special inspections are used to confirm the condition of the primary structural components and existing lifting points, cranes and other topsides structures and accommodation facilities and typically include:

— survey of the topsides and substructure to determine the condition of the lifting points and padeyes;

— survey to identify suspended debris;

— survey of the seabed surrounding the structure to determine extent of site clearance;

— condition of the cranes and accommodation facilities.

A.10.2.3.3 Unscheduled inspection

Post-event inspections are used to determine the extent of damage primarily through GVI. Missing members can be identified with adjacent components inspected for collateral damage. The extent of damage to connections is quantified using assessment methods. Where damage has occurred to a component, connections to that component and to successive components are inspected. Damage can sometimes be located by looking for isolated submerged areas of little or no marine growth, indicating possible overload.

Post-incident inspection focuses on areas local to the actual or possible impact location(s) (e.g. inspection of members in the path of a dropped object or areas above and below water in the vicinity of an impact). In the case of vessel impact, hidden damage can occur on the underside of members when a vessel is lifted by a wave or by swell.

Post-event inspection strategy should:

— establish a threshold for triggering inspection;

— define a nominal or default inspection scope of work (subject to modification, based on initial evaluation when an event occurs);

— specify a method for measuring or estimating the magnitude and severity of an environmental event, accounting for the required accuracy and speed of provision of the information.

These items should be addressed before commencement of operations and should be based on a SIM engineering evaluation.

Typical methods for estimating the magnitude or severity of an environmental event include:

— in general, from observations by personnel on the platform or on nearby platforms;

— for winds and waves, primarily from sensors or hindcast studies;

— for extreme crest elevation, local damage to handrails or other small members;

— for an earthquake, from accelerometers, reported Richter magnitude, and distance from epicentre to platform; and

— for current, from current meters.

Structure-specific event and incident thresholds and scopes of work should be established in advance (preferably during the design), to avoid unnecessary inspection and enable quick execution of the inspection activities. The inspection strategy should allow the flexibility to combine post-event and periodic inspection scopes of work and adjust the interval for the next periodic inspection.

A post-incident inspection strategy should include the following:

— prompt reporting of incidents - operators should establish protocols and notification procedures;

— early involvement of personnel to judge the potential significance of the incident and develop an inspection scope of work;

— consultation with personnel during offshore execution, review of findings, and assessment of requirement for repairs, mitigation, future monitoring, etc.

For L1 and L2 structures, incidents are usually noted and reported. However, for L3 structures, incidents are sometimes not noted or reported. This possible difference in reporting incidents can require differing strategies between L1, L2 and L3 structures (e.g. installation of sensors with automatic reporting or more frequent periodic inspections on L3 structures).

Inspection is more efficient and more likely to produce the data required for analysis if the SIM personnel are familiar with the structure and can integrate the post-incident work scope, schedule, and/or findings with other inspection activities for the structure or group of similar structures.

A.10.2.4 Inspection method

A.10.2.4.1 General

The inspection strategy accounts the range of inspection techniques, the methods of deployment and the purpose of each inspection. Table A.6 illustrates how the techniques can fulfil the requirement of the different types of inspection, while Table A.7 lists several inspection techniques and applicable deployment systems.

Table A.6 — Examples of inspection motives

Tool or technique	Inspection type				
	Baseline	Periodic	Special	Post-event	Post-incident
Air gap measurement	Initial	Trends	[b]	[a]	
Cathodic potential readings	Initial	Trends	[b]		
Sacrificial anode condition – visual	Existence check	Depletion check		Existence check	
Marine growth measurement		Anomaly detection	[b]		
Visual – without cleaning	Scour Damage Defects Debris	Scour Damage Defects Debris	[b]	Scour Damage Defects Debris	Damage
Flooded member detection (FMD)	Damage	Damage	[a,b]	Damage	Damage
Ultrasonic testing (UT)	[a]	[a]	[a,b]	[a]	[a]
Visual – with marine growth cleaning	[a]	Selected locations	[a,b]	[a]	[a]
Non-destructive examination (NDE)	[a]	Selected locations	[a, b]	[a]	[a]

[a] Used if warranted, based on evidence from inspection, analysis, etc.

[b] Use depends on what is being monitored: repair performance, known defects or damage, scour sensitive areas, local corrosion, high or low cathodic potential readings, subsidence, excessive marine growth, etc.

Table A.7 — Inspection technique capabilities and deployment methods

Inspection technique	Suitability	Possible deployment methods				
		Surface	Diving			ROV
			Air	Sat.	ADS	
Air gap measurement	Where air gap measurement devices are correctly set up, calibrated and maintained, continuous records of wave heights and tide can provide very useful information on environmental conditions. Where this can be combined with directionality data and ideally some method of estimating actions (e.g. strain gauges), the data can be used in analyses and assessment of defects and of remaining life, possibly reducing conservatisms. Satellite surveying techniques can often be used to determine levels.	X				
Marine growth recording	Marine growth comes in different forms, broadly divided into hard (generally animal, such as mussels and barnacles) and soft (seaweeds and kelps). Hard growth is generally thinner (less effective increase in member diameter), but rougher (increase in drag coefficient C_d) than soft growth. Marine growth measurements are notoriously unreliable, particularly for soft growth and for single estimates for large components. Marine growth varies with location and depth, see ISO 19901-1. Requirements for estimation of the length, type and extent of marine growth should depend on the structure's tolerance to the additional actions caused by the growth. Some structures have antifouling claddings that have performed reliably for more than 20 years.		X	X	X	X

Table A.7 *(continued)*

Inspection technique	Suitability	Possible deployment methods				
		Surface	Diving			ROV
			Air	Sat.	ADS	
Visual inspection without marine growth cleaning	Suitable for detection of gross damage (e.g. large deformations, severed connections, missing members), indirect signs of gross damage (e.g. gaps in or spalling of marine growth or surface coatings), and debris. When performed by ROV, visual acuity should be such that the 20/20 line can be read by the video camera system. Still camera, preferably digital, and stereo-photogrammetry provide the maximum detail and accuracy.	X	X	X	X	X
Visual inspection with marine growth cleaning	Generally used to follow-up damage identified without cleaning (e.g. corrosion, visible cracks, dents, gouges, abrasion, deformations) or targeted inspection of selected locations. Generally, extent of cleaning is limited to that required for inspection. When performed by ROV, visual acuity should be such that the 20/20 line can be read by the video camera system. Still camera, preferably digital, and stereo-photogrammetry provide the maximum detail and accuracy.	X	X	X	X	X
Dimensional measurements	Usually to measure marine growth thickness, scour depth at seafloor, dent size, out-of-straightness, crack length, corrosion pit size, etc. Generally undertaken by divers using tape measures or by ROVs using scale rules and cameras or photogrammetry.	N/A	X	X	X	X
Cathodic potential readings	Measures performance of cathodic protection system. Two types of probes are available (proximity probes and contact probes). Both require calibration in the field. Proximity probes enable readings to be taken quickly and efficiently. For efficiency, evaluation of cathodic potential can often be performed with visual inspection to determine anode wastage and its interdependency with potential measurements.	N/A	X	X	X	X
Flooded member detection (FMD)	Able to determine if member is flooded or not. Suitable for detecting existence of through thickness crack or other damage. Through wall damage on the leg side of connections where the leg is intentionally flooded or grout filled cannot be detected. Effectiveness depends on water depth, crack size and porosity of crack, i.e. what proportion of time is the crack open and how long it takes to flood. A crack open for only a few seconds in each storm can grow without the member flooding significantly, particularly for shallow members. Finding the cause of flooding requires further investigation with other inspection techniques. Procedure is relatively fast, particularly when undertaken by ROV. Procedure provides an excellent tool for rapid screening of structure members for gross damage.	N/A	X	X	X	X
	Ultrasonic technique (UT FMD) — relatively diver intense and requires accurate placing of the probes to achieve reliability. Can be used to determine the water level in members providing evidence for the cause of flooding.	N/A	X	X	X	
	Radiography (RT FMD) — Readily deployable, even from smaller ROVs. Allows for rapid coverage of many components. Source and detector mounted to U shaped frame to permit rapid and accurate placement.	N/A				X

Table A.7 *(continued)*

Inspection technique	Suitability	Possible deployment methods				
		Surface	Diving			ROV
			Air	Sat.	ADS	
Ultrasonic (UT) - compression wave	Used mainly for wall thickness measurements and lamination detection. The technique is straightforward and reliable for these applications. Usually performed by diver, although ROV capability exists.	X	X	X		X
Ultrasonic (UT) - shear wave, creeping wave, and time-of-flight-detection (TOFD)	Used for detecting internal volumetric indications as well as cracks and used to size indications found by other (surface) NDE techniques. Requires qualified UT inspector if performed remotely (e.g. if the probe is manipulated by divers, a qualified NDE inspector monitoring via a display screen highly improves reliability).	X	X	X		
Magnetic particle inspection (MPI) (also known as MT)	Used for detection of surface breaking defects. Surface cleaning or coating removal is normally required prior to MPI application. However, cleaning to bright metal is not always necessary underwater. Different types of MPI equipment are available including articulating yokes, permanent magnets, coils and prods. Articulating yokes are the fastest and most accurate.	X	X	X	X	
Alternating current potential drop (ACPD)	Generally used for sizing defects found by other NDE methods, multiple measurements are required along the crack length, spaced (typically 5 mm – 10 mm) in relation to the resolution required. Requires cleaning to bare metal and trained diver.		X	X	X	
Alternating current field measurement (ACFM)	Used to locate and size (length and depth) surface flaws. Cleaning to bright metal is not necessary, as it can operate through coatings. Training is necessary to avoid poor reliability. ACFM cannot find indications in certain geometries such as edges of gussets due to the edge effect produced from the geometry.		X	X	X	
Eddy current (also known as ET)	Used to locate and size (length) surface cracks. Cleaning to white metal is not necessary, can operate through coating. Can be used to inspect underwater welds. This requires a diver and an inspection technician above water to read the screen. Training is required.		X	X		
Radiographic inspection (RT)	Used for detecting internal defects. Not routinely used for underwater inspection of offshore structures due to health and safety concerns.	X	X	X		

Options for deployment of inspection tools and techniques are addressed in developing the inspection program. Available deployment systems include the following, where the indicative diving depths can vary with regionally applied industry criteria:

a) Surface use

Surface use inspection methods that are routinely used for performing above water inspections.

b) Air diving

Majority of inspection and NDE systems and tools are available in diver operable configurations. Trained divers have the adaptability and dexterity to perform complex tasks and make judgments with the benefit of tactile feedback and binocular vision normally denied to ROV operators. The weight and size of inspection systems are not a major issue, as divers can rig and trim buoyancy and support as required.

Most tools can be configured to operate at depth. Air divers can operate at up to 50 m (albeit that the working time decreases with depth due to decompression requirements) and have relatively simple support requirements. Surface supplied mixed gas can extend the dive depth. Diving is a hazardous occupation and divers can suffer long-term health decline. When operating in cold waters (e.g. North Sea), the complexity of the equipment increases, as hot water systems are required.

Limitations of divers are generally high cost (particularly with a diving support vessel) and limited operational duration due to diver fatigue.

c) Saturation diving

Similar to those for air diving, except that the divers stay at operating depth pressure for considerable times (up to 28 days), living in pressurized chambers except when working. Mixed-gas divers dive in the range of 16 m to 300 m (typically) and normally operate in saturation. The long-term health implications become greater and the options for assisting a diver in trouble are severely limited.

d) Atmospheric diving suit (ADS)

These "hard suit", one-person diving systems put a human on-site, but require the pilot to operate with manipulators. ADS can have two manipulators to deploy tools. Systems are normally designed for either bottom-oriented or mid-water working. Tool interfaces are designed or adapted to suit the manipulators. ADS is normally selected for installation, maintenance and drilling support rather than inspection programs. Its main limitation is that the manipulator cannot always work between members with small angles.

Advantages of ADS are rapid deployment to depth, operations to 750 m and avoidance of hyperbaric exposure to the operator (pilot) and, therefore, no long-term health implications. ADS is often air transportable and suitable for deployment from some platforms. However, there are a limited number of such systems available.

e) Remotely operated vehicle (ROV)

ROV avoids the human health and safety issues associated with having divers underwater. ROV can be used to assist divers by providing additional light and cameras, but such ROV should be small enough to avoid becoming a significant hazard to the divers. Operational duration is normally unlimited other than by maintenance requirements and ROVs can operate over the full depth range required for fixed platform inspections.

Dexterity and adaptability are limited in comparison with divers, while tools for specific tasks can often be developed prior to deployment.

The smallest ROV systems are helicopter-transportable, camera-only and camera/sonar/cathodic potential/digital- ultrasonic UT systems. Even these systems can be used to deploy radiological FMD equipment and other specialized systems subject to payload capacity. ROVs are preferred for radiological FMD as radiological protection precautions are simplified.

Larger vehicles can be equipped with tether management systems, subsea garages, manipulators, suction arms or grabs for stability at worksite, onboard hydraulic power units, marine growth removal and cleaning capabilities (high-pressure water jets, rotary wire brush). Larger ROVs can have difficulties moving within the confines of a structure and the experience of the pilot can be critical in such circumstances.

ROVs can have weld NDE (e.g. MPI) capability and remedial grinding capability.

A.10.2.4.2 General visual inspection (GVI)

A GVI does not normally require cleaning of the inspected area, nor does it require the inspector to be within arm's length of the structure (i.e. no rope access, scaffolding). The items selected for this type of inspection may be either viewed directly or using binoculars from a safe vantage point (i.e. from a walkway, access platform, boat).

A GVI should include the measurement of cathodic potentials of pre-selected locations using divers or ROV. Detection of significant structural damage during a GVI should become the basis for the initiation of a CVI or NDE inspection. The CVI or NDE inspection, if required, should be performed as soon as conditions permit.

A GVI can be performed underwater by a diver or ROV. This should consist of a single fly-by of area and does not normally require marine growth cleaning of the inspected area.

GVI can be specified to detect the following:

— deterioration due to corrosion on structural members or plating;

— areas of generalized pitting or local pits;

— rust staining from welds (can indicate weld failure on coated surfaces)

— deformation or fracture due to accidental or abnormal events;

— scour, seafloor instability, etc.;

— advanced fatigue cracking detectable in a visual swim-around;

— in-service damage (e.g. dents, holes, bows, cracks, abrasion, buckles or distortion in plates, beams, tubular members, stiffeners or brackets);

— areas of coating breakdown;

— debris lodged on structural members (or piled on decks) that could damage coatings or influence corrosion;

— compressed soft or hard marine growth;

— condition of appurtenances;

— anode deterioration;

— loose or otherwise damaged pipe clamps or other appurtenances;

— loose structural cladding or passive fire protection;

— areas of standing water on decks;

— damage to items that could affect safety (e.g. stairways, grating, ladders, doors/hatches);

— missing bolts;

— disturbed areas of marine growth.

A.10.2.4.3 Close visual inspection (CVI)

CVI should be directed at a well-defined location or part (e.g. a structural member, a welded or bolted joint) of the CS.

CVI should deliver an understanding of the condition of a structural component that was reported as anomalous during a GVI. Cleaning, possibly including grit blasting, can be required, depending on the intended purpose of the CVI.

Detection of significant structural damage during a CVI should become the basis for initiation of an NDE in those instances where visual inspection alone cannot determine the extent of damage. The NDE, if required, should be performed as soon as conditions permit.

Above water, CVI requires the structural component to be cleaned of adherent deposits, but damaging or removing coating should be avoided. Access should be provided that allows physical contact with the area in question (i.e. within arm's length). The use of rope access inspectors and remote viewing high definition camera systems can be used to view at height inspection points.

Underwater, CVI should consist of visual inspection of preselected locations and/or based on results of the GVI or areas of known or suspected damage. Underwater such locations should be cleaned of marine growth to permit inspection (e.g. closure welds for prefabricated or cast nodes). Pre-selected survey areas should be based on an engineering evaluation of areas susceptible to structural damage, or to areas where repeated inspections are required to monitor their condition over time. CVI of pre-selected locations for corrosion monitoring should be included.

CVI can detect the following:

— local damage;

— through thickness cracks;

— local coating failure;

— local corrosion;

— local pitting or grooving.

A.10.2.4.4 Flooded member detection (FMD)

FMD should be used to complement a GVI and/or CVI to detect through thickness cracks in the wall of members that would otherwise be dry. FMD works on the principle that air and water have different transmission characteristics that can be measured. FMD is primarily designed to detect in-service through-wall discontinuities such as fatigue cracks, corrosion holes and punctures.

Engineering judgment should be used to determine optimum use of FMD. If including FMD as part of an underwater inspection strategy the following limitations in the use of FMD should be included:

— legs or members that are flooded or grouted by design cannot be inspected using FMD;

— FMD does not provide information on the presence of cracks prior to their becoming through-wall. (i.e. insipient fatigue cracks cannot be found using FMD);

— FMD cannot provide information on the remaining ligament of a crack;

— unless there are connections between members, FMD only inspects the specific component being tested;

— FMD cannot detect punching shear or fatigue failure of the chord at the ends of the member being surveyed.

FMD can provide the operator with go/no-go information regarding the presence of water intrusion, but cannot provide information on a discontinuity existing prior to loss of through-wall integrity. FMD is a cost-effective method used to verify that a total member is devoid of through-wall discontinuities from a small sampled area. FMD could provide a baseline if used in the first initial periodic inspection, and could rule out unpredicted installation or design damage, e.g. anode core cracking or conductor bay frame cracking.

Primary methods used for FMD are ultrasonic (UT) and radiometric (RT). The strategy, principles, and surveying factors of FMD are similar regardless of the method. These FMD techniques are used in many underwater inspection programs to detect a flooded member and to determine the cause of flooding.

There are many commonalities between ultrasonic and radiometric FMD such as predicted flooding levels and determining the cause of flooding. However, the intervention strategy used will likely determine the FMD method used. In addition to UT and RT FMD, other methods such as tone burst UT, thermal systems, and other NDT systems may be available for detecting flooded members. Research has shown that the UT and RT systems described in the accompanying recommended practice have a high confidence level and reliability and are preferred for flooded member detection.

Information on FMD methods and the advantages and disadvantages of including FMD as part of an underwater inspection strategy are provided in Reference [43].

A.10.2.4.5 Non-destructive examination (NDE)

An NDE should consist of a survey of preselected locations and/or, based on the results of the CVI, areas of known or suspected damage. An NDE survey of fatigue-sensitive joints and/or locations known to be susceptible to cracking can be used to detect early stage fatigue cracking.

If crack indications are reported, they should be assessed. Suspected false alarms should be resolved by a second inspection using a different method, or by shallow surface grinding. Monitoring fatigue-sensitive joints, and/or reported crack-like indications, can be an acceptable alternative to analytical verification. If crack indications are reported, they should be assessed by a qualified engineer familiar with the structural integrity aspects of the platform(s).

Engineers specifying NDE should be knowledgeable of the different methods available and their relative merits and their probability of detection, and understand the intended purpose of the inspection and the level of information required from the NDE.

There are various NDE methods available used to inspect welds for indications of surface cracking. ACFM and eddy current inspection (ECI) are common methods enable inspection of welds with coatings and light surface film. For uncoated surfaces, light oxidation is acceptable, but scale should be removed. ACFM can be used above water and underwater. For underwater inspections, the surface should be clean of marine growth and scale.

In cases where ACFM or ECI identifies an indication of a crack, MPI may be warranted to confirm and fully characterize the anomaly. MPI can be used to detect cracks as well as provide a definitive description of the extent of cracks. MPI is more manually intensive than ACFM and ECI techniques and it requires clean bare metal. For coated structures, the paint should be removed at the suspect area. MPI can be used above water and underwater.

MPI, as with ACFM and ECI, can only detect surface cracks. MPI cannot provide information on the crack depth or continuation of the crack sub-surface. There are other techniques (e.g. shearwave ultrasonic testing) that can provide more information on the crack below the surface, but these can be difficult to use effectively, especially in marine environments where access can be difficult.

A.10.2.5 Inspection interval

A.10.2.5.1 General

Risk-based development enables tailoring the inspection strategy around the specific features of the structure, aligning the survey activities with the identified risks.

Risk can be used as a basis for developing an in-service inspection program. A risk-based approach allows an operator to prioritize and optimize the use of inspection resources. The risk-based strategy for the development of inspection scopes of work requires an understanding of a platform's susceptibility to damage, the tolerance of damage, and the known condition.

A.10.2.5.2 Periodic above water inspection

A.10.2.5.2.1 General

No guidance is offered.

A.10.2.5.2.2 Consequence-based inspection interval

Consequence-based requirements do not address underdesign or design errors, unless an assessment is performed and the assessment results are incorporated into an inspection strategy. The consequence-based inspection intervals assume the topside has been designed and constructed in conformance to ISO 19901-3[2] and there is no damage that would prevent it from achieving the tolerable risks.

A.10.2.5.2.3 Risk-based inspection interval

Concept of risk is central to setting topsides CS risk-based intervals. In summary, risk is defined as the product of likelihood and consequence of failure. In the set-up phase of the risk-based inspection methodology for each platform, a risk assessment is made of each topside structural system. This method is based on judgment regarding the likelihood of failure and the consequence of such a failure. It is used in the first instance to define the inspection plans for all structural items, but it can also be used as a screening tool to select elements for more detailed consideration, as and when more data is available.

Qualitative and/or quantitative risk techniques may be used to evaluate the CS level of risk in combination with the collated CS conditional data. The CS risk evaluation should be refined with time, as the quantity and quality of inspection data increases.

For some of the more critical areas with more available data, more complex methods of assessment can also be used to quantify the probability of failure. It is recognized that with time, as further analysis and inspection data becomes available, it can be necessary to apply more complex assessment methods to more of the structural systems.

Indicative inspection intervals that may be used for setting the above water CS are provided in Table A.8. The actual interval will depend on the magnitude and uncertainty of the risk, the method of inspection, statutory requirements, and the operator's policy on acceptable risk. The method of inspection (i.e. GVI, CVI and/or NDE) to be used with the risk-based interval should be selected based on the type of expected deterioration/degradation and the present known condition of the topsides CS.

Table A.8 — Above water CS — Indicative risk-based inspection intervals

Consequence	Inspection interval		
Possible life-safety incident	Annual	Annual	Annual
Possible high environmental pollution incident	1 to 3 years	1 to 2 years	Annual
Possible low environmental pollution incident	1 to 5 years	1 to 3 years	1 to 2 years
	Low	Medium	High
	Likelihood of failure		

Topsides CS inspection planning process can be divided into the following activities:

— identify major accident hazards;

— identify CS;

— define performance standards for the CS;

— identify degradation mechanisms for these elements;

— evaluate likelihood of failure for each element;

— evaluate consequence of failure for each element;

— evaluate risk rating and determine inspection intervals and technique;

— as inspection data becomes available, loop back to refine the evaluation.

Ideally, for each CS on the risk register an evaluation will be performed that accounts for the following:

— failure modes and degradation mechanisms;

— condition assessment;

— service history;

— industry experience;

— robustness and redundancy;

— basis of design;

— fatigue and strength analysis results.

Where the relevant information does not exist, or it is not practical to perform an individual review for each CS on the risk register, an evaluation of a similar 'generic system' can be performed to establish the 'typical' parameters for the purposes of performing a risk assessment and development of subsequent inspection regimes.

A.10.2.5.3 Periodic underwater inspection

A.10.2.5.3.1 Consequence-based inspection interval

Consequence-based requirements do not address underdesign or design errors, unless an assessment is performed and the assessment results incorporated into an inspection strategy. The consequence-based inspection intervals assume the structure has been designed and constructed in conformance to ISO 19902 and there is no damage that would prevent it from achieving the tolerable risks.

A.10.2.5.3.2 Risk-based inspection interval

Reasons for selecting a risk-based approach to inspection planning are:

— A systematic overview of the platform is achieved together with a breakdown of the platform's risks showing the risk drivers and risk mitigation actions.

— Inspection efforts are focused on items where the safety, environmental or financial risks are identified as high, and efforts applied to low-risk systems are reduced.

— Probabilistic methods can be used in projecting the rate and extent of degradations incorporating variations and uncertainties in controlling parameters.

— Consequences of failure are accounted for, so that inspection efforts are focused to where they can have the greatest effect. Uncertainties in the outcomes can be modelled by investigating the probabilities of the various outcomes using an event tree approach.

— Contributing to a pro-active and focused manner for demonstrating that the overall platform risk does not exceed the risk tolerance limit set by the authorities and/or operator.

— Identifying the optimal inspection or monitoring methods required to establish the deterioration and degradation mechanisms.

Where the operator has adopted a risk-based structural integrity strategy, the inspection intervals provided in Table A.9 should be used. he actual interval will depend on the magnitude and uncertainty of the risk, the method of inspection, statutory requirements, and the operator's policy on acceptable risk.

Table A.9 — Underwater — Risk-based inspection intervals

Exposure level	Inspection interval		
L1 structures	3 to 5 years	3 to 5 years	1 to 3 years
L2 structures	6 to 10 years	3 to 5 years	3 to 5 years
L3 structures	11 to 15 years	6 to 10 years	6 to 10 years
	Low $\leq 10^{-4}$	Medium $>10^{-4}$ and $\leq 4 \times 10^{-4}$	High $>4 \times 10^{-4}$

Table A.9 *(continued)*

Exposure level	Inspection interval
	Likelihood of failure / annum

Setting risk-based inspection intervals should be based on the susceptibility of the structure to the various damage mechanisms that could occur. For possible cracking induced by fatigue, the time interval to the next inspection can be estimated based on fracture mechanics and probabilistic analysis taking the uncertainty in the inspection method into account.

Figure 9-5 in DNV-GL RP C203:2014[18] illustrates the calculated accumulated probability of fatigue failure for uncertainty in *S-N* data corresponding to a standard deviation of 0,20 in log N scale. A normal distribution in logarithmic scale is assumed. The uncertainty in Miner summation is described as lognormal with median 1,0 and CoV of 30 %. Other uncertainties on load and response are assumed as normally distributed with CoV of 15 % to 20 %, and the hot spot stress derivation is assumed as normal distributed with CoV of 5 % to 10 %.

Uncertainties associated with fatigue life calculation imply that some in-service inspection for fatigue cracks is required during service life depending on consequence of a fatigue failure and calculated fatigue life. Figure 9-5 in DNV-GL RP C203:2014[18] provides a first estimate of time to a first inspection based on the lower graph in this figure, if normal uncertainties are associated with the fatigue life calculation. Figure 9-5 in DNV-GL RP C203:2014[18] is derived for a calculated fatigue life of 20 years. For other calculated fatigue lives (*Lcalc*), the numbers on the abscissa axis can be scaled by a factor $f = Lcalc/20$ for an estimate of time to first required inspection.

If a fatigue crack has no substantial consequences, an accumulated probability of 10^{-2} can be acceptable and inspection is not required during the first six years based on Figure 9-5 in DNV-GL RP C203: 2014[18]. If the consequence of a fatigue crack is substantial, the accumulated probability of a fatigue failure will be less than 10^{-4} and inspection will be required after two years based on Figure 9-5 in DNV-GL RP C203:2014[18] if the calculated fatigue life (*Lcalc*) is 20 years.

A.10.2.6 Inspection scope

A.10.2.6.1 General

No guidance is offered.

A.10.2.6.2 Baseline inspection scope

Minimum baseline above water scope should include:

— visual survey of structural members in the splash zone and above water;

— visual survey of topsides CS (i.e. critical areas such as deck legs, girders, trusses, crane support connections);

— visual survey of appurtenances and their supports (e.g. conductor guides and conductor guide frames);

— visual survey of personnel safety devices surveys and emergency escape routes;

— measurement of the deck elevation.

Minimum underwater baseline scope should include:

a) a visual inspection without marine growth cleaning that provides coverage of the structure (members and joints), conductors, risers, and various appurtenances, and which includes benchmarking the seafloor conditions at the legs/piles and inspecting for debris and damage;

b) a set of cathodic potential readings that provides coverage of the underwater structure (members and joints), conductors, risers, and various appurtenances;

c) visual confirmation of the existence of sacrificial anodes, electrodes, and other corrosion protection material/equipment;

d) measurement of the actual mean water surface elevation relative to the as-installed structure, with correction for tide and sea state conditions;

e) measurement of the as-installed conductor top elevation;

f) tilt and structure orientation;

g) riser and J-tube contact with the seafloor;

h) seafloor profile and scouring around the platform legs.

Scope of work for the baseline inspection should account for the type and extent of the inspection performed during the platform fabrication and installation.

A.10.2.6.3 Above water periodic inspection scope

Above water inspection scope of work should be tailored to the inspection motivations and should primarily focus on surveying the presence of damage, straightness, corrosion and modifications to CS.

Above water periodic inspection scope of work should include one or more of the following:

— visual survey of structural members in the splash zone and above water;

— visual survey of topsides CS (i.e. critical areas such as deck legs, girders, trusses, crane support connections);

— visual survey to detect deteriorating coating systems, excessive corrosion, and bent, missing, or damaged members;

— below-water verification of performance of the cathodic protection system (i.e. dropped cell), if this is not included in the underwater inspection scope;

— visual survey to capture the condition secondary/tertiary structures, such as walkways (handrails, grating) and their supports, lifeboat davit connections, and blast walls;

— visual survey of appurtenances and their supports (e.g., conductor guides and conductor guide frames);

— visual survey of personnel safety devices surveys and emergency escape routes;

— measurement of the deck elevation;

— CVI of selected critical welds/joints;

— damage survey.

CVI and/or NDE should be specified in the above water scope of work to be used when visual inspection cannot fully determine the extent of damage.

Purpose of the above water periodic inspection is to detect or verify the following:

— indications of overloading, deteriorating coating systems, corrosion, and bent, missing, or damaged members of the structure in the splash zone and above water;

— damage or deterioration to appurtenances and personnel safety, escape and evacuation devices.

A.10.2.6.4 Underwater periodic inspection scope

Underwater inspection scopes of work should be developed using a risk-based approach. However, in-lieu of adopting a risk-based underwater inspection strategy, the operator may adopt a consequence-based (default) inspection scope of work.

In the absence of a risk-based underwater inspection strategy, periodic underwater inspections should be performed using the scope of work in conformance to Table A.10. The consequence-based inspection scopes of work only address the concerns of safeguarding human life and protecting the environment. The consequence-based requirements do not address underdesign or design errors, unless an assessment is performed (see Clause 12) and the assessment results are incorporated into the inspection strategy.

Table A.10 — Underwater consequence-based inspection scope of work

Method	Scope of work
GVI	— Visual inspection of the above water parts of the structure. — Cathodic potential readings of at least one structure leg using a drop cell or other suitable equipment. — A general visual survey of the full structure that includes members, joints, appurtenances, and appurtenance connections. — Marine growth measurements on selected members at a representative set of elevations from mean sea level to the seafloor. — For structures with sacrificial anodes: an estimate of the approximate depletion of the anodes, original or retrofit, located on the structure. — For structures with impressed current systems: a visual survey of the state of the anodes and reference electrodes. Dielectric shields should be inspected to conform that they are undamaged, free from discontinuities, and satisfactorily bonded to the structure.

CVI	— CVI smaller of:
	    — at least 20 primary member end connections;
	    — 5 % of the total population of primary member end connections, including a minimum of five primary brace to leg connections.
	— CVI critical support members (e.g. riser and/or caisson supports).
	— In lieu of CVI, FMD of the following components may be used:
	    — at least 50 % of primary structural members selected as representative of the full structure and covering potentially damage/fatigue prone areas (e.g. conductor guide framing in the upper structural bays);
	    — support members for risers, J-tubes, conductors (first underwater framing level only), service caissons and other appurtenances.
	— Periodic NDE inspection may be substituted for CVI

NDE	— Marine growth cleaning (as required) and detailed inspection of representative welds at nodal joints (member end connections) and other critical locations as determined from the inspection program. — Inspection of 100 % of each weld length.

Objective of the periodic inspection is to detect degradation that can reduce the reserve capacity of the structure in the interval between inspections. Industry experience shows that general visual survey techniques are adequate for conventional multi-leg fixed steel platforms that are inspected within the risk-based intervals. The general visual approach should be used to confirm that the platform has not suffered gross structural damage (e.g. heavily deformed or missing structural elements). The general visual strategy should include surveys to confirm that the CP system is operating effectively, the extent of corrosion, the extent of marine growth and, in pre-disposed regions, the extent of scour or seafloor instability.

Structures that are not suitable for the general visual approach can include those susceptible to fatigue damage and/or are not robust to safely tolerate minor damage. In this case, the inspection strategy should detect the existence of such minor damage through close visual surveys concurrent with suitable NDE techniques.

In some cases, FMD can provide an alternative to close-visual surveys (e.g. conductor guide frame and appurtenance connections that are known fatigue sensitive connections). Reliance on more widespread use of FMD in lieu of close visual surveys can be of questionable value for some structures (e.g. those having single diagonal bracing framing into the legs or structures with members intentionally flooded). In the former, fatigue cracks that occur, often do so on the chord (leg) side of the connection. In-service experience shows these members usually do not flood the brace even after severance of the brace and will test as dry by FMD.

Main mechanisms for degradation and deterioration in offshore jackets are corrosion and accidental damage. Industry experience indicates that, for multi-planar joints in multi-leg jackets, in-service (actual) fatigue cracking is not well predicted by analytical techniques. Fatigue cracking has occurred in older jackets mainly due to plated horizontal conductor bays, but can occur in platforms due to fabrication defects, installation damage, and at improperly designed appurtenance connections (e.g. caissons, sumps, J-tubes). As such, fatigue-based probabilistic methods can provide an additional means to determine the inspection frequency and the location of weld inspection requirements, but can be very conservative in predicting cracks at end connections of primary members in newer structures.

Subsea corrosion is typically not a problem, provided the cathodic protection system is well designed and maintained. Splash zone corrosion is very common as paint or other protective coatings wear over time and/or are damaged or abraded.

Possible fatigue cracking at joints in the first horizontal conductor framing below water is normally attributed to not including the vertical wave load and plating in the conductor ladder in design. It is also possible that the conductor guides frame elevation is closer to the water surface. This could be due to lack of penetration of the mud mats at installation or subsequent seabed subsidence, which could result in the theoretical fatigue lives calculated in design being unconservative.

A.10.2.6.5 Special inspection scope

Special inspection scope should consist of a GVI, CVI and/or NDE survey, tailored to the inspection motives.

A.10.2.6.6 Unscheduled inspection scope

Unscheduled inspection should be performed to establish the extent of damage, and mitigation measures (e.g. demanning, repairs and/or strengthening) required.

Typical scope for an unscheduled inspection should include a visual inspection without marine growth cleaning that provides full coverage from seafloor to top of the structure (members and joints), conductors, risers, and various appurtenances, and which includes checking the seabed conditions at the legs/piles and looking for debris and damage.

Underwater inspection should focus on detecting damage and indirect signs of damage (e.g. areas of missing marine growth). When an unscheduled inspection is performed following an actual or possible dropped object, the location of the dropped object and its route of falling should be identified.

Above water inspection should be targeted based on the evaluation of the event. Inspection can include surveying the deck/leg/hull connections and looking for tie-down failures, debris or damage.

A.10.2.7 Pre-selected inspection areas

Effectiveness of each survey is dependent on the selection of enough inspection locations to provide representative condition data on the overall structure.

Topsides elements selected for inspection can be based on:

— criticality of member or joint;

— effect on global structural integrity;

— consequence of failure;

— degree of redundancy;

— stress state complexity;

— strength level;

— degree of plastic straining;

— exposure to fatigue loading;

— service temperature.

Topsides components, which are commonly pre-selected for inspection, include:

— main deck girders;

— transitions to substructures;

— transition frames for concrete gravity base structures;

— module trusses and support units;

— accommodation module;

— drilling rigs;

— bridges;

— flare booms and vent stacks;

— cranes;

— helidecks;

— lifeboats and other evacuation, escape and rescue equipment;

— laydown areas;

— hull-deck connections;

— changes to equipment weights and support location points and deck load;

— riser guards.

While fatigue has not been a common problem for primary structural members in US Gulf of Mexico platforms, fatigue damage and subsequent structural member failures have occurred in the upper conductor guide framing of some older platforms. This damage can occur, if conductor framing is plated which increases the vertical wave loading area. Conductor guides located at (-) 12 m or shallower, are particularly susceptible, although cracking has been seen in water depths up to (-) 43 m. This type of fatigue damage is identified by fatigue cracks at the twelve o'clock and/or six o'clock positions of the members supporting the conductor tray and is not typically identified by standard structural strength or fatigue analysis. Specific inspection of these areas should be performed for platforms with this type of conductor framing. FMD can be useful in locating this type of damage.

A.10.3 Maintenance strategy

No guidance is offered.

A.10.4 Monitoring strategy

A.10.4.1 General

No guidance is offered.

A.10.4.2 Weight and centre of gravity (CoG) monitoring

The partial action factors provided in ISO 19902:2007, Clause 9 are intended to cover variations in the intensity of direct actions from the specified representative values and as far as appropriate the uncertainties in predicting internal forces. To reduce the uncertainties in the weights used in SIM assessment models, the weight databases should have:

— topsides permanent and variable weight, with drilling modules and in-line drilling equipment included;

— no significant permanent and variable weight or CoG errors or omissions;

— no consistent non-conservatisms in the weight estimate of the items;

— no consistent conservatism in the weight estimate of the items (for brownfield project viability).

Weight control process involves data gathering from many sources, including discipline weight input from the main contractor, the drilling contractor, the accommodation contractor and equipment vendors. Generally, one individual does not have the time, background or skills to single-handedly manage the whole process. Usually, a team with the requisite skills and background is needed to effectively implement weight control. The engineer (or group of engineers) involved in the process should be:

— familiar with weight control principles and procedures;

— knowledgeable about multi-discipline weights;

— knowledgeable about CAD extractions and downloads;

— familiar with drilling techniques and loads;

— familiar with laydown and storage requirements;

— familiar with equipment and module weighing requirements;

— familiar with weight control requirements of offshore structural engineers.

A.10.4.3 Deck elevation monitoring

Long term wave radar measurements are one technique for determining the sea level elevation.

A.10.4.4 Natural frequency monitoring

On-line monitoring has the advantage of providing a continuous evaluation on the structural integrity and can complement onsite inspection. The technique is based on the principle that in low redundancy structures, the annual probability of failure is dominated by a few critical members. The significant effect of critical members on structural strength implies that their failure would have a significant effect on structural stiffness and hence a structure's response to periodic actions (i.e. wave actions). The loss of critical members can be detected by an on-line monitoring scheme. This will enable targeted assessment at damage as soon as it occurs and reduces the time to repair and therefore minimizes the damage caused to adjacent members due to load redistribution.

When deploying a structural monitoring system, the following should be accounted for:

— inspection strategy motivations;

— evaluation of jacket member severance detection using a structural analysis of the platform, which confirms that the changes to natural frequency and mode shape following a member severance, can be measured;

— performance of an evaluation of jacket structural integrity following the element failure;

— baseline measurements of as-built platform response to determine the baseline structural response.

Incorporation of online monitoring into SIM has many potential advantages. For topsides, this methodology can be effective depending on the design configuration and ability to identify and monitor the critical responses.

Structural integrity of fixed offshore jackets can be inferred from measurements of its structural response characteristics. Measurements can identify and quantify the natural frequencies and associated mode shapes of the fundamental normal modes of the structure (i.e. at least two orthogonal sway modes and one torsion mode).

Response characteristics can be monitored on a continuous basis or by repeat measurements at regular intervals. Changes in the response characteristics over time can indicate a degradation of structural integrity as such changes arise from the following:

— severance (or severe cracking in low redundancy jackets) of a jacket member;

— reduction in foundation stiffness (e.g. due to scour);

— changes in the mass or distribution of mass on the platform deck.

Response of a structure can be measured using sensors that respond to dynamic force or motions, most commonly accelerometers or strain gauges. The signals can be recorded and stored by a computer for data analysis and processing. In setting-up the monitoring device, account should be given to noise performance, synchronization and calibration of the signals. The sample rate at which signals are converted to digital format should be set to allow the frequencies are captured. Sound practice is required for avoidance of aliasing and interference pick-up. Since wave action on the jacket is normally the dominant loading source, it is worth recording wave height data in conjunction with the response data. This provides a further benefit in that platform subsidence can be detected, along with deck displacement per unit wave.

Information on structural monitoring can be found in References [32] and [42].

A.10.4.5 Corrosion protection monitoring

No guidance is offered.

A.10.4.6 Metocean monitoring

No guidance is offered.

A.10.5 Evacuation strategy

An evacuation strategy establishes procedures to temporarily relocate personnel from a manned platform to an adjacent platform or to onshore ahead of an event that is predictable (i.e. a typhoon or hurricane event, an impact from a passing vessel, a metocean sea state).

A platform can have an evacuation strategy, if the following requirements are met:

— A reliable forecast of the pre-determined metocean threshold being exceeded is technically and operationally feasible, and the weather between forecast and the occurrence of the metocean threshold is not likely to inhibit an evacuation.

— Procedures are in place for obtaining forecasts and effecting evacuation prior to the exceedance of the pre-determined metocean threshold, and these procedures are included in the platform operations manual.

— Following the forecast of the exceedance of the pre-determined metocean threshold, time and resources exist to evacuate personnel from the platform and adjacent structures that can be affected by the failure of the platform that accounts for the other demands on those resources (e.g. the evacuation of other manned platforms in the area).

In determining the length of time required for evacuation, it is typical to account for:

— distances involved;

— number of personnel;

— capacity and operating limitations of the evacuating equipment;

— type and size of docking/landings, refuelling, egress facilities on the platform;

— metocean conditions anticipated to occur throughout the evacuation effort.

A.10.6 Marine site investigations

No guidance is offered.

A.11 SIM Program

A.11.1 General

SIM program is the execution of the monitoring, inspection and maintenance measures developed from the structural integrity strategy. Subsea intervention is typically reactive only, in response to an inspection finding that can require strengthening of the platform. Regular planned maintenance subsea is not normally required due to low corrosion rates.

A.11.2 Inspection program

A.11.2.1 General

The inspection program contains two main elements: its specification and its execution. The qualifications required for the elements are different, but complementary.

Engineers should:

— provide advice during development of work scope and schedule;

— establish specifications for inspection tasks; and

— establish procedures for quality assurance, quality control, and data validation.

UK CSWIP is an example of a comprehensive scheme for the examination and certification of individuals to demonstrate their knowledge and competence. The CSWIP[16] underwater inspection committee has representatives from offshore operators, diving contractors, classification societies, and academia. The scheme covers both underwater and topsides inspection personnel. The categories of certification for underwater inspection are as follows:

a) grade 3.1U Underwater (diver) inspector (visual, cathodic protection, and ultrasonic);

b) grade 3.2U Underwater (diver) inspector (as 3.1U plus MPI, weld toe grinding);

c) grade 3.3U ROV inspector;

d) grade 3.4U Underwater inspection controller.

EN 473[23] provides another example of qualification levels for those responsible for offshore inspections and for NDE inspectors.

A.11.2.2 Specifications

In conjunction with the inspection plan, it is good practice to provide additional detailed field guidance for each survey. The additional field guidance can consist of detailed inspection work packs or checklists that identify each of the individual inspection locations, the inspection methods and provide a means to document the observations. The field guidance should include details on required access, cleaning, and equipment required to successfully execute each inspection within the survey. The detailed field guidance efficiently conveys the operator's expectations to the inspection team, where and how to inspect, and provides a consistent means to document inspection observations.

A.11.2.3 Inspection method

A.11.2.3.1 General

No guidance is offered.

A.11.2.3.2 General visual inspection (GVI)

Main objective of the GVI is to confirm that the member/component is present and to inspect for defects, deformation or damage. GVI requires no prior marine growth cleaning or paint removal of the component and is usually performed as a first step in an inspection program. GVI is usually performed from the best available access without requiring staging or rope access for hands-on inspections.

Inspection requirements for the splash zone (sea-level up to the module support frame) are typically covered in the topsides inspection strategy. Although the inspection techniques available for this area are different from the subsea inspection techniques, the general process to arrive at inspection requirements for structural elements is the same as that for subsea structural elements.

Structural failure modes and degradation mechanisms for members in the splash zone, and which can require focused inspection, include:

— impact damage from ships, debris and dropped objects;

— paint system breakdown and corrosion;

— fatigue failure of jacket members and appurtenances due to exposure to wave loading;

— protective devices (e.g. riser guards);

— condition of riser and caisson supports;

— escape to sea arrangements.

Structures are usually designed with a corrosion allowance in the splash zone. A coating applied during the fabrication of the structure delays using up the corrosion allowance. When the coating starts to break down, the structure in the splash zone should be monitored and the corrosion rate should be determined. This helps determining risk and estimating when a repair to this area should be developed and executed.

A.11.2.3.3 Coating survey (including passive fire protection)

No guidance is offered.

A.11.2.3.4 Survey of underwater cathodic protection

No guidance is offered.

A.11.2.3.5 Appurtenance and personnel safety devices surveys

A.11.2.3.5.1 Conductor visual survey

The conductors should be inspected for coating condition, deterioration of the conductor guide, wear on the conductor wall, extent of corrosion, damage, presence of shims, movement, and operational status (i.e. flowing, shut-in, temporarily abandon, or permanently abandon).

A.11.2.3.5.2 Riser survey

The risers should be inspected for breakdown of coating, the extent of corrosion, the condition of supporting steelwork and clamps, and operational status (i.e. live or out-of-service).

As well as riser guides, the dead weight support and guide connection to main structure should be included in the inspection. Guides could require 'opening' to determine the condition of the riser wall beneath the guide.

A.11.2.3.5.3 Pipeline flange isolation

The purpose of this inspection is to assess the condition of pipeline flange insulation kits to determine if the pipeline riser is electrically isolated from the structure. In general, the survey should be accomplished by taking measurements (e.g. resistance) on either side of an actual or potential isolation barrier. Identical measurements indicate electric continuity whereas different measurements indicate isolation.

A.11.2.3.5.4 Attachment tie-down points

A survey to assess the vulnerability of personnel safety equipment and tie-down points installed to mitigate damage from shock loading and strong vibration induced from extreme or abnormal metocean or seismic events or accidental loadings should be performed.

Attachment tie-down surveys are primarily a visual inspection and may be performed to coincide with the routine topsides inspection. The support can be permanent or temporary and the data should be recorded to allow engineering personnel to evaluate the ability of the tie-down to resist lateral loads.

A.11.2.3.5.5 Escape routes

During the above water inspection, a visual survey of the personnel escape routes should be performed.

Escape routes consist of open decks, walkways, stairs, and landings. The routes should be established and surveyed to confirm clear access to the escape routes is provided from locations on the structure. Swing ropes and connections should be examined for signs of damage or deterioration.

A.11.2.3.6 Air gap survey

No guidance is offered.

A.11.2.3.7 Close visual weld/joint survey

No guidance is offered.

A.11.2.3.8 Damage survey

No guidance is offered.

A.11.2.3.9 Supplemental surveys

No guidance is offered.

A.11.3 Maintenance program

No guidance is offered.

A.11.4 Monitoring program

No guidance is offered.

A.12 Assessment

A.12.1 General

Assessment is generic and forms one part of the SIM process and involves:

— gathering the known facts about a structure's configuration, condition and loading;

— analysing the structure using proven techniques;

— comparing analysis results with the evidence from survey of the structure;

— correlating and refining analysis and survey.

This information can be used to make an engineering judgment on structural integrity and fitness-for-service. As the definition implies, assessment is concerned with real situations as opposed to the process of new design, which is concerned with future unbuilt facilities.

A.12.2 Assessment information

Hazard curves and actions should be based on the latest industry methods (e.g. WiDA should be based on latest industry approaches for estimating the annual exceedance probability of crest height).

Quality of structural assessments is determined by the quality of the data available, see Clause 8 and A.8 for lists of data expected to be included and maintained in the SIM system.

Desired assessment data is contingent on the system of interest (e.g. substructure, topsides structure, bridge) and the assessment type (i.e. simplified assessment, risk assessment, or system analysis). However, regardless of the system or assessment type, design, condition and operational data are required to accurately represent, compare, assess or analyze the specific system.

Missing or limited data can prevent certain types of assessments from being performed or require the collection of additional information, generated via engineering studies or analysis prior to or during the assessment.

Lack of data can increase uncertainty in the evaluation, assessments and analyses. In these cases, the operator should supplement missing or lost data. This can entail performing additional inspections, collecting current information (e.g. monitoring, weight or operations data) or in some cases performing additional engineering studies to develop information to account for the missing or lost data (see 8.7).

Additional above water and underwater information can be required other than that recorded during a platform inspection. Local soils information can be required if the platform was designed using offsite or general area soils data.

If original design data or as-built drawings are not available, assessment data can be obtained by field measurements of dimensions and sizes of structural members and appurtenances. The thickness of tubular members can be determined by ultrasonic procedures for members except the piles. If the wall thickness and penetration of the piles cannot be determined and the foundation is a critical element in assessing the fitness-for-service of the structure, it is not always possible to perform an assessment. In this case, it can be necessary to downgrade the use of the structure to a lower consequence of failure category by reducing the risk or to demonstrate fitness-for-service by prior exposure.

Additional above water data collection can benefit from interaction with the offshore operations personnel. The offshore personnel are often able to fill in information gaps and provide background on potential observed discrepancies.

Additional information on geotechnical information that could be required in structure assessment is provided in ISO 19901-8[4] and ISO 19901-4.

A.12.3 Assessment method

A.12.3.1 General

Assessment can be performed in consecutive order of increasing complexity which results in decreasing levels of conservatism, with the simple methods being the most conservative and the USM and reliability methods being the least conservative. If a structure does not achieve the limit state verification using simple methods, the structure should be assessed using the DLM. Similarly, if the structure does not achieve the limit state using a DLM, USM should be used. Conversely, should a structure achieve the limit state using simple methods, no further assessment is required, and similarly for the other levels. In most cases, it is not necessary to initiate the structural assessment process at the lowest level assessment method.

Based upon experience, it can be evident that the structure will not achieve the limit state, using a more conservative DLM and a USM should be performed from the onset. For example, the operator should start the process with USM when the structure cannot achieve the limit state using other more conservative approaches.

A flowchart that can be used in the selection of the assessment method is provided in Figure A.6.

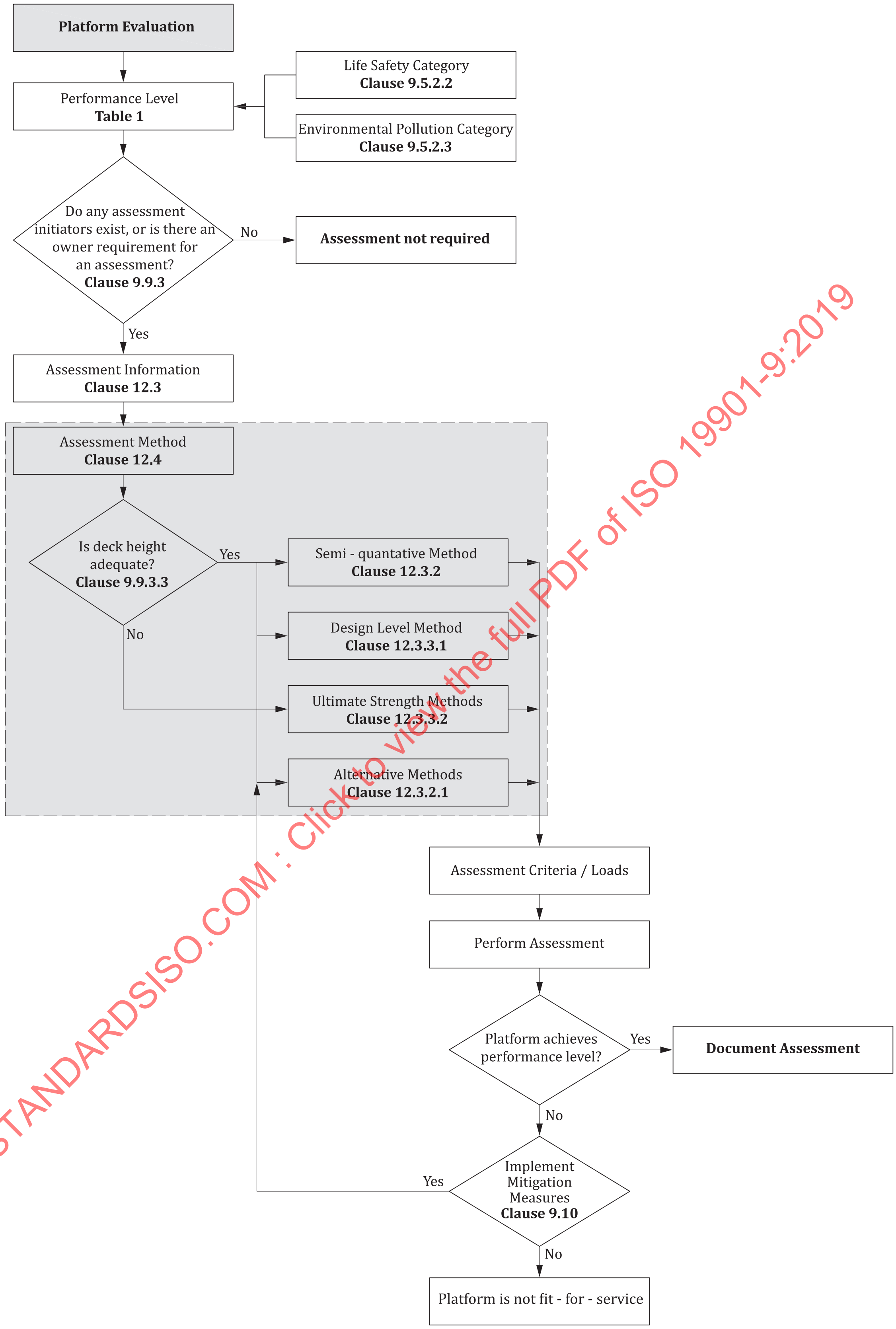


Figure A.6 — Assessment method selection

A.12.3.2 Qualitative method

No guidance is offered.

A.12.3.3 Semi-quantitative methods

A.12.3.3.1 General

No guidance is offered.

A.12.3.3.2 Simplified procedure

No guidance is offered.

A.12.3.3.3 Previous assessment

No guidance is offered.

A.12.3.3.4 Prior exposure

The procedure is to determine from measurements or a calibrated hindcast, the expected maximum base shear that the structure has been exposed to and confirm it exceeds the base shear required to achieve the limit state.

Margin depends on the uncertainty of the wave actions during the prior exposure, the uncertainty in structure ultimate strength, and the degree to which the structure's weakest direction was tested by the exposure actions. Sources of uncertainty (i.e. natural variability and modelling uncertainty) are incorporated. The margin can be substantiated by calculations to show that it achieves the limit state. Analogous procedures may be used to assess existing structures based on prior exposure to seismic or ice loading.

Prior exposure is useful for relatively short return period hazardous events for L3 exposure level structures, governed by financial risk.

Hurricanes Ivan (2004), Katrina (2005), Rita (2005) and Ike (2008) exposed thousands of US Gulf of Mexico platforms to extreme hurricane conditions. Many of these structures experienced metocean conditions close to, or larger than API RP 2A-WSD[9] 22nd edition, 100-year conditions. Some waves in the central region reached 23 m to 27 m (75 ft to 90 ft) in height and in some instances higher, due to Ivan and Katrina. This provides an opportunity to use prior exposure, otherwise known as "proof-testing," to assess the structure. Prior exposure means that the platform was subjected to and survived, without significant damage, metocean conditions greater than or equal to the assessment limit state.

When performing an assessment by prior exposure, account of the specific metocean conditions during the storm event, typically determined through a hindcast study, and how these compare to the assessment limit state, should be performed. Directionality of the waves, winds, and currents and how these align with each of the structure's primary strength directions should be addressed. For example, if a structure experienced an action in one of the orthogonal directions, this does not mean that the structure has been fully "proof tested" via prior exposure. The direction of action should have aligned with the weakest of a structure's strength directions. Also, currents and winds should be accounted for in the prior exposure assessment.

In summary, prior exposure can be a useful method for assessments, if performed in a manner that uses the specific actions on the structure during an extreme/abnormal event as well as the characteristics of the structure's strength, including orientation.

A.12.3.3.5 Similarity

Results from a DLM or USM assessment of a specific platform can be used to infer the fitness-for-service of other similar structures, provided their framing, foundation support, service history, structural condition and actions are not significantly different from the analyzed structure. The following criteria can be used to verify that two structures are “similar” for assessment purposes:

— no more than 25 km between the two structures;

— located in the same water depth;

— environmental and seismic conditions at the site of the assessed structure are not more severe than those at the location of the structure that has been assessed;

— topsides arrangements of the two structures are similar and the topsides weights on the assessed structure are not greater than those on the structure that has been assessed;

— structures are of the same configuration (i.e. same number of legs and same bracing pattern);

— foundation arrangements are the same (i.e. same number and diameter of piles with similar pile penetration);

— assessed structure has not suffered accidental damage;

— materials and welding strengths and ductility on the assessed structure are greater than or equal to those on the structure that has been assessed;

— component dimensions (diameters, thicknesses and lengths) on the assessed structure are equal to those on the structure that has been assessed, except that thicknesses can be greater on the assessed structure;

— soil conditions at the location of the assessed structure are no less competent than those at the location of the structure that has been assessed;

— ages of the structures are within 5 years.

A.12.3.4 Quantitative methods

A.12.3.4.1 General

No guidance is offered.

A.12.3.4.2 Design level method (DLM)

DLM metocean criteria provided in ISO 19902 were calibrated for structures that did not have wave loading on their decks. It is therefore unconservative to consider wave loading on decks in a DLM, and a USM is required instead.

It is generally more efficient to begin with a DLM, since it is usually simpler to implement than the USM. There can be an existing computer model that was used for design of upgrades or other modifications that can be readily updated for assessment.

If ongoing research is being used to determine the strength of members, the research results should be carefully evaluated to assure applicability to the type of member and the actual in-situ condition, its level of stress, and the level of confidence in the results. For example, the use of smaller values for effective length (K) factors might be appropriate for members developing large end moments and high levels of stress, but might not be appropriate for lower levels of stress.

Because of steel availability during construction and possibly other non-structural reasons, tubular members can have steel with yield stress higher than the specified minimum. If no such data exist, coupon tensile tests can be used to determine the actual yield stress. Joint industry studies have indicated that higher yield stresses can be justified statistically. However, this should be justified on a case-by-case basis for a structure or for a fleet of structures with similar fabrication histories. The use of indentation tests to determine yield strength is not acceptable due to the large scatter in correlation with yield strength from coupon tests.