Risk-Based Structural Integrity Management of Offshore Jacket Structures

Guidance Note

April 2017

NI 624 DT R00 E

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Marine & Offshore
92571 Neuilly sur Seine Cedex – France
Tel: + 33 (0)1 55 24 70 00 – Fax: + 33 (0)1 55 24 70 25
Website: http://www.veristar.com
Email: veristarinfo@bureauveritas.com

Bureau Veritas Marine & Offshore General Conditions

1. INDEPENDENCY OF THE SOCIETY AND APPLICABLE TERMS

1.1 The Society shall remain at all times an independent contractor and neither the Society nor any of its officers, employees, servants, agents or subcontractors shall be or act as an employee, servant or agent of any other party hereto in the performance of the Services.

1.2 The operations of the Society in providing its Services are exclusively conducted by way of random inspections and do not, in any circumstances, involve monitoring or exhaustive verification.

1.3 The Society acts as a services provider. This cannot be construed as an obligation bearing on the Society to obtain a result or as a warranty. The Society is not and may not be considered as an underwriter, broker in Unit's sale or chartering, expert in Unit's valuation, consulting engineer, controller, naval architect, manufacturer, shipbuilder, repair or conversion yard, charterer or shipowner; none of them above listed being relieved of any of their expressed or implied obligations as a result of the interventions of the Society.

1.4 The Services are carried out by the Society according to the applicable Rules and to the Bureau Veritas' Code of Ethics. The Society only is qualified to apply and interpret its Rules.

1.5 The Client acknowledges the latest versions of the Conditions and of the applicable Rules applying to the Services' performance.

1.6 Unless an express written agreement is made between the Parties on the applicable Rules, the applicable Rules shall be the rules applicable at the time of the Services' performance and contract's execution.

1.7 The Services' performance is solely based on the Conditions. No other terms shall apply whether express or implied.

2. DEFINITIONS

2.1 "Certificate(s)" means class certificates, attestations and reports following the Society's intervention. The Certificates are an appraisement given by the Society to the Client, at a certain date, following surveys by its surveyors on the level of compliance of the Unit to the Society's Rules or to the documents of reference for the Services provided. They cannot be construed as an implied or express warranty of safety, fitness for the purpose, seaworthiness of the Unit or of its value for sale, insurance or chartering.

2.2 "Certification" means the activity of certification in application of national and international regulations or standards, in particular by delegation from different governments that can result in the issuance of a certificate.

2.3 "Classification" means the classification of a Unit that can result or not in the issuance of a class certificate with reference to the Rules.

2.4 "Client" means the Party and/or its representative requesting the Services.

2.5 "Conditions" means the terms and conditions set out in the present document.

2.6 "Industry Practice" means International Maritime and/or Offshore industry practices.

2.7 "Intellectual Property" means all patents, rights to inventions, utility models, copyright and related rights, trade marks, logos, service marks, trade dress, business and domain names, rights in trade dress or get-up, rights in goodwill or to sue for passing off, unfair competition rights, rights in designs, rights in computer software, database rights, topography rights, moral rights, rights in confidential information (including know-how and trade secrets), methods and protocols for Services, and any other intellectual property rights, in each case whether capable of registration, registered or unregistered and including all applications for and renewals, reversions or extensions of such rights, and all similar or equivalent rights or forms of protection in any part of the world.

2.8 "Parties" means the Society and Client together.

2.9 "Party" means the Society or the Client.

2.10 "Register" means the register published annually by the Society.

2.11 "Rules" means the Society's classification rules, guidance notes and other documents. The Rules, procedures and instructions of the Society take into account at the date of their preparation the state of currently available and proven technical minimum requirements but are not a standard or a code of construction neither a guide for maintenance, a safety handbook or a guide of professional practices, all of which are assumed to be known in detail and carefully followed at all times by the Client.

2.12 "Services" means the services set out in clauses 2.2 and 2.3 but also other services related to Classification and Certification such as, but not limited to: ship and company safety management certification, ship and port security certification, training activities, all activities and duties incidental thereto such as documentation on any supporting means, software, instrumentation, measurements, tests and trials on board.

2.13 "Society" means the classification society **'Bureau Veritas Marine & Offshore SAS'**, a company organized and existing under the laws of France, registered in Nanterre under the number 821 131 844, or any other legal entity of Bureau Veritas Group as may be specified in the relevant contract, and whose main activities are Classification and Certification of ships or offshore units.

2.14 "Unit" means any ship or vessel or offshore unit or structure of any type or part of it or system whether linked to shore, river bed or sea bed or not, whether operated or located at sea or in inland waters or partly on land, including submarines, hovercrafts, drilling rigs, offshore installations of any type and of any purpose, their related and ancillary equipment, subsea or not, such as well head and pipelines, mooring legs and mooring points or otherwise as decided by the Society.

3. SCOPE AND PERFORMANCE

3.1 The Society shall perform the Services according to the applicable national and international standards and Industry Practice and always on the assumption that the Client is aware of such standards and Industry Practice.

3.2 Subject to the Services performance and always by reference to the Rules, the Society shall:

- review the construction arrangements of the Unit as shown on the documents provided by the Client;
- conduct the Unit surveys at the place of the Unit construction;
- class the Unit and enters the Unit's class in the Society's Register;
- survey the Unit periodically in service to note that the requirements for the maintenance of class are met. The Client shall inform the Society without delay of any circumstances which may cause any changes on the conducted surveys or Services.

The Society will not:

- declare the acceptance or commissioning of a Unit, nor its construction in conformity with its design, such activities remaining under the exclusive responsibility of the Unit's owner or builder;
- engage in any work relating to the design, construction, production or repair checks, neither in the operation of the Unit or the Unit's trade, neither in any advisory services, and cannot be held liable on those accounts.

4. RESERVATION CLAUSE

4.1 The Client shall always: (i) maintain the Unit in good condition after surveys; (ii) present the Unit after surveys; (iii) present the Unit for surveys; and (iv) inform the Society in due course of any circumstances that may affect the given appraisement of the Unit or cause to modify the scope of the Services.

4.2 Certificates referring to the Society's Rules are only valid if issued by the Society.

4.3 The Society has entire control over the Certificates issued and may at any time withdraw a Certificate at its entire discretion including, but not limited to, in the following situations: where the Client fails to comply in due time with instructions of the Society or where the Client fails to pay in accordance with clause 6.2 hereunder.

5. ACCESS AND SAFETY

5.1 The Client shall give to the Society all access and information necessary for the efficient performance of the requested Services. The Client shall be the sole responsible for the conditions of presentation of the Unit for tests, trials and surveys and the conditions under which tests and trials are carried out. Any information, drawings, etc. required for the performance of the Services must be made available in due time.

5.2 The Client shall notify the Society of any relevant safety issue and shall take all necessary safety-related measures to ensure a safe work environment for the Society or any of its officers, employees, servants, agents or subcontractors and shall comply with all applicable safety regulations.

6. PAYMENT OF INVOICES

6.1 The provision of the Services by the Society, whether complete or not, involve, for the part carried out, the payment of fees thirty (30) days upon issuance of the invoice.

6.2 Without prejudice to any other rights hereunder, in case of Client's payment default, the Society shall be entitled to charge, in addition to the amount not properly paid, interests equal to twelve (12) months LIBOR plus two (2) per cent as of due date calculated on the number of days such payment is delinquent. The Society shall also have the right to withhold certificates and other documents and/or to suspend or revoke the validity of certificates.

6.3 In case of dispute on the invoice amount, the undisputed portion of the invoice shall be paid and an explanation on the dispute shall accompany payment so that action can be taken to solve the dispute.

7. LIABILITY

7.1 The Society bears no liability for consequential loss. For the purpose of this clause consequential loss shall include, without limitation:

- Indirect or consequential loss;
- Any loss and/or deferral of production, loss of product, loss of use, loss of bargain, loss of revenue, loss of profit or anticipated profit, loss of business and business interruption, in each case whether direct or indirect.

The Client shall save, indemnify, defend and hold harmless the Society from the Client's own consequential loss regardless of cause.

7.2 In any case, the Society's maximum liability towards the Client is limited to one hundred and fifty per-cents (150%) of the price paid by the Client to the Society for the performance of the Services. This limit applies regardless of fault by the Society, including breach of contract, breach of warranty, tort, strict liability, breach of statute.

7.3 All claims shall be presented to the Society in writing within three (3) months of the Services' performance or (if later) the date when the events which are relied on were first discovered by the Client. Any claim not so presented as defined above shall be deemed waived and absolutely time barred.

8. INDEMNITY CLAUSE

8.1 The Client agrees to release, indemnify and hold harmless the Society from and against any and all claims, demands, lawsuits or actions for damages, including legal fees, for harm or loss to persons and/or property tangible, intangible or otherwise which may be brought against the Society, incidental to, arising out of or in connection with the performance of the Services except for those claims caused solely and completely by the negligence of the Society, its officers, employees, servants, agents or subcontractors.

9. TERMINATION

9.1 The Parties shall have the right to terminate the Services (and the relevant contract) for convenience after giving the other Party thirty (30) days' written notice, and without prejudice to clause 6 above.

9.2 In such a case, the class granted to the concerned Unit and the previously issued certificates shall remain valid until the date of effect of the termination notice issued, subject to compliance with clause 4.1 and 6 above.

10. FORCE MAJEURE

10.1 Neither Party shall be responsible for any failure to fulfil any term or provision of the Conditions if and to the extent that fulfilment has been delayed or temporarily prevented by a force majeure occurrence without the fault or negligence of the Party affected and which, by the exercise of reasonable diligence, the said Party is unable to provide against.

10.2 For the purpose of this clause, force majeure shall mean any circumstance not being within a Party's reasonable control including, but not limited to: acts of God, natural disasters, epidemics or pandemics, wars, terrorist attacks, riots, sabotages, impositions of sanctions, embargoes, nuclear, chemical or biological contaminations, laws or action taken by a government or public authority, quotas or prohibition, expropriations, destructions of the worksite, explosions, fires, accidents, any labour or trade disputes, strikes or lockouts

11. CONFIDENTIALITY

11.1 The documents and data provided to or prepared by the Society in performing the Services, and the information made available to the Society, are treated as confidential except where the information:

- is already known by the receiving Party from another source and is properly and lawfully in the possession of the receiving Party prior to the date that it is disclosed;
- is already in possession of the public or has entered the public domain, otherwise than through a breach of this obligation;
- is acquired independently from a third party that has the right to disseminate such information;
- is required to be disclosed under applicable law or by a governmental order, decree, regulation or rule or by a stock exchange authority (provided that the receiving Party shall make all reasonable efforts to give prompt written notice to the disclosing Party prior to such disclosure.

11.2 The Society and the Client shall use the confidential information exclusively within the framework of their activity underlying these Conditions.

11.3 Confidential information shall only be provided to third parties with the prior written consent of the other Party. However, such prior consent shall not be required when the Society provides the confidential information to a subsidiary.

11.4 The Society shall have the right to disclose the confidential information if required to do so under regulations of the International Association of Classifications Societies (IACS) or any statutory obligations.

12. INTELLECTUAL PROPERTY

12.1 Each Party exclusively owns all rights to its Intellectual Property created before or after the commencement date of the Conditions and whether or not associated with any contract between the Parties.

12.2 The Intellectual Property developed for the performance of the Services including, but not limited to drawings, calculations, and reports shall remain exclusive property of the Society.

13. ASSIGNMENT

13.1 The contract resulting from to these Conditions cannot be assigned or transferred by any means by a Party to a third party without the prior written consent of the other Party.

13.2 The Society shall however have the right to assign or transfer by any means the said contract to a subsidiary of the Bureau Veritas Group.

14. SEVERABILITY

14.1 Invalidity of one or more provisions does not affect the remaining provisions.

14.2 Definitions herein take precedence over other definitions which may appear in other documents issued by the Society.

14.3 In case of doubt as to the interpretation of the Conditions, the English text shall prevail.

15. GOVERNING LAW AND DISPUTE RESOLUTION

15.1 The Conditions shall be construed and governed by the laws of England and Wales.

15.2 The Society and the Client shall make every effort to settle any dispute amicably and in good faith by way of negotiation within thirty (30) days from the date of receipt by either one of the Parties of a written notice of such a dispute.

15.3 Failing that, the dispute shall finally be settled by arbitration under the LCIA rules, which rules are deemed to be incorporated by reference into this clause. The number of arbitrators shall be three (3). The place of arbitration shall be London (UK).

16. PROFESSIONNAL ETHICS

16.1 Each Party shall conduct all activities in compliance with all laws, statutes, rules, and regulations applicable to such Party including but not limited to: child labour, forced labour, collective bargaining, discrimination, abuse, working hours and minimum wages, anti-bribery, anti-corruption. Each of the Parties warrants that neither it, nor its affiliates, has made or will make, with respect to the matters provided for hereunder, any offer, payment, gift or authorization of the payment of any money directly or indirectly, to or for the use or benefit of any official or employee of the government, political party, official, or candidate.

16.2 In addition, the Client shall act consistently with the Society's Code of Ethics of Bureau Veritas. http://www.bureauveritas.com/home/about-us/ethics+and+compliance/

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Section 1 General

Section 2 Risk-based Structural Integrity Management of Offshore Jacket Platforms

Section 3 Service Provision

Appendix 1 Typical Platform's Data

SECTION 1 GENERAL

1 General

1.1 Context

1.1.1 The API-RP-2SIM has emphasized the value of using risk-based approach to develop effective inspection strategy and program. It provides general guidelines to assign a risk category to a platform and details on the inspection strategy derived from the risk results. It sets out, also, the main factors to consider in assessing platforms' risks when owner/operators decide to adopt specific risk categorization e.g. detail risk assessment techniques or complex risk matrices.

The Society contributed to the joint industry project for the development of the API-RP-2SIM. It has produced risk-based structural integrity methodologies for offshore jacket platforms based on API recommendations. It has, also, developed a fatigue-based probabilistic method to determine inspection frequency of tubular welds with higher likelihoods of fatigue failure.

1.2 Scope of the document

1.2.1 This Guidance Note sets out the main recommendations and requirements of the API-RP-2SIM for implementing a risk-based structural integrity management for offshore jacket platforms. It includes, also, relevant guidance from other international standards and from reference reports and papers.

The Society service offer is also presented. It includes methods which apply, respectively, to a fleet of platforms, a platform unit and the structural components. It implements all types of risk assessment from qualitative to fully quantitative.

1.3 Overview of API guidance

1.3.1 The API-RP-2SIM includes guidance for risk-based approach to structural integrity management of offshore jacket platforms. It provides general guidelines for assigning a risk category to the platforms in terms of the exposure category and the likelihood of failure. The exposure category is defined with respect to life safety exposure and consequence of failure including the environmental and the economic impact. A description of the relevant factors to consider for determining the life safety exposure category and the level of consequence of failure is also given. The standard allows qualitative, semiquantitative, or fully quantitative methods to be used in assessing the level of likelihood of failure. However no detail is given on how to implement those methods. Only general guidelines are defined for the assessment of the likelihood of failure category.

The risk-based inspection strategy is specifically concerned with the routine underwater inspections. However, it requires that a baseline inspection was conducted and it should use the findings from the above-water inspections and the eventual post-event inspections. The API-RP-2SIM gives detailed recommendations for determining inspection strategy from the risk categorization, including risk-based inspection intervals and work scope, survey techniques and deployment methods. Typical ranges of risk-based inspection intervals are provided with respect to the platform risk level along with a description of the inspection scope of work. The associated risk-based inspection program has to be a minimum level II survey, according to the API classification of survey levels, but has to specify if higher survey levels (e.g. level III and IV) are required.

When risk-based approach is not adopted, API provides a default inspection program including pre-defined in-service inspection intervals and survey levels based on the exposure category only.

The recommended practice provides, in addition, general guidelines on risk reduction options when a jacket platform is deemed as no longer fit-for-purpose.

1.4 Overview of the Society's methods

1.4.1 The Society has developed three methods for risk assessment and inspection plan development as part of the risk-based structural integrity management of offshore jacket platforms, namely:

- a high level risk-based SIM method
- a risk-based SIM method for a jacket platform
- and a fatigue-based probabilistic method.

1.4.2 The high level method applies to a fleet of jacket platforms and uses a qualitative risk assessment method. It allows a risk category to be assigned to each platform of a fleet and inspection intervals and general inspection requirements to be developed based on the API guidance and the inspection trends. The risk assessment method serves as a mean to provide relative risk ranking of the platforms in a fleet, in order to identify the platforms most at risk and which require more inspection focus or a detailed risk analysis. It can also serve as a mean to compare given inspection strategies in order to identify the best one with respect to the risk impact or to another specific decision criteria adopted by owner/operators.

1.4.3 The risk-based SIM method for a jacket platform provides a global risk assessment which allows inspection interval and inspection requirements based on API guidance to be defined. It provides also local risk ranking of the platform's structural components, which allows, if required, the local inspections' scope of work to be defined. The global risk assessment allows using of the qualitative approach of the high level method or structural analysis results (e.g. reserve strength ratio) to develop inspection planning. The local risk ranking uses a semi-quantitative approach based on the results from in-place analysis and fatigue analysis. The method should be applied, following the high level method, on the platforms the most at risk and which require a more detailed risk analysis.

1.4.4 The fatigue-based probabilistic method uses a full probabilistic approach to develop inspection planning for a platform's welded joints subject to fatigue. It requires a fatigue analysis and several ultimate strength analyses to be carried out. The fatigue analysis allows the welded joints with higher likelihood of fatigue failure to be identified. The ultimate strength analyses include a pushover analysis of the structure in its intact condition and pushover analyses of the structure in damage condition assuming a fatigue failure on the identified higher-fatigue welded joints taken separately. Structural reliability methods are used to compute the probabilities. The probabilities of fatigue failure of the selected welded joints and the probabilities of collapse failure of the associated damaged structures are computed. Those probabilities are then combined to derive the probability of collapse failure of the platform. The optimal inspection plan is given by the one that minimizes the expected operational cost, including inspection and maintenance cost and failure cost. This method suits the jacket platforms for which the welded joints that are critical for the structural integrity (e.g. end connections of primary members) are reported to have higher likelihood of fatigue failure.

1.5 Organization of the document

1.5.1 In addition to the current introductive section, this Guidance Note includes two sections. The first one addresses the key elements the risk-based SIM of offshore jacket structures according to the API-RP-2SIM supplemented with relevant guidelines from other international standards and reference reports and papers. The second one presents the Society service provision, including the high level SIM method, the SIM method for one jacket platform and the fatigue-based probabilistic method.

2 References

2.1

2.1.1

a) API-RP-2SIM, Structural Integrity Management of Fixed Offshore Structures, 1st ed., Washington: API Publishing Services, 2014.

b) API-RP-2A-WSD, Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms-Working Stress Design, 22nd ed., Washington: API Publishing Services, 2014.

c) API-RP-2A-WSD, Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms-Working Stress Design, 21st ed., Washington: API Publishing Services, 2000.

d) API-RP-580, Risk-Based Inspection Technology, 2nd ed., Washington: API Publishing Services, 2009.

e) API-RP-581, Risk-Based Inspection Technology, 2nd ed., Washington: API Publishing Services, 2008.

f) API-581-BRD, Base Ressource Document - Risk-Based Inspection Technology, 2nd ed., Washington: API Publishing Services, 2000.

g) ISO 19902:2007, Petroleum and natural gas industries - Fixed steel offshore structures, ISO, Ed., Geneva: ISO, 2007.

h) ISO 19901-9, Structural integrity management Offshore structures, ISO, under preparation.

i) MSL, "Rationalization and Optimization of Underwater Inspection Planning consistent with API-RP-2A section 14": JIP Final Report, 2000.

j) Atkins, "Development of Guidance on Structural Integrity Management of Fixed Offshore Structures": JIP Final Report, 2011.

k) Nelson A., Technical Performance Measures for North Sea Jacket Structures, HSE Research report, 2003.

l) DeFranco S., O'Connor P., Tallin A., Roy R. and Puskar F., Development of a Risk Based Underwater Inspection (RBUI) Process for Prioritizing Inspections of Larger Numbers of Platforms, OTC 10846, 1999.

m) Turner J. W., Wisch D. J. and Guynes S. J., A Review of Operations and Mitigation Methods for Offshore Platforms, OTC 7486, 1994.

n) Faber, M. H,. Risk-based inspection: The framework. Structural engineering international, 12(3), 186-195, 2002.

o) Goyet J., Boutillier V. and Rouhan A., Risk-based Inspection for Offshore Structures, Ships and Offshore Structures, 8 (3-4), 303-318, 2013.

3 Acronyms

3.1

3.1.1

ACFM	:	Alternating Current Field Measurement
ACPD	:	Alternative Current Potential Drop
API	:	American Petroleum Institute
CoF	:	Consequence of failure
CP	:	Cathodic Protection
CVI	:	Close Visual Inspection
ECD	:	Eddy Current Detection
ETA	:	Event Tree Analysis
FEM	:	Finite Element Model
FFP	:	Fitness-For-Purpose
FMD	:	Flooded Member Detection
FORM	:	First Order Reliability Method
FTA	:	Fault Tree Analysis
GPS	:	Global Positioning System
GVI	:	General Visual Inspection
HAZID	:	HAZard IDentification
JIP	:	Joint Industry Project
LAT	:	Lowest Astronomical Tide

LoF : Likelihood of Failure
MPI : Magnetic Particle Inspection
NDT : Non Destructive Testing
PA : Phase Array
PLL : Potential Loss of Life
POB : Personnel On Board
PoD : Probability of Detection
PoF : Probability of Failure
QRA : Quantitative Risk Assessment
RAC : Risk Acceptance Criteria
RAO : Response Amplitude Operator
RBI : Risk-Based Inspection
ROC : Receiver Operating Curve
ROV : Remote Operating Vehicle
RP : Recommended Practice
RSR : Reserve Strength Ratio
RT : Radiographic Technique
SCF : Stress Concentration Factor
SIM : Structural Integrity Management
SMR : Strengthening Modification and Repair
TOFD : Time of Flight Diffraction.

SECTION 2 RISK-BASED STRUCTURAL INTEGRITY MANAGEMENT OF OFFSHORE JACKET PLATFORMS

1 Introduction

1.1 General

1.1.1 Risk-based SIM uses risk analysis to develop SIM strategy, including inspection strategy and risk reduction measures, with respect to the actual risk level.

1.2 Inspection plan

1.2.1 The overall inspection plan for offshore jacket structures includes the following types of inspections:

- routine above-water inspections to evaluate the condition of the platform topsides and which should be conducted on an annual basis
- a baseline underwater inspection to determine the as-installed condition of the platform
- routine underwater inspections to evaluate the condition of the underwater portion of the platform and appurtenances
- and special or post-event inspections to determine the condition of the platform after events such as extreme metocean event or collision.

Among them, only the routine underwater inspections can be driven by the platform risk level. However, implementing risk-based routine underwater inspections requires that a baseline inspection was conducted and should take into consideration data from the other inspections types e.g. above-water inspections and post-event inspections.

A risk-based routine underwater inspection provides:

- an inspection interval or a next inspection date consistent with the platform risk level
- the inspection coverage
- the inspection techniques to be used
- and the expected residual level of risk after inspection or the mitigation actions.

In particular, inspection coverage can specify the critical structural details from a risk point of view and which have to be inspected or a percentage of structural details to be inspected in order to provide representative condition data on the overall structure.

1.3 Risk reduction

1.3.1 Whenever the estimated risk level for the platform is higher than an acceptable limit, modifications on the platform should be considered to reduce this risk level. Two categories of risk reduction measures can be carried out:

- Exposure mitigation e.g. reduction of hydrocarbon inventory, reduction of the manning level
- Likelihood reduction e.g. deck load reduction, global or local strengthening.

1.4 Benefits of risk-based approach for SIM

1.4.1 Risk-based approaches allow owners/operators to develop inspection strategies which prioritized the structural items the most at risk. This results in:

- an overall reduction in risk
- a cost optimization as the approach aims at providing an effective inspection plan
- an effective data collection as data need not be collected for all the structural items but higher priority should be given to those more at risk. Thus, more effort can be spent on those structural items, which allows more accurate information to be collected
- and an understanding and acceptance of current risk as the approach is based on the assessment of the current condition of the structure under study.

1.5 Issues for jacket offshore structure

1.5.1 The implementation of a risk-based approach for the SIM of jacket offshore structures raises some specific issues, described in the following sections.

1.5.2 Availability of the platform's data

Some useful data (e.g. fabrication and installation data, baseline inspection records or other previous inspection records) may not be available, especially for ageing platforms. This is mostly because those records don't exist or because the operator is not aware of what data he has, where those data are being kept and who is in charge of data management.

There are two main ways to deal with missing data:

- The first and recommended option is to consider survey to collect the necessary information. This option is more expensive but it will provide accurate data on the platform condition and allow for an accurate risk level assessment.

- The second one is to perform the risk analysis using appropriate conservative assumptions where the information is missing. This option is simple but could result in a rough risk assessment.

1.5.3 Accuracy of the risk assessment

Platform collapse failures are rare events. Therefore, there are little data to develop comprehensive collapse failure statistics of jacket platforms like other items such as machinery or equipment.

In an attempt to compute the risk level accurately, model-based quantitative methods are used. However, these methods usually require more data and more computational effort. Moreover, care should be taken in formulating the model of the damage mechanism and in selecting the probabilistic distributions that represent the uncertainties involved. It is usually recommended that a knowledgeable person be involved in implementing such methods.

Most often a relative risk ranking approach is used. It consists in assessing the risk level based on experience with other structures taken as a benchmark. In this case, detailed quantitative assessment is not necessary, but simply assigning scores to the structural items with respect to relevant factors that influence the risk level can be well enough. The scoring process can be carried out in a systematic way with a dedicated mathematic formulation or by gathering experts' opinion through dedicated workshops or meetings. Even if this relative risk ranking does not allow the ideal inspection strategy to be determined, it shows on what structural items the risk management effort should focus: the higher ranked ones.

1.5.4 Relationship between risk level and inspection frequency

There is no objective means to link the results of a relative risk ranking assessment to an inspection plan, especially to an inspection frequency, as the risk values are not absolute. In this case, risk-based inspection strategies rely on:

- standards' requirements or recommendations, which gather the good practices of the dedicated industry
- and experts' opinion, who could provide inspection strategies all the more suitable as their level of expertise is higher.

However, relative ranking can allow different inspection strategies to be compared, by simply measuring their respective risk impacts, in order to find the best one. In this case, the ability of the risk ranking process to properly compare inspection strategies should be validated first.

1.6 Risk-based SIM framework

1.6.1 The overall SIM process consists of four primary elements: DATA, EVALUATION, STRATEGY and PROGRAM (see Fig 1):

- DATA relates to the implementation of a data management system for collecting, compiling and updating the platforms' data.
- EVALUATION aims at assessing the impact that new platforms' data have on the structural integrity and leads to carry out risk categorization and structural analysis for the assessment of fitness-for-purpose and to consider risk reduction actions when the estimated risk level is higher than an acceptable limit.
- STRATEGY relates to the development and the implementation of inspection strategy and possibly risk reduction actions from the results of the evaluation step.
- PROGRAM refers to the execution of the inspection and the possible risk reduction scope of work, including the requirements for the recording and the reporting of the inspection findings.

The SIM process provides the opportunity for owners/operators to adopt risk principles to develop in-service inspection strategy according to the framework depicted in Fig 2.

Figure 1 : SIM process

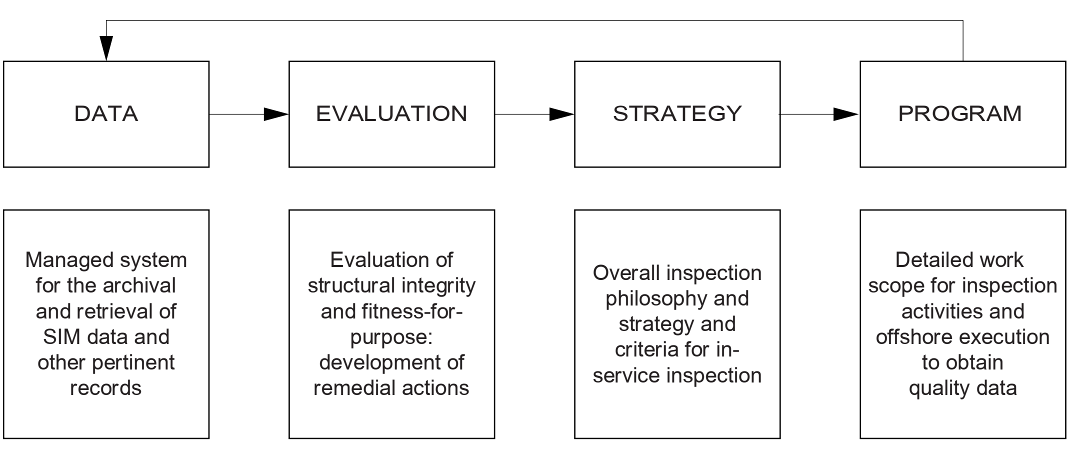
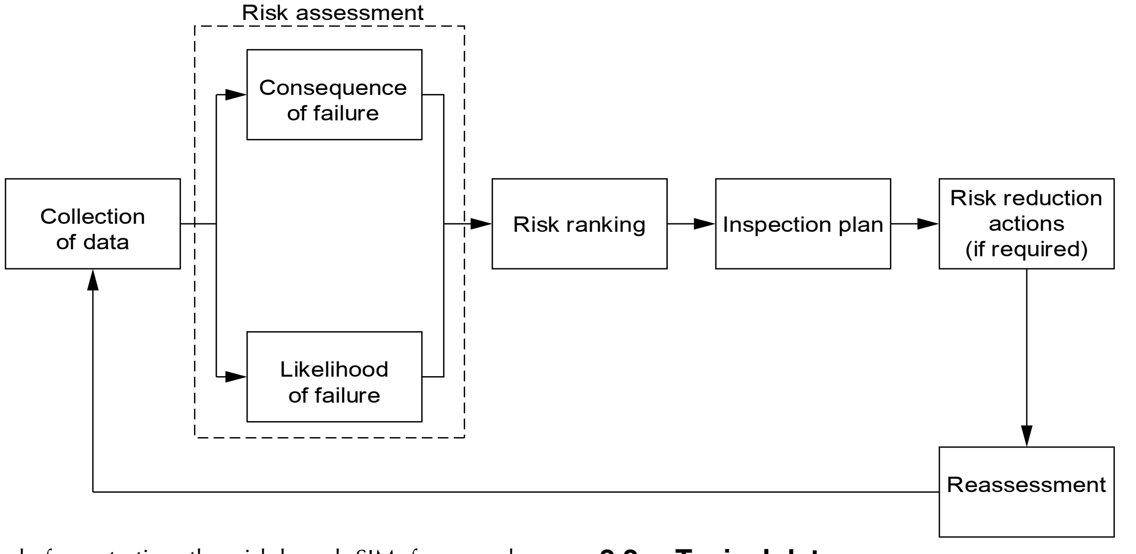


Figure 2 : Framework for developing risk-based in-service inspection strategy



However, before starting the risk-based SIM framework itself, some key issues have to be addressed:

- The objectives of the risk assessment should be clearly stated (e.g. risks understanding, reducing costs, establishing risk criteria).
- The team involved in the risk-based SIM process has to be formed and the competencies, roles and accountabilities of its members have to be defined.
- The scope of the risk-based SIM should be defined. Risk-based SIM could be applied to a fleet or to a platform including eventually its individual structural details. For this purpose, an initial screening could be performed to identify the structural items that are most susceptible to failure under the design event. Those structural items can be a group of platforms when the analysis is performed at a fleet level or a group of structural details when the analysis is performed for one platform only.
- The settings of the risk-based SIM have to be defined, namely:
  - the applicable standards or codes
  - the inspection plan period
  - and the period of validity of the results and when they have to be revisited.
- A type of risk assessment should be selected (e.g. qualitative or quantitative) with respect to the objective of the risk assessment.
- The resources and time required have to be estimated.

2 Collection of data

2.1 Purpose

2.1.1 The collection of data and information aims at providing the necessary input:

- to assess the potential factors and their respective influence on the platform's susceptibility to failure
- to give values to the required inputs for the calculation of the likelihood and consequence of failure
- to assist in inspection planning.

2.2 Typical data

2.2.1 SIM data are divided into two broad categories: platform's characteristic data and platform's condition data:

- The platform's characteristic data is the baseline data that represents the structure at installation. The characteristic data includes:
  - general platform data
  - design data
  - fabrication data
  - and installation data.
- The platform condition data represents the changes to the characteristic data that may occur during the life of the platform. The condition data includes the following:
  - in-service inspection data
  - damage evaluation data
  - corrosion protection data
  - SMR data
  - platform modifications
  - condition monitoring data
  - and operational incident data.

The list of typical platform's data for the SIM process provided in the API-RP-2SIM is repeated in appendix for information.

2.3 Source of data

2.3.1 The main sources of data are the following:

- design report including initial drawings
- fabrication report
- installation report
- most recent engineering assessment report including drawings
- site conditions report including metocean climate data and soil data
- in-service inspections records
- cathodic protection records
- incidents investigation reports

- modification, strengthening and repairs records
- industry or in-house failure data.

If other risk/hazard analysis results are available, they may provide valuable data to the risk analysis for the SIM, e.g. process QRA consequence analysis.

2.4 Quality of data

2.4.1 In order to ensure relevant risk analysis:

- up-to-date data should be used including most recent engineering assessment report and last inspection records
- the input data should be validated by knowledgeable persons to avoid abnormal data or inaccurate inspection measurement to be used
- the potential impact of the conservative assumptions made in case of missing or incorrectly measured data has to be understood
- sensitivity analysis should be carried out whenever possible to identify the data, the uncertainties of which affect more the risk results and which need more care
- and reference to the standards and codes which were used for design and for in-service inspection should be made, as they might contain requirement for ensuring quality of data.

3 Risk assessment

3.1 General

3.1.1 Risk is defined according to API-RP-2SIM as the combination of the likelihood of some event occurring during a time period of interest (e.g. one year) and the consequences (generally negative) associated with the event.

Sometimes the terms probability or frequency are used, instead of likelihood. Likewise, the term severity is used, instead of consequence.

The API-RP-2SIM defines the failure of a jacket platform as the collapse of the platform or its inoperability as the result of the occurrence of an extreme design event (e.g. extreme storm, hurricane, ice movement or earthquake, etc.). The factors that could render a jacket platform vulnerable to its extreme design event are

- an accidental event (e.g. fire, blast, vessel impact, dropped object,…)
- or the degradation of one or many structural components (especially primary structural components) by fatigue or corrosion.

Risk-based in-service inspections intend to control specifically the second type of failure cause. However, data from accidental events that have occurred should also be considered, if they exist, in defining the frequency and scope of risk-based in-service inspections.

API-RP-2SIM provides general guidelines for assigning a risk category to a given platform. Owner/operators may decide to adopt more detailed risk categorization. This requires factors relevant for the platforms' susceptibility to failure and for the impact of failure to be considered.

3.2 API risk categorization for existing platforms

3.2.1 API defines a general risk categorization for existing platforms as the product of their exposure category and their likelihood of failure category.

3.2.2 Exposure categories

The exposure category of an existing platform is given in terms of life safety exposure categories and consequence of failure categories, accounting for possible environmental consequence and economic losses. It should be determined by the more restrictive of either life safety or consequence of failure using the exposure category matrix provided in Tab 1.

Table 1 : Exposure category matrix

Life safety category	Consequence of failure category		
	C-1 High	C-2 Medium	C-3 Low
S-1 Manned - nonevacuated	L-1	L-1	L-1
S-2 Manned - evacuated	L-1	L-2	L-2
S-3 Unmanned	L-1	L-2	L-3
L-1 : High L-2 : Medium L-3 : Low			

The life safety exposure should consider the maximum anticipated environmental event that would be expected to occur while personnel are on the platform. It is divided into three main categories:

- S-1: Manned-Nonevacuated category refers to a platform that is continuously (or nearly continuously) occupied by persons accommodated and living thereon and from which personnel evacuation prior to the design environmental event (e.g. winter storms, sudden hurricanes, and earthquakes) is either not intended or impractical.
- S-2: Manned-Evacuated category refers to a platform that is normally manned except during a forecast design environmental event and requires that all of the following hold:
  - reliable forecast of design environmental event and weather condition before the occurrence of such event not likely to inhibit an evacuation
  - planned evacuation prior to a design environmental event
  - sufficient time and resources to safely evacuate the actual platform and all other platforms likely to require evacuation.
- S-3: Unmanned category refers to a platform that is not normally manned or a platform that is not classified as either manned-nonevacuated or manned-evacuated e.g. emergency shelters.

The consequence of failure should consider the anticipated impact to the environment, and the possible economic impact through losses to the owner (platform and equipment repair or replacement, lost production, etc), the anticipated losses to other operators (lost production through trunk lines), and anticipated losses to industry and government. It is divided into three main categories:

- C-1: High Consequence of Failure category refers to:
  - major platforms and/or those platforms that have the potential for well flow of either oil or scour gas in the event of failure
  - platforms where the shut-in of the oil or scour gas production is not planned or not practical prior the occurrence of the design environmental event
  - and platforms that support major transport lines and/or storage facilities for intermittent oil shipment
- C-2: Medium Consequence of Failure category refers to platforms that would be shut-in during the design event and requires that:
  - all wells, that could flow on their own in the event of platform failure, contain fully functional subsurface safety valves (SSVs) compliant with API specifications
  - oil storage is limited to process inventory and surge tanks to pipeline transfer.
- C-3: Low Consequence of Failure category refers to minimal platforms where production would be shut-in during design event and requires that:
  - all wells, that could flow on their own in the event of platform failure, contain fully functional subsurface safety valves (SSVs) compliant with API specifications
  - oil storage is limited to process inventory.

3.2.3 Likelihood of failure categories

The likelihood of failure of a platform depends on key structural characteristics e.g. the deck elevation, structural configuration given by the number of legs and the bracing system, while existing damage or deterioration may indicate a reduction in the platform's strength, thus an increase in the platform's likelihood of failure.

The API allows qualitative, semiquantitative or quantitative methods to be used in categorizing the likelihood of failure of a platform. However, no specific guidance is provided to implement such methods, but general guidelines are defined for three categories of likelihood of failure.

- The High Likelihood category refers to platforms that are likely to fail in the design event, meaning that their reserve strength ratio (RSR) against the 100-year environmental design event is less than 1 in their present condition and overload may lead to wave-in-deck load.
- The Medium Likelihood category refers to platforms that are not expected to fail in the design event (with a RSR larger than 1), but which can sustain damage that requires inspections after occurrence of the environmental design event.
- The Low Likelihood category refers to platforms that are very unlikely to fail in the design event (with sufficient reserve strength) and are tolerant to any damage or overload that does occur in the environmental design event.

3.2.4 Risk matrix

The risk matrix may be used to present the risk categorization results. Generally, its rows represent the likelihood of failure categories while its columns represent the exposure categories. It is sectored into regions corresponding to risk categories.

The API provides an example 3 x 3 risk matrix (Tab 2) with symmetrical risk categories that can be used for platforms risk categorization as follows:

- Risk Level 1 refers to platforms that should be considered for a major focus of resource, including an increased inspection frequency and intensity and/or more detailed engineering.
- Risk Level 2 refers to platforms that should be considered for a moderate focus of resource.
- Risk Level 3 refers to platforms that should be considered for a less focus of resource, including a reduced inspection frequency and scope.

Table 2 : Risk categorization matrix example

Exposure category	Likelihood category		
	Low	Medium	High
High	Risk level 2	Risk level 1	Risk level 1
Medium	Risk level 3	Risk level 2	Risk level 1
Low	Risk level 3	Risk level 3	Risk level 2

3.3 Factors to consider for specific risk assessment

3.3.1 General

Owner/operators may decide to adopt specific risk categorization e.g. further subdivide exposure and likelihood of failure categories to adopt a more complex risk matrix or use detailed risk assessment techniques. General guidance is provided in the sequel on the factors to consider when a specific risk assessment is to be set up.

3.3.2 Likelihood of failure factors

Three basic elements have the potential to influence the likelihood of failure of a jacket platform:

- the expected extreme loads over the platform's lifetime or service life
- the strength or capacity to bear those extreme loads
- the management system of inspection, analysis and repair.

In fact, a change in the anticipated extreme load such as a lower deck elevation or an increase in the topside load may increase the likelihood of failure. Likewise, existing damage or deterioration may reduce the system capacity, and therefore, may increase the likelihood of failure. The management system of inspection, analysis and repair reflect the ability of the owner/operator to detect existing damage for example; thus a poor management system increase the uncertainties in the detection of such damage, which may lead to an increase in the likelihood of failure.

Therefore, the assessment of the likelihood of failure should be based on relevant factors that affect the platform strength, the expected extreme loads and the management system in place.

- The jacket platform strength may be affected by the following factors:
  - the deck height
  - the framing configuration
  - the number of legs
  - the water depth
  - the foundation stability (e.g. piles, grouted piles, mudmat)
  - the existing damages and/or deterioration
  - the scour
  - the debris
  - and the performance of the corrosion protection system.
- The loads applied to the jacket platform are affected by the following factors:
  - the operational metocean loads (e.g. wave, wind, tides, currents and ice)
  - the extreme metocean loads
  - the platform orientation
  - the platform weight
  - the equipment and material layouts
  - the size and the number of appurtenances (e.g. risers, conductors)
  - the active geological processes (e.g. earthquakes, fault planes, seafloor instability, shallow gas)
  - and the marine growth.
- The performance of the management system to inspection, analysis and repair is usually evaluated through a questionnaire and is affected by the following factors:
  - the asset integrity management (AIM) and the health, safety and environment (HSE) policy
  - the existing procedure for inspection, repair and analysis as well as for the qualification of personnel involved in such activities
  - existing management of change (MOC) process
  - existing data management system and availability of platform's characteristic and condition data, including design, fabrication, installation and inspections data
  - the level of confidence in structural analysis results.

3.3.3 Assessment of the likelihood of failure

The assessment of the likelihood of failure accounts for:

- the as-installed condition of the platform which represents the baseline likelihood of failure
- the present condition of the platform
- the history of maintenance carried out on the platform
- and the analysis results and assumptions for the subsequent structural assessment to the original design.

The baseline LoF is assessed with respect to:

- the original design criteria in terms of the strength and loads factors listed above, including the degree of conservatism in the metocean criteria and the degree of structural redundancy
- the structural analysis results and assumptions from the original design
- the inspection findings and the strengthening modification and repair (SMR) carried out during fabrication, transport and installation and their effects on the strength factors.

Then, the present condition and the maintenance history adjust the baseline LoF accounting for the effects of the current values of the strength and loads factors compared to their design values.

When the available data allow it, one uses comparison of the actual platform to reference's ones in the assessment of LoF. In this case, one can consider:

- the platform age in comparison to recent platforms
- the original design code in comparison to current design practices
- learning from other similar platforms.

3.3.4 Consequence of failure factors

The consequence of failure is the impact that a platform failure has on:

- the health and safety
- the environment
- the business
- and the company reputation.

In order to evaluate the CoF, the following factors have to be considered:

- the platform functionality or type
- the manning level or the number of personnel on board
- the platform location e.g. distance to the shoreline
- the production rate
- and the anticipated financial costs due to production lost, cleanup, replacing the platform and redrilling wells, etc.

3.3.5 Assessment of the consequence of failure

The value of the CoF measures the level or the significance of the impact of failure. Its evaluation is relatively easier in a risk-based SIM study than in a traditional risk analysis for which a detailed consequence analysis is required.

- When a qualitative risk assessment is adopted, descriptive qualitative values are assigned and the overall CoF rating is the most conservative in terms of safety, environment or economic consequences.

3.4 Risk ranking

3.4.1 Once LoF and CoF are developed, the risk ranking process consists in rating the platforms' risk levels from lower to higher risk levels with respect to LoF and CoF.

The results of the risk ranking are presented in simple formats to decision-makers and inspection planners to help them prioritizing the inspection efforts. The common formats are the risk matrix, the risk plot and the risk index table.

For the purpose of inspection planning, the risk levels are categorized. There is a general consensus on the criteria to categorize the risk to safety and environment and such categories are set out in dedicated standards. However, for financial risks, companies generally will develop their own criteria. Cost-benefit analysis is a useful mean to achieve this.

3.4.2 Risk matrix

The risk matrix is very effective mean to present the risk ranking results. It uses a categorization of the LoF and the CoF. The platforms' risk levels are positioned into the boxes of the risk matrix. Different sizes of matrices may be used (e.g. 3 x 3, 5 x 5, etc.) along with different numbers of risk categories (e.g. 3, 5, etc.).

The risk matrix is sectored into regions corresponding to risk categories. Many risk matrix format can be encountered depending on the risk acceptance criteria. Fig 3 shows some typical examples of risk matrix format. A symmetrical risk matrix gives the same weight to both LoF and CoF. An unsymmetrical risk matrix assigns especially more weight to CoF to reflect the risk aversion of a company. Special risk matrix format may be adopted that may classify the box having lowest LoF and highest CoF in critical risk region to reflect the fact that lower LoF are usually inaccurately estimated and therefore high consequence structures with lower LoF are to be classified into the critical risk region.

Table 3 : Example of risk index table

Platform	LoF	CoF	Risk level	Risk index	Category
P – 7	100	83	8283	0,83	V
P – 18	93	88	8132	0,81	V
P – 17	97	79	7671	0,77	IV
P – 9	75	97	7231	0,72	IV
P – 4	76	94	7179	0,72	IV
P – 13	65	98	6371	0,64	III
P – 1	99	52	5159	0,52	III
P – 16	58	77	4433	0,44	II
P – 19	89	40	3597	0,36	II
P – 11	31	87	2675	0,27	I
P – 14	22	91	2017	0,20	I
P – 8	54	33	1775	0,18	I
P – 6	18	81	1443	0,14	I
P – 10	78	15	1151	0,12	I
P – 5	77	9	663	0,07	I
P – 15	7	77	537	0,05	I
P – 2	5	60	292	0,03	I
P – 20	4	63	267	0,03	I
P – 12	37	4	156	0,02	I
P – 3	2	64	140	0,01	I

3.4.3 Risk plot

The risk plot is better suited to present the risk ranking results, should numerical risk values be more meaningful to the stakeholders. It is often drawn using log-log scales allowing categorizing the risk levels with iso-risk lines. (See Fig 4).

3.4.4 Risk index table

The risk rankings can also be displayed in terms of a risk index in a tabular form (Tab 3). The risk index is the ratio of the actual risk level to the acceptable risk threshold allowing the risk levels to be simply categorized with respect to that acceptable risk threshold.

Figure 3 : Example of risk matrix formats: (a) symmetrical, (b) unsymmetrical, (c) special

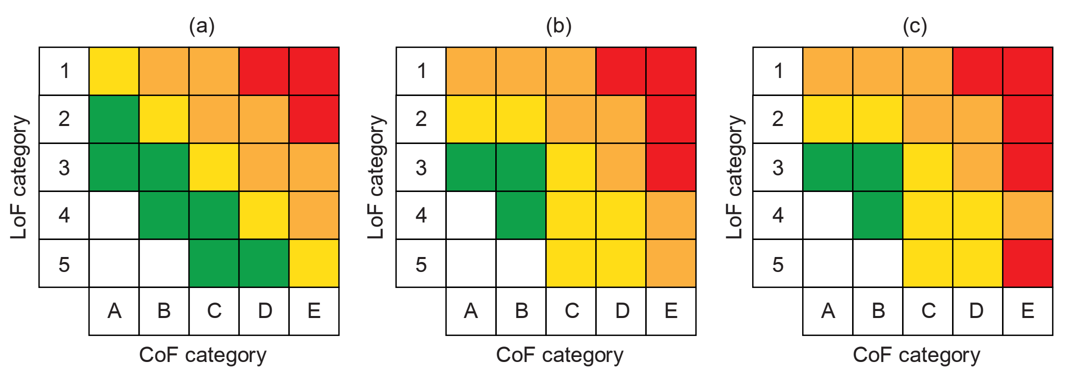
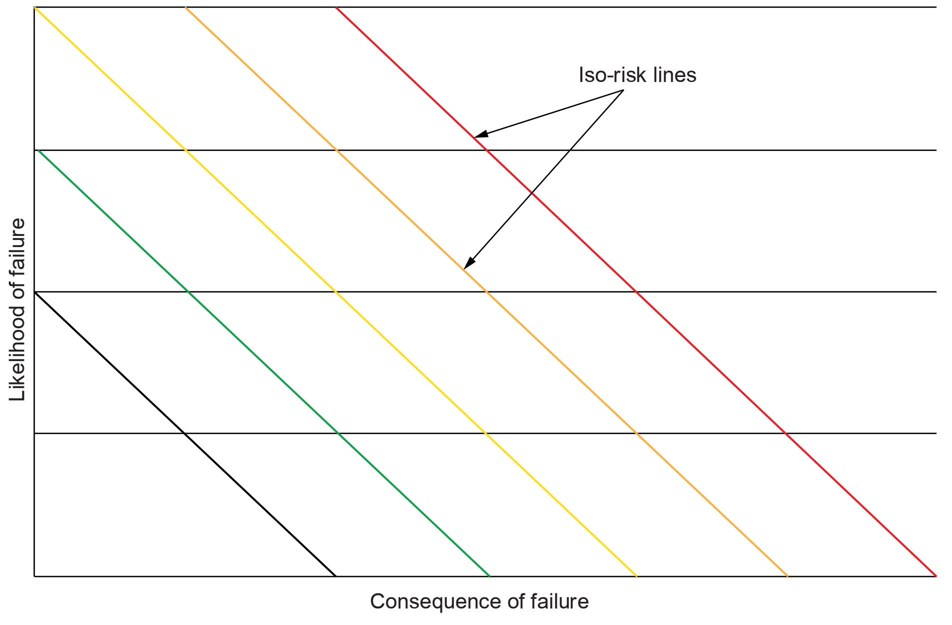


Figure 4 : Example of risk plot



4 Inspection plan

4.1 Definition of risk-based inspection plan

4.1.1 The risk-based inspection plan is defined by:

- an interval or frequency
- a scope
- the survey techniques
- and the relevant deployment method.

Risk-based approaches are used to develop strategies for the periodic or routine underwater inspections only. The other types of inspections included in the SIM strategy e.g. the routine above-water inspections, the baseline inspection and the special and unscheduled inspections should be developed according to requirements defined in the API-RP-2SIM. The section 5.4 of the API-RP-2SIM provides guidance on SIM strategy and the section 6.5 provides guidance for developing risk-based routine underwater inspections.

4.2 Motives for risk-based inspection strategy

4.2.1 The motives for routine inspection are to detect, properly measure and record any degradation, deterioration or anomalies that affect the structural integrity.

The API-RP-2SIM defines deterioration as the reduction in the ability of a component to provide its intended purpose. Platform deterioration may include:

- excessive corrosion to welds and members
- weld/joint damage (e.g. deformation due to overload and fatigue cracking)
- and mechanical damage (e.g. dents, holes, bows and gouges).

The API-RP-2SIM defines anomaly as an in-service survey measurement that is outside the threshold considered acceptable from the design or most recent FFP assessment. Platform anomaly may include:

- non-operating or ineffective corrosion protection system
- scour
- seafloor instability
- hazardous or detrimental debris
- and excessive marine growth.

4.3 Some knowledge from inspection experience

4.3.1 The main mechanisms of degradation of a jacket structure are corrosion and accidental damage (API-RP-2SIM).

4.3.2 Fatigue issue

It is recognized, from operating experience, that fatigue crack damages are sparse for offshore jacket structures, excepted, at some known susceptible details. Fatigue cracks occurred scarcely on jacket platforms designed after 1979; and the fatigue cracks found were likely due to fabrication defects, installation damage and improperly designed appurtenance connections. Moreover, not many joint fatigues occurred in complex multi-planar connections, but they may be a concern in platforms having stiffer joint connections. Platforms designed before 1979 are more fatigue sensitive especially at susceptible details such as conductors guide framing that are plated and appurtenance connections (MSL, 2000).

4.3.3 Some areas are more prone to the occurrence of mechanical damages from accidental loadings e.g. boat landing and area subject to dropped objects.

4.3.4 Corrosion issue

Subsea corrosion is not generally a problem provided the CP system is adequately designed and maintained. Special attention needs to be given to impressed current which rely on external power to provide protection.

Splash zone corrosion is very common as paint or other protective coatings wear over time and/or are damaged or abraded.

4.4 Inspection frequency

4.4.1 General

The objective of the inspection frequency is to ensure that any deterioration or anomaly, which can affect the structural integrity, can be identified at an early stage.

The risk-based inspection frequency is based on the information provided by the risk analysis. Ideally, it must ensure that the accumulated risk during the interval between inspections is lower than a tolerable risk level. However, this is difficult to demonstrate, because the assessment of accumulated risk and the definition of an appropriate risk target need detailed data, which are usually not available.

In any case, the risk-based inspection intervals should have a conservatism level that covers the uncertainty in the estimated future risk.

The API provides general guidelines in setting risk-based inspection intervals. It also sets out predefined inspection intervals and inspection requirements based on the platform's exposure category only, to be used by default when the owner/operator has not adopted a risk-based strategy.

4.4.2 API's risk-based inspection intervals

The recommended risk-based inspection intervals are defined with respect to three risk categories, namely lower, medium and higher (Tab 4). These intervals are only applicable to structures designed to API-2A-WSD, 20th Edition and later. They may be adjusted to account for platforms with higher consequence appurtenances, the design life or the present condition of the CP system.

The API allows more flexibility in the choice of the inspection intervals when higher redundancy level is demonstrated for a jacket structure. This flexibility can be useful to reduce operational costs or to take operational constraint into account. The redundancy level depends on the framing configuration of the jacket structure.

The setting of an inspection interval larger than 10 years requires the operator/owner to demonstrate that the platform is unmanned, the risk level is assessed using ultimate strength analysis and annual Level I CP readings are performed and acceptable.

Acceptance criteria for economic consequence may differ from one company to another. If specific economic consequence has to be taken into account, these intervals may not be suitable and specific intervals should be developed accordingly.

4.4.3 API's default inspection program

The default inspection program includes predefined inspection intervals and inspection requirements based on the platform exposure category only (Tab 5).

Table 4 : API's risk-based inspection intervals

Risk category	Inspection interval ranges
Higher	3 years to 5 years
Medium	6 years to 10 years
Lower	11 years to 15 years

Table 5 : API's default inspection program

Interval (years)	Exposure category **(1)**		
	L-3	L-2	L-1
	5 - 10	5 - 10	3 - 5
Level II			
General visual survey	X **(2)**	X **(2)**	X **(2)**
Damage survey	X	X	X
Debris survey	X	X	X
Marine growth survey	X	X	X
Scour survey	X **(3)**	X **(3)**	X **(3)**
Anode survey	X	X	X
Cathodic potential	X	X	X
Riser/J-tubes/caisson	X	X	X

Interval (years)	Exposure category **(1)**		
	L-3	L-2	L-1
	(4)	11 - 15	6 - 10
Level III			
Visual corrosion survey	X **(5)**	X **(5)**	X
Flooded member detection or member close visual inspection	X	X	X
Weld/joint close visual inspection, after cleaning to bright metal			X
Level IV (6)			
Weld/joint NDT	**(7)**	**(7)**	**(7)**
Wall thickness	**(7)**	**(7)**	**(7)**

(1) Exposure category is defined in Tab 1
(2) Detection of significant structural damage should from the basis for initiation of a Level III survey
(3) If seafloor is conducive (loose sand) or seafloor instability is known/suspected, a scour survey should be performed
(4) Only required if the results from the Level II survey indicate suspected damage
(5) Not required if the annual above-water inspection CP survey indicates uninterrupted protection below water
(6) Only required if the results from the Level III survey indicate suspected damage
(7) Surveys should be performed as indicated in API-RP2-SIM.

4.5 Inspection scope

4.5.1 General

Usually, risk-based inspection of an offshore jacket structure deals with underwater inspection, which comprises the structural members below LAT including J-tubes, conductors, supports and connections to the structure.

Appurtenances such as CP system and fire caissons are included in the scope, since survey results on these components may provide relevant information on the structural integrity of the platform. However, pressure boundaries such as risers are usually excluded from the scope.

The splash zone (between LAT and the module support frame), although in the jacket structure, is typically covered by the above-water inspections.

4.5.2 Inspection coverage

Two main issues drive the selection of survey locations:

- the desire to focus the inspection effort on the hotspots only
- the will to limit the inspection on a sufficient number of locations representative of the condition of the overall structure.

Structural hotspots can be identified with respect to local risk levels and/or structural analysis results. They should include, in addition, areas known to be prone to structural damage or areas where repeated inspections are desirable in order to monitor their integrity over time.

In order to identify the areas prone to structural damage, consideration should be given to:

- areas likely to be subjected to vessel collision (e.g. boat landing) or dropped objects
- records of fabrication inspections
- records of in-service inspections
- and welds repaired regions, since repairs imply risk of creating welding defect, high residual stresses, strain aged heat affected zone.

It is sometime important for inspection cost reason, especially for large welded structure, to reduce the scope of work by selecting a reasonable number of inspection locations. This selection should provide a representative condition of the overall structure for the effectiveness of the inspection. The following considerations may be used:

- The proportion of welds to inspect may be based on statistical theory assuming welding defects are randomly distributed.
- Grouping of structural components having similar characteristics and operating histories, if such grouping is appropriate, may be useful to reduce the scope of work.

4.6 Inspection methods

4.6.1 General

Risk-based inspection of offshore jacket structures requires at least Level II survey techniques. Level III and, eventually, Level IV surveys are required when some damages are found or suspected from the Level II survey; or/and when critical structural components are identified from the risk analysis results.

A wide range of inspection techniques are available. The SIM strategy should select the inspection techniques that are most effective to detect the type of damage and/or deterioration likely to occur in-service.

4.6.2 Criteria for the fitness for purpose of an inspection technique

The fitness for purpose of the inspection technique and the associated inspection procedure should be demonstrated in terms of:

- Reporting level related to the minimum deterioration to be reported
- Effectiveness related to the capability to achieve the objectives of the inspection (e.g. detection or sizing)
- Reliability related to the probability of detection and eventually sizing accuracy. It depends on human factor and is therefore sensitive to the inspection procedure.

4.6.3 Common inspection techniques

The appendix to section 23 of the ISO 19902:2007 provides details on the applicability and the capabilities of several common inspection techniques. Those applicable to routine underwater inspections are summarized below with respect to API survey levels.

a) Level II inspection techniques
   - Visual inspection without marine growth cleaning: it uses the eyesight of the inspector with eventually aids ranging from magnifying glasses to fully remote computerized video camera system when performed by ROV. It is suitable for detection of gross structural damage (e.g. large deformation, severed connection, missing member) and presence of debris.
   - Air gap measurement: Simple methods such as a tape measurement from the cellar deck have been used. They have been replaced in time by radar measurement, which turned out to yield ambiguous values and are sensitive to the ocean environment condition (e.g. wave heights and tide). Modern methods use GPS.
   - Marine growth thickness measurement using Photogrammetry or more advanced NDT based on AFCM.
   - CP potentials measurement using proximity or contact probes.

b) Level III inspection techniques
   - Visual inspection with marine growth cleaning: This technique is used for CVI to determine more accurately the condition of a member or a welded connection and to check for local defects or damage. Generally, extent of cleaning is limited to that required for inspection.
   - Flooded Member Detection: It determines if a tubular member is flooded as a result of through-thickness crack or other through-wall defect associated with fabrication, mechanical damage or corrosion. However, FMD technique is not able to detect cracks on the leg side of connections where the leg is intentionally flooded or grout filled. There are 2 kinds of techniques: Ultrasonic technique (UT FMD) and Radiography technique (RT FMD). The later allows rapid coverage of many components.

c) Level IV inspection techniques

These are Non Destructive Testing techniques used for the following purposes:

- wall thickness measurements for corrosion inspection
- detection and eventually sizing of surface breaking defects
- detection and eventually sizing of flaws in welds
- and detection and eventually sizing of internal volumetric flaws.

Some of existing techniques are listed below:

- Ultrasonic (compression wave) technique for wall thickness measurements.
- Magnetic Particle Inspection (MPI) for surface breaking defects (requires coating removal).
- Eddy Current Detection (ECD) for finding and sizing surface breaking defects (usually does not require coating removal).
- Long range ultrasonic for detection of defects of all sizes and orientations. It is generally used as a screening tool to identify areas which require more detailed NDT with alternative techniques.
- Phase Array ultrasonic (PA) for detection of flaws in welds.
- Time of Flight Diffraction (TOFD) for detecting internal volumetric flaws and sizing defects found by other NDT techniques.
- Alternating Current Potential Drop (ACPD) for sizing defects found by other NDT techniques.
- Alternating Current Field Measurement (ACFM) for finding and sizing (in length and depth) surface flaws (usually does not require coating removal).
- Radiographic Techniques (RT) for detecting internal defects.

4.7 Deployment method

4.7.1 The appendix to section 23 of the ISO 19902:2007 provides details on the options for deployment of inspection tools, which is summarized below, especially, those applicable to routine underwater inspections.

- Air Diving (Air) is carried out by suitably trained divers up to 50m depth in a limited operational duration.
- Saturation Diving (Sat) for which the divers can stay longer at operating depth pressure 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.
- Atmospheric Diving Suit (ADS) these are "hard" diving system allowing to put a person on-site. The pilot of the system generally deploys the inspection tools using manipulators.
- Remotely Operated Vehicle (ROV) is an unmanned underwater robots used to deploy inspection tools.

5 Risk reduction

5.1 General

5.1.1 Risk reduction measures should be considered whenever a platform is assessed non-compliant with the fitness for purpose performance criteria. In fact, risk reduction may be more cost-effective than a more complex and finer structural analysis which could enable the platform to meet the criteria.

Risk reduction includes consequence mitigation measures, that reduce the exposure of the platform, and risk prevention measures, that reduce the likelihood of the platform failure.

Many documents, including the section 13 of the API-RP-2SIM and the reference article of J. W. Turner, et al (1994) provide details on the risk reduction measures commonly used for jacket platforms, which is compiled below for information.

5.2 Exposure reduction

5.2.1 Life safety

Life Safety Mitigation measures include demanning the platform either permanently or temporarily during a forecasted extreme event.

5.2.2 Environment

Environmental Safety Mitigation measures include:

- installation of production shutdown systems (e.g. subsurface safety valves, pipeline shutdown systems)
- removal or reduction of on-board hydrocarbon storage or inventory volume
- use of special containment
- removal or rerouting of major oil and gas flow lines
- permanent or temporary abandonment of nonproducing wells
- and isolation of the pipeline to reduce the potential volume of hydrocarbon release.

Knock-on effects must be considered in developing environmental mitigation measures, for example by ensuring that the integrity of a shutdown system does not depend on some other ones.

5.2.3 Emergency preparedness

Emergency Preparedness (e.g. evacuation planning, storage and securing of equipment) for possible extreme event (e.g. hurricane) can reduce risks and improve post-event response.

5.2.4 Inspection monitoring

Inspection Monitoring Program can sometimes be a good mean to mitigate risks.

5.3 Likelihood reduction

5.3.1 Likelihood reduction measures can be categorized either as loading reduction or as structural strengthening.

5.3.2 Loading reduction

a) Vertical Gravity Loading

- Accurately determine the actual deck weight is a simple mean to reduce vertical gravity loads, for example by considering the current equipment loading which may be far lower than the live load considered from the design.
- Revision of the upper bound of the deck payload and setting up of appropriate operational procedures to meet the revised payload criteria.
- Partial removal of unnecessary equipment and/or deck structures to reduce the stresses in the legs and piles and the reactions forces of the piles, which has a beneficial effect, although generally small, on the platform dynamic and could reduce the windage area.

b) Hydrodynamic Loading

- Refinement of loading calculation:
  - use of defensible site specific criteria as allowed by the API-RP-2A-WSD
  - use of blockage factors for currents
  - reevaluation of force parameters based on the specificity of the platform (e.g. dense framing which develops internal shielding of the members and may result in lower overall global loads)
- Reduction of nonessential hydrodynamic components (i.e. not essential for current or future operation and not useful for the overall integrity of the platform), including:
  - excess items such as barge bumpers, boatlandings, walkways, stairs, drilling caissons, risers, pipelines, abandoned wells and unused conductors
  - and some structural members if demonstrated to be overall beneficial, e.g. launch truss members and redundant members.
- Removal of Marine Growth:
  - installation of marine growth reduction devices, e.g. copper-nickel cladding, sliding marine growth preventers or introduction of marine growth predator colonies
  - and adding periodic removal of marine growth as part of the SIM program for the platform.
- Avoidance of wave-in-deck loading or reduction of their impact on the platform:
  - raising the deck above the expected wave crest without that increase of legs lengths significantly affecting the structural stability
  - remove or relocate equipment and nonessential structures from the lower deck elevations
  - use deck grating instead of plating
  - use reservoir pressure techniques (e.g. water or gas injection) as a mean to slow future subsidence
  - direct bracing of the lower deck platform to a modern adjacent platform where process and control equipment can be placed too, reducing the affected platform to a well-head platform
  - and placement of wave barrier around the affected platform.

Care should be taken when performing ultimate strength analysis on a jacket platform with lower air gap, since the increase factored loading can be associated with larger crests yielding wave-in-deck loadings.

5.3.3 Structural Strengthening

Structural strengthening aims at increasing the strength capacity of the structure to the level necessary to meet the fitness-for-purpose criteria. The structural strengthening scheme can be localized or global. The localized strengthening consists in repairing a damaged component or enhancing the capacity of a structural member or joint without altering load paths within the structure, while the global strengthening consists in diverting the load paths away from the damaged or under-strength component.

a) Localized strengthening

- Grouting is one of the most cost effective localized strengthening methods. However, the impact it has on gravity loads, dynamic mass increase and eventually decommissioning should be considered before implementing it. The common grouting options are:
  - filling completely an intact or damaged tubular member with grout to enhances its axial compressive capacity, provided there is no voids at the member ends. However, as far as bending strength near midspan is concerned, the presence of voids at the member ends is less critical
  - filling completely a joint chord member or only the local region near the joint (using grout bags), especially for non-leg joints, can be used to improve the static strength of the joint and increase their fatigue performance. However, this can be prejudicial for seismically loaded structures, because the grouting increases the joint stiffness and reduces its ductility.
- Structural clamps can be used to add new members into the structure to increase redundancy, to increase the capacity of existing members or joints, and/or to reinstate the capacity of damaged members of joints. They can be stressed by the application of bolt tensioning to induce hoop stress around the member or joint to resist axial and bending loads in the structure. Most often, the annulus between the stressed clamp and the structure is filled with grout as a medium to transfer load.

  However, bolting the clamps could be required over time, since loss of bolt tension can occur by elastic relaxation or creep in stressed grouted clamps.

- Underwater welding is an efficacious technique to strengthen or repair local structural components. The common techniques are:
  - dry welding at or below sea surface at one atmosphere using a cofferdam or pressure-resisting chamber
  - hyperbaric welding using habitats
  - and underwater wet welding.

  However, significant cost and extended schedules are generally involved by the design of welding habitat or chamber, while wet welding requires low stress weld and compatible parent material to be a viable solution.
- Intentionally flood of structural members can be used to increase the load carrying capacity of the member, however, its impact on gravity loads, dynamic mass increase and eventually decommissioning should be considered before.
- Cold forming techniques, namely swaging or mechanical connectors can be used for local strengthening or repair.

b) Global Strengthening

- Leg-pile annulus grouting is a reliable and cost-effective method to increase the global capacity of the structure. It has the advantage of increasing the stiffness of the jacket leg and locally strengthening the jacket joints against bracing loads by allowing the pile and jacket leg to act compositely.

  However, its impact on gravity loads, dynamic mass increase and eventually decommissioning should be considered before.
- Modifications of the platform foundation can be considered to improve the foundation capacity. Some solutions have already been applied, namely:
  - installation of external pilestruts
  - addition of soldier piles that are parallel and in close vicinity with the existing piles
  - clamping and grouting external sleeves on the jacket legs
  - application of insert piles and pile tip grouting to increase piles' penetration and generate full pile end bearing
  - and placement of sand or rock to prevent the effect of platform scour.
- Installation of a new adjacent structure with its own piled foundation to brace the existing structure.

6 Reassessment of the risk-based inspection strategy

6.1 General

6.1.1 The RBI reassessment is an updating of the inspection plan to take into account the most recent information from the inspection and maintenance activities, and the operating conditions, especially if they are significantly different from the last risk assessment.

6.1.2 RBI reassessment has to be conducted mainly because risk assessment is based on data and knowledge at the time of the assessment, and this information can change over the time and modify the risk level of the platform, causing a need to perform a reassessment to update the inspection strategy accordingly.

6.1.3 The codes and standards dedicated to SIM of jacket platforms do not address especially the issue of RBI reassessment. Nevertheless, they set out the conditions which require a fitness-for-purpose assessment. These conditions describe negative situations that require checking the FFP of a platform. The need for RBI reassessment is broader and includes the positive situations associated to those FFP assessment initiators. Therefore, the factors considered in the standards for jacket platforms FFP assessment are still relevant for their RBI reassessment, including their negative and positive aspects.

6.1.4 These are the codes and standards for RBI of equipment that explicitly address this issue and provide some key factors that could trigger an RBI re-assessment. Although these factors suit typically process equipment some general considerations apply to RBI of structures too.

The following sections provide guidance on when to conduct an RBI re-assessment of the jacket platform. That guidance is gathered from the relevant standards.

6.2 Significant change of the assessment premise

6.2.1 A RBI reassessment should be conducted when some conditions, which can modify the exposure level or the likelihood of failure of the platform, exist, namely:

- modification of the operational conditions, i.e. addition or removal of personnel or facilities, that can change the platform exposure level
- modification to the facilities (e.g. pipelines, wells, topsides hydrocarbon inventory capacity) that can change the effects of the combined environmental and operational loading on the structure
- modification of the environmental conditions and/or criteria
- change in component or foundation resistance data and/or criteria
- physical changes to structure design basis, e.g. excessive scour or subsidence
- and change in deck height which can modify the susceptibility of the platform to wave-in-deck load.

Some other changes in the economic and social context could lead to a RBI reassessment, namely:

- change in product values
- change in SMR costs
- and revision in safety and environmental laws and regulation, including the governing SIM codes and standards.

6.3 After an inspection

6.3.1 The inspection activities increase the information on the platform condition, which is worth to be included in a RBI reassessment for a more accurate risk evaluation.

Moreover, the damage found on primary structural component during inspections requires performing a RBI reassessment when that damage is deemed significant. When minor damages are found during inspections, their cumulative effects should be considered and if it is deemed significant a RBI reassessment is required too.

The standards define a significant damage as able to decrease the platform capacity over 10%.

6.4 After the implementation of a mitigation strategy

6.4.1 Once a mitigation strategy is implemented and is effective, it should result in reducing the risk to a level acceptable for the company. This should be reflected in the inspection program. Therefore, a RBI reassessment needs to be performed with the expected current risk level.

6.5 After a set of time period

6.5.1 When a risk-based SIM is developed, users have to set an inspection plan period and a maximum default time period of validity of the risk analysis results. Therefore, a RBI reassessment is required when one of these time periods is exceeded.

6.5.2 A RBI reassessment is required when life extension over the design service life is considered for the platform, and especially if either

- the fatigue life (including safety factor) is lower than the required extended service life
- or corrosion degradation is present or likely to occur within the required extended service life.

7 Types of risk assessment

7.1 General

7.1.1 Approaches to risk assessment

There are typically three types of risk assessment, namely: Qualitative, Quantitative and Semi-quantitative assessment.

7.1.2 SIM standards point of view

The issue of risk assessment, especially how it should be performed for fixed platform, is currently too little addressed in the standards dedicated to the SIM of fixed offshore platform.

The API-RP-2SIM states only “the platform likelihood of failure should be categorized using qualitative, semi-quantitative or fully quantitative methods". The ISO 19902 considers risk matrix as a useful tool for risk assessment and recommends supplementing it with more detailed risk assessment, e.g. probability-based inspection methods, if the overall exposure level is too coarse or too general to address specific potential concerns, aspects of performance or individual components (without details).

7.1.3 Selection of the risk assessment method

The level of detail in the input data and the amount of effort in performing the assessment increase from qualitative assessment to more quantitative assessment (semi-quantitative, full quantitative).

The choice of the type of risk assessment method depends on:

- the objective of the study, including:
  - the complexity of the scope especially whether the analysis is applied at a fleet level, a platform level or a structural component level
  - the desired level of information required to better understand the risk and manage it
  - and the need to refine an analysis for an estimated risk too close or above the acceptable limit
- the available resources, especially the nature and the quality of the available data
- the assessment time frame
- and the amount of risk discrimination needed.

Qualitative and semi-quantitative approaches are generally considered more appropriate when the risks are low enough and not expected to be intolerable, while full quantitative approach suits structural items with higher risks. However, when qualitative or semi-quantitative assessment provides critical risk levels, it may be better to proceed with an appropriate remedial measure rather than spending effort on an extensive and detailed quantitative assessment.

Quantitative approach is normally applied and well developed at the component level, but some attempts to apply it to structural systems exist.

7.1.4 Complementarity of the approaches

The three approaches are not considered as competing but rather as complementary.

One approach for instance is to use them in an iterative manner. One could start with a qualitative method, then one could iteratively perform a more detailed analysis (either using more accurate data with the current method or choosing the next method) whenever the current method is deemed unable to provide:

- sufficient discrimination between the risks of the structural items under consideration
- assistance in making compliance judgments.

However, it may sometime be preferable to start directly with a semi-quantitative or quantitative assessment to avoid unnecessary iterations.

Another approach is to combine them, including the following possible options given as examples:

- a qualitative method can be used at the fleet level to select the platforms with higher risks for further quantitative or semi-quantitative analysis
- the structural components (members and/or joints) of a platform can be screened using qualitative method and the higher ones analyzed using a quantitative or semi-quantitative approach

- a qualitative consequence analysis can be used in combination with a quantitative or semi-quantitative likelihood analysis
- the results of a quantitative consequence analysis can be used to justify qualitative or semi-quantitative consequence categories.

7.1.5 Uncertainties in the risk assessment

Although all types of risk assessment are intended to provide some structure for evaluating risk levels, they are all subjected to uncertainty since they all make assumptions in some area and involve subjective and arbitrary judgments.

It is generally accepted that there are three main sources of uncertainties:

- the inherent uncertainty in the data used in the assessment with respect to the amount and the relevance of the available data, e.g. environmental conditions (wave, current and wind) is subjected to many uncertainties, the inspection results such as dimensional measurements of marine growth, members' damage size,… are affected by uncertainty.
- the extent of simplification made for the assessment, e.g. assessment premises, assumptions made to take missing information into account, the structural assessment model and the degree of conservatism introduced produce some uncertainties
- and the completeness of the knowledge about relevant phenomena and mechanism e.g. deterioration rate due to fatigue crack growth or corrosion are still difficult to predict.

It is important for the confidence in the risk assessment to understand and describe the uncertainty present in the analysis. There are many ways to deal with uncertainty:

- Expert judgment: Experts may be able to use their experience to assess the uncertainties. In fact, the use of expert judgment is a simple means to deal with the uncertainties and in most cases it is the only possible means for that.
- Sensitivity analysis: it consists in systematically varying the input parameters to determine how sensitive the final risk ranking is to each input. It is an appropriate technique for quantifying the effect of uncertainty in the input data in case where they may affect the results in terms of final risk ranking. Thus, it allows identifying the key input variables that deserve more care.
- Classical probability and statistical tools such as distribution fitting, parameters estimation and hypothesis testing are useful to quantify uncertainties, especially from databases or case studies.
- “Reality Check": it consists in comparing the risk assessment results with the available historical data, provided they cover the current study characteristics, to determine if it conforms to reality.
- Performing more detailed studies: when the uncertainties are deemed too large, providing too conservative risk assessment, it may be useful to proceed with a more detailed assessment.

7.2 Qualitative risk assessment

7.2.1 Definition

This approach provides risk results in qualitative terms based on expert judgments.

7.2.2 Risk expressions

The qualitative method categorizes the likelihood and the consequence of failure using qualitative scale, such as low, medium, high. The categories are based on some criteria expressed in descriptive terms. In some cases, ranges of numerical values are associated to the descriptive categories.

Risk levels are estimated by selecting likelihood and consequence categories on a risk matrix. This approach is considered as the basic risk matrix approach.

7.2.3 Assessment methods

The risk evaluation can be undertaken either through workshop sessions or using a workbook or scorecard approach.

- Workshop sessions: The workshops gather experts in the relevant disciplines, with one person facilitating the debate between the people attending. The workshops are normally oriented according to a dedicated methodology, including guidelines, questionnaires and reporting format. The methodology is similar to HAZID study, but an operator can develop its own guidelines.
- Workbook/scorecard approach: This approach uses a series of tables to guide the analyst through the risk evaluation. Normally, the workbook should reflect the expertise and experience on structural integrity management of offshore jackets. This approach has been developed and standardized by the API for pressure containing equipment, but there is no such codified workbook for fixed platform especially jacket platforms. Nevertheless, some operators have developed their own workbook based on information on key structural characteristics and previous inspections' results of their fleet.

7.2.4 Main features of the approach

The qualitative approach is easy to carry out and does not require detailed quantitative data. However, its accuracy depends on the background and expertise of the risk analyst and expert team members.

This approach is effective in:

- Relative risk ranking of the platforms within a fleet or the structural components of a platform with a risk matrix.
- Screening the platforms within a fleet or the structural components of a platform to select the level of analysis needed and to ascertain the benefit of further analyses (e.g. quantitative analysis or some other technique).
- Identifying structural items of potential concern, which may require enhanced inspection programs.

This approach may be used to develop inspection plan, however, its conservatism should be considered when making final inspection plan and mitigation decisions.

7.3 Quantitative risk assessment

7.3.1 General

Quantitative risk assessment provides numerical estimates of CoF and LoF based on historical data and computer simulations.

The quantitative risk assessment method involved in risk-based SIM usually requires much less detailed evaluation than the traditional QRA method such as that applied to hydrocarbon and chemical process facilities. The traditional QRA method considers many failure scenarios including those resulting from human errors while risk-based SIM focuses on structural damage mechanisms.

Whilst there are specific QRA studies for structural failure especially due to special events, e.g. collision failure, dropped object,… QRA generally omits structural failure due to deterioration mechanism, which is clearly in the scope of the risk-based SIM.

The quantitative methods involved in risk-based SIM may share many techniques and data requirement with QRA. Therefore, when QRA studies have been prepared for a facility, they can borrow extensively from this effort, especially the consequence analysis.

7.3.2 Risk expression

a) Likelihood of failure

The LoF is assessed using structural reliability analysis. It is based on the construction of numerical models, namely, logical models and physical models.

- Logical models depict combinations of failure events of structural components that could result in an overall failure of the platform. It is generally built using two techniques:
  - Fault Tree Analysis (FTA) evaluates the probability of failure of the jacket platform from the probabilities of pre-requisite preceding failure events of the structural components.
  - Event Tree Analysis (ETA) builds all the scenarios of failure of the jacket platform from an initiating event such as damage (e.g. fatigue or corrosion) of a given structural component. The probability of failure of the jacket platform is given with respect to the probability of occurrence of each of these scenarios.
- Physical models depict deterioration or degradation mechanism causing failure of structural components. Probabilistic models for fatigue, crack growth and localized or uniform corrosion have been developed. They are based on semi-empirical models where the parameters follow relevant statistical distributions, including eventually a random variable accounting for the uncertainties in modelling.

  Expert opinion and calibration procedures are needed to ensure that all relevant deterioration mechanisms have been identified and are correctly modeled.

b) Consequence of failure

The risk-based SIM for jacket platform does not require a detailed consequence analysis, but can borrow extensively from QRA consequence analysis if it is available. The QRA expressions for consequence of failure to personnel, environment and asset are summarized below for information.

- Personnel consequence is expressed in terms of the following typical parameters:
  - Potential Loss of Life (PLL) is the number of fatalities experience in a given period (e.g. one year), obtained from accident statistics or from modelling of accident scenarios.
  - Personnel On Board (POB) is the number or average number of personnel on the platform at any one time.
- Environment consequence can be given by:
  - the expected amount of hydrocarbon spilled
  - a restauration time, which is the time needed for the environment to recover after a spill
  - or the frequency of events with similar consequences for the environment.
- Asset consequence can be given by
  - the extent of damage to the jacket structure (e.g. number of load bearing structural members affected) or the expected repair cost
  - or the disruption to production in terms of production delay or production loss.

c) Risk expression

The risk is generally expressed numerically as the expected value of the consequence:

$$R = \sum_i p_i C_i$$

where p_i and C_i are respectively the probability and the consequence of the failure scenario i.

7.3.3 Main features of the approach

The quantitative risk assessment intends to provide an accurate, reproducible and justifiable estimate of the risk of structural failure of the jacket platform. However, its application is relatively rare due to difficulty in defining appropriate statistical distribution of the loading and resistance variables and the computation effort needed to complete the assessment.

This approach is useful where a formal method is required e.g. for high risk structural items, significant uncertainty involved.

Quantitative risk assessment often makes use of the Bayesian approach to assess the probability of failure from the failure scenarios depicted by ETA or FTA. It allows alternatives inspection plans to be compared with respect to their respective impact on the risk level in order to find the optimal one. It allows also the current inspection plan to be updated based on last inspection results.

The proper attention to evaluation of uncertainty and evaluation of model sensitivity is crucial in quantitative risk assessment.

Relevance of data and model should be justified when full quantitative risk assessment is used.

7.4 Semi-quantitative risk assessment

7.4.1 Definition

Semi-quantitative risk assessment refers to many methods that use both aspects of qualitative and quantitative approaches and uses numerical values for CoF and PoF.

7.4.2 Risk expression

This approach develops parametric models to assess CoF and PoF. The models are calibrated based on historical data or assumed or simulated performances of an arbitrary sample of structural items.

Most of the data used in quantitative risk assessment are needed for semi-quantitative risk assessment but in less detail. Moreover, the models may not be as rigorous as those for the quantitative approach.

Semi-quantitative methods use risk matrix too and provides risk results in terms of CoF and PoF categories or risk numbers associated to each category.

7.4.3 Main features

It intends to combine the major benefit of the qualitative and quantitative approaches, namely the speed of qualitative and the rigor of quantitative.

8 Reporting on risk-based SIM

8.1 General

8.1.1 Documenting the study carried out to develop a risk-based inspection strategy is an important issue as it should provide to the operator/owner an understanding of the risks of structural collapse of its platforms, which is one of the main objectives of the risk-based SIM.

8.2 Recommended content

8.2.1 The risk-based SIM documentation should include the following important data:

- the type of assessment and objectives
- team members performing the risk assessment and their skill set relative to risk analysis
- time frame over which the assessment is applicable
- the inputs and sources used to determine risk
- assumptions made during the assessment
- the risk assessment results (including information on probability and consequence)
- follow-up mitigation strategy, if applicable, to manage risk
- the mitigated risk levels (i.e. residual risk after mitigation is implemented)
- and references to in-service codes or standards being applied.

Ideally, sufficient data should be captured and maintained such that the assessment can be recreated or updated at a later time by others who were not involved in the original assessment. To facilitate this, it is preferable to store the information in a computerized database. This will enhance the analysis, retrieval, and stewardship capabilities. The usefulness of the database will be particularly important in stewarding recommendations developed from the risk-based SIM, and managing overall risk over the specified time frame.

9 Reference documents

9.1 API-RP-2SIM

9.1.1 Background

The API-RP-2SIM provides a standalone recommendation practice for SIM of fixed platform, intending to separate RP for design included in API-RP-2A and RP for assessment of existing structures.

It incorporates and expands the sections 14 and 17 of the API-RP-2A-WSD 21st editions providing, respectively, survey requirements and assessment process of existing offshore structures. It formulates them more specifically for the existing fixed offshore structures, considering also the results from more recent published works on this topic.

It recognizes the SIM process and the guidance on assessment of existing structures established in the ISO-19902 respectively in sections 23 and 24.

It clarifies the link between the four phases of the SIM process as defined by the ISO-19902: data, evaluation, strategy and program.

9.1.2 Overview

The API-RP-2SIM provides guidance on how an operator or an owner should manage the structural integrity of the platforms it operates. The provided recommendations are applicable to the SIM of existing fixed offshore structures. They cover the SIM overall approach, the SIM process and include specific guidance for:

- Evaluation of structural damage
- Above and under water structural inspection
- Fitness-for-purpose assessment
- Risk reduction
- Mitigation planning
- Process of decommissioning.

It provides also specific assessment procedures and reduced criteria, especially metocean criteria applicable for US waters (e.g. US Gulf of Mexico and US west coast).

The guidance given in the corps text are supplemented with useful commentaries in appendix providing feedbacks and lessons learnt from the practice of the various activities involved in a SIM, including reference to relevant research works.

9.1.3 Key concepts

The standard introduces the concept of risk based approach to SIM. However, no specific guidance is provided on how to assess the risk level of the platform. Platforms' exposure categories (Tab 1) are proposed in terms of life safety, environmental and possible economic consequences. Moreover, risk-based inspection intervals (Tab 4) are recommended for underwater routine inspections, including specific requirements for inspection intervals larger than 10 years.

Specific reduced metocean criteria applicable to platforms located in the U.S. Gulf of Mexico are provided for design level and ultimate strength assessments respectively (Tab 6 and Tab 7).

Table 6 : Design level metocean criteria, U.S. Golf of Mexico

Category	Design edition		
	API-2A-WSD, 19th Edition and Earlier	API-2A-WSD, 20th or 21st Edition	API-2A-WSD, 22nd Edition and Later
L-1	50 - year	100 - year	100 - year
S-2	NA	NA	NA
C-2	15 - year	50 - year	50 - year
L-3	10 - year	25 - year	25 - year
Note 1:NA: Not Applicable			

Table 7 : Ultimate strength criteria, U.S. Gulf of Mexico

Category	Design edition		
	API-2A-WSD, 19th Edition and Earlier	API-2A-WSD, 20th or 21st Edition	API-2A-WSD, 22nd Edition and Later
L-1	300 - year	100 - year	1000 - year
S-2	2500 - year sudden hurricane	Not applicable	500 - year
C-2	25 - year	300 - year	500 - year
L-3	10 - year	100 - year	100 - year

9.2 ISO 19901 - 9

9.2.1 General

The standard ISO 19901 - 9, about SIM of offshore structures, is in preparation and has not been released yet (at the time of producing this guidance note). The information provided here about the expected content of this standard are based on presentations delivered during specific workshop meeting.

9.2.2 Expected scope

This International Standard intends to specify requirements and provide recommendations applicable to fixed and floating structures, subsea structures and mooring systems. It incorporates the sections 23 and 24 of the ISO 19902, but adds new content, especially on the management framework which refers to the integrated systems, work processes and documentation, which are used together to deliver structural integrity.

9.2.3 Key features

a) This standard is consistent with the API-RP-2SIM.

b) SIM Framework

It develops a general SIM framework using the ISO and API workflows as elements of a more general/extended workflow. In particular, it includes the following interrelated elements, as shown in Fig 5:

- SIM policy, which sets out the overall intention and direction of the owner/operator with respect to SIM
- written description, which documents the processes and procedures adopted by the owner/operator for the management of the structural integrity
- SIM management structure, which describes the reporting lines, accountabilities, roles and responsibilities, and necessary competencies required for the SIM personnel
- SIM process, which is used for demonstrating fit-for-purpose assets
- SIM documentation, which are to be followed for implementation of the required SIM activities
- validation, which are used to measure and verify performance against a set of defined metrics
- continual improvement, which reviews the process periodically and implement required changes.

Figure 5 : SIM framework from ISO 19901-9

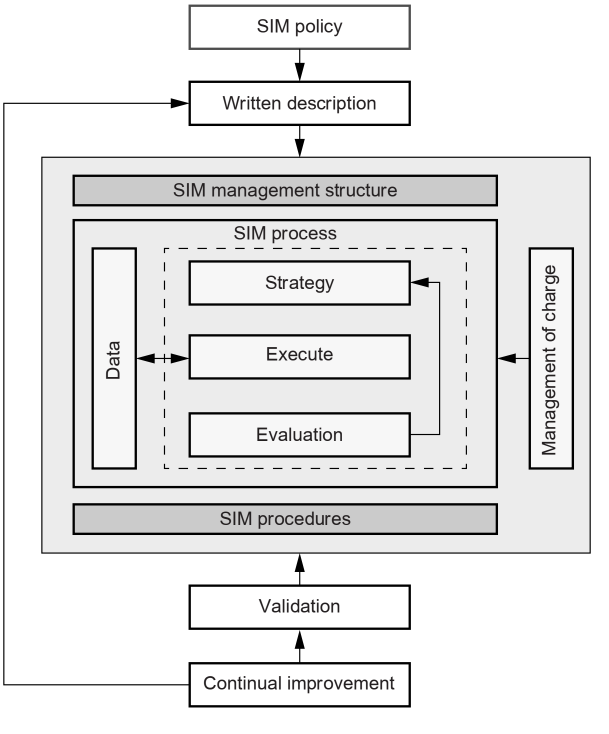
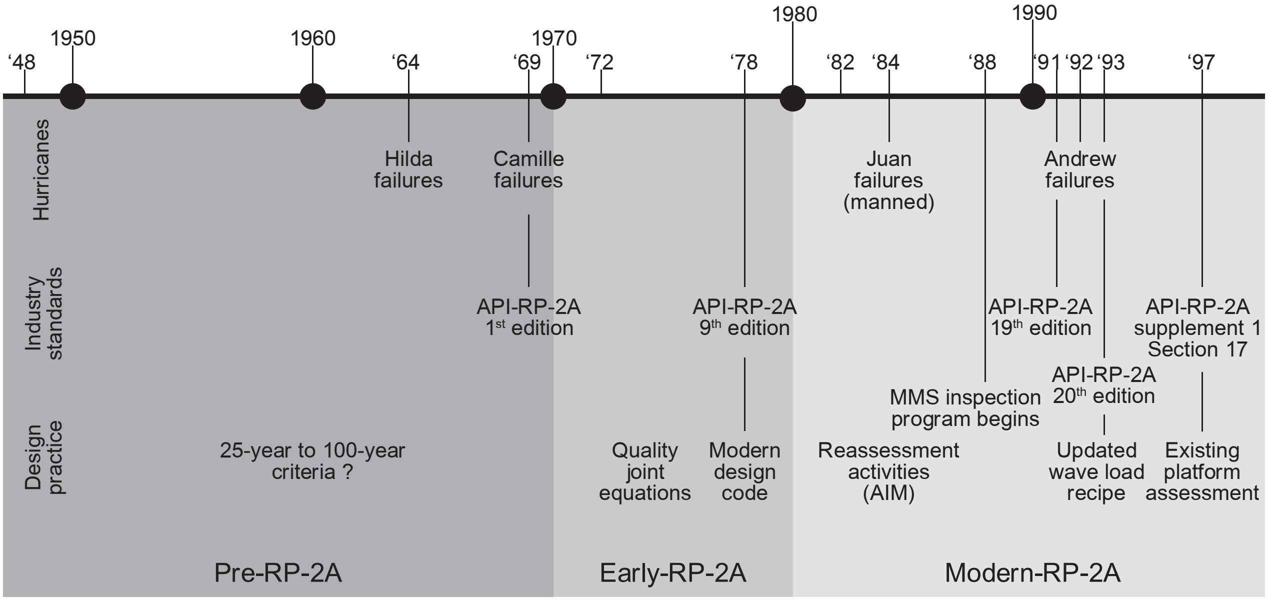


Figure 6 : Platforms'vintages



c) Worldwide Consistency

This standard provides minimum performance requirement against environmental overload applicable worldwide, leaving regional preferences for more onerous requirements to the regional regulator.

d) Reliability analysis

The standard adds another assessment method to the four methods already defined in the API-RP-2SIM, and which is reliability analysis. It provides guidance on how to carry out this reliability analysis as well.

9.3 Final report of the JIP on underwater inspection

9.3.1 Overview

This JIP, entitled "Rationalization and Optimization of Underwater Inspection Planning Consistent with API-RP-2A section 14", has been prepared by MSL Services Corporation with contribution from EQE International. A deep analysis of inspection data from Gulf of Mexico platforms was conducted to identify inspection's trends. Guidelines for underwater inspection were developed consistent with the findings of the inspection data analysis. Those guidelines include inspections' scope of work and frequencies, requirements for survey data recording and reporting, and recommendations for defining platforms' anomalies with respect to scour, debris and marine growth surveys.

The proposed guidelines were benchmarked with a set of 6 platforms representative of the Gulf of Mexico fleet.

9.3.2 Proposed guidelines for routine underwater inspection frequency

The proposed guidelines for inspection interval are based on the platform's vintage and the platform's exposure category (Tab 8). Platforms' vintages are divided into three generations with respect to the improvements of the design practice over the years (Fig 6). The exposure categories are the ones defined by the API (Tab 1).

Appropriate engineering judgment on the relative robustness of alternative platform configurations (e.g. number of legs, framing system, joint details,…) and associated analytical data or assessment information will support the selection of extended intervals towards the upper bounds of the ranges provided.

Table 8 : Guidelines for routine underwater inspection intervals

Exposure category	Susceptibility to defects				
	Pre-RP-2A		Early-RP-2A		Modern-RP-2A
	Corroded or unknown CP history and/or more than 100 ft water depth	Pre	Corroded or unknown CP history	Early	Modern
L - 1	3 - 5 years		5 - 10 years		10 years
L - 2	5 - 10 years		10 years		10 - 15 years
L - 3	5 - 10 years		10 - 15 years		15 years

9.3.3 Proposed guidelines for underwater inspection scope of work

Three regimes for routine underwater inspection program have been identified and are denoted level II, level III and level IV (Tab 9). The selection of the applicable regime depends on the platform's vintage and the platform's functionality (Tab 10).

9.4 Final report of the JIP on SIM

9.4.1 General

This JIP, entitled "Development of Guidance on Structural Integrity Management of fixed offshore structures", has been prepared by Atkins with contribution from various companies of the oil & gas industry. The standard API-RP-2SIM has been written as part of this JIP. The final report of this JIP includes, in addition, a methodology based on reliability analysis to develop minimum acceptance criteria for fixed offshore jacket structures under environmental loading for any region of the world.

9.4.2 Guidance for developing regional criteria

Acceptance criteria are given in terms of the minimum structural capacity against target reliability. Defining the minimum structural capacity against target reliability can only be achieved by considering the probability of failure of the platform against an extreme load (eg environmental load) causing collapse.

The JIP report provides a reliability analysis method to compute this probability of failure.

The target structural reliability for an existing platform, which equates to an acceptable probability of failure, is typically a function of the consequence of failure of the platform, in terms of life safety, environmental impact, public perception and financial loss to the region, nation or asset owner. The maximum acceptable annual failure probabilities provided in Tab 11 are suggested by general consensus of the JIP participants.

The high, medium and low consequence definitions are provided in the API-RP-2SIM document. The above target values of PoF are consistent with ISO 19902 too.

Table 9 : Regimes of underwater inspection program

		Inspection regime		
		Level II	Level III	Level IV
Defect surveys	General visual	X	X	X
	Anode	X	X	X
	Flooded member detection		X^p	X^p
	Visual corrosion	**(1)**	X	
	Weld/joint			X
	Cathodic potential		X^p	X
Anomaly surveys	Debris	X	X	X
	Scour	**(2)**	**(2)**	**(2)**
	Marine growth			X
Appurtenance surveys	Riser/J-tube/ Caisson			

Note 1:

X^p : Part survey

(1) Not required if a continuous annual drop cell record so indicates.

(2) If seafloor is conductive (loose sand) or seafloor instability is known or suspected.

The report presents a framework based on a reliability analysis to compute the annual probability of failure of a jacket structure. The methodology includes:

- the development of statistical distribution for loading and resistance parameters, including model uncertainty characterization
- the development of a limit state function for the structural collapse failure using surface response technique
- the derivation of probability of failure using appropriate structural reliability methods. Simulation methods are recommended for their accuracies, but they can be supplemented with FORM to perform sensitivity analysis. A simplified method was also presented during the course of the JIP for a single collapse mechanism due to brace failure.

Table 10 : Guidelines for routine underwater inspection intervals

Susceptibility to mechanical damage	Susceptibility to defects					
	Pre - RP 2A			Early - RP 2A		Modern - RP 2A
	Corroded or unknown CP history and/or more than 100 ft water depth	Inadequate deck elevation	Pre	Corroded or unknown CP history	Early	Modern
High (drilling)	IV	IV	IV	IV	IV	III
Medium (other)	IV	IV	III	IV	III	II
Low (caisson, well prot.)	IV	III	III	III	III	II

Table 11 : Target reliability

Consequence category	Maximum acceptable failure probability
Manned and non-evacuated (high life safety)	10^{-4}
Evacuated but with high business or environmental consequence	10^{-3}
Unmanned with medium or low business or environmental consequence	$5.\ 10^{-3}$

9.5 ISO 19902

9.5.1 Only sections 23 and 24 deal with the SIM of fixed offshore structures. Section 23 sets out SIM framework and default inspection plan, but just little general recommendations on risk assessment and inspection strategy. Section 24 provides recommendations for the assessment of existing structures.

9.6 API-RP-580

9.6.1 This standard presents the concepts and principles of RBI and provides recommendations for RBI analysis of pressure containing equipment. However, the general recommendations hold for fixed offshore structures too.

9.7 API-581-BRD

9.7.1 This standard describes the basic technology and methods adopted within the API-RBI methodology, including qualitative and quantitative assessment methods. Although, dedicated to pressure containing equipment, the general principles of the methodologies apply to fixed offshore structures too.

An unsymmetrical risk matrix, which reflects risk aversion, is proposed. A typical formulation of the LoF as the product of a generic LoF, a management factor and an equipment factor is also given, which could be adapted to fixed offshore structures.

SECTION 3 SERVICE PROVISION

1 High level risk-based SIM method

1.1 General

1.1.1 Scope

The high level Risk-Based SIM method applies to a fleet of jacket platforms and uses a qualitative approach for risk assessment to perform global relative risk ranking and develop inspection strategy with global inspection requirements based on the API guidance and inspection trends. The developed inspection program focuses on the underwater portion of the jacket platforms.

This method is also effective in identifying the higher risks platforms which should benefit enhanced inspection effort or further detailed risk assessment with an appropriate method e.g. semi-quantitative or quantitative assessment.

In addition, the risk assessment process that it implements may be used to compare given inspection strategies in order to identify the best one with respect to the risk impact or to another specific decision criteria adopted by owner/operators.

1.1.2 Background

The method is inspired from a risk-based underwater inspection process initially developed by BP Amoco for its own fleet and presented at the OTC conference in 1999 (DeFranco, et. al., 1999). This process is based on a similar approach being developed by the American Petroleum Institute for refineries and chemical plants. It has then been customized and applied by other oil & gas companies.

1.1.3 Applicability

The method is to be used for the relative risk ranking of jacket platforms or the planning of in-service inspection of the underwater portion of jacket platforms in a fleet.

It considers failure as collapse of a platform due to deterioration (e.g. fatigue, corrosion), environmental overload or combination of both. Special hazard such as fire, blast, and other accidental events are not considered and should be treated separately.

1.1.4 Reference standards

The method is consistent with the structural integrity management process defined in API-RP-2SIM (Sec 2, Fig 1).

It assesses risk using a workbook approach similar to those defined for equipment in API-581-BRD.

1.2 Method description

1.2.1 This method includes the following basic steps:

- data gathering
- likelihood of failure assessment
- consequence of failure assessment
- risk ranking
- and inspection planning.

1.3 Data gathering

1.3.1 General

The analysis uses two broad categories of data:

- characteristic data of each platform
- and condition data of each platform in the operational phase.

The relevant data should be extracted from a dedicated data management system.

1.3.2 Characteristic data

The characteristic data include:

- general data such as top level information (e.g. platform's name, installation year, location, manning level), jacket arrangement data (e.g. type of foundation, number of legs, bracing configuration); platform's function (e.g. drilling, production, well-head,…) and production (e.g. oil and gas production)
- design data (e.g. applied design code, design criteria)

1.3.3 Condition data

The condition data include:

- assessment data e.g. analysis year, structural analysis results, current state of the platform, current environmental loads
- inspection results e.g. inspection year, CP measurements, number of flooded or damaged members, measured marine growth profile.

1.4 Likelihood of failure

1.4.1 General

Likelihood is determined using a rule-based scoring system in terms of key factors that affect the platform strength and loads. Each factor is assigned a weight to account for its importance in the occurrence of failure.

The key factors associated to the likelihood scoring rules are divided into four broad categories:

- as-installed condition
- present condition
- platform modification
- and loading exposure.

1.4.2 As-installed condition

The factors in this category are the following:

- design year accounts for how the significant changes in the design practices over the time have improved the strength of the platform and the accuracy of the design load
- installation year and location account for how the design loads have varied over the time and from one region to another
- the number of legs and the bracing system account for the robustness of the structure
- the type of foundation accounts for grouting the annulus between the piles and the legs which strengthen the joints between the legs and the braces. It accounts also for the availability of pile penetration records, which allows checking whether piles' installation defects detrimental to the structural integrity have occurred.

1.4.3 Present condition

The factors in this category are the following:

- the year and the level of the last underwater inspection intend to penalize platforms that were left for a long time without being inspected with a suitable survey level
- damaged members accounts for the number of observed damage members and the tolerance of the jacket structure to the observed damages
- flooded members accounts for the number of detected flooded members and the tolerance of the jacket structure to the detected flooded members
- remaining wall or extent of observed corrosion accounts for the number of members marked as corroded and the tolerance of the jacket structure to the detected members wall corrosion
- marine growth accounts for the increase in the loading on a jacket platform due to observed marine growth especially above that required from the design or from the last structural assessment
- scour accounts for the reduction in a jacket platform strength due to observed scour especially above that required from the design or from the last structural assessment
- the status of the CP system accounts for how well the structure is protected against corrosion. It is given in terms of the last cathodic potential readings and the condition of the anodes
- splash zone damage and corrosion account for the suspected damage underwater as the result of falling debris from the above water structure
- debris can be detrimental to personnel safety e.g. heavy debris may injure personnel involved in inspection or repair. Debris can be detrimental to the structure integrity too by causing abrasion or fretting damage, or by modifying the cathodic potential, thus affecting the CP system.

1.4.4 Platform modification

The factors in this category are the following:

- deck load accounts for the actual topside load on the jacket structure and whether it complies with that required from design or from the last structural assessment
- appurtenances number change accounts for the actual number of appurtenances and whether it complies with that required from design or from the last structural assessment

1.4.5 Loading exposure

The factors in this category are the following:

- deck elevation accounts for how likely a jacket platform can be subjected to wave in deck loading as a result of subsidence, low cellar deck or higher wave heights
- fatigue sensitivity accounts for the existence of fatigue-sensitive joints and/or location susceptible to fatigue cracking
- damage susceptibility accounts for the likelihood of occurrence of mechanical damage from vessel impact or dropped object with respect to the platform type
- appurtenances exposure accounts for the risk that a rupture or a leak of hydrocarbon carrying riser or conductor escalates to a platform failure. It depends on the current number of risers and conductors
- earthquake penalizes platforms installed in an earthquake zone while they have not been designed for that.

1.4.6 Interaction between the factors

There may be interactions between the various factors, which must be accounted for in developing the likelihood scoring rules. Examples of interaction are provided below:

- The effect of the number of legs on the LoF is strongly correlated to the bracing system, since the structural redundancy depends on the interaction of these two parameters
- The effect of corroded or damaged members of the LoF depends on the structural redundancy, therefore the assessment of LoF due to the number of damaged, flooded or corroded members should consider the number of legs and the bracing systems
- The number of legs is correlated to the location of the platform e.g. the water depth; the marine growth and the scour are also correlated to the location of the platform
- The extent of corrosion and damage due to fatigue for instance depends of the year since the last survey was undertaken.

In the actual method, relevant interactions between the various factors have been identified and evaluated. These interactions are implemented in the adopted LoF scoring rule system.

1.5 Consequence of failure

1.5.1 General

The consequences of failure are assessed in regard to:

- life safety
- environment
- and business.

Like the API, the method defines the consequence of platform failure qualitatively as an exposure category in terms of life safety and environmental safety and business consequence. The platform exposure to be used is the most restrictive of the three types of consequence, each of them being divided into 5 categories.

1.5.2 Life safety

The life safety consequence considers the impact on personnel which are on the platform should a platform failure occur.

The life safety exposure categories are described in Tab 1.

1.5.3 Environmental safety

The environmental consequence considers the impact to the environment as a result of pollution by spilled hydrocarbon should a platform failure occur. It depends on the volume of hydrocarbon released during platform failure and the proximity of the platform to the shoreline and/or environmentally sensitive areas.

The environment exposure categories are described in Tab 2.

1.5.4 Business

The business consequence considers the economic costs associated to platform repair or replacement and to lost production should platform failure occur. Operator will generally develop their own criteria to categorize economic consequence.

The economic exposure categories are described in Tab 3 with qualitative criteria. An operator could assign specific values to those criteria in terms of its own perception of economic risks.

1.6 Risk ranking

1.6.1 A five by five risk matrix is used for the risk ranking. According to the risk acceptance criteria different matrix formats and numbers of risk categories can be adopted.

Table 1 : Safety exposure categories

CoF	Terminology	Description
E	Manned non-evacuated	The manned, non-evacuated category refers to a platform that is continuously occupied by persons accommodated and living thereon, and personnel evacuation prior to the design metocean event is either not intended, or it is impractical.
D	Occasionally manned with temporary accommodation	Platform with temporary accommodation
C	Occasionally manned - evacuated by emergency shelters (boat landing)	Platform with emergency shelters (boat landing)
B	Occasionally manned - evacuated by bridged link to quarters platform	Platform with bridged link to quarters platform
A	Unmanned	The unmanned category refers to a platform that is not normally manned or a platform that is not classified as either, manned non-evacuated or manned-evacuated.

Table 2 : Environment exposure categories

CoF	Terminology	Description
E	Catastrophic	Event where structural failure is expected to cause very high volume of oil leak.
D	Major	Event where structural failure is expected to cause high volume of oil leak.
C	Localized	Event where structural failure is expected to cause moderate volume of oil leak.
B	Minor	Event where failure is expected to cause low volume of oil leak.
A	Slight	Event where failure is expected to cause very low volume of oil leak.

Table 3 : Economic exposure categories

CoF	Terminology	Description
E	Very high	The consequence of failure represents very high cost.
D	High	The consequence of failure represents high cost.
C	Medium	The consequence of failure represents medium cost.
B	Low	The consequence of failure represents low cost.
A	Very low	The consequence of failure represents very low cost.

1.7 Inspection planning

1.7.1 The method allows routine underwater inspection to be developed. The inspection intervals are determined from the risk level. A relationship has been established between the risk level and the inspection interval consistent with the API recommendations and the inspection trends.

Nevertheless, the inspection intervals may be adjusted to account for:

- High Consequence Appurtenances
- Ineffective Corrosion Protection Systems
- Regulations
- Operational feasibility.

In some cases, the current risk categorization may not allow the platforms of a fleet to be discriminated in terms of risk levels, for instance, when all the platforms have been designed according to current design practices. In such cases, the method allows the LoF scoring system to be adapted to the fleet under study in order to provide relative risk ranking of the platforms.

Then, the inspection plan can be obtained from an adapted LoF scoring system by comparing several possible inspection plans with respect to their impact on the risk level.

In fact, the inspection plan only affects the likelihood of failure which depends among others on last inspection date and level of inspection. Those two factors can be changed to model a trial of inspection plan by entering future inspection dates and levels, along with the expected amount of future deterioration. Thus, the risk assessment can be run, at future inspection dates, to compare various inspection plans in terms of the risk, with the intent of selecting the inspection plan that provides the lowest risk level.

2 Risk-based SIM method for one jacket platform

2.1 General

2.1.1 Scope

This method allows a risk-based inspection strategy to be developed for a jacket platform. In addition to the minimum requirement for a level II survey, it can provide the scope of the level III survey, when this is required from the level II survey findings or for a higher-risk platform.

The method computes separately:

- a global risk level for the whole structure disregarding the condition of the structural components, which drives inspection interval and the level II survey scope of work
- local risk levels of the individual structural components, which allows, if required, level III and eventually level IV survey scope of work to be defined.

2.1.2 Applicability

In order to develop an inspection strategy, the method assumes that the structure is fit-for-purpose in its current condition. This requires that the current metocean loading and the deck loading have not deviated significantly from the design requirement or from the last structural assessment requirement. It requires also that no anomalous finding was reported from last inspection e.g. anomalous cathodic potential readings, observed marine growth profile outside the specifications. Thus, whenever a significant change in loading occurs or an anomalous inspection finding is reported, a preliminary assessment is carried out to check that the structure is still fit-for-purpose before applying the method. If the structure is not fit-for-purpose, risk reduction measures should be undertaken.

The method considers failure due to operating condition (i.e. fatigue) and extreme design loads. At its current stage of development, it does not take into account failure due to regional conditions such as earthquake, hurricane or tsunami.

2.1.3 Reference standards

The method is consistent with the structural integrity management process defined in the API-RP-2SIM (Sec 2, Fig 1). It uses a formula for the local likelihood of failure and a risk matrix format similar to those defined for equipment in API-581-BRD.

2.2 Method description

2.2.1 This method includes the following basic steps:

- data gathering
- preliminary assessment if required
- global risk level assessment
- local risk levels assessment
- inspection strategy
- inspection program.

2.3 Data Gathering

2.3.1 General

The analysis uses two broad categories of data:

- characteristic data of the platform
- and condition data of the platform in the operational phase.

The relevant data should be extracted from a dedicated data management system.

2.3.2 Source of data

Design, structural assessment and inspection documents are useful source of data for the risk assessment. They include:

- weight report
- metocean report
- geotechnical report
- drawings
- structural analysis report from design or subsequent structural assessment
- other standards used as references
- inspection reports
- and inspection photos and videos.

2.3.3 Characteristic data

The characteristic data are listed below.

a) Platform main data
   - platform type
   - field data (oil reservoir capacity)
   - personnel on board (POB)
   - year of installation
   - year of the first risk assessment for SIM (especially performed by the Society)
   - design lifetime
   - design weight
   - and the documents attesting the quality of the safety management system.

   Optional data, such as platform's name, operator's name and platform situation can be included for information only.

b) Design site conditions
   - 100 - year wave crest
   - LAT
   - marine growth profile used for the design
   - and scour design criterion.

c) Operation conditions
   - production type
   - oil production or transit
   - and gas production or transit.

d) Corrosion protection

   The corrosion protection data, including painting, anode type and number of anodes specified for the design, are only indicative.

e) Design assessment data
   - max operational weight
   - pile penetration ratios
   - RSR if available
   - physical properties, corrosion allowance, in-service unity check and initial flood status of the tubular members
   - and geometry, type, in-place punching UC and fatigue damage of the tubular joints.

   The S-N curve description can be included for information only.

f) Jacket arrangement
   - lower deck elevation
   - vertical framing
   - number of legs
   - and types of legs e.g. piled legs, skirt piles, suction anchor or grouted piles-legs.

   Optional data such as horizontal framing and number of levels can be included for information only.

g) Other site specific information
   - platform location
   - coast type
   - intervention capacity
   - intervention efficiency
   - and halieutic resources.

2.3.4 Condition data

a) Structural assessment data

   This category includes the current value of the calculation data.

b) Previous inspection data
   - Site inspection results:
     - max scour depth
     - debris
     - scour
     - measured marine growth profile
     - and metocean measurements (e.g. LAT, 100 - year wave crest).
   - Corrosion protection system inspection results:
     - painting deterioration
     - cathodic potential measurements
     - and anode depletion.
   - Detected fatigue cracking in tubular joints (e.g. crack depth, used NDT)
   - Tubular members inspection results:
     - dent depth
     - out-of-straightness
     - and wall thickness measurements.
   - Detected deformation or fracture on boat landing
   - Detected damage on appurtenances (e.g. risers, J-tube, caisson).

   Any other defect regarding the site condition, the corrosion protection system or the jacket structure that was reported should be included for information. Although not directly used in the assessment they could give indication on the condition of the platform and could be appraised by a knowledgeable person to adjust the risk assessment accordingly.

2.4 Preliminary assessment

2.4.1 General

A preliminary assessment must be carried out to ascertain applicability of the method. It intends to check:

- whether some basic design criteria are met
- and whether the current conditions meet the original design requirements or the last structural assessment requirements.

2.4.2 Basic criteria

The basic design criteria include the current API design criteria regarding air gap and foundation. A platform not fully compliant with these criteria may be subjected to a push-over analysis and deemed eligible to undergo a SIM by the current method, should it exhibits sufficient reserve strength.

2.4.3 Deviation from original API design conditions

Some key design parameters are considered for evaluating whether they have deviated from the current design above the margins defined by that design code. However, the analyst is allowed to slightly modify (e.g. of 5%) the original margins.

The following key design parameters are considered:

- 100 - year wave crest
- average marine growth thickness
- members' thicknesses, e.g. minimum measured thickness on a member
- tubular members and joints unity check
- tubular joints fatigue damage
- and RSR (only for applying ultimate strength assessment).

A platform not fully compliant with these criteria may be subjected to structural assessment with the current values of the design parameters and deemed eligible to undergo a SIM with the current method should it is assessed fit for purpose.

2.5 Global risk level assessment

2.5.1 General

Platform global risk assessment is assessed with respect to the general condition of the platform and disregarding local structural data (e.g. related to joints and members).

2.5.2 Global likelihood of failure

The global likelihood defines the likelihood of failure of the whole structure regardless of the prevailing failure mechanism.

It is based especially on the global structural characteristics (e.g. robustness) of the platform and on the findings from the last underwater inspection. It can be evaluated, either, simply by the same qualitative rule-based scoring approach used for the high-level risk-based method (section 1.4) or from the available structural analysis results e.g. ultimate strength analysis. In fact, when structural analysis has been performed, it provides a measure of the structural capacity (e.g. maximum unity check, RSR) which can be correlated to the likelihood of failure. However, non-structural factors (e.g. time since last inspection, effectiveness of the CP system) that influence the likelihood of failure, should also be taken into account, if they are relevant, to adjust the LoF from the structural capacity.

2.5.3 Global consequence of failure

The global consequence is given by the sum of appropriately weighted scores assigned to threats, respectively to personnel, environment and property.

The threats to personnel, environment and property are estimated in terms of platform functionality and manning levels using a consequence scoring methodology set out in the research report of EQE on technical performance measures for North Sea Jacket (Nelson, 2003).

Especially for the threat to environment, an additional score has been introduced by the Society to take into account the platform's specific environmental conditions (e.g. type of shore, location, intervention capacity and efficiency).

2.5.4 Global risk ranking

The global risk level is assessed using a dedicated risk matrix in terms of the global likelihood and consequence of failure. Risk matrices are generally operators specific. By default, the current method considers 5 risk level categories with an unsymmetrical format to reflect risk aversion (Fig 1).

Figure 1 : Default risk matrix format

Likelihood	A	B	C	D	E
5	IV	IV	IV	V	V
4	III	III	IV	IV	V
3	II	II	III	IV	V
2	I	II	III	III	IV
1	I	I	III	III	IV
	Consequence				

2.6 Local risk levels assessment

2.6.1 General

The local risk levels assessment is focused on the tubular joints of jacket structure. It aims at providing a relative risk ranking of the platform's welded tubular joints to allow inspection location to be selected when local inspections are required (i.e. level III survey).

2.6.2 Local likelihood of failure

The local likelihood of failure assessment uses a rule-based scoring approach. It is given by the weighted sum of partial scores assigned to factors that influence the likelihood of failure of the joint under consideration.

The factors that affect local likelihood of failure are divided into two main categories:

- Structural analysis local results:
  - Fatigue
  - Static strength.
- Inspection history:
  - Existing local inspection
  - Inspection indication if inspected
  - Reliability of the inspection technique if inspected.

Simple scoring rules have been developed for each influencing factor. Structural analysis results allow the likelihood of failure to be estimated as a function of stress and fatigue damage, while inspection history penalizes this likelihood to account for observed defects on inspected joints and members or uncertainty on the condition of non-inspected joints and members.

The fatigue scoring rule depends on the fatigue damage provided by the fatigue analysis. A larger weight is assigned to fatigue which is considered to be the most important driver of the local failure assuming that all the punching ratio are lower than 1.

The static strength score depends on the punching ratio provided by the in-place analysis. This factor is critical for local failure only when an exceptional overloading occurs; therefore a lower weight is assigned to this factor. It serves mainly to compare the likelihood of failure of joints that have approximately the same fatigue damage.

The existing inspection score penalizes joints which have not been inspected previously to account for the uncertainty on their current condition.

For the joints which have been inspected previously, the inspection indication score penalizes joints for which defect was found either on the welded joint itself or on the members attached to it. The score for the reliability of the inspection technique penalizes less accurate techniques (e.g. NDT is assumed more accurate than CVI or FMD).

Five categories are considered for the local likelihood of failure. The ranges in which the scores lie are calibrated on a set of representative joints data, the failure susceptibilities of which are assessed by engineering judgment.

2.6.3 Local consequence of failure

The local consequence is given by the global consequence of failure reduced by a redundancy factor:

$C_i = C - RF_i$

where C is the global consequence of failure and RF_i the redundancy factor. Thus, the local consequence of failure of a non-redundant structural component is almost equal to the global consequence, while it is significantly reduced for a redundant component.

The redundancy factor is given in terms of:

- the number of legs of the platform,
- the type of member attached to the joint (e.g. primary, secondary or tertiary member)
- the punching ratio of the joint.

2.6.4 Local risk ranking

The local risk ranking provides only relative risk ranking of the platform tubular welded joints. It uses, by default, the same unsymmetrical risk matrix format as the global risk ranking (Fig 1). The number of joints per risk level category is set out on the matrix to show the distribution of the local risk levels.

2.7 Inspection strategy

2.7.1 Risk-based inspection intervals

The API-RP-2SIM provides guidelines for the risk-based inspection intervals with respect to three risk levels (Sec 2, Tab 4).

By default, the inspection intervals range from 3 years to 12 years with respect to the global risk level (Fig 2). However, the inspection interval may be adjusted to account for the design life, the present condition of the CP system or operational feasibility and regulations.

2.7.2 Inspection scope of work

In accordance with API recommendations, the inspection program should be a minimum of level II survey and damage or deterioration found during a level II survey is the basis to trigger a Level III or Level IV inspection.

The inspection scope of work is based on the default inspection program provided by the API. The method considers the respective inspection programs per exposure category (Sec 2, Tab 5) as three inspection regimes, denoted low regime for exposure category L-3, medium regime for exposure category L-2 and high regime for exposure category L-1. Those inspection regimes are applied with respect to the risk level as indicated on the Fig 3.

When level III surveys are required, they should include pre-selected joints or members with respect to the local risk ranking, in addition to the locations where damage are suspected from level II survey.

A weighted average model is used to provide risks scores to the tubular joints to rank them in order of priority for inspection. This model involves the local likelihood and consequence of failure along with the local risk level and gives more weight to the consequence of failure to reflect risk aversion. Then, the mean value of the risks scores is used to determine the percentage of joints with the higher risks scores to be inspected.

The method proposes two options to define the local inspection scope of work, either:

- applying CVI on preselected tubular joints,
- or using FMD technique on the members attached to the preselected joints.

2.7.3 Final inspection plan validation

The current methodology suggests an inspection plan for the next campaign. However, depending on the operator's specific constraints, the final inspection plan can be modified by the operator. In all cases, the validation of the final inspection plan is to be endorsed by the operator.

Figure 2 : Inspection intervals

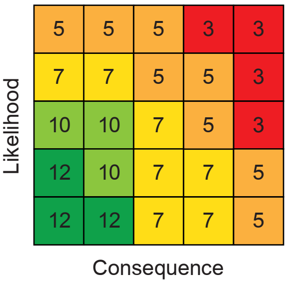
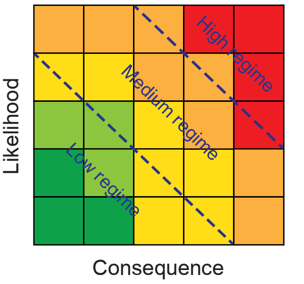


Figure 3 : Inspection program



3 Fatigue-based probabilistic method

3.1 General

3.1.1 Scope

This method uses a full quantitative approach to develop inspection planning for a platform's welded joints subject to fatigue. It provides, for each of the tubular joints under consideration, an optimal inspection plan with respect to the overall service life cost of the facility under the constraint to fulfil overall facility risk acceptance criteria.

This method suits tubular joints reported to have higher risk of failure from fatigue analysis, e.g. joints, the fatigue lives of which are lower than ten times the expected service life.

3.1.2 Background

The formulation of the optimization problem to determine the joints' inspection plans is based on the so called preposterior analysis from the classical decision theory (Faber, 2002).

3.1.3 Applicability

This method focuses on the risk of fatigue failure of the welded connections of the jacket structure. It does not consider corrosion degradation mechanism assuming that corrosion is well controlled by barrier measure such as cathodic protection system.

3.1.4 Reference standards

This method implements a recognized and documented RBI method applied to risk of fatigue failure of welded connections and based on a crack growth model along with structural reliability analysis (Goyet, et. al., 2013).

3.2 Method description

3.2.1 This method includes the following basic steps:

- data gathering
- risk acceptance criteria
- tag system
- fatigue analysis
- pushover analysis
- detailed RBI analysis
- scheduling.

3.3 Data Gathering

3.3.1 General

This method uses three broad categories of data:

- characteristic data of the platform
- condition data of the platform in the operational phase
- and inspection and maintenance policy of the operator.

3.3.2 Source of data

The relevant data are to collect from:

- design report
- construction and installation report
- previous inspection reports
- and operation and maintenance history.

3.3.3 Characteristic data

The main characteristic data to collect are the following:

- drawings of the jacket structure, deck and appurtenances
- mechanical properties of the jacket members, the piles, the deck members and the risers and conductors
- soil characteristics
- service life of the jacket
- manning levels
- and design metocean conditions e.g. extreme and operational waves.

3.3.4 Condition data

The condition data to collect are the following:

- fatigue assessment reports
- up-to-date weight control
- previous inspection campaign results
- marine growth measurement
- and thickness measurement.

3.3.5 Inspection and maintenance policy of the operator

The data related to operator's policy for inspection and maintenance are the following:

- risk acceptance criteria
- preferred NDT technique
- control actions in case of crack finding
- existing and planned revamping phases over time
- and tag system in place for inspection results reporting.

3.4 Risk acceptance criteria

3.4.1 General

The purpose of this step is to derive risk acceptance criteria of the individual tubular joints from the risk acceptance criteria of the facility with respect to risk to personnel, environment and asset.

3.4.2 Risk acceptance criteria for the facility

Risk acceptance criteria are defined with respect to risk to personnel, environment and asset.

The risk acceptance criterion (RAC) for risk to personnel can be given in terms of individual risk or group risk. A typical RAC for individual risk is set by an upper bound of the average number of fatalities per exposed individual, while group RAC can be modeled by the frequency of exceeding the so-called F-N curve, which represents the cumulative distribution of the number of fatalities per accident.

The RAC for risk to environment can be represented by a given volume of oil and/or gas release

The RAC for risk to asset is set by an upper bound of the probability of collapse of the platform under extreme weather conditions given a fatigue failure at a defined tubular joint.

Normally, risk acceptance criteria for the facility are given by the operator or the owner. For new buildings, they must have been defined at the design stage and found in the Risk Assessment documents of the facility. Local authorities may also have some requirement regarding risk acceptance criteria.

When they are not available, they should be provided by the operator or the owner. However, when these are neither available nor documented, they must be defined jointly together with the operator/owner.

3.4.3 Risk acceptance criteria for the structure

For a given offshore platform, risk to personnel, environment and asset are related to process hazards or structural collapse. RAC for the structure accounts only for the contribution of collapse structural failure to the overall risk acceptance level.

The RAC for the collapse of the structure is given in terms of the maximum annual probability of collapse.

It is computed from the overall risk acceptance criteria for the facility and the probabilities of process hazards obtained from QRA analysis of the process, using the relationships between process failure modes and collapse failure leading to the same consequence. These relationships are established by typical event trees.

However, when QRA for process are not available, the risk acceptance criteria may be directly derived for the structure, using only the overall risk acceptance criteria for the facility. This assumes that the contribution of the process to the risks is negligible, which has to be checked when further data from process QRA are available, or agreed with the operator. All concerns with risk acceptance criteria need in any case agreements with the operator.

3.4.4 Risk acceptance criteria for the tubular joints

Once the RAC has been established for the structure, risk acceptance criteria have to be derived for the individual tubular joints. The RAC for a given joint is represented by the maximum annual probability of the joint fatigue failure. It is computed using the reserve strength ratio (RSR) for the structure given a fatigue failure of the joint under consideration. This is the ratio between the base shear at structural collapse for the damaged structure to the design base shear.

At this stage of the method, the objective is not to define explicitly the risk acceptance criteria for the tubular joints, but to establish a clear relationship between the RSR for the damaged structure and the annual probability of collapse failure. This relationship will be used later with the RSR computed by the pushover analysis to derive the risk acceptance criteria for the individual tubular joints selected for a detailed RBI analysis.

In order to evaluate this relationship, the platform's ultimate limit state function is set as the difference between the platform's effective capacity and the static base shear load on the platform, and appropriately chosen probability distributions are used to modelled those variables e.g. log-normal distribution for the capacity and extreme value distribution for the static base shear. Then, the annual probability of collapse failure for different characteristic values of the RSR for the damaged structure is computed using classical structural reliability methods e.g. Monte-Carlo simulation, First or Second order reliability methods.

3.5 Tag system

3.5.1 The inspection of the tubular joints of a jacket requires that these joints be clearly identified: this is a prerequisite for the tracing and the management of the structural integrity of the platform. When using a finite element analysis, the nodes that represent the joints have given numbers. Unfortunately, node numbers are not convenient for use for a tag system. Moreover, most operators have already a set of inspection sheets with tag system to report inspection findings. The objective of this task is to establish the link between the finite element node numbers and the tag system provided by the operator.

When not available (in case of new buildings for example), a new tag has to be established.

3.6 Fatigue analysis

3.6.1 Objective

The main objective of the fatigue analysis is to provide the fatigue lives for all tubular connections and to select the higher risk connections that need a detailed RBI analysis.

3.6.2 Required input data

The main inputs to carry out the fatigue analysis are the following:

- structural model of the jacket structure, including among others actual deck weight which can be taken from up-to-date weight control report and soil characteristics
- design S-N curve, including SCF and thickness correction
- history of measurement of marine growth profile. For newly installed jacket platform, it is necessary to look for typical stabilized marine growth for near-located platforms of other fields. When data is available, evolution of marine growth with time is to be predicted
- operational metocean wave conditions e.g. scatter diagram of sea states
- planned revamping phases with corresponding loads
- and tag system.

3.6.3 Method

The fatigue analysis is based on spectral dynamic analysis in compliance with the API calculation procedure and follows these steps:

- Characterization of metocean wave climate by a set of representative sea states defined by a power spectral density model associated with relevant physical parameters e.g. significant wave height, wave period and direction, along with a probability of occurrence over the long term. This characterization is conveniently achieved by wave scatter diagram

- Structural modelling, including:
  - geometric space frame model with increased cross-sectional area to account for existing marine growth
  - physical and material properties of the members
  - boundary conditions
  - mass model including that of all platform steel, all appurtenances, conductors, deck, existing marine growth and the added mass of submerged members
  - damping model in which drag coefficients factor in existing marine growth
  - stiffness model accounting for the elastic behavior of the platform
  - and two-dimensional wave kinematics obtained from an appropriate wave theory with respect to the sea state condition.

Note that, effects of the current and the hydrodynamic shielding from appurtenances and conductors may be neglected. Moreover, dynamic effects such as the introduction of dynamic amplification factors and elastic stiffness should be considered for sea states having significant energy near the platform's natural period.

- stress response computation, including nominal members' stresses and local stresses within tubular connections. Members' nominal stress response spectra are obtained by applying the relevant stress transfer function, in terms of response amplitude operator (RAO), to each of the representative sea state spectra. Local stresses within tubular connections are obtained by applying suitable stress concentration factors (SCF) to the nominal stress of the members around the intersection of interest
- fatigue damage computation for each hot spots around the tubular intersections of interest. This computation is performed for each of the stress response spectra for each sea state using Miner rule and the appropriate choice of the S-N curve. The allowable stress range related to the S-N curve includes the thickness correction for tubular member with greater wall thickness.

  The fatigue damages due to the stress response spectra for each sea state are combined into the long term sea state distribution. In the case of existing revamping phase, the fatigue life of a tubular joint is computed by summing the damage contribution of each phase for the hot spots taken one by one. Then, the hot spot having the highest fatigue damage over all phases provides the total fatigue life of the tubular connection under consideration.

3.6.4 Main outputs

The fatigue analysis provides:

- the fatigue lives of all the tubular joints of the jacket structure in terms of the so-called fatigue design factor (FDF), given by the ratio between the fatigue life and the service life. In case of existing revamping phases, FDF values are computed for each phase
- the most loaded hot spot location in terms of weld - side (e.g. chord or brace) and hot spot position.

The detailed RBI is to be performed for tubular joint with a FDF lower than 10. For each such tubular joint, the following data are provided:

- FDF value
- number from the FEM model of the associated node and beam member of the related brace
- type of tubular joint e.g. T, Y, K, KT,…
- most loaded hot spot location
- thickness of the most loaded weld - side e.g. chord or brace thickness
- and tag number.

3.7 Pushover analysis

3.7.1 General

The objective of the pushover analysis is to compute the RSR values for the structure given a fatigue failure in each of the higher risk joints taken separately. These RSR values are to be used with the relationship established between RSR and annual probability of collapse failure to derive RAC for each of those higher risk joints selected to undergo a detailed RBI analysis.

3.7.2 Required input data

The structural model is quite the same as the one used for the fatigue analysis, but it must include additional parameters to account for the fact that stresses have exceeded elastic levels, and detailed modelling of foundation and deck load are required for this type of analysis. The input data especially include:

- 100 - year wave crest and related probability of occurrence in each direction
- loads on the deck as defined for the in-place analysis. However, special attention should be given to modelling the deck should wave inundation be expected
- yield stresses, actual or expected mean values are recommended instead of nominal values
- marine growth profile, especially most recent measurement
- and soil characteristics.

3.7.3 Method

A non-linear pushover analysis is considered to assess the ultimate limit state behavior of the platform, and the fatigue failure in the given tubular joint is modelled as complete failure of the tubular joint, assuming that the associated brace and chord members are detached from each other.

3.7.4 Main output

The analysis provides for each relevant tubular joint, the RSR of the damaged structure in each direction. It is recommended to use the lowest value of the RSR among all directions to derive joints' RAC to be used in the detailed RBI analysis.

3.8 Detailed RBI analysis

3.8.1 General

The detailed RBI analysis provides, for each relevant tubular joint, an inspection plan that minimizes the expected total operational cost over the service lifetime of the platform.

3.8.2 Formulation of the inspection planning problem

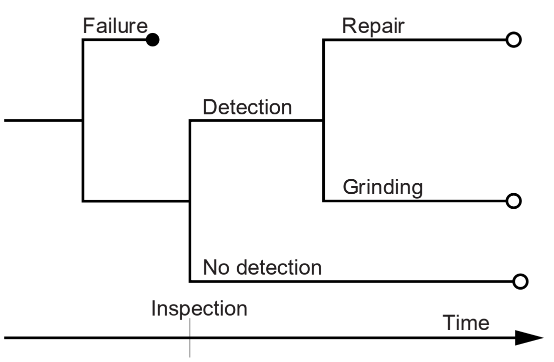
The determination of the optimal inspection plan is based on a decision tree approach. The typical decision tree used for the actual detailed RBI analysis is shown on Fig 4.

For a given inspection plan, the expected total operational cost involves:

- the nominal costs of inspection and repair
- the cost of platform collapse
- the probability of fatigue failure of the joint under consideration over the time
- the probability of crack detection on the joint under consideration at a an inspection date
- the probability of repair of the joint under consideration at a an inspection date
- and the probability of platform collapse given fatigue failure of the joint under consideration.

The optimal inspection plan with respect to the expected total operational cost is to be found under the constraint that the annual probability of fatigue failure over the time does not exceed the RAC of the joint under consideration. For the sake of simplicity and to meet operational constraints, the possible inspection plans are limited to constant inspection interval plans and so-called constant threshold plans, for which the dates of inspection are determined so that the annual probability of fatigue failure does not exceed a given threshold lower than the RAC.

Figure 4 : Actual decision tree



3.8.3 Assessment of probability of fatigue failure

The probability of fatigue failure is computed using classical structural reliability methods with an appropriate fatigue limit state function.

The fatigue limit state function is based on the through thickness crack and is defined as the difference between the member's thickness and the crack depth in time. A limit state function based on the crack depth instead of the S-N curve is preferred in this analysis in order to have a link with the limit state function for crack detection, which is express in terms of crack depth too.

The crack depth is modelized using Paris's law for crack growth in two dimensions. This model is calibrated on a S-N probabilistic model from the S-N curve of the fatigue analysis so that the probabilities of fatigue failure in time of both models are as close as possible.

3.8.4 Assessment of probability of crack detection

The actual method assumes that the inspection of the selected joints for the detailed RBI analysis is carried out using NDT which allows sizing a crack both in length and depth.

The probability of crack detection reflects the performance of the NDT tool used and is computed with Probability of Detection (PoD). The PoD curve represents the probability to detect an existing crack of a given depth or length by using the NDT tool under consideration.

One could also use the Receiver Operating Curve (ROC) which combines probability of detection and probability of false alarm detection.

3.8.5 Probability of repair

The probability of repair is computed using classical structural reliability methods with an appropriate repair limit state function.

The repair limit state function is defined as the difference between a given threshold and the crack depth in time. That threshold represents the crack size above which a repair or a grinding is decided.

The threshold for grinding is lower than the one for repair. These thresholds are established conjointly with the operator depending on its practice.

3.8.6 Probability updating after inspection

When an inspection is performed, the probability of failure is updated. This updating makes use of Bayesian approach to modelize the assumed condition of the joint under consideration after an inspection.

In the actual methodology, it is assumed that, at time of inspection, the welded joint has not failed and the inspection has given no detection.

3.8.7 Assessment of costs

The nominal costs of inspection and repair as well as the cost of collapse failure are given fixed values in agreement with the operator or owner.

3.8.8 Generic approach to RBI

Implementing the actual methodology in a general asset integrity management is a complex task since there are many tubular joints involved and the computation of the probabilities requires much numerical efforts to be efficient. Therefore, a generic approach is introduced to facilitate the application of the detailed RBI method.

The generic approach develops a database containing suitable inspection plans for a set of different types of tubular joints which are representative for the particular joints in the considered structures. Then, the inspection plans for the individual joints in the structure under consideration are obtained from that database through an interpolation procedure.

These prefabricated inspection plans are termed generic inspection plans and the corresponding types of joint are described by so-called generic parameters which characterize the fatigue behavior of the joint under consideration. In the actual methodology, the generic parameters are:

- the FDF
- the RSR of the damaged structure
- the member wall thickness
- the inspection technique
- and the relative costs of failure, inspection and repair.

3.9 Scheduling

3.9.1 General

It would be unpractical to inspect each single tubular joint at the optimal inspection dates provided for that particular joint by the detailed RBI method since these inspection dates are generally different from one joint to another. Therefore, a scheduling procedure is set up:

- to merge inspection times into reasonable inspection campaigns
- and to reduce inspection scope by taking system effects, e.g. correlation between closer tubular joints, into consideration.

3.9.2 Grouping of inspections

There are two main reasons for grouping joints inspections:

- The nominal inspection cost for an individual joint contains a large part of fixed costs, e.g. access cost, cost of structure unavailability,… and only a minor part of variable cost related to the survey of the joint itself. Therefore, a slight shift of the inspection date to meet operational constraints is unlikely to modify significantly the cost of inspection of an individual joint and change the optimality of resulting inspection plan.
- Moreover, the collapse failure of the platform is generally not due to fatigue failure in one joint only but in many ones, since offshore platforms are often redundant. Thus, it is beneficial to inspect many joints together in an inspection campaign so that the probability of many joints failure coinciding is acceptably small.

The grouping is performed as follows:

- So-called master inspection dates are identified. They correspond to the dates around which the number of optimal inspection dates for the individual joints are maximal. Then, all the inspections near these master dates are shifted and merged with.
- For the joints inspection dates too far away from these master dates, so-called secondary inspection dates may be defined.

3.9.3 Reducing inspection coverage

Taking into account the existing interrelation between the joints' conditions allows developing effective inspection scope of work. These interrelations are due to common influencing factors of the joints conditions. For example, the sea state condition are the same for all the joints; the weld quality may be similar within one production series, leading to similar initial defect sizes and S-N curve; the same inspection technique and inspector's may be applied to many joints.

For a given jacket structure, the common influencing factors of the joints' conditions can be modeled to provide a correlation structure between the joints under consideration. The development of this correlation structure is described either by functional relationship based on expert judgment or by a covariance matrix based on statistical considerations.

This correlation structure allows inferring, from the inspection results on some joints, the conditions of other joints and enables to reduce the inspection scope of work accordingly.

APPENDIX 1 TYPICAL PLATFORM'S DATA

1 Platform's data

1.1 Characteristic data

1.1.1 General information

- original and current owner/operator
- original and current platform use and function
- location, water depth, and orientation
- platform type-caisson, tripod, 4/6/8-leg, etc.
- number of wells, risers, and production rate
- other site-specific information, manning level, etc.

1.1.2 Original design

- design contractor and date of design
- design drawings and material specifications
- design code (e.g. edition API 2A-WSD used in the platform design)
- metocean criteria-wind, wave, current, seismic, ice, etc.
- deck clearance elevation (underside of cellar deck steel)
- operational criteria-deck loading and equipment arrangement
- foundation/soil data
- number, size, and design penetration of piles and conductors appurtenances-list and location as designed.

1.1.3 Construction

- fabrication and installation contractors and date of installation
- approved for construction drawings or as-built drawings
- fabrication, welding, and construction specifications
- material documents, such as construction specifications and/or mill certificates and material traceability
- pile and conductor driving records
- pile grouting records, (if applicable).

1.2 Condition data

1.2.1 Platform history

- metocean loading history-hurricanes, earthquakes, etc.
- operational loading history-collisions and accidental loads
- performance during past metocean events
- survey and maintenance records
- repairs-descriptions, analyses, drawings, and dates
- modifications-descriptions, analyses, drawings, and dates.

1.2.2 Present condition

- 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-current list, sizes, and locations
- wells-number, size, and location of existing conductors
- recent above-water survey results
- recent underwater platform survey results.