Risk-Based Inspection for the Hull Structure of Floating Offshore Units

June 2021

Guidance Note
NI 664 DT R00 E

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BUREAU VERITAS MARINE & OFFSHORE

GENERAL CONDITIONS

1. INDEPENDENCE 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, designer, manufacturer, shipbuilder, repair or conversion yard, charterer or shipowner; none of the above listed being relieved from any of their expressed or implied obligations as a result of the interventions of the Society.

1.4 Only the Society 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 entering into the relevant contract for the performance of the Services.

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 classification or statutory certificates, attestations and reports following the Society's intervention.

2.2 **"Certification"** means the activity of certification in application of national and international regulations or standards ("Applicable Referential"), 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 classification Certificate with reference to the Rules. Classification (or Certification as defined in clause 2.2) is 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 and/or to Applicable Referential 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.

2.4 **"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 public electronic register of ships updated regularly by the Society.

2.11 **"Rules"** means the Society's classification rules (available online on veristar.com), guidance notes and other documents. The Society's Rules 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, maritime labour certification, training activities, all activities and duties incidental thereto such as documentation on any supporting means, software, instrumentation, measurements, tests and trials on board. The Services are carried out by the Society according to the Rules and/or the Applicable Referential and to the Bureau Veritas' Code of Ethics. 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.

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 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 Subject to the Services requested and always by reference to the Rules, and/or to the Applicable Referential, 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 enter the Unit's class in the Society's Register;
- survey the Unit periodically in service to note whether 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.

3.2 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 for surveys; and (iii) inform the Society in due time of any circumstances that may affect the given appraisement of the Unit or cause to modify the scope of the Services.

4.2 Certificates 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.

4.4 The Society may at times and at its sole discretion give an opinion on a design or any technical element that would 'in principle' be acceptable to the Society. This opinion shall not presume on the final issuance of any Certificate nor on its content in the event of the actual issuance of a Certificate. This opinion shall only be an appraisement made by the Society which shall not be held liable for it.

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, drawing, 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, involves, 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, interest 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 resolve 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 defend, release, save, indemnify, defend and hold harmless the Society from the Client's own consequential loss regardless of cause.

7.2 Except in case of wilful misconduct of the Society, death or bodily injury caused by the Society's negligence and any other liability that could not be, by law, limited, the Society's maximum liability towards the Client is limited to one hundred and fifty per-cent (150%) of the price paid by the Client to the Society for the Services having caused the damage. This limit applies to any liability of whatsoever nature and howsoever arising, including fault by the Society, 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 completion of 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 shall defend, release, save, 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 (including for damages arising out of or in connection with opinions delivered according to clause 4.4 above) except for those claims caused solely and completely by the gross 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 The Services shall be automatically and immediately terminated in the event the Client can no longer establish any form of interest in the Unit (e.g. sale, scrapping).

9.3 The Classification granted to the concerned Unit and the previously issued Certificates shall remain valid until the date of effect of the termination notice issued, or immediately in the event of termination under clause 9.2, subject to compliance with clause 4.1 and 6 above.

9.4 In the event where, in the reasonable opinion of the Society, the Client is in breach, or is suspected to be in breach of clause 16 of the Conditions, the Society shall have the right to terminate the Services (and the relevant contracts associated) with immediate effect.

10. FORCE MAJEURE

10.1 Neither Party shall be responsible or liable 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, will be treated as confidential except where the information:

- is properly and lawfully in the possession of the Society;
- is already in possession of the public or has entered the public domain, other than through a breach of this obligation;
- is acquired or received 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 Parties 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 Without prejudice to sub-clause 11.1, 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 by the Society for the performance of the Services including, but not limited to drawings, calculations, and reports shall remain the 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 any 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 These Conditions shall be construed in accordance with and governed by the laws of England and Wales.

15.2 Any dispute shall be finally settled under the Rules of Arbitration of the Maritime Arbitration Chamber of Paris ("CAMP"), 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 Paris (France). The Parties agree to keep the arbitration proceedings confidential.

15.3 Notwithstanding clause 15.2, disputes relating to the payment of the Society's invoices may be submitted by the Society to the *Tribunal de Commerce de Nanterre*, France, or to any other competent local Court, at the Society's entire discretion.

16. PROFESSIONAL ETHICS

16.1 Each Party shall conduct all activities in compliance with all laws, statutes, rules, economic and trade sanctions (including but not limited to US sanctions and EU sanctions) 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, copyright and trademark protection, personal data protection (https://personaldataprotection.bureauveritas.com/privacypolicy).

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 Bureau Veritas' Code of Ethics and, when applicable, Business Partner Code of Conduct both available at https://group.bureauveritas.com/group/corporate-social-responsibility/operational-excellence.

GUIDANCE NOTE NI 664

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Section 1 General

Section 2 Existing Guidelines

Section 3 Semi-Quantitative Risk Assessment Method for Inspection Planning

Appendix 1 Implementation of The Semi-Quantitative Risk Assessment for Inspection Planning

Appendix 2 Degradation or Damage Mechanisms and Failure Modes

Appendix 3 Implementation of Hull Inspection

SECTION 1 GENERAL

1 General

1.1 Context

1.1.1 The current inspection practice for the hull structure of offshore floating units is governed by prescriptive class rules. However, operational constraints and technology development within the offshore industry have raised the need for more flexibility in the inspection requirements especially for the hull structure of offshore floating units. Risk-based approaches which allow the risk exposure of the system to be understood and inspection strategy to be defined accordingly, are therefore seen as interesting alternatives to the prescriptive class rules. Thus, there is a common trend for the offshore production units to move from prescriptive rules to risk-based approaches for inspection and maintenance.

1.1.2 Risk-based Inspection (RBI) is now included in the Society's class rules as stated in the Guidance Note NI657. It is defined as a means to establish and update the inspection, maintenance and repair plan of systems all along the service life. The Guidance Note NI657, especially, provides the classification process of offshore units under RBI regime and the Society requirements in conducting RBI for developing the inspection program of their hull structure.

1.1.3 the Society has also developed a semi-quantitative risk assessment method, which can help in selecting an appropriate inspection strategy. In particular, the results provided by this method should be taken into account by the qualitative risk assessment process required by the class for RBI development.

1.2 Scope of the document

1.2.1 This Guidance Note provides a guideline for developing a risk-based inspection program for the hull structure of offshore floating units. It includes references to relevant international standards, technical reports and research papers.

This Guidance Note presents also the semi-quantitative risk assessment method of the Society for developing a risk-based inspection plan.

Note 1: In this Guidance Note, for reasons of brevity, the term "hull structure of a floating offshore unit" will be shortened to "hull structure".

Note 2: The term "structure" is used as a generic term to indicate any part or structural components of the hull structure.

1.2.2 The following types of floating systems are explicitly covered by this Guidance Note:

- ship-shaped floating units and barges (monohull or otherwise)
- offloading buoy
- semisubmersibles and column stabilized units
- spars
- tension leg platforms (TLP) including tendon systems.

1.2.3 The following types of components are included within the context of this Guidance Note:

- hull compartments, including above water, below water and internal structure and corrosion protection systems (e.g. coatings, cathodic protection, etc.)
- structural interfaces between the hull structure and structural systems; such structural systems can be turrets, topsides structure, helidecks, flares, cranes and process decks
- mooring system support structure on the hull (e.g. foundations for chain jacks, fairleads, chain stoppers, chains, anchors, etc.)
- tendon systems including foundations
- the interface between the hull structure and marine systems; such marine systems can be ballast, bilge, venting, soundings, firefighting systems, cargo systems, emergency power, propulsion, steering, sensors, alarms and controls
- permanent means of access and egress including walkways, grating, handrails
- structural interfaces between hull structure and riser system.

1.3 Overview of existing guidelines

1.3.1 There is no published international standard that provides specific guidance on how to perform RBI for hull structures. The American Petroleum Institute (API) has released a standard on the integrity management of offshore floating system, but it only recognize RBI as an alternative means to define an inspection program without providing any specific guidance.

However, risk-based approach for inspection is a well developed discipline and many applications can be found, especially for other type of offshore structures such as pressure vessel equipment and fixed platforms. For those offshore structures API has published some standards e.g. the API-RP-580 and its companion the API-RP-581, and the API-RP-2SIM that provides guidance for conducting RBI for fixed platforms. Although, they are specific to those type of offshore structures, they provide general guidelines that hold also for other structures especially the hull structure.

The Society has gained a significant experience on RBI from previous projects (Goyet, et. al., 2004; Biasotto & Rouhan, 2004), providing benefits to develop guidelines.

Moreover, the issue of risk-based approaches for the integrity management of hull structures in general is addressed in some Joint Industry Project (JIP) (e.g. FPSO Structural Performance JIP and LCM JIP) and many technical reports and research papers deal also with that topic. Experience-based data related to the risk exposure of hull structures are also available, especially for ship structures (e.g. SSC – 416, 2001 and SSC – 421, 2002). They may be used also for the floating offshore units in virtue of the similarities between their respective hull structures.

1.3.2 The existing international standards (e.g. API-RP-2FSIM) address the following issues regarding the RBI of the hull structure:

- implementation of RBI
- structural data requirements
- common degradation and damage mechanisms, and failure modes
- critical structural components and locations for the inspection
- hull inspection specifications.

However, the following key issues are still not addressed for the specific case of the hull structure of offshore units:

- risk assessment
- rate of degradation
- risk-based inspection intervals.

Guidance on risk assessment may be found in most of the international standards dealing with risk assessment or other related topic such as risk management and risk analysis.

The Society has published indicative corrosion rates with respect to compartment type (NI593). Indicative corrosion rates are also available for the hull structure of ships in some published guidelines (e.g. TSCF) and that may be considered for offshore units in virtue of their similarities with ship structures.

There is currently no guidance for risk-based inspection intervals to be applied to the hull structures of floating offshore units when qualitative risk assessment methods are used. Quantitative risk assessment methods, which compute the change in risk level over time, may be used to establish inspection intervals in terms of achievement of a target risk level. However, quantitative risk assessment needs sufficient data and computational effort to provide accurate results, which may not always be possible. Therefore, whatever the type of risk assessment used, competent person should be involved to set appropriate risk-based inspection interval and scope for each part of the hull structure based on expert judgment and experience.

1.4 Overview of the Society's semi-quantitative risk assessment method

1.4.1 The Society has developed a semi-quantitative risk assessment method for developing risk-based inspection strategy for hull structures.

The method allows global risk level to be computed for the hull compartments so as to define inspection intervals and general inspection requirements. It allows also local risk levels to be computed for the structural components of the hull compartments so as to identify risk drivers and critical inspection locations which should be considered to provide more details on the inspection strategy.

In particular, the method:

- compute the LoF using a rule-based scoring approach, where the set of scoring rules is established based on design data, expertise and experience on the risk exposure of the structure
- assess the CoF using a categorization in terms of life-safety consequence, environmental consequence and financial loss

This method may be used as a complement to the qualitative risk assessment process required by the class for the hull structure of a offshore floating unit within the Society rule. In this case, the results obtained from the application of this method should be used as input to the risk assessment process required by the class.

This method must not be an alternative to the qualitative risk assessment process required by the Society. However, for those units not within class rule regime, a procedure has been established to develop an inspection strategy directly from the risk data provided by the risk assessment method (App 1).

1.5 Organization of the document

1.5.1 The existing Guidelines for performing RBI for hull structures are set out in Sec 2.

The semi-quantitative risk assessment method developed by the Society for developing risk-based inspection strategy of hull structures is presented in Sec 3.

The procedure for developing an inspection strategy of hull structures directly from the results of the semi-quantitative risk assessment is set out in App 1.

Typical examples degradation and damage mechanisms, and failure modes of the hull structure are provided in App 2.

The activities that should be implemented for the inspection of the hull structure are set out in App 3.

2 References, definitions and acronyms

2.1 References

2.1.1 Standards

API-RP-580, Risk-Based Inspection (2nd ed.). Washington: API Publishing Services, 2016.

API-RP-581, Risk-Based Inspection Technology, 3rd ed., Washington: API Publishing Services, 2016; Addendum 1, April 2019; Addendum 2, October 2020.

API-RP-2FSIM, Floating Systems Integrity Management. Washington: API Publishing Services, 2019.

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

ISO 19904-1, Petroleum and natural gas industries -- Floating offshore structures – Part 1: Monohulls, semi-submersibles and spars, 2019.

ISO/IEC 31010, Risk management – Risk assessment techniques, 2019.

ISO 6520-1, Welding and allied processes – Classification of geometric imperfections in metallic materials – Part 1: Fusion welding, 2007.

2.1.2 BV rules

NI657, Classification Scheme under Risk Based Inspection

NR445, Rules for the Classification of Offshore Units

NI593, Ship Conversion into Offshore Units – Redeployment and Life Extension of Offshore Units

2.1.3 Other guidance

IACS Rec. N° 20, Non-destructive testing of ship hull steel welds, 2007.

SSC – 416, Risk Based Life Cycle Management of Ship Structure, 2001.

SSC – 421, Risk Informed Inspection of Marine Vessels, 2002.

HSE, Best practice for risk based inspection as a part of plant integrity management, 2001.

HSE, Marine risk assessment, 2001.

ISSC, Committee V.6, Condition Assessment of Aged Ships and Offshore Structures, 17th International Ship and Offshore Structures Congress, Seoul, Korea, 2009.

TSCF, Inspection, Repair and Maintenance of Ship Structures, 2nd edition, Witherbys Publishing, 2009.

2.1.4 JIP reports

LCM JIP, Life Cycle Management of Hull Structures, JIP Report, 2013.

2.1.5 Books

Paik J. K. and Melchers R. E., Condition Assessment of Aged Structures, Woodhead Publishing Limited, England, 2008.

2.1.6 Conferences papers

Biasotto P. and Rouhan A., Survey and Inspection Management for FPSOS, OMAE, Vancouver - Canada, 2004.

Goyet J., Rouhan A. and Faber M. H., Industrial Implementation of Risk-based Inspection Planning Lesson Learnt from Experience: The case of FPSO's, OMAE, Vancouver - Canada, 2004.

Serratella C. and Spong R., Understanding Through Experience Key Findings from the FPSO Structural Performance Joint Industry Project, OTC, Houston, 2005.

2.2 Terms and definitions

2.2.1 Anomaly

In-service survey measurement, which is outside the threshold acceptable from the design or most recent fitness-for-service assessment.

2.2.2 Assessment

Detailed qualitative or quantitative determination of the value or the level of a feature of the structure.

2.2.3 Consequence

Effects of an abnormal event, such as extreme metocean event, ice or accidental event, on personnel, the environment, or the asset.

2.2.4 Defect

Imperfection, fault, or flaw in a structural component.

2.2.5 Degradation / deterioration

Process in which the condition of a component is becoming worse or weaker than its initial condition.

2.2.6 Degradation exposure

Degradation exposure characterizes what parts of the hull structure is subjected to degradation mechanisms (e.g. corrosion, cracking) and how high their respective rates are.

2.2.7 Evaluation

Review of condition of the structure compared to that when it was last assessed and of other parameters that affect the integrity and risk levels to confirm or otherwise that the existing structural assessments still apply.

2.2.8 Failure

Insufficient strength or inadequate performance of a structure or system, preventing it from fulfilling its intended performance requirements.

2.2.9 Fire integrity

In a piece of construction material, the quality that prevents fire on one side of the material from being transmitted to the opposite side within a designated time period (e.g. Passive Fire Protection).

2.2.10 Fitness-for-service

Engineering evaluations performed to demonstrate the structural integrity of structural component that could contain a flaw or damage or that could be operating under specific conditions that could produce a failure.

2.2.11 Floating structure

Structure where the full weight is supported by buoyancy.

2.2.12 Global risk level

A risk estimate at the level of the whole hull structure.

2.2.13 Hull structural configuration

The hull structural configuration denotes all the structural elements that make up the hull structure, their disposition and arrangement. It includes also groups of structural elements, defined with respect to considerations such as the type of the structural element, redundancy level, degradation exposure,... in order to facilitate risk assessment and inspection activities.

2.2.14 In-process inspection

Application of various tests on the structures or equipment at each stage of the fabrication, the construction, the commissioning, the transportation and the installation processes to ensure that they are installed in conformance with project specifications and/or industry standards.

2.2.15 In-service inspection

All inspection activities associated with a structure once it has been installed but before it is de-commissioned.

2.2.16 Inspection

Visit to the floating unit and the associated examination activities. These, for the purposes of collecting data required in evaluating its structural integrity for continued operation.

2.2.17 Inspection plan

A plan for the in-service inspections of a structure including the scheduled dates and the expected scope of the inspections.

2.2.18 Inspection program

Scope of work for the execution of the inspection activities to determine the condition of the structure.

2.2.19 Local risk level

A risk estimate at the level of a structural part, a structural component or a structural detail.

2.2.20 Mitigation

Limitation of negative consequence or reduction in likelihood of particular event or condition.

2.2.21 Operator

The firm, corporation, or other organization which conducts operations on behalf of the owner.

2.2.22 Owner

Party who owns the physical infrastructure and is responsible for maintaining structural integrity.

2.2.23 Preventive maintenance

Upkeep of the required condition of the structure by proactive intervention e.g. painting, repair, replacement, greasing, etc.

2.2.24 Primary, secondary and tertiary structural components/members

Primary structural components provide stiffness and strength to the overall structure e.g. plate girders, stringers.

Secondary structural components are essential to the local integrity of the structure where failure of these components will not affect the overall integrity e.g. ordinary stiffeners, anti buckling stiffeners of primary structural component, walkways and stairs.

Tertiary structural components are ancillary structural components including structural members and attachments that do not significantly contribute to the local integrity of the structure e.g. handrails, supports connections, anti buckling stiffeners of secondary structural component.

2.2.25 Procedure

Written directive, usually arranged chronologically, which provides details and steps required to perform a given activity.

2.2.26 Redundancy

Availability of alternate load paths in a structure following the failure of one or more structural components.

2.2.27 Residual strength

Ultimate strength of a structure in a damaged condition.

2.2.28 Riser

Piping connecting the process facilities or drilling equipment on the floating structure with the subsea facilities or pipelines.

2.2.29 Risk-based inspection

Inspection strategies developed from an evaluation of the risk associated with a structure with the intention of tailoring inspection scope and frequency to risk magnitude and location.

In this Guidance Note and according to the Society Class rule (NI657) mitigation action plan (e.g. maintenance and repair) and their respective risk criteria must be set out as part of risk-based inspection.

2.2.30 Risk exposure

The risk exposure characterize what or who is exposed to a specific hazard and how much they are at risk.

2.2.31 Robustness

Ability of a structure to tolerate damage without failure.

2.2.32 Service life

Time period associated with the structure’s anticipated end of field life or decommissioning date.

2.2.33 SIM Policy

Intention and direction of the top management with respect to the SIM related processes and activities.

2.2.34 SIM Review

Process used to determine how the SIM processes can be improved on the basis of in house and external experience and industry best practice.

2.2.35 Special area

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

2.2.36 Stakeholder

A person, group, or organization that is actively involved in a project, is affected by its outcome, or can influence its outcome.

2.2.37 Strategy

Process for delivering the structural integrity consistent with the SIM policy.

2.2.38 Structural analysis

Calculation to predict the behavior of the structure usually relative to specified code requirements.

2.2.39 Structural assessment

Interpretation of available information including available analysis results used to confirm or otherwise the integrity of the structure.

2.2.40 Structural component

Physically distinguishable part of a structure.

2.2.41 Structural integrity

Ability of a structure to perform its required functions over a defined time period whilst protecting health, safety and the environment.

2.2.42 Structural integrity management (SIM)

Means of demonstrating that the people, systems, processes and resources that deliver integrity are in place, in use and will perform when required.

2.2.43 Watertight

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

2.2.44 Weathertight

Capable of preventing the penetration of water into the structure during temporary exposure to water.

2.3 Acronyms

2.3.1 List of acronyms

ACFM	:	Alternating current field measurement
API	:	American petroleum institute
CoF	:	Consequence of failure
CP	:	Cathodic potential
CUI	:	Corrosion underneath the insulation
CVI	:	Close visual inspection
ECI	:	Eddy current inspection
FLNG	:	Floating liquefied natural gas
FMD	:	Flooded member detection
FPSO	:	Floating production storage and offloading
FSO	:	Floating storage and offloading
GVI	:	General visual inspection
HSE	:	Health and safety executive
ICCP	:	Impressed current cathodic protection
IEC	:	International electrotechnical commission
IOGP	:	International association of oil & gas producers
ISSC	:	International ship and offshore structures congress
ISO	:	International organization for standardization
JIP	:	Joint Industry project
LoF	:	Likelihood of failure
MOC	:	Management of change
MPI	:	Magnetic particle inspection
NDT	:	Non destructive testing
PFP	:	Passive fire protection
RBI	:	Risk-based inspection
RIT	:	Remote inspection technique
SIM	:	Structural integrity management
SSC	:	Ship structure committee
TLP	:	Tension-leg platform
TSCF	:	Tanker structure cooperative forum
UT	:	Ultrasonic testing
UTM	:	Ultrasonic thickness measurement
VIM	:	Vortex induced motion
VIV	:	Vortex induced vibration
WT	:	Watertight.

SECTION 2 EXISTING GUIDELINES

1 General

1.1 Source of the guidelines

1.1.1 There is no international standard for the RBI of the hull structure of floating offshore unit, such as API-RP-581 for the pressure vessels. However, Risk-based approaches are now well developed and mature applications of those techniques can be found for offshore structures such as trading tankers, jacket structures and the hull structure of floating offshore unit.

1.1.2 The guidelines set out in this section for the RBI of the hull structure are derived from the standards which have been developed for other offshore structures (e.g API-RP-581, API-RP-2SIM) where they are applicable. For RBI related issues that are specific to the hull structure, the guidelines are based on the Society's experience. Moreover, references to national or professional bodies data (e.g. HSE, IOGP, etc) or to the existing technical publications on that topic are also made.

1.2 Main benefits of RBI

1.2.1 The main benefit of RBI is that it provides a deep understanding of the risk exposure of the structure and as a matter of fact delivers an inspection program tailored to that risk exposure. Therefore, it enables an effective management of the inspection and maintenance resources.

1.2.2 RBI is a dynamic process, and as such it allows adjustments to be made over the time on the inspection strategy as better knowledge is gained on the structure's condition, which results in improved performance of the SIM.

2 General requirements

2.1 RBI Team

2.1.1 General

An RBI assessment requires inputs from various sources. For example, the top management defines the risk criteria applicable to the unit, experts on relevant subject matter provide the necessary engineering knowledge for deep understanding of the structural condition and the operating personnel experience helps identify main risk exposure of the structure and the operational restrictions.

Therefore, the RBI assessment should be conducted by a team and the make-up of that team and the skills of the team members have an influence on the quality of the RBI assessment.

2.1.2 A multi-disciplinary team

The team members should have skills and backgrounds in many disciplines, including:

- risk analysis
- offshore structural engineering specifically related to the type of floating system under consideration
- deterioration/degradation and damage mechanisms, and failure modes
- offshore maintenance and inspection techniques and technologies
- material, corrosion and coating engineering
- environmental, safety and health systems and regulations
- operations
- general industry-wide and historical performance of floating offshore structures.

2.1.3 Team make-up

The RBI team should be composed of:

- a team leader to coordinate the RBI project (personnel from the operator)
- RBI contractor to perform the RBI study
- facility management as the main stakeholders
- personnel from the project team
- subject matter experts to serve as advisor
- personnel from the operating team to provide experience and operating constraints.

2.2 Scope of work

2.2.1 General

The structural elements on which the RBI assessment will be applied should be identified and agreed in advance in order to differentiate those structures under RBI regime and those under other inspection regimes.

2.2.2 Interfaces

There are interfaces between the hull structure and other parts of the unit which require, on one hand, their attachments to be included in the scope of work; on the other hand, the interrelation between the requirements of their respective integrity management to be addressed.

These interface issues can be considered through a system level approach by developing a single inspection plan of the overall floating system, inclusive of all structures and systems. However, the inspection plan of the overall floating system is usually broken down into individual plans of the specific structures or systems. Therefore, the interface between the inspection plan of the hull structures and the other specific inspection plan should be defined and clearly understood.

2.2.3 Typical structural interfaces

Special attention should be paid to the attachments to the hull structure of other parts of the unit, since they are usually critical locations.

Typical structural interfaces to be considered are:

- interfaces between the hull structure and structural systems such as turrets, topsides structure, helidecks, flares, cranes and process decks
- mooring foundations (e.g. foundations for chain jacks, fairleads, chain stoppers, chains, anchors, etc.)
- structural interfaces between hull structure and riser system
- appurtenances (e.g. caisson, hard piping, access structures, anodes, etc.).

Especially, the interfaces between the hull, the riser system and the moorings are key interfaces that should be addressed in the risk analysis.

2.3 Data collection

2.3.1 General

Once the scope of the RBI has been established, the RBI process starts with gathering of data that is useful to understand the overall risk of the hull structure. Up-to-date data is required for the RBI process. Those data fall into five broad categories:

- general unit data
- original design data (e.g. drawings and calculations reports)
- fabrication & installation data
- condition data (e.g. inspection reports)
- operating data.

Also required are the statutory and the regulatory requirement for the facility, since they may include some restrictions for using RBI on some parts of the facility, on which the prescriptive rules must be applied instead.

2.3.2 General unit data

General information on the offshore floating unit should be collected as it allows the context of the RBI assessment to be understood. It typically includes:

- appropriate details of ownership (e.g. operator and owner name)
- management framework including SIM policy, SIM processes and procedures, chains of command
- unit general arrangements including hull structure, topsides and process equipment
- details of the unit location (e.g. latitude, longitude, water depth)
- regulatory and classification requirements.

2.3.3 Original design data

The design data typically include:

- design criteria (e.g. metocean, geotechnical, seismic, ice, corrosion allowances, etc.)
- standards to which the structure was designed
- structural design drawings
- design analyses' reports including computer models, structural assessment
- areas, elements, components and other aspects of the design that were of concern to the designers or needed special attention during design
- results of any design risk assessment in which integrity and safety-critical elements have been identified.

2.3.4 Fabrication & installation data

The fabrication and installation data typically include:

- material data from fabrication and construction (e.g. material certificates)
- fabrication, construction and installation inspection records, including weld inspection, anomaly register, observed defects, baseline inspection and quality assurance and quality control records
- data on the rectifications and repair conducted from design to installation, including Management of Change (MOC), Non Conformity Report (NCR) and Technical Query and Deviation (TQD)
- as-built drawings.

2.3.5 Condition data

The condition data are one of the most important data for the RBI assessment, especially for units that are already in service. Those data are related to the current condition of the structure and they typically include:

- in-service inspection data (e.g. inspection reports, measurements and checklists)
- corrosion protection data
- in-service structural maintenance data
- condition monitoring data including interpretations, review and evaluations of the data
- evaluation and assessment data that confirm fitness-for-service and which can include structural assessment or testing reports, and risk assessment reports
- anomaly register, including observed damage and deviation from the design that can affect the structural integrity. The anomaly register should provide for each recorded anomalous condition, potential cause, any mitigation or assessments conducted or additional activities that need to be performed based on the fitness-for-service evaluation (e.g. monitoring) and whether the anomaly is open or closed (i.e. requires no further action).

2.3.6 Operating data

The operating data represent the service exposure (i.e. variation and duration of the service conditions compared to design limits). They typically include:

- permanent and variable loads, including information on the changes in topside and deck loads and their influence in the floating system's weight management program
- drafts
- mooring tensions (if instrumented)
- compartment service conditions, including information on tank service conditions including general variations and durations and whether any change to the tank service (e.g. from cargo to ballast tank) has occurred
- actual environmental condition versus design metocean data.

2.3.7 Baselining

The implementation of a RBI program requires that baseline data be collected and that will serve as a benchmark for the subsequent risk assessments. Those data are typically collected through inspections conducted prior to the unit coming into operation to determine its condition at installation.

In cases where baseline inspection to establish the as-installed condition of the hull structure was not conducted for an already operating unit, there may be a need for enhanced inspection to eliminate any unknowns on the current condition of the structure, and that will serve for the future risk assessments. Otherwise, appropriate conservative assumptions should be made where key information required for the structural integrity assessment is missing. The latter option is simple but could result in a rough risk assessment.

2.3.8 Data management system

The data collected throughout the life of a platform should be included and maintained in a data management system. The data should be compiled in a timely manner and be in a form suitable to be retained as a permanent record.

The data management system should facilitate the identification and the selection of the relevant data of the structural elements that make up the hull structure so that their risk levels can be estimated. The resulting risk information of the hull structural elements will then help identify the structural elements and locations that should be prioritized for inspection.

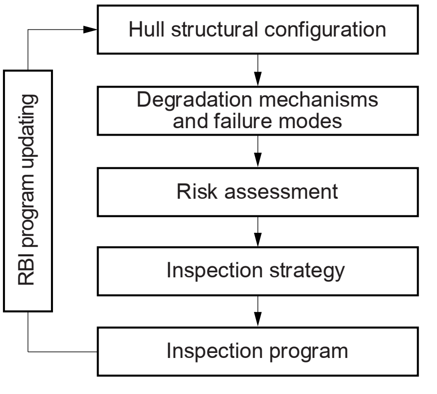
The data management system should include a consistent identification system that allows accurate exchange of data with other SIM activities (e.g. structural assessment) that interface with the RBI program.

2.4 RBI process

2.4.1 The development of a RBI program for the hull structure of an offshore floating unit includes the following steps in Fig 1:

- setting the hull structural configuration
- identifying degradation and damage mechanisms, and failure modes
- conducting risk assessment
- defining risk-based inspection strategy
- developing inspection program
- loop back to refine evaluation as inspection data becomes available.

Figure 1 : RBI Process.



3 Hull structural configuration

3.1 Hull structural system

3.1.1 Definition

The hull structural system represents the structural elements that make up the hull structure, along with their disposition and arrangement in the hull structure. The hull configuration may also need to include the non-structural systems that interface with the hull structure as they would be affected in case of structural failure.

3.1.2 Grouping

The failure of some structural components (e.g. a weld, an ordinary stiffener), when they are taken individually, is of minor effect on the hull structure integrity. However, the failure of a group of such structural components taken as a whole may significantly contribute to the failure of the entire hull structure. Therefore, for the purpose of risk-based inspection decision, the structural elements of the hull structure should be arranged so as to identify relevant structural groups that are meaningful for the inspection management.

The grouping of the structural elements of the hull structure may be established with respect to:

- the type of structural components (e.g. ordinary stiffeners) or structural details (e.g. welds, openings)
- the redundancy level
- the structural function in the hull structure integrity (e.g. plates girders, secondary web frame, foundations of safety critical elements, etc)
- the degradation exposure (e.g. coated and uncoated part of a structure)
- the specific areas that are worth being considered as a whole in SIM analysis (e.g. walkways, stairs, etc).

3.2 Partitioning scheme

3.2.1 General

For the purpose of RBI, the hull structure is partitioned into a number of parts of the structure, each possessing a number of identifiable compartments, which can be in turn broken down into structural elements from the principal components to a level of structural detail relevant for the RBI program.

The partitioning method should reflect the principles of naval architecture, construction and operation that apply to the hull structures.

3.2.2 Typical structural elements of the hull structure

The main portions of the hull structure are:

- the bottom structure
- the side shell
- the decks
- the bulkheads.

The structural members of the hull structure can be categorized as:

- plating
- ordinary stiffeners (e.g. longitudinal and vertical stiffeners)
- primary supporting members (e.g. girder, stringer).

3.2.3 Structural details

Structural details that are part of the hull structure include:

- connections
  - welded connections
  - bolted connections
- brackets
  - end bracket
  - bracket toe
- tripping bracket
- cut out and opening
  - slot hole
  - scallop
  - collar plate
- man hole
- drain hole
- air hole
- cross tie.

3.2.4 Hull interface with other elements

The other elements which interface with the hull structure include:

- screw shaft
- safety-critical systems
- moorings
- riser supports
- J-tube
- hull appurtenances
- corrosion protection system
- insulation for the interior and exterior surfaces
- engine and machinery
- equipment
- pipeline.

4 Degradation mechanisms and failure modes

4.1 General

4.1.1 Typical structural degradations

The typical structural degradations experienced by hull structures, and that can be managed through RBI, are:

- fatigue cracking
- coating damage
- corrosion wastage
- buckling deformation
- tear and wear.

4.1.2 Identification of structural components most prone to degradation

The RBI requires that structural components and structural locations most prone to structural degradation be identified since the goal is to minimize the risk associated with those degradations.

This identification process should use the following:

- the hot spot map provided at the design stage or at the last structural assessment, which shows critical structural details
- the history of the unit while in service through the anomaly register or risk register, and the feedback of the staff operating the unit daily
- the existing industry-specific guidelines.

4.1.3 Existing guidelines

The existing guidelines on the common damage to the hull structure are usually based on the experience gained from oil tankers such as the published guidelines of the Tanker Structural Cooperative Forum (TSCF). Those guidelines may be used for the hull structure of offshore floating units using their similarities with oil tankers in terms of damage and degradation exposure.

Some work has been performed to collect data on the structural defects to the hull structure of offshore floating units (LCM JIP, 2013). App 2 provides an overview of possible degradation and damage mechanisms that can be encountered during a floating system's service life.

Those guidelines may be used to help identify the degradation mechanisms to which a given hull structure is exposed, by checking whether they are relevant for the unit under consideration and to find other similar degradation mechanisms that apply to the hull structure of that unit.

4.2 Structural components most prone to structural degradation

4.2.1 General

Here general guidelines are provided based on experience data of oil tankers, with, when possible, additional data specific to floating offshore unit.

The provided list of structural components or locations susceptible to experienced structural damage is not exhaustive.

4.2.2 Coating damage susceptibility

Coating degradation can take the form of coating cracking, blistering, rust and flaking.

- structural locations susceptible to structural deformation are likely locations of coating cracking e.g. structural areas prone to dent damage, contact damage
- lack of flexibility of the coating increases the possibility of coating cracking
- rust appears on a film paint usually due to low film thickness
- blistering and flaking are forms of loss of paint adhesion which are often due to unsatisfactory surface preparation, incompatibility with under-layer and contamination between layers; therefore they are likely to occur on structural area where coating application is difficult.

Coating breakdown is mainly due to aging. The range in coating lives can be related to the structural component location and environment.

4.2.3 Structural components prone to corrosion

Most common corrosion-susceptible areas are:

- top and bottom of ballast tanks
- bottom of cargo tanks
- Any horizontal surface that may entrap water, such as horizontal stringers or transverse bulkheads
- welds, sharp edges, and any areas in which protective coating would be difficult to apply
- local stiffening members
- structures located adjacent to heating devices
- areas that are always wet, such as bilges
- areas where dissimilar metals are either in close proximity or in contact with each other
- areas where the paint appears to be raised, uneven, or flaky
- areas near non-ferrous metals where pitting is likely to occur
- the underside of frames, seating areas
- weather-deck scuppers, beneath lockers
- the lower edges of bulkheads that bound frequently-washed areas (e.g. passageways)
- plate butt and seam welds
- junctions of longitudinal bulkhead plating and longitudinals
- support of tertiary items not aligned with primary or secondary structure.

4.2.4 Corrosion rate

There is currently no statistical data for the corrosion rate applicable to the hull structure of offshore floating units available in the public domain. Nevertheless, some data have been published especially for the hull structure of oil tankers and trading ships. They may be used in defining corrosion rate for offshore floating structure in virtue of their similar hull structures. Examples of such data are provided in TSCF, 2009, SSC – 421, 2002 and Wang et. al., 2003.

Especially for the deck corrosion risk, consideration should be given to nature of the process module on the deck in order to define the severity of the potential corrosion aggression on the deck due to the operational process it is exposed to and how it affect the corrosion rate.

4.2.5 Structural components prone to cracking

The principal details of the hull structure that are prone to fatigue cracking include:

- intersections of longitudinal stiffeners with transverse bulkheads or transverse web frames
- bracketed end-connections of primary and secondary supporting components
- discontinuities in highly-stressed face plates, stiffeners, and longitudinal members
- openings and cut-outs in primary structures
- deck and bulkhead openings, especially if not rounded and smooth
- abrupt changes in cross section
- stiff connection points such as the intersection of longitudinals and transverse stiffeners
- the blocks join from construction
- welds.

4.2.6 Structural components prone to buckling

The hull girder compressive flange (i.e. deck and bottom), stringer, shell plating, and stiffening are the components most susceptible to buckling in ship-shaped offshore structure.

Web frames and stringers may also experience shear bucking.

5 Risk Assessment

5.1 General

5.1.1 Definition

Risk assessment is a process that includes the understanding and the estimation of the likelihood of failure and the consequence of failure. It combines both estimates to rank the risks. In the framework of RBI, it allows the inspection resources to be prioritized for the higher risk items.

For the purpose of RBI, the risk assessment is focused on the failure modes initiated by material deterioration and degradation mechanisms that can be managed and controlled through structural inspection.

5.1.2 Risk assessment methods

The risk assessment can be qualitative, quantitative or a combination of both (i.e. semi-quantitative).

a) Qualitative assessment

The qualitative risk assessment uses expert judgment and experience as a basis for the estimation of the likelihood and consequence of failure. Generally this will involve a structured risk workshop where risks associated with the system are systematically identified and assessed.

The accuracy of the assessment is dependent upon the background and expertise of the people involved.

The most typical use of qualitative assessment is for the purpose of screening out low-risk items for which the time and cost of a quantitative study cannot be justified. It may be used for inspection plan development, however, the conservatism inherent in this approach should be considered when making final inspection plan decision.

b) Quantitative assessment

The quantitative risk assessment uses logic models depicting combination of events that could result in failure and physical models depicting the progression of degradation mechanisms. Those models have a stochastic nature, which allows a numerical value for the likelihood of failure to be computed.

However, not all the degradation mechanisms to be considered in the risk assessment can be explicitly quantified. While some degradation mechanisms such as fatigue and generalized corrosion can be quantified in a probabilistic manner, other degradation mechanism such as the effectiveness of the corrosion protection system can not be evaluated other than through qualitative or semi-quantitative approaches. Therefore, qualitative risk assessment can be still performed as part of a quantitative risk assessment to assess the overall risk exposure level of the structure.

The quantitative risk assessment requires considerable quantities of detailed data to be used. It should be performed by analysts with enough experience in such methods to interpret the uncertainties involved and select appropriate analytical models to represent them.

Quantitative risk assessment is usually performed on selected critical structural during a qualitative analysis, items for which a deep analysis is required.

In practice, a risk assessment typically uses aspects of qualitative and quantitative approaches. These approaches should not be considered as competing but rather as complementary. It is usual to perform a first-pass qualitative analysis in advance of the quantitative in order to screen for components where the use of quantitative methods would be neither technically appropriate nor cost-effective due to low risk.

Guidelines for the selection and application of the existing risk assessment techniques are provided in ISO 31010.

5.2 Likelihood of failure

5.2.1 General

Likelihood of failure determines how often a failure can be expected. It can be defined in qualitative terms such as seldom, common or frequent; or in quantitative terms such as annual probability of failure or lifetime probability of failure, where supporting data is available.

The likelihood of failure should account for the degradation mechanisms that the structure could suffer. It can be assessed using specific analysis of the available degradation data or generic or specific degradation models.

5.2.2 Influencing factors

The likelihood assessment should consider the as-installed condition, the current condition and the loading and damage exposure of the structure from its operating condition. This includes the following factors, for example:

- design margins, reserves and redundancies (e.g. corrosion allowances, fatigue safety factors)
- limitations and assumptions of the original design premise or analysis (e.g. simplified analysis, same coating systems used for all tank service conditions)
- degree of conservatism or uncertainty in metocean criteria
- fabrication quality and occurrence of any rework or welding repair
- occurrence of any damage during transportation or installation or extended layout of floating system prior to installation
- extent of inspection during fabrication, transportation, and installation
- extent of the damage or deterioration (e.g. local or widespread)
- rate of deterioration (e.g. rapid breakdown of coatings, anode depletion or corrosion wastage, crack growth, reduction in pump discharge)
- past performance of corrosion protection system

- maintenance program in place, whether it is appropriately resourced and managed
- uncertainty in information quality (e.g. poor weight control records, poor maintenance records, no data on tank service conditions)
- modifications, additions, and repairs/strengthening (e.g. loading changes, offshore repair quality)
- knowledge from owner's installations or offshore industry (e.g., failures of similar systems)
- quality of welding detail used (e.g. fillet weld, partial pen weld and full pen weld).

Less confidence in the information, for example on the condition of a structure or system, should be treated as increased likelihood of failure.

5.3 Consequence of failure

5.3.1 General

Consequence assessment determines the impacts of a failure. Consequences are typically divided into three types:

- life safety which includes potential for injuries and deaths
- environmental which is used to define quantities of hazardous materials that can be released or other detrimental actions to the environment.
- financial which includes cost impact of the failure (e.g. repair or replacement of the directly damaged structure as well as repair to collateral damage, schedule delays and business interruption).

5.3.2 Influencing factors

The assessment should consider for example the following factors:

- type of tank
- type of cargo
- storage capacity
- structural importance (i.e. primary, secondary or tertiary structure)
- function of the structure (e.g. critical safety function such as personnel walkways, critical operation function such as needed propulsion for station-keeping or drive away).

5.4 Risk ranking

5.4.1 General

The estimated likelihood and consequence of failure are combined to determine the failure risks.

For the purpose of making risk-based inspection decisions, risk level categories should be defined and the acceptable risk levels should be established.

5.4.2 Risk level categories

The risk level categories are defined from the categories that have been established for the likelihood and consequence of failure, which allows to identify higher, intermediate and lower risk items.

The number of likelihood and consequence categories may vary from one RBI assessment to another, however it should provide sufficient discrimination between the structural items assessed.

The risk level categories are assigned to the boxes on the risk matrix, which is an effective way of communicating the distribution of risks throughout the overall structure.

5.4.3 Risk acceptance criteria

The risk level categories are used to make risk-based inspection decision through defining risk acceptance criteria.

The risk acceptance criteria are defined by the upper limit of acceptable likelihood of failure for a given consequence of failure category. As such, they establish a partition of the risk matrix and may be used to develop risk-based inspection strategy.

Thresholds that divide the risks into acceptable and unacceptable regions may be established using:

- owner risk acceptance criteria in terms of their safety and financial policies and constraints
- current codes and recommended practices
- regulations and laws.

Owner risk acceptance criteria, when available, should be used when making risk-based inspection decision.

6 Inspection Strategy

6.1 General

6.1.1 General

The risk-based inspection strategy defines an inspection plan from the risk assessment results along with the maintenance and repair actions to be carried out when the resulting risk levels exceeds the acceptable level.

This article sets out, especially, guidance and requirements in developing a risk-based inspection plan.

6.1.2 Inspection plan

The inspection plan should define:

- the frequency of the inspections (when to inspect)
- the scope of the inspection (what to inspect, where and how much to inspect)
- the inspection technique and the deployment method (how to inspect).

Definition of the scope and the technique of inspection, will be facilitated by the risk ranking since inspections are prioritized based on the risk levels. However, defining inspection frequency will require an understanding of how risk levels vary with time.

Moreover, using RBI enables a comparison to be made between alternative inspection plans in order to select the best option. The comparison could be based on factors such as cost savings, risk reduction achieved and expected degraded condition as well as any effects that delayed inspection may have on these factors.

6.1.3 RBI as part of the overall SIM strategy

Risk-based inspection strategy is part of the overall SIM strategy including inspection, maintenance, repair and assessment. Together, those measures aim at providing a satisfactory safety level.

There are many types of inspections that can be conducted over the lifetime of the structure, namely:

- scheduled inspection, including:
  - baseline inspection
  - periodic inspection
- unscheduled inspection (i.e. post-event inspection) conducted after an event such as extreme metocean event or collision.

Among them, only the periodic inspections can be driven by the risk level. However, implementing risk-based inspections requires that a baseline inspection was conducted or, instead of baseline inspection, that appropriate assumptions was made on the as-installed condition of the structure. In addition, it should take into consideration data from unscheduled inspections, maintenance and repair.

In the overall SIM strategy, the risk-based inspections should be effective in improving the ability to predict degradation mechanisms and rate of deterioration so as other mitigation measures such as repair, replacement and changes can be planned and implemented prior failure occurrence.

Not all the damage mechanism can be effectively monitored by inspection. Example of such cases are:

- instantaneous failures related to operating conditions such as brittle fracture
- too short a time frame from the onset of deterioration to final failure for periodic inspection to be effective (e.g. cracking due to low-cycle fatigue or high frequency vibration not properly addressed during design)
- event-driven failures (circumstances that cannot be predicted).

In such cases, an alternative form of mitigation may be required.

6.1.4 Factors to consider in developing risk-based inspection strategy

The risk ranking provided as a result of the RBI process is the main data to use for the inspections to be prioritized.

Moreover, the estimated LoF and CoF should be considered too, in order to identify whether LoF, CoF or both is driving risk. In situation where risk is being driven by LoF, inspection is an effective risk treatment measure.

In addition to those risk data, all the data that enable to understand the risk should be considered, namely:

- expected or active degradation mechanisms and rates of deterioration in relation to the service lifetime
- potential failure modes
- structural components or areas that may be particularly susceptible to degradation or failure
- tolerance of the structure to damage, flaws, defects or deterioration
- structural item history
- condition of similar structural items.

This information serves to identify risk drivers for inspection e.g. panels and components driving risk and critical inspection locations.

6.2 Requirements

6.2.1 Using inspection results

The data gathered through inspection should be properly analyzed, interpreted and acted upon where needed in a timely manner.

6.2.2 RBI as a risk management measure

Operators should be deliberate and systematic in assigning the level of risk management achieved through inspection and should be cautious not to assume that there is an unending capacity for risk management through inspection.

6.2.3 Involvement of the operating team

The development of the initial RBI plan should include full participation of the operating team to ensure that the design, the inspection strategy and program are aligned.

6.3 Inspection intervals

6.3.1 General

Setting appropriate inspection intervals should be based on expert opinion and experience.

The general aim of the inspection intervals should be to ensure that inspections are carried out sufficiently frequently to identify, at an early stage, any deterioration or anomaly which is likely to affect the structural integrity.

Structures should not be allowed to deteriorate to a point where the minimum design basis, or fitness-for-purpose, could be threatened.

Inspection intervals should have a degree of conservatism that reflects the amount of uncertainty in the estimated future risk.

6.3.2 Relevant factors

The factors that should be considered in deciding for an appropriate interval between inspections are mainly those affecting the LoF, including:

- the age and historical performance
- the current condition
- any information about the particular type of structure under consideration
- the expected future operating or loading condition
- any relevant maintenance program in place
- the applicability of any on-line monitoring
- the possible or active degradation mechanisms as far as these are known
- the degradation rate
- the tolerance to damage
- uncertainties in the current condition and degradation rate.

It is also important to consider whether there is an applicable statutory or regulatory requirement fixing maximum inspection intervals for the type of structure under consideration.

6.3.3 Approaches for setting risk-based inspection intervals

The possible approaches for setting risk-based inspection depend on whether quantitative or qualitative/semi-quantitative risk assessment was used.

a) For qualitative/semiquantitative assessment

   In this case, time dependency of the risk level cannot be assessed, then best practice is to use the following:

   - historical operating data and failure data
   - industry guideline.

   However, caution is necessary when using guidelines (e.g. published generic data, standards or codes default values and published corrosion rate tables) and one should ensure that they are relevant for their specific circumstances before applying them.

b) For quantitative assessment

   In this case, the time dependency of the risk level can be quantified allowing best time for inspection to be defined according to the computation of the degradation phenomena and the maximum acceptable risk level. In practice, inspection is scheduled just before the LoF reach the target acceptable LoF with respect to the CoF.

6.4 Inspection scope

6.4.1 General

The inspection scope should include:

- selection of hull tanks to be inspected
- the critical structural locations or structural components for inspection (if required)
- checks and function tests of for example:

The inspection scope may include, in addition, checks and function tests of for example:

- sensors and tank level alarms
- marine systems (e.g. pumps, propulsion, steering)
- other critical systems (e.g. turret bearings, watertightness/weathertightness hatch seals).

6.4.2 Sample inspections of similar hull tanks

Hull tanks of the same type and having similar conditions may be grouped. It may then be considered to inspect a representative sample of them at each required inspection campaign.

However, the applicable regulatory stakeholder may require that all tanks of the hull structure be inspected within the maximum time interval specified for each of them in the inspection plan. Where there are several similar tanks that have been assessed to have the same inspection interval, it is permissible to inspect a sample of them each year so that all the tanks have been inspected once within their specified maximum inspection interval.

The sequencing of inspections of a group of similar tanks within their maximum inspection interval may be defined based on their relative risk.

6.4.3 Local inspection coverage

When local detailed inspection of the hull structure is required, RBI assessment may advise on how many structural components (e.g. ordinary stiffeners, platings) or structural details (e.g. welds, end bracket and bracket toes, openings) can be inspected in order to provide a representative condition of the overall structure, especially for larger structures.

The following considerations may be used for the effectiveness of the inspection:

- Grouping of structural components or details having similar characteristics and operating histories, if such grouping is appropriate, and selecting a representative sample of them
- The size of the representative sample may be based on statistical theory assuming that the defects are randomly distributed.

6.5 Inspection technique

6.5.1 Types of inspection techniques

Inspection techniques are divided into two categories:

- Visual methods include:
  - General visual inspection (GVI)
  - Close visual inspection (CVI)
- Non-destructive technique (NDT) with specialized equipment include but are not limited to:
  - crack detection techniques, e.g. volumetric crack detection - Ultrasonic testing (UT)
  - thickness measurements - Ultrasonic thickness measurement (UTM)
  - Cathodic potential (CP) measurements

The type of inspection to be used with the risk-based inspection interval should be selected based on the type of expected deterioration/degradation and the present known condition of the hull structure. Usually GVI should be carried out first. Then, close-up inspection i.e. CVI or NDT are performed where GVI cannot determine the extent of the damage.

The specifications of the inspection techniques are set out in [7.2] and the implementation of the inspection of the hull structure are provided in App 3.

6.5.2 Effectiveness of the inspection technique

The likely effectiveness of the selected inspection technique should be reviewed especially where there is complex weld geometry, poor surface finish or restricted access.

6.5.3 Using advanced techniques

Advances in inspection technique have now made it possible to determine structural integrity remotely without access to the structure, which have the advantage of avoiding system shutdowns, lowering inspection costs and reducing risks and hazard to inspection personnel. Example of such techniques used for the hull structure include:

- unmanned aerial vehicles (UAV)
- remote screening NDT (e.g. ultrasonic thickness gauging).

Those techniques are relatively new, therefore their capability and coverage should be demonstrated when they are used.

7 Inspection Program

7.1 General

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

7.1.2 Inspection specifications should, as a minimum, include:

- anomaly reporting requirements
- NDT technician qualifications
- notification requirements following discovery of an anomaly
- measurement procedures
- sensors and instrumentation
- reporting formats and procedures
- photography and video recording procedures.

7.2 Inspection specifications

7.2.1 General

This sub-article provides specifications of the inspection techniques in terms of objective, requirements for their usage and eventually the typical anomalies that can be detected.

7.2.2 General Visual Inspection (GVI)

a) Objective

   The intent of a GVI is to obtain an understanding of the general condition a structure or system.

   It can also be performed underwater by a diver or a ROV.

b) Typical anomalies that can be detected with GVI include:
   - dents, buckles or distortion in plates, beams, tubular members, stiffeners or brackets
   - areas of significant coating breakdown
   - areas of severe corrosion on structural members or plating
   - large areas of generalized pitting or significant local pits
   - rust staining from welds (can indicate weld failure on coated surfaces)
   - excessive anode deterioration
   - debris located on structural members (or piled on decks) that could damage coatings or influence corrosion
   - damage to internal hull pipework or ductwork
   - any loose or otherwise damaged pipe clamps or other appurtenances
   - any loose structural cladding or passive fire protection
   - any areas of standing water
   - damage to items such as stairways, grating, ladders, doors/hatches, etc. that could affect safety
   - missing bolts
   - excessive marine growth or areas of disturbed/missing marine growth.

7.2.3 Close Visual Inspection (CVI)

a) Objective

   The purpose of a close visual inspection is to obtain a detailed understanding of the condition of a structural item or for identifying, quantifying, and documenting any anomalies detected during GVI.

   CVI is generally directed at a well-defined location or part (e.g. a structural member, a welded or bolted joint, etc.).

   The use of Remote Inspection Techniques (RIT) can also be used to view areas of interest.

   CVI can also be performed underwater by diver or ROV.

b) Requirements

   Access should be provided that allows physical contact with the area in question (i.e. within arm’s length).

   CVI normally requires cleaning of any adherent deposits to enable the area to be visible, but damaging or removing coating should be avoided.

c) Typical anomalies to inspect for by CVI are:
   - cracks
   - local coating failure
   - local corrosion/erosion
   - pitting or grooving
   - local deformation
   - excessive wear between contact-loading surfaces.

7.2.4 NDT Crack Detection

a) Objective

NDT crack detection are used to inspect a structure for indications of cracking.

Various NDT methods are available, including:

- Alternating current field measurement (ACFM)
- Eddy current inspection (ECI)
- Magnetic particle inspection (MPI)
- Ultrasonic testing.

These techniques can be used above water and underwater.

b) Requirements

- ACFM and ECI enable inspection of welds with coatings and light surface film
- MPI can be warranted, after ACFM or ECI identifies a potential crack, to confirm and fully characterize the anomaly
- for uncoated surfaces, some oxidation is acceptable, but all scale shall be removed prior to inspection
- MPI for coated structures requires that the coating be removed at the suspect area
- for underwater inspections, the surface shall be clean of marine growth and scale.

7.2.5 Ultrasonic Thickness Measurement – Thickness Gauging

a) Objective

UTM is used to assess the thickness of a plate panel, beam web or flange or tubular member wall.

UTM can be used above water and underwater.

b) Requirements

- If UTM is to be performed on coated surfaces it is required that the UT equipment be capable of measuring steel thickness through coatings
- Both coated and uncoated surfaces shall be cleaned sufficiently and scale shall be removed to allow the UT probe to make enough contact.

7.2.6 Tank testing

a) Objective

Tank Testing is a hydrostatic test carried out to demonstrate the structural adequacy of design and tightness of tank boundaries.

b) Requirements

Tanks are to be tested with a head of liquid to the highest extent possible but not less than the highest point that liquid will rise under service condition for crude oil storage tanks, and for ballast tanks.

Salt water ballast tanks and fuel oil tanks are to be tested with a head of liquid to the top of air pipes.

Boundaries of ballast tanks are to be tested with a head of liquid to the top of air pipes.

Boundaries of cargo tanks are to be tested to the highest point that liquid will rise under service conditions.

7.2.7 Cathodic Potential Measurements

a) Objective

CP measurements are used to ensure that the cathodic protection system is protecting underwater structures properly.

b) Requirements

- the probe is placed directly on the protected steel surface
- marine growth removal should not be required
- it is critical that the probe be calibrated and tested on deck before any CP measurements are taken.

7.2.8 Flooded Member Detection (FMD)

FMD can be used to determine whether a hollow structural component (e.g. tendon) is flooded, partially flooded or dry. FMD can be performed by e.g. ultrasonic or radiographic techniques, etc.

7.2.9 Photographs and Videos

a) Objective

Photographs and videos are used for all inspections to document observations.

b) Requirements

- photographs should be taken of representative structures and systems to record the general condition and at all detailed inspection locations where CVI and NDT crack detection are conducted
- photographs should be taken of indications noted as anomalous
- video recording should be used for underwater inspections with still photographs at all detailed or anomalous inspection locations.

SECTION 3 SEMI-QUANTITATIVE RISK ASSESSMENT METHOD FOR INSPECTION PLANNING

1 General

1.1 Main features of the method

1.1.1 The risk assessment uses a rule-based scoring approach for the LoF assessment and a qualitative categorization of the CoF. In particular, the rule-based scoring approach establishes a set of scoring rules for relevant factors that influence the likelihood of failure.

1.1.2 The method offers the possibility of providing risk assessment both at the compartment level (i.e. global risk level) and at the structural component level (i.e. local risk level). The risk levels of the structural components can be aggregated to obtain the risk level of the compartment to which they belong, or they can complement the risk level of their compartment to better understand it and to define close-up inspection scope if required.

1.1.3 Risk assessment models, including LoF scoring rules and CoF categories, have been established for various geographical zones.

1.1.4 This method can be included in the RBI assessment process required by the Society, as per NI 657, by providing input to the required qualitative risk assessment. In this context, it will:

- provide an initial overview of the risk exposure of the structure
- allow risk drivers based on the influencing factors to be identified and used as a source of inspiration for the identification of failure scenarios and their corresponding risk assessment, which is a task required by the class as part of the RBI assessment
- carry out a risk screening to identify higher risk structures which require more emphasis.

1.1.5 In a more general context outside the class requirement, a complete RBI assessment method, based on the risk assessment method presented in this section, has been set up. In particular, it allows specific risk assessment to be developed by mapping this risk assessment method to the operating experience and the requirements of the operator (e.g. corporate risk matrix), and a risk-based inspection strategy to be developed directly from the risk results obtained. This is further explained in App 1.

1.2 Scope of application

1.2.1 General

The risk assessment method covers and addresses:

- the hull compartments including corrosion protection system
- the structural components
- the structural interfaces between the hull structure and other systems.

1.2.2 Hull compartments

The hull compartments should be considered together with their corrosion protection systems (e.g. coatings and cathodic potential) and their permanent means of access and egress including walkways, grating, handrails.

They are the main parts of the hull structure to which the risk assessment is applied, since the outcome of the assessment is their inspection plan. However, where available data allow, their risk assessment should include their structural components and their structural interfaces so as to better understand their risk exposure and to identify best locations for inspection.

1.2.3 Structural components

The structural components include:

- structural members such as:
  - platings
  - ordinary stiffeners
  - primary supporting members (e.g. web frame).
- structural details
  - connections (e.g. welds, bolted connections)
  - brackets
  - cut outs and openings
  - holes.

The structural components are categorized, for RBI assessment purpose, as primary, secondary and tertiary structures with respect to their criticality for the overall structural integrity.

1.2.4 Interfaces of the hull structure with other systems

The method includes in the scope the interfaces between the hull structure and the following systems:

- structural systems such as turrets, topsides structure, helidecks, flares, cranes and process decks
- mooring systems
- riser systems
- marine systems.

Special attention is paid to those interfaces since they are likely to be critical inspection locations.

2 Risk Assessment

2.1 Scoring of the LoF

2.1.1 Assumptions

The application of the scoring rules for the assessment of LoF presumes that the following assumptions hold:

- the structure is fit-for-purpose
- good/best engineering design practice have been applied
- required minimum extent of in-process inspections have been applied
- standard quality control requirements have been applied
- good/best industry practices for fabrication, construction and installation have been applied
- there is no significant deviation of environmental loading conditions from the design ones or from the last structural assessment
- there is no significant deviation of operating loading conditions from the design ones or from the last structural assessment.

In case any of these assumptions is violated, this should be analysed in order to assess how it increases the baseline risk level of the structure.

2.1.2 Scoring rules

The assessment process consists in, first assigning a score to LoF using the following formula:

$$S = \sum_i w_i \cdot S_i$$

where:

S : Overall score

S_i : Partial scores assigned to influencing factors

w_i : Weights to account for how sensitive is the LoF to the factors.

Then, a LoF category is allocated to the structural item (e.g. hull compartment or structural component) under consideration with respect to the range in which the overall score lies.

The ranges for the LoF categories and the weights of the influencing factors are calibrated with respect to typical inspection data of given geographical zones.

2.1.3 Influencing factors

The LoF is affected by the following main factors for which a set of scoring rules are established. They are denoted by:

- stress level
- corrosion exposure
- cracking exposure
- condition uncertainty
- previous inspection findings.

2.1.4 Stress level

This factor accounts for the likelihood of the structure to be subjected to high operating and environmental loading. Its scoring rule involves the following variables:

- design stress level for yield and buckling
- location
- whether the structure is in a special area, with higher stress, or not
- severity of environmental condition
- operational profile.

2.1.5 Corrosion exposure

This factor accounts for the likelihood of experiencing corrosion. Its scoring rule involves the following variables:

- tank type
- inerting type
- location
- whether the structure is in a special area, prone to corrosion, or not
- detrimental marine fouling occurrence
- corrosion control measure in place.

2.1.6 Cracking exposure

This factor accounts for the likelihood of crack occurrence on the structure. Its scoring rule involves the following variables:

- design fatigue life
- quality of welding detail
- location
- whether the structure is in a special area, sensitive to fatigue, or not
- whether the structure is exposed to low temperature
- detrimental marine fouling occurrence
- crack control measure in place.

2.1.7 Condition uncertainty

This factor accounts for the uncertainty on the condition of the unit given the time elapsed since last inspection time. Its scoring rule involves the following variables:

- operational lifetime
- extended life, if applicable
- time since last inspection
- level of last inspection.

2.1.8 Previous inspection findings

This factor accounts for the likelihood of failure due to the current condition of the structure that is provided by the previous inspections findings. Its scoring rule involves the following variables:

- condition of the corrosion protection system (e.g. coating breakdown, anode depletion, CP measurement)
- damage characteristic (e.g. size, intensity)
- thickness measured
- residual strength from engineering assessment
- crack.

2.2 Qualitative categorization of the CoF

2.2.1 General

The consequence of failure is given by the most severe of the life-safety, environmental and financial consequences.

2.2.2 Life-safety consequence

The life-safety consequence level depends on whether the unit's personnel are exposed or not when a structural failure occurs.

The factors which affect the life-safety consequence are:

- the possibility of loss of human life
- the possibility of injuries on personnel
- the expected effect on personnel health and safety.
- mitigation measure that is in place to reduce the life-safety consequence.

2.2.3 Environmental consequence

The environmental consequence depends on the expected volume of hydrocarbon released as the result of the structural failure.

The factors which affect the environmental consequence are:

- the possibility of losing unit cargo
- the capacity of the processing and / or storage facilities supported by the hull compartment
- the proximity of the failing structure to major process or storage equipment or to major pipework that will cause environmental pollution
- mitigation measure that is in place to reduce the environmental consequence.

2.2.4 Financial consequence

The financial consequence level depends on the expected financial loss as the result of the structural failure and/or repair.

The factors which affect the financial consequence are:

- the possibility of losing the tank structure
- the repair costs
- the possibility of loss or reduction of serviceability
- the possibility of unit class withdrawal.
- mitigation measure that is in place to reduce the financial consequence.

2.3 Risk ranking

2.3.1 Typical acceptance criteria

The risk assessment must be carried out against acceptance criteria. The acceptance criteria applied to the risk assessment are given bellow:

a) Effectiveness of corrosion protection system based on the requirements of the NR445 Pt A, Ch 2, namely:
   - effective CP system with respect to potential measurement
   - sacrificial anode less than 50% depleted
   - coating condition in GOOD or FAIR condition depending on Tank Type and area location.

b) Maximum acceptable thickness loss based on the requirements of the NR445, Pt A, Ch 2, App 1, including:
   - maximum allowable corrosion wastage for isolated area, item and zone
   - maximum allowable pitting depth in terms of pitting intensity.

c) Acceptance criteria for crack indication based on the requirements of IACS Rec. n°20 (2007), especially crack designated 100 according to ISO 6520-1 classification is not accepted.

Note 1: Crack ISO 6520-1-100 is defined as an imperfection produced by a local rupture in the solid state which can arise from the effect of cooling or stresses.

d) Maximum acceptable deformation size set at 50mm, which is commonly applied for floating structures (ISSC 2009).

e) Strength design criteria for the residual strength of a damaged structure.

2.3.2 Risk matrix

The risk matrix adopted by this method is shown on Fig 1. It is 5 x 5 asymmetrical matrix which provide more weight to the consequence to reflect risk aversion.

3 Inspection Strategy

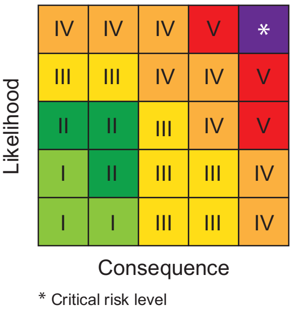
3.1 Risk-based inspection strategy

3.1.1 The risk-based inspection strategy should give more inspection effort to higher risk structures and should take account of interaction with high risk appurtenances, workability and regulations according to the operating staff requirements.

3.1.2 Example of risk-based inspection intervals which can be applied with the typical risk matrix of Fig 1 are set out in Fig 2.

3.1.3 Example of general inspection requirement which can be applied with the typical risk matrix of Fig 1 is shown on Fig 3.

Figure 1 : Risk Matrix.



* Critical risk level

Figure 2 : Example of risk-based inspection maximum intervals [in years].

Risk level

Likelihood

IV	IV	IV	V	*
III	III	IV	IV	V
II	II	III	IV	V
I	II	III	III	IV
I	I	III	III	IV

Consequence

* Mitigation required

Risk-based inspection intervals

Likelihood

3	3	3	1	*
5	5	3	3	1
5	5	5	3	1
8	5	5	5	3
8	8	5	5	3

Consequence

Figure 3 : Example of general inspection requirement.

Likelihood

CVI & UTM	CVI & UTM	CVI & UTM	CVI & UTM	*
CVI	CVI	CVI & UTM	CVI & UTM	CVI & UTM
GVI	GVI	CVI	CVI & UTM	CVI & UTM
GVI	GVI	CVI	CVI	CVI & UTM
GVI	GVI	CVI	CVI	CVI & UTM

Consequence

* Mitigation required

APPENDIX 1 IMPLEMENTATION OF THE SEMI-QUANTITATIVE RISK ASSESSMENT FOR INSPECTION PLANNING

1 Introduction

1.1 General

1.1.1 This appendix shows how the semi-quantitative risk assessment approach is implemented, in a more general context and outside the class requirements, in order to develop a risk-based inspection strategy. In particular it provides guidance on how to establish and implement the RBI assessment model.

2 RBI Assessment Model Development

2.1 General

2.1.1 The RBI assessment model includes:

- a risk assessment model
- a risk-based inspection decision system

2.1.2 Risk assessment model

The risk assessment model includes:

- a rule-based scoring model for the LoF assessment
- a classification system for the CoF assessment.

The classification system for the CoF is based on regulatory requirements complemented with the operator's own criteria. However, the key task in setting up the RBI assessment model is developing a rule-based scoring model for the LoF, which will require more time and effort.

2.1.3 Risk-based inspection decision system

The risk-based inspection decision system defines the inspection interval, scope and technique required with respect to the risk level represented on the risk matrix.

The definition of the risk-based inspection decision system is straightforward and establishes a direct relationship between the risk level and the required inspection effort.

2.2 Definition of the scope of the RBI assessment

2.2.1 Structures covered by the model

At the very beginning of a project, the structures on which the RBI assessment model will be applicable must be defined, since there may be some restrictions that prevent the use of that model on some part of the facility.

Therefore, it is important to understand the underlying assumptions of the model. For example, some structural elements, the failure of which impacts all the unit, will have extremely high consequence of failure that are not comparable to other parts of the unit. Likewise, some tanks may be operated in critical conditions, which will require them to be analysed separately by involving expert judgement.

Moreover, it is important to understand the regulatory and the classification society's requirements that prevent the use of RBI assessment on some parts of the unit and for which prescriptive inspection program are required.

2.2.2 Domain of validity

The extent to which the RBI assessment model is applicable should be defined, especially whether it is applicable to a specific unit only, to a defined region or to the whole fleet of the operator.

2.3 Development of the rule-based scoring for LoF

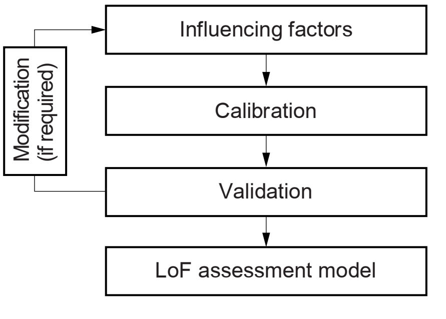
2.3.1 General

The process for developing the rule-based scoring model for the LoF is shown on Fig 1.

Each step of the process requires involvement of relevant stakeholders:

- Identification of the influencing factor and the calibration steps require contribution from the personnel responsible for the operation of a floating unit
- The validation step requires all the RBI team to be involved, but the endorsement of the model is the responsibility of the owner.

Figure 1 : Process for setting up LoF rule-based scoring model



2.3.2 Influencing factors

The influencing factors are those factors which have the potential to cause failure. They must be well identified and a scoring rule along with a weight on how strongly they affect the LoF must be assigned to each one of them.

In selecting the factors that will serve in the assessment of the LoF, one should ensure that they are not correlated so as not to include a same effect multiple times.

For a robust assessment, not too many factors should be included. It is usually possible to reflect the likelihood of failure of the structure with a limited number of influencing factors. No more than 10 factors should be included.

2.3.3 Calibration

The calibration step will compute, using an optimization procedure, the appropriate score range values of the LoF levels and the appropriate values of the influencing factor weights.

The calibration process is set out in detailed in [4].

2.3.4 Validation

In order to ensure robustness of the scoring model, it should be benchmarked on set of structures different from the one generated for the calibration step to check whether the results provided are still relevant.

The scoring rule model and the whole process for its development should be submitted to the stakeholders for review. Any modification required should then be implemented so as to reach a model that is validated by the main stakeholders especially the operator.

2.4 Customized model

2.4.1 General

The process described in the above paragraphs has been used to develop the Society semi-quantitative risk assessment method and the corresponding risk-based inspection strategies.

However, the Society model may not be used directly for any RBI project for example because there may be some difference between the risk matrix of the method and the corporate risk matrix. Moreover, the operator may require to reduce the domain of validity for the model to be more specific to some units and to focus more on some influencing factors for better accuracy.

In this case, the process described in the above paragraphs and which served for the development of the Society RBI assessment model, could be applied to develop a customized RBI assessment model. However, it is recommended instead to perform, if necessary, a mapping of the specific parameters (e.g. risk matrix, influencing factors' weight) of the RBI project under consideration to the generic parameters of the Society RBI assessment model.

2.4.2 Models mapping

The mapping of a specific corporate risk matrix to the generic risk matrix of the proposed RBI method should be carried out by mapping their respective LoF and CoF scales.

The weights of the influencing factors for a specific RBI project can be computed using the same technique (e.g. least square method) applied for the generic model with a different calibration set. This calibration set should include selected inspection data from the calibration set used for the generic model and which are relevant to the units of the RBI projects under consideration. It should include in addition other inspection data specific to the units of the RBI projects under consideration. Those additional data should be provided by the operator.

3 Implementation

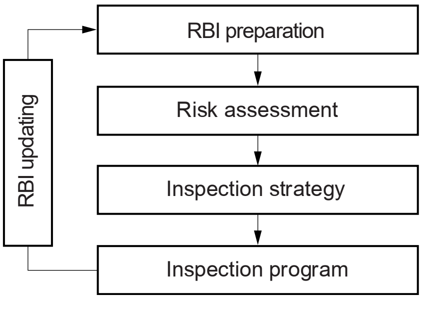
3.1 General process

3.1.1 The implementation of the RBI assessment model involves the following main steps (see Fig 2):

- preparation of the RBI assessment
- risk assessment
- development of a risk-based inspection strategy
- development of the inspection program
- updating risk assessment as inspection results become available.

Those steps are set out in detail in the following sub-articles.

Figure 2 : General Process of the RBI Method.



3.2 RBI preparation

3.2.1 General

This initial step allows some key elements of the RBI assessment to be defined:

- the objective of the RBI program
- the RBI team make-up
- the hull structure model (e.g. structure subdivision, structural hierarchy)
- data collection and requirements.

3.2.2 Objective of the RBI program

The objective of the RBI program should be established regarding the operator overall SIM policy and should address the following key elements:

- the applicable risk acceptance criteria (i.e. risk matrix)
- the hull compartments selected for the RBI assessment
- the type or level of risk assessment method to be used
- the time and resource required
- the deliverables
- the period of validity of the RBI assessment and when it should be updated
- the applicable codes and standards.

it is important that an agreement is achieved among all the stakeholders on those key elements.

3.2.3 RBI team

The composition of the RBI team should follow the general requirements provided in Sec 2, [2.1].

RBI assessment requires the commitment and the cooperation of the operating organization, in particular, it is essential that the Offshore Installation Manager (OIM) or a representative of the operating staff is involved.

3.2.4 Hull structure model

Guidelines for building up the hull structure model are set out in Sec 2, [3].

3.2.5 Data requirements

Typical data required for the RBI assessment are provided in Sec 2, [2.3].

3.3 Risk assessment

3.3.1 General

The RBI method provides a global risk assessment for the hull compartments and local risk assessment for their structural components.

For both global and local risk assessment a rule-based scoring method is used for the assessment of the LoF and a qualitative categorization is used for the CoF.

3.3.2 Corporate risk matrix

Owner or operator specific risk matrix should be adopted when available. In this case, the likelihood scoring method should be suitable to it and the consequence should be categorized according to it.

3.4 Inspection strategy

3.4.1 An inspection plan must be developed for each hull compartment selected for the RBI assessment.

The inspection strategy must cover the service life of the offshore unit and must be reviewed periodically throughout this lifetime.

It must specify:

- the inspection interval or inspection schedule
- the inspection technique
- the inspection coverage when close-up inspection is required on a group of structural components.

The inspection strategy can be modified by consideration of the regulation requirements and the operational feasibility. Therefore, it is important that operational team members be involved at this stage to demonstrate that the final inspection strategy conforms to regional regulations and is workable based on operational constraints.

3.5 Inspection program

3.5.1 General

The implementation of the inspection program is under the responsibility of the owner or operator who is in charge of conducting the detailed inspection work scope to complete the activities defined in the inspection strategy. Therefore, this part of the guidance note is not part of the RBI method developed by the Society. It is provided in order to draw attention to important requirements for the implementation of the inspection program, which may be useful when the Society needs to appraise the inspection program or is involved in its specifications.

The inspection program contains two main elements:

- its specification
- its execution.

3.5.2 Specification of the inspection program

a) Some requirements for the inspection tasks should be established in advance to enable effective execution of the inspections. The specifications to be provided as minimum are set out in Sec 2, [8.1.2]

b) In addition, it is recommended to provide detailed field guidance for each inspection in the form of detailed work packs or checklists. This field guidance identifies each of the individual inspection locations, the inspection methods and provides a means to document the observations. It includes also details on required access, cleaning, and equipment required to successfully execute each examination within the inspection

c) All the inspection instructions may be issued as an inspection workbook, including drawings, procedures, reporting formats and calibration logs.

3.5.3 Execution of the inspection program

a) The inspection technicians and engineers and their associated companies conducting the inspections and reviewing the results must be qualified in accordance with owner requirements

b) If during the course of an inspection program, anomalies are discovered that can potentially affect the structural integrity, personnel should perform an evaluation to determine if and when additional inspection and/or remedial measures should be performed. Additional inspection can require use of more detailed techniques.

3.6 RBI updating

3.6.1 RBI updating process should follow the requirements set out in the NI657, especially in the following circumstances, when applicable:

- in case of outstanding structure condition or from class recommendation
- when significant changes in operating conditions has occurred
- every five years.

4 Calibration process of the LoF scoring

4.1 General

4.1.1 The calibration process allows computing the weights of the influencing factors and the limits values of the ranges of the scores for the LoF categories.

In the current scoring process, the range of the scores for the likelihood category are fixed. Therefore, the calibration of the scoring formula consists in finding the weight values that yield a result as close as possible to the expected LoF category.

The calibration process involves the following steps:

a) select influencing factors with larger importance for the likelihood
b) generate a sample of structural data with respect to the parameters of the selected influencing factors
c) assign a LoF category to each one of the sample data based on expertise and experience
d) compute the weights of the selected factors
e) validate the computed weight on another generated sample set involving all the structural integrity parameters.

4.2 Selection of factors for the calibration

4.2.1 Factors with larger importance are selected. They should allow a likelihood category corresponding to typical values of their respective parameters to be perceived. These are factors for which simple rules can be defined on how they influence the likelihood. For example, such factor may move the structural component from one category to another when its parameters are changed from the lowest to the highest value.

4.2.2 Several important factors may be considered having the same weight. In those cases, only one of them should be selected for the calibration, and then its computed weight will be allocated to the others

4.2.3 The weights of the remaining factors with smaller importance will be allocated marginal values in comparison to larger importance factors selected for the calibration. For example, they may be assigned a fraction of the lowest computed weight so that they could not allow a structural component to move from one category to another over the full range of their variation. However, due consideration of their cumulative effect should be made in establishing their weight that way.

4.3 Calibration set

4.3.1 The sample set of structural components for the calibration is given by a certain number of relevant combinations of the parameters of the selected influencing factors.

4.4 Expected category allocation

4.4.1 The sample set of structural components defined for the calibration is submitted to knowledgeable people so they can provide a likelihood category to each one of the selected structural components from their expertise and experience. The provided categories will be all the more suitable as their level of expertise is higher.

4.4.2 Specific requirements from the operator or owner with respect to his risk perception or risk aversion can be taken into account in the allocation of an expected LoF category. In this case, it must be ensured that the minimum acceptable performance is still met.

4.5 Weight computation

4.5.1 The weights of the selected factors are computed by a least square method so that the scoring formula provides results as close as possible to the expected ones. However, it is recommended to ensure that when the scoring provides likelihood different from expected, it should be on the conservative side.

4.6 Validation

4.6.1 Another sample set is generated involving preferably all the structural integrity parameters. Their respective LoF category is computed with the obtained scoring formula. Those computed LoF are then checked by knowledgeable people in order to validate the scoring formula.

APPENDIX 2 DEGRADATION OR DAMAGE MECHANISMS AND FAILURE MODES

1 Degradation or damage mechanisms

1.1 General

1.1.1 An overview of possible degradation and damage mechanisms, is provided.

The information provided is not exhaustive, and an evaluation of possible degradation mechanisms and damages should be considered for each facility.

This information can be used to help identify the degradation mechanisms and damages that may occur in a given facility by checking whether they are relevant for the facility under study or by considering other similar degradation or damage mechanisms more specific to the facility under study.

1.2 Common degradation mechanisms

1.2.1 Corrosion of the hull

This typically results from failure of corrosion protection systems such as coatings (hard and soft), anodes, dehumidification, inert gas, impressed current cathodic protection, crude oil washing causing partial damage on coating, etc. Note that coating system failures often initiate in areas where the original coating surface preparation and application is more difficult to achieve. Some of these locations can include weld seams, sharp corners or edges and member connections and flanges. Corrosion can occur throughout a facility, and the following list provides likely corrosion locations and drivers for the failure of the corrosion protection system:

a) Atmospheric
- external above water
  - areas under process equipment
  - primary and secondary structures
  - personnel walkways, stairs, hand rails and other tertiary structure
  - areas that are prone to frequent wet/dry cycles.
- machinery space.

b) Saltwater
- hull plating
- hull external appurtenances and their connections to the hull
  - caissons
  - hard piping and associated hull connections (bolted and welded)
  - riser porches
  - access structures.
- ballast tanks

c) Splash zones are particularly susceptible to corrosion due to the constant wave action wearing on the coating (and bare steel eventually) and the inability to repair coatings or use cathodic protection to limit corrosion

d) Corrosion under insulation in way of Passive fire protection (PFP) on structurally critical members

e) Other corrosive fluids or environments
- slops
- off-spec
- bilge spaces (e.g. pump rooms, machinery spaces, etc.)
- tanks (above fluid level) and voids; deckhead is most vulnerable as there is no backup (anodes, crude oil, etc.) for coating
- cargo tank bottoms
- produced water tanks.

f) Microbial activity (local corrosion) – Most likely on tank bottoms or other horizontal surfaces where sediment can collect and trap organisms leading to deep local pitting

g) Insufficient cathodic protection will leave the steel vulnerable to corrosion

h) Too much CP can cause coating problems and lead to hydrogen embrittlement of the steel and cracking.

1.2.2 Fatigue cracking

Fatigue cracking can occur in any of the following locations. Various data sources (operating, condition, etc.) are crucial to a reasonable evaluation of fatigue.

a) Any known low margin fatigue details

b) Areas with fabrication flaws or deviations from original design

c) Areas of past repairs carried out in-situ

d) Areas where local corrosion can affect fatigue performance

e) Hull/topside structural interfaces such as:
- module/skid connections to the deck and column mating posts
- internal/external turret support structures
- flare towers
- crane pedestals
- helideck
- boarding structures
- lifeboat davits.

f) Hull appurtenance connections to the shell and internal backup structures such as:
   - riser porches
   - riser tensioner structures
   - mooring components
   - TLP tendon porches.

g) At various locations within the tendon system.

1.2.3 Local erosion

Local erosion that may occur in way of pipe suction/discharges or other fluid impingement locations.

1.3 Common damage mechanism

1.3.1 Inaccurate weight management

The installed lightship weight and centre of gravity is accurately determined through field measurement before or during installation. This should be managed over time to verify the floating system stays within the safe operating envelope. Poor weight management can lead to inaccurate lightship weight and centre (often evidenced by significant "phantom weights") leaving the operator unaware of potential effects on the hull stability. The severity of this type degradation is significantly influenced by the total displacement of the facility as well as the amount of margin inherent in the design. For lightweight, low waterplane (i.e. low motion) hulls, small errors in weight management can be critical, whereas for large hulls with a great deal stability margin, significant errors in weight tracking can have little effect on the centre of gravity and stability.

1.3.2 Degradation of watertight barriers

a) Deck hatches and watertight (WT) doors
   - corrosion of bolts, sealing surfaces, closure plates, etc.
   - damage/wear of dogging/hinges/closing mechanisms
   - gasket degradation.

b) WT barrier penetrations
   - valves and piping (e.g., vent, seachest cargo and ballast lines, etc.)
   - multi-cable transit that provide watertight barriers in way of conduit penetrations. Damage mechanisms can include:
     - corrosion in the structure in or around the multi-cable transit
     - the seals or cables can deteriorate or move (e.g. thermal expansion or pressure changes).

1.4 Asset specific degradation and damage mechanisms

1.4.1 FSO/FPSO

a) Lack of tank capacity to handle inspections/repairs; inability to inspect and repair without effect on production can lead to escalating damage

b) Lack of harsh service tank redundancy

c) Repair of one tank can lead to significant damage in other tank pressed into temporary service without protection

d) Improper loading conditions resulting in still-water bending moments and shear more than hull design

e) Overload/cracks at hull/module interface due to improper incorporation into the module support design of global hull deflections

f) Low cycle fatigue driven by cargo loading cycles.

1.4.2 Disconnectable FPSO (Additional Mechanisms)

a) Inability to evade a storm can be caused by Marine growth on hull

b) Cargo and ballast system failure causing inability to prepare for the navigation loading condition.

1.4.3 Column Stabilized Unit

a) Fatigue due to diagonal and longitudinal squeezepry loads in way of inboard corners of nodes, pontoons and column junctions

b) Pontoon fatigue (fatigue due to waves normal/off-diagonal to pontoon with wave lengths close to the length of the pontoon causing fluctuating flexural and torsional stresses)

c) Knee brace to hull connection fatigue due to wave loading

d) Drilling/production riser tensioner support structure corrosion, mechanical damage or cracks.

1.4.4 Spar

a) Truss to hard tank connection fatigue due to both wave-frequency and low-frequency motions of the spar

b) Truss to soft tank connection fatigue due to both wave-frequency and low-frequency motions of the spar

c) Fatigue of fixed ballast tanks compartmented in the soft tank

d) Soft tank loss of ballast

e) Drilling/production riser tensioner support structure corrosion, mechanical damage or cracks.

1.4.5 Tension-Leg Platform (TLP)

a) All items noted above for column stabilized units

b) Tendon fatigue (connectors, joints, welds)

c) Wind/wave/current events exceeding design
- changes in flex bearing stiffness
- inaccurate analysis such as improper accounting for wave loading and vessel motions, vortex-induced vibrations (VIV) of tendon compounded with vortex-induced motions (VIM) of hull, 2nd order springing/ringing, slow drift loads, and/or seismic loading
- changes in the configuration of the facility
- increased loading due to excessive marine growth build up.

d) Flex element
- aging of elastomer leading to stiffness increase
- loss of elastomer through creep
- degradation of elastomer material leading to cracking, loss of bond, stiffness change, or loss of material in element.

e) Tendon coating
- loss of coating due to breakdown
- loss of coating due to mechanical abrasion.

f) Tendon tension monitoring system
- zero drift of load measuring device
- zero drift due to mechanical overload of supports
- zero drift due to loosening of supports
- loss of signal due to cable failure
- loss of signal due to issues with electrical connections.

g) Tendon flooding
- water ingress through fatigue crack
- water ingress through leaky tendon end plug
- water ingress through leaky intermediate connector.

h) Tendon loss of wall thickness
- external corrosion
  - coating loss
  - mechanical abrasion
  - improper cathodic protection.
- internal corrosion due to water ingress through crack or another defect.

1.4.6 FLNG

a) Failure of heating systems in the voids between cargo tanks

b) Failure of pump tower and pump tower base supports
- sloshing
- debris.

c) Failure of cargo containment system caused by
- sloshing
- debris
- thermal cycles
- over/under-pressurization.

d) Failure of primary or secondary barrier

e) Tank insulation deterioration

f) Failure of gas detection in inter-barrier spaces

g) Failure of Nitrogen purge in inter-barrier spaces

h) Liquid dome opening failure

i) Failure of cargo handling system e.g. cryogenic spill.

2 Failure Modes

2.1 General

2.1.1 An overview of possible failure modes that can result from the degradation and damage mechanisms.

The information provided is not exhaustive, and the identification of asset-specific failure modes should be considered for each facility.

This information can be used to help identify the failure modes that may occur in a given facility by checking whether they are relevant for the facility under study or by helping considering other similar failure modes more specific to the facility under study.

2.2 Common failure modes

2.2.1 Loss of Stability

Loss of stability occurs either when the weight condition becomes such that metacentric height is negative and the facility is at risk of severe trim/list and even overturning. The following drivers, particularly in combination, can lead to loss of stability:
- poor weight management
- improper tank loading
- ballast/cargo system failure leading to improper tank loading (weight and free surface), inadequate freeboard, or inability to respond to unplanned hull flooding
- failure of external watertight barriers leading to uncontrolled flooding of hull spaces
- failure of internal watertight boundaries leading to progressive flooding of hull spaces in a damaged condition.

2.2.2 Loss of stationkeeping

Loss of stationkeeping can lead to rupture of risers and damage to host and other assets, and even total asset loss of the asset.

Loss of mooring lines or stationkeeping assist thrusters can lead to:
- production shut-in (partial loss of mooring lines)
- offsets beyond riser limits
- complete loss of station keeping.

2.2.3 Loss of structural integrity

a) Global loss of structural integrity due to

- corrosion - loss of gross section modulus
- fatigue leading to major cracks and hull failure
- fire and blast that can overload the structure or degrade structural properties leading to collapse. This is made worse where PFP has failed or there is corrosion underneath the insulation (CUI). Fire and blast sources can be:
  - hydrocarbon release for example from risers, on cargo offloading system
  - internal to tank from improper inerting
  - hydrocarbon release due to breach of tank boundaries either by structural failure (cracks) or failure of tank closure devices (access, vent, sounding, etc.)
- improper weight distribution (hull loading condition) leading to overload in severe metocean conditions.

b) Local loss of system Integrity due to the following:

- accumulation of many small failures can lead to point where repair cannot be managed without ceasing operation
- splash zone corrosion with no practical way to renew steel
- over/under pressure of tank leading to local buckling
  - overfilling
  - blocked vents
  - failure of pressure relief devices.

c) Fatigue

- cracks in way of critical details
- cracks in way hull appurtenances
- cracks in way of topside/hull connections.

2.2.4 Loss of Hydrocarbon Containment

a) Internal

- cracks leading to communication between cargo/slops tank and ballast/void tank
- local pitting leading to communication between cargo/slops tank and ballast/void tank
- piping/valve failure leading to communication between cargo/slops tank and ballast/void tank.

b) External

- cracks leading to communication between cargo/slops tank and sea/atmosphere
- local pitting leading to communication between cargo/slops tank and sea/atmosphere
- failure of offloading system.

2.2.5 Loss of life / injury

a) Failure of life safety systems due to improper maintenance of:

- lifeboats/liferafts
- firefighting systems
- fire and gas detection
- emergency shutdown systems
- alarms.

b) Failure of personnel walkways

c) Failure of blast walls.

2.3 Asset specific failure modes

2.3.1 FSO/FPSO

a) All FPSO/FSOs: Unmanageable repair due to cascading damage (chasing tail) if no redundancy provision in place

b) Permanently moored units: Partial loss of mooring/stationkeeping leading to beam-on orientation to waves with potential stability consequences due to:

- loss of multiple mooring lines
- loss of heading/thrust assist
- loss of turret rotation.

c) Disconnectable units

- inability to move off station (completely or quickly enough) leads to overloading of hull structure
- inability to move off station (completely or quickly enough) leads to loss of stability
- inability to manage hull fluids leads to loss of stability underway
- inability to maneuver leads to loss of stability underway.

2.3.2 TLP & Column Stabilized Unit

Loss of stability (potential overturning) due to tendon failure which can be caused by:

a) Loss of load carrying capacity leading to:

- fatigue crack (girth weld) grows to critical size, fails under design load
- fatigue crack (mechanical hot spot) grows to critical size, fails under design load
- unlatch of tendon bottom connector.

b) Increase of flex bearing stiffness leading to:

- accelerated fatigue crack growth
- overload of tendon.

c) Point contact with tendon

- contact between tendon body and keel of hull during extreme lateral offset
- contact between tendon body and pile top during extreme offset.

d) Tendon flooding leading to:
   - loss of bottom tension, unexpected unlatch of bottom connector
   - changed dynamics of tendon
   - loss of tendon tension monitoring
   - center of gravity exceeding the allowable envelope
   - tendon tension below lower limit.

e) Ineffective vortex suppression device leading to:
   - fairings lock up so that drag area increases and platform exceeds allowable offset limits
   - device (fairings or strakes) does not perform as expected.

2.3.3 FLNG

a) Hull cracking due to:
   - cryogenic spill from cargo handling system
   - failure of heating systems in void
   - failure of tank containment due to:
     - primary and secondary barrier failures:
       → damage from debris
       → damage pump tower supports
     - gas detection and purge system failures.

b) Fire and blast from loss of containment.

APPENDIX 3 IMPLEMENTATION OF HULL INSPECTION

1 Hull Inspection Implementation

1.1 General

1.1.1 This Appendix describes the activities that should be implemented by the operator within an inspection program for the hull structure of offshore floating units.

However, for the RBI of floating units within the class rule, the inspections are to be carried out in accordance with the class requirements.

1.2 Internal hull

1.2.1 General visual inspections is to include all compartments, like water ballast tanks, cargo tanks, any structural tank and void spaces.

1.2.2 More detailed inspections of the internal hull structure can be performed and should typically include the following structures and systems:

- special areas
- manway hatches, bolts and coamings
- interior walkways, stairs and handrails
- interior surfaces of primary load bearing structures, including hull plating, transverse and radial frames, and longitudinal and vertical stiffeners
- internal backup structure (e.g. fairlead, riser porches, caisson supports, etc.)
- condition of coatings and anodes, as applicable
- equipment function testing (e.g., ballast pumps, leak detection systems, etc.)
- piping, valves and conduit and associated supports and compartment penetrations
- pump and engine foundations.

1.3 External Hull Below Water

1.3.1 The inspections should cover below water structures including:

- any special area
- external marine systems components
- the mooring system hull attachments or tendon system, including propulsion, steering and seachests, as applicable.

1.3.2 External hull underwater inspections should be performed also to confirm that the corrosion protection system on the external hull is functioning adequately, and to assess the extent of marine growth.

1.3.3 The inspections may incorporate different inspection methods and techniques (e.g. general visual of entire hull with ROV at a specified interval and more detailed inspection techniques of critical locations with diver and ROV on an alternating schedule).

1.3.4 Typical structures and systems that should be included in the underwater inspection are:

- accessible hull exterior surfaces and appurtenances below the waterline (e.g. caissons, hard piping, and their associated external guards, clamps and standoff supports)
- structural bracing and associated connections
- external mooring/tendon system to hull connections (e.g. fairleads, tendon porches, etc.)
- riser and umbilical porch structures and I-tubes
- seachests and hull penetrations
- special areas
- propulsion and steering, as applicable (e.g. rudder, propeller, thruster, etc.)
- corrosion protection system (e.g. coating, anode and impressed current system as applicable)
- hull markings.

1.4 Marine Systems

1.4.1 The marine systems within the hull should be inspected and functionality should be verified during the internal inspection of the compartments containing the equipment. Marine systems include:

- ballast
- bilge
- process equipment and piping (if within the hull)
- inert gas
- firewater
- Heating, Ventilating, Air-Conditioning (HVAC)
- propulsion
- steering
- vents
- sounding systems.

1.5 Mooring components

1.5.1 The mooring system support structure on the hull should be inspected in conjunction with the external inspection.

1.6 Tendons

1.6.1 In conjunction with the underwater inspection, the tendon system of TLPs should also be inspected, including:

- the full length of the tendons
- flex joints
- connections
- piles/foundations
- the components of the tendon tension monitoring system (TTMS) and any other instrumentation.

1.7 Coating

1.7.1 It is normally possible using a GVI to assess the condition of coatings without resorting to a CVI, as follows:

- Good: a condition with only minor spot rusting
- Fair: a condition with local breakdown of the edges of stiffeners and weld connections or light rusting over 20% or more of areas under consideration, but less than as defined for poor condition
- Poor: a condition with general breakdown of coating over 20%, or hard scale at 10% or more of the areas under consideration.

If the coating is Good, CVI and UTM are not normally required. If the coating is Fair, consideration should be given to performing a CVI and UTM at an appropriate time period.

1.8 Other inspections and checks

1.8.1 Sacrificial anodes shall be examined for excessive depletion. If anodes do not appear to be depleting or if they are depleting at a much slower rate than expected, continuity with the protected structure can be insufficient. CP measurements shall be used to demonstrate the satisfactory performance of sacrificial anodes.

1.8.2 Impressed current cathodic protection (ICCP) system anodes, cathodes, and reference cells shall be checked for damage, fouling by marine growth and carbonate deposits.

1.8.3 Inspections should include inspection of walkways and egress routes to confirm no safety hazards are present (e.g. damaged handrails, missing/loose grating, etc.).

1.8.4 Inspections should include checks and function tests.

Examples of systems requiring confirmation of function include:

- sensors and alarms (e.g. tank level alarms, etc.)
- marine systems (e.g. pumps, propulsion, steering, etc.)
- other critical systems (e.g. turret bearings, watertight/weathertight hatch seals, etc.).

1.9 Tank testing and watertightness/ weathertightness

1.9.1 FPSO and FLNG cargo tanks and associated penetrations should be tested with a head of liquid to the top of access hatches. Ballast tanks and associated penetrations should be tested for the full tank height plus 2/3 of the air vent height. These tests should be performed at a specified time-span based on risk assessment.

1.9.2 Hydrostatic testing may be not necessary if coatings remain intact and no significant thickness reductions are found during routine inspections, unless structural modification to the tank has been performed. Lack of leakage during operational filling of adjacent tanks may be taken to demonstrate watertight/weathertight integrity.

1.9.3 The loaded condition of adjacent tanks when the test head is to be imposed should be evaluated. It is important to establish that the corresponding conditions were considered and checked within the design. Caution should be exercised, owing to the risk of damage arising during these tests.

1.9.4 For other floating systems that do not store large quantities of product, the watertight/weathertight integrity of tanks, bulkheads, and other compartments should be verified by visual inspection. Corroded areas should be evaluated for watertightness/weathertightness and subject to thickness gauging or NDT as necessary.

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