

Mooring Integrity Management

API RECOMMENDED PRACTICE 2MIM
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Contents

	Page
1 Scope	1
2 Normative References	1
3 Terms, Definitions, and Abbreviations	1
3.1 Terms and Definitions	1
3.2 Abbreviations	5
4 Mooring Integrity Management Process	6
4.1 General	6
4.2 Mooring Integrity Management Overview	6
4.3 Data	8
4.4 Evaluation	9
4.5 Strategy	13
4.6 Process	15
5 Inspection and Monitoring	17
5.1 General	17
5.2 Inspections	17
5.3 Monitoring	20
6 Assessment Process	21
6.1 General	21
6.2 Simplified Assessment	21
6.3 Design Assessment	23
7 Assessment Methods	24
7.1 General	24
7.2 Assessment Initiators	25
7.3 Assessment Information	25
7.4 Implementation Feasibility	27
7.5 Risk Assessment	27
7.6 Performance Criteria	27
8 Risk Reduction	28
Annex A (informative) Commentary—Additional Information and Guidance	29
Annex B (informative) Mooring Integrity Management System Objectives	35
Annex C (informative) Causes of Failure	37
Annex D (informative) Incident Response Planning	47
Annex E (informative) Inspection Methods and Objectives	55
Bibliography	72
Figures	
Physical Interfaces between API IM Standards	vii
1 IM Process Map	7
2 Steps in the IM Process	8
3 Risk Categorization Matrix Example	11
4 Mooring Damage Assessment Process	22

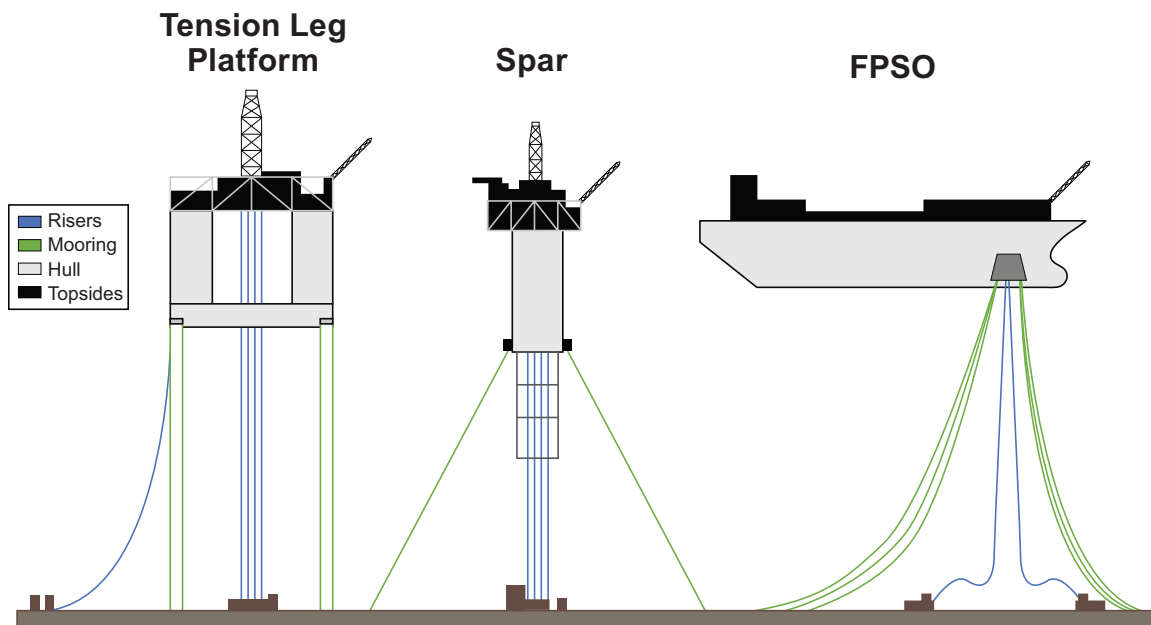
	Page
A.1 Example System Block Diagram (SBD) for an RTM Mooring System	30
C.1 Rate of Failure per Line per Exposed Year	37
C.2 Failure Causes Chain and Wire Rope	37
C.3 Failure Location by Component Type	38
C.4 Introduction of Causes of Failure	39
E.1 Vessel Navigation around Mooring Line	63
E.2 Example Inspection Work Pack (Sheet 1 of 3)	65
E.3 Example Inspection Work Pack (Sheet 2 of 3)	66
E.4 Example Inspection Work Pack (Sheet 3 of 3)	67
E.5 Example Inspection Checklist	68
 Tables	
B.1 Mooring IM Objectives by Project Phase	35
C.1 Material and Configuration-based Vulnerabilities	41
C.2 Event-based Causes of Failure	42
C.3 Indications of Degradation Causes	43
E.1 Inspection Methods	56
E.2 Inspection Method Requirements	59

Introduction

This recommended practice (RP) is one of three additions to API's portfolio of offshore floating structures standards that address integrity management (IM) of floating systems (API 2FSIM), mooring systems (API 2MIM), and riser systems (API 2RIM).

This RP is intended to be used by owners and engineers in the development, implementation, and delivery of a process to maintain system integrity of floating production systems (FPSs), *not* including tension leg platforms (TLPs). The specifications, procedures, and guidance provided herein are based on internationally recognized industry standards and on global industry best practices.

API's existing suite of recommended practices such as API 2FPS, API 2T, API 2SK, API 2RD, and API 2SIM address several aspects of life cycle integrity management expectations, and the three new standards add to that suite by capturing experiences from owners, operators, integrity management specialists, recognized classification society (RCSs), and regulators, establishing a common framework for IM for FPSs. Figure Intro 1 pictorially depicts the interfaces between the hull and mooring and risers for various types of FPSs and the IM standard that addresses the specific systems.



Physical Interfaces between API IM Standards

Implementation of effective integrity management for floating systems requires an understanding of the interfaces between the hull, mooring, and risers and how they translate to stewardship of IM activities in the field. The new standards have been developed with the objective of recognizing and identifying key interfaces, and they emphasize the criticality of a systems level approach.

By having a consistent systems level approach and by pursuing a risk-based framework to develop, evaluate, plan, and implement an integrity management program for a floating system, the user can tailor the IM program around the unique design drivers, in-service and operating conditions while conforming to the owner's organizational safety, health and environment risk management policies and regulatory requirements.

Mooring Integrity Management

1 Scope

This recommended practice (RP) provides guidance for the integrity management (IM) of mooring systems connected to a permanent floating production system (FPS) used for the drilling, development, production, and/or storage of hydrocarbons in offshore areas. The scope of this RP extends from the anchor to the connection to the floating unit (e.g. chain stopper) and includes components critical to the mooring system (e.g. turret bearings, fairleads, chain stoppers, anchors, suction piles).

Specific guidance is provided for the inspection, monitoring, evaluation of damage, fitness-for-service assessment, risk reduction, mitigation planning, and the process of decommissioning. This RP incorporates and expands on the IM recommendations found in API 2I and API 2SK. In the event of any discrepancy between API 2MIM and API 2I/API 2SK, API 2I/API 2SK will govern.

This RP is not intended for:

- structural steelwork of turret systems and TLP tendons, which are addressed by API 2FSIM;
- thrusters, power generation, or control system;
- mobile offshore drilling unit (MODU) or other temporary moorings that are deployed and retrieved frequently;
- vessels holding station via a dynamic positioning (DP) system, without the use of mooring.

2 Normative References

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any addenda) applies.

API Recommended Practice 2I, *In-service Inspection of Mooring Hardware for Floating Structures*

API Recommended Practice 2SM, *Design, Manufacture, Installation, and Maintenance of Synthetic Fiber Rope for Offshore Mooring*

3 Terms, Definitions, and Abbreviations

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

3.1 Terms and Definitions

3.1.1

anomaly

An observation or finding indicating the possibility that a certain parameter could be outside an acceptable design or performance threshold.

3.1.2

assessment

A technical review process triggered by an assessment initiator (as identified during an evaluation) to demonstrate that a system or structure is fit-for-service or to determine the need for risk reduction.

3.1.3

assessment initiator

Changes in mooring condition or operating experience, such as storms, which require an existing mooring to undergo an assessment to demonstrate fitness-for-service.

3.1.4**baseline inspection**

Establishes the condition and status of a mooring system at the time it is installed or commissioned, or the current condition if the inspection had not been done when it was installed.

3.1.5**condition assessment**

The process of gathering information on a mooring system's present condition to perform a fitness-for-service assessment.

3.1.6**continued service**

The continued in-situ operation of a mooring system beyond its original service life or approved regulatory operating life.

NOTE Sometimes referred to as "life extension."

3.1.7**defect**

An imperfection or flaw in a component of an existing mooring system.

NOTE As used in this RP, the term "defect" does not necessarily denote that the mooring system is not fit-for-service.

3.1.8**design life**

The time period assumed for defining various design parameters such as corrosion allowance and fatigue life.

3.1.9**disconnectable floating structure**

A floating structure capable of discontinuing production and rapidly separating from its ancillary components, such as risers, moorings, and well systems in response to the occurrence of a threshold event.

3.1.10**emergency response**

A response to unexpected failure including loss of one or more mooring lines, incidents arising from known degraded/degrading mooring components, or mechanical parts failure causing functionality issue.

3.1.11**evaluation**

An engineering review of integrity data, using engineering judgment, risk assessment, calculations, analysis, or other methods to identify anomalous conditions (i.e. assessment initiator) and determine whether additional detailed assessment or risk reduction is required to demonstrate fitness-for-service.

NOTE An evaluation can also consist of an engineering review of proposed changes to the mooring system to determine their significance on fitness-for-service.

3.1.12**extreme event**

A design metocean, seismic, and/or ice condition, with a low probability of exceedance, that a mooring system can be subjected to during its operational life.

3.1.13**failure**

Insufficient strength or inadequate serviceability of a system or component to fulfill its performance requirements.

3.1.14**fitness-for-service**

A demonstration that a mooring system has adequate integrity for the intended operating conditions while maintaining design functionality.

3.1.15**floating production system**

A permanently moored floating platform that utilizes the mooring system under consideration (same as “host platform.”)

3.1.16**hazard identification**

The process of identifying hazards in the facility.

3.1.17**hazardous operations**

Operations that have a concerning probability of causing injury to personnel or pollution to the environment.

3.1.18**in-service**

The condition that characterizes a mooring system that has been commissioned and placed in operation.

3.1.19**inspection**

A specific visual or nondestructive examination performed for collecting data required in evaluation of a mooring system’s integrity.

3.1.20**installation**

Complete assembly including structure, topsides, foundations and stationkeeping system.

3.1.21**integrity data**

Information on the design, condition, and operation of a mooring system.

3.1.22**life extension**

The procedure of demonstrating the extension of the operational life of a mooring system beyond the life specified during the original design and/or as originally permitted.

3.1.23**management of change**

A system for review and approval of changes in processes, procedures, or physical components prior to implementation of the change.

NOTE This usually includes assessment of risk, economic, and schedule implications.

3.1.24**mechanical damage**

A defect type that can include dents, bows, gouges, holes, and separated or severed members.

3.1.25**mitigation**

Actions taken to limit negative consequences or to reduce the likelihood of occurrence of an event or condition.

3.1.26**mooring**

An arrangement of chains, wire or synthetic ropes, anchors and various connecting components that forms a stationkeeping system for an FPS.

3.1.27**operator**

The person, firm, corporation, or other organization employed by the owners to operate a floating production system.

3.1.28**original design criteria**

Design basis and design codes used in the original mooring system design.

NOTE The design criteria include reference codes, metocean conditions, analysis methods, safety factors, and original design assumptions.

3.1.29**original operating configuration**

The operating configuration that the mooring system was originally designed for.

3.1.30**owner**

A party who owns the physical infrastructure assets (pipelines, floating systems, or terminals) and/or a party who owns capacity rights in those physical assets but does not own the assets themselves.

3.1.31**performance criteria**

Criteria used in a fitness-for-service assessment of the mooring system.

3.1.32**performance parameter**

Specifies a performance goal of the mooring system (e.g., FPS offset).

3.1.33**performance standard**

Benchmark against which actual performance is measured.

3.1.34**qualitative risk assessment**

Project management technique concerned with discovering the probability of a risk event occurring and the impact the risk will have if it does occur.

3.1.35**repair**

The work necessary to restore a deteriorated structure or system to a condition deemed fit-for-service.

3.1.36**residual strength**

The ultimate strength of a mooring system in a damaged or degraded condition.

3.1.37**risk based inspection**

A process that defines inspection frequency and methods based on the probability and consequence of failure of the component or system.

3.1.38**semi-submersible**

A floating system normally consisting of a deck structure with several widely spaced, large cross-sections supporting columns connected to submerged pontoons.

3.1.39**service life**

The time period between a mooring system's installation date and the anticipated end of service.

3.1.40**spar**

A deep-draft, small water-plane area floating structure.

3.1.41**splash zone**

The area of the mooring system that is intermittently wet or dry due to wave and tidal actions or change in operating draft.

3.1.42**stationkeeping system**

A system capable of limiting the excursions of a floating system within prescribed limits.

3.1.43**survey**

A general view, examination, or other activities performed for collecting data required in evaluation of system integrity.

3.2 Abbreviations

CALM	catenary anchor leg mooring
CP	cathodic protection
CVI	close visual inspection
DVI	detailed visual inspection
DMS	data management system
FAT	factory acceptance test
FEED	front end engineering design
FMEA	failure modes and effects analysis
FMECA	failure modes, effects, and criticality analysis
FPS	floating production system
FPSO	floating production, storage, and offloading
GVI	general visual inspection
HAZID	hazardous identification
HAZOP	hazardous operations
IM	integrity management
MIM	mooring integrity management
MODU	mobile offshore drilling unit
NDE	nondestructive examination

RAT	rope access team
RBI	risk-based inspection
RCS	recognized classification society
RTM	riser turret mooring
TSA	thermal sprayed aluminum

4 Mooring Integrity Management Process

4.1 General

Mooring integrity management (MIM) is the process for ensuring a mooring's fitness-for-service over its entire life. IM is a process for managing the effects of deterioration, changes in loading, and accidental overload. The objectives of a mooring IM process include detection of possible degradation of a mooring component sufficiently early to allow for remedial action and thereby protect against accidents, loss of life, environmental pollution, as well as minimizing downtime and risk of economic loss. The process should be designed to provide data and information that may be used to develop remaining service life estimates and to support the possibility of life extension requests. The IM process should detect abnormal conditions or parameters outside of design envelopes through regular inspection and monitoring programs.

The IM process provides the opportunity for owners/operators and engineers to adopt risk-based principles for developing IM strategies that consider the current condition of a mooring, the likelihood of damage or degradation of a mooring, and the potential consequences. A risk-based approach recognizes that moorings with higher risks can warrant more frequent and more focused inspection than lower risk moorings. During the development of an inspection strategy, the mooring risk category may be used for setting survey intervals and work scopes as part of a risk-based IM strategy.

The IM process consists of four elements, which are described in detail in this section, and flowchart showing the components of the IM process is shown in Figure 1:

- data;
- evaluation;
- strategy;
- program.

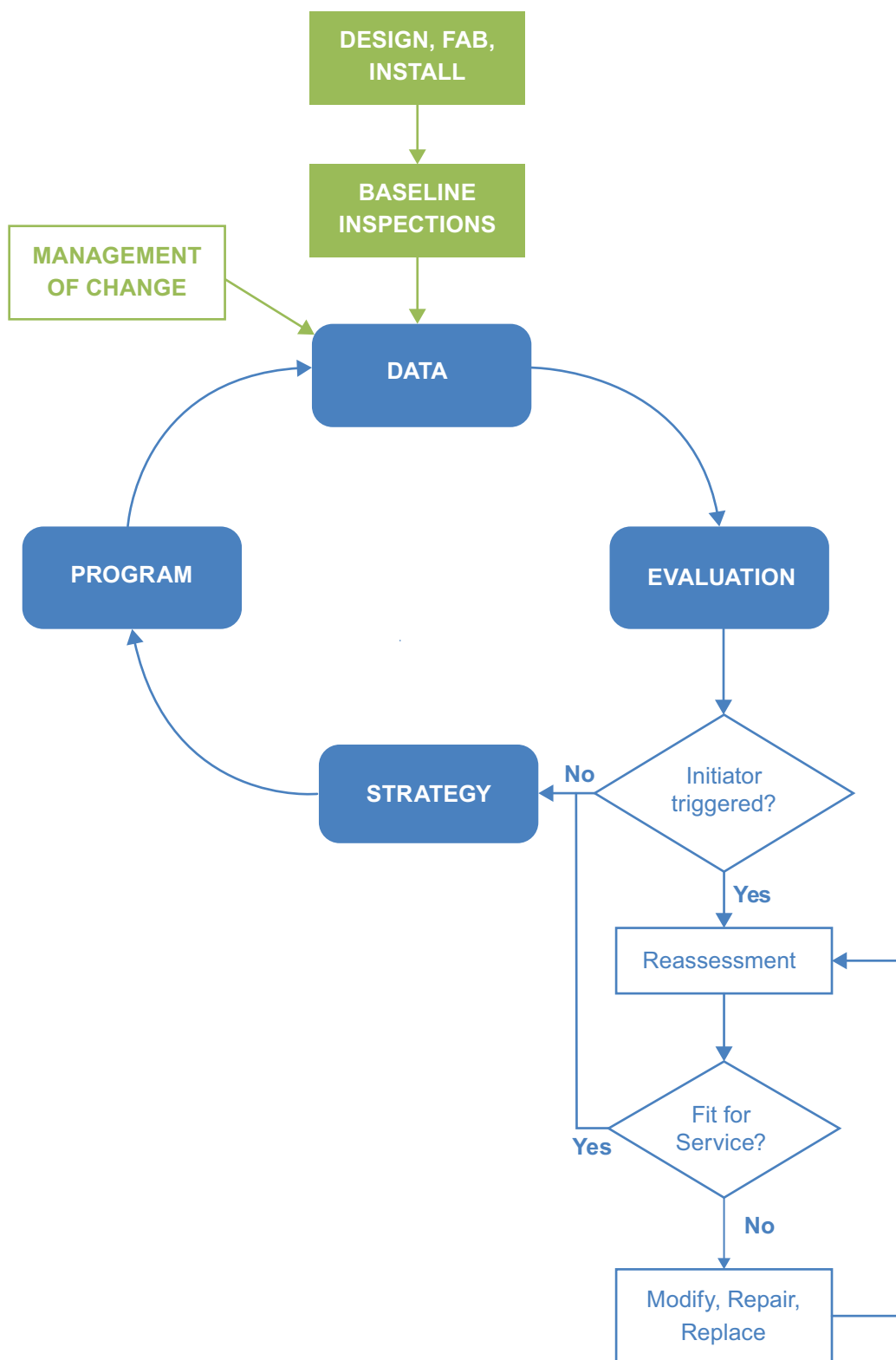
Periodic updates to the IM process should be performed and should follow a performance improvement cycle process, taking into account the latest information on the mooring system, as well as the host platform.

Throughout the IM life cycle there are different system objectives. Examples are provided in Annex B.

4.2 Mooring Integrity Management Overview

IM is a continuous process used for demonstrating the fitness-for-service of a mooring system from installation through to decommissioning. IM provides the process for understanding the effects of deterioration, damage, changes in loading, and accidental overloading. In addition, IM provides a framework for inspection planning, maintenance, and repair of a mooring. The IM process is shown in Figure 2 with the four primary elements it consists of and information on their intended purposes.

Data categories include design, inspection, monitoring, and operations. Data can come from technology development and experience within industry. The data are evaluated to demonstrate fitness-for-service, and the IM strategy is adjusted, if necessary. The results from the evaluation are used to develop and implement an inspection strategy. The process is the implementation of the inspection, maintenance, and repair work scopes, as defined from the IM strategy.

**Figure 1—IM Process Map**

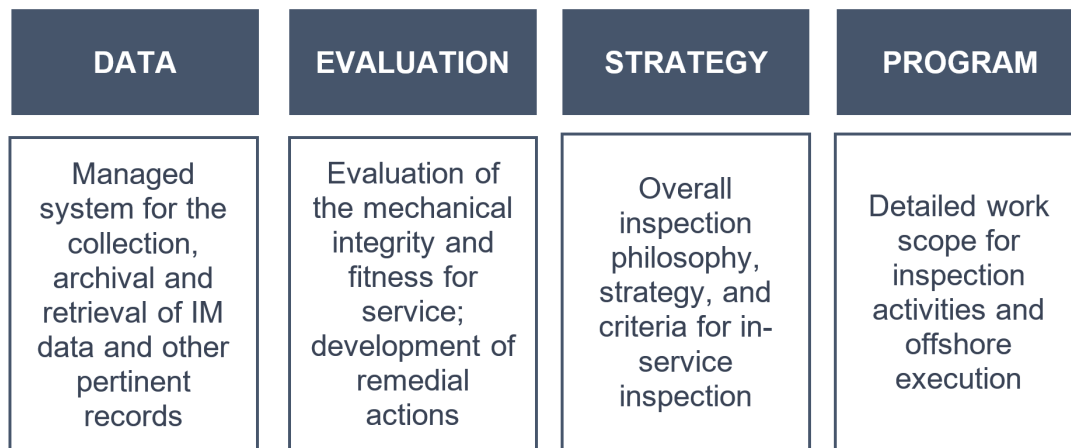


Figure 2—Steps in the IM Process

4.3 Data

4.3.1 General

The most recent representative mooring information shall be used for the IM process. Data collection starts from design and continues throughout the life of the mooring. Information on the original design, fabrication, and installation, in-service inspections, engineering evaluations, structural and mechanical assessments, modifications, strengthening, repairs, and operational incidents, all constitute parts of the IM database.

IM data fall into two broad categories: (1) characteristic data and (2) condition data.

4.3.2 Characteristic Data

The mooring's characteristic data are the baseline data that represent the mooring at installation. The characteristic data include:

- *General mooring data* should include the mooring design basis, containing the design information, including design criteria, codes and standards used, as well as water depth, seabed topography, geotechnical data, metocean conditions, platform configuration, dependence on related systems, etc.
- *Mooring design data* should provide a record of the as-designed condition of the mooring. It should include the design calculations, drawings, and installation or operating information that affects the design (e.g. corrosion protection), and reference the mooring analysis software/program and its version as used for design approval. It should also include any hazard identification and risk assessment work that may be used in the design and future IM.
- *Mooring fabrication data* should provide a record of the as-built condition of the mooring components after FAT and prior to installation. It should include the specifications, material testing reports, welding procedure qualifications, NDE records, FAT records, repair and nonconformance records, coating records, as-built information, and vendor data books.
- *Mooring installation data* should provide a record of how the mooring was installed, including installation specifications, procedures, activity logs, welding and NDE procedures, coating information, repair and nonconformance records, material tracking, and as-installed information.

- *As-installed data* collected from the baseline inspection, including deviations from the design or installation drawings, and as-laid surveys.

Collectively, these data form the as-installed, baseline condition of the mooring.

These data are most easily collated into a data management system (DMS) at the completion of the mooring design, fabrication, and installation phases of a project.

For older moorings that have been installed without an IM plan in place, some of the characteristic data might not be available. This will be a factor in determining the appropriate IM strategy for the mooring system.

4.3.3 Condition Data

The mooring condition data represent the changes to the characteristic data that have occurred during the life of the mooring. Condition data should include the following:

- in-service inspection data;
- damage evaluation data;
- corrosion protection data;
- strengthening, modification, repair (SMR) data;
- condition monitoring data;
- operational incident data.

Missing data can affect the evaluation, strategy, and process for the ongoing IM of the mooring. Where characteristic data are not available or are inaccurate, surveys of the mooring system should be performed to collect the necessary information. If limited or no condition data are available, data from survey or inspection of the mooring system recommended in this section become baseline inspection data.

4.3.4 Data Management

IM data collected throughout the life of an FPS should be maintained in a DMS. Data should be compiled and updated to provide a record of the mooring's current condition. Data should be collected during inspections as defined by the IM strategy.

The owner/operator should retain records for the life of the FPS. During change of ownership, the owner/operator should transfer all FPS data to the new owner/operator.

4.4 Evaluation

4.4.1 General

The evaluation element of the IM process shall assess the current condition of the mooring, as represented by the data, to determine if the mooring remains fit for service. To do this, the IM plan shall identify threats and potential consequences of failure, and ultimately, the risk profile of the mooring. The risk profile can change over time as the condition of the mooring changes, as reflected in new data from inspections and monitoring (see Section 5). Hence, evaluation is an ongoing, evolving process that changes over the life of the mooring.

The evaluation phase can result in no change or it can indicate degradation or damage that requires assessment. The assessment can result in some combination of remediation, modification of operating procedures, additional monitoring, and additional or more frequent inspection.

The assessment process includes developing a list of initiation triggers that are used in the evaluation process to determine if parameters have changed in a way that are outside of the original design or the most recent fitness for service assessment, requiring reassessment to confirm continuing fitness for service. Assessment initiation does not necessarily mean any remediation will be required. It only indicates that the parameter is outside what was previously considered acceptable and hence requires reassessment.

IM evaluation is the method of applying engineering to assess the effect that new data have on the fitness-for-service and the IM strategy for the mooring. Evaluation is routinely performed throughout the life of the mooring. As additional data are collected, an evaluation should be performed by a competent mooring engineer. The evaluation should consider all IM data for the mooring and similar moorings where appropriate. Evaluation does not automatically imply a mooring analysis; evaluation may include engineering judgment based on specialist knowledge or operational experience, simplified (screening) analysis, or reference to research data, analysis of similar moorings, etc.

4.4.2 Factors to Consider

Evaluation phase should account for the following factors that affect mooring integrity:

- design (e.g. criteria, analysis results, assumptions, redundancy);
- fabrication (e.g. quality, rework);
- condition (e.g. installation data, load sharing, reserve strength, modifications, damage, degradation);
- inspection & monitoring (e.g. anomalies);
- industry experience (e.g. manufacturing defects, failure statistics);
- industry-wide knowledge of known manufacturing process deficiencies or similar.

The status of as-built documentation, as-installed documentation, inspection strategies and plans, system monitoring, and system numerical modeling should be determined. The immediate and short-term incident response planning should be evaluated, along with the availability and condition of any sparing or emergency repair equipment. Information provided in Annex D may be used for developing incident response.

Identified potential threats should be evaluated in terms of risk of failure, and mitigation put in place to reduce or remove the risk of failure or the consequences of failure. This information will be used to help establish the assessment initiators.

Risk factors for residual capacity and system loading estimation are given in Annex A.

4.4.3 Risk

4.4.3.1 General

This RP includes a risk-based approach to managing the integrity for existing moorings. Within this context, risk is defined as the combination of the likelihood of some event occurring during a period of interest and the consequences (generally negative) associated with the event.

In mathematical terms, risk is expressed as:

$$\text{Risk} = \text{Likelihood} \times \text{Consequence}$$

The primary purpose of developing and implementing a risk-based approach is to highlight to the owner/operator risks from a safety/health/environment perspective and/or from an economic standpoint and to appropriately target inspection, maintenance, and repair resources.

4.4.3.2 Risk Categorization

An owner/operator may choose to adopt a risk-based IM strategy to focus inspection resources and optimize inspection planning. If a risk-based IM strategy is adopted, the mooring should be assigned to a risk category based upon its consequence and the likelihood of failure.

4.4.3.3 Risk Assessment

4.4.3.3.1 General

A risk assessment assists to identify changes in the mooring system that could increase the likelihood of failure. A risk assessment can be used to evaluate actions to mitigate risk. Risk assessment methods should conform to ISO/IEC 31010.

4.4.3.3.2 Risk Matrix

Risk may be presented in a variety of ways to communicate the results of the analysis to decision-makers and inspection planners. One goal of the risk determination is to communicate the results in a common format that all involved parties can understand. A risk matrix can be helpful in accomplishing this goal.

An example of a simple risk matrix is shown in Figure 3. In this figure, the consequence and likelihood categories are arranged such that the highest risk ranking is toward the upper right-hand corner. Owner/operators may adopt risk assessment techniques or more complex matrices to further subdivide the mooring consequence category and/or likelihood. Most owner/operators have more risk assessment matrices for general hazard assessment that may be adopted for mooring IM.

Consequence of Failure	High	Risk Level 2	Risk Level 1	Risk Level 1
	Medium	Risk Level 3	Risk Level 2	Risk Level 1
	Low	Risk Level 3	Risk Level 3	Risk Level 2
		Low	Medium	High
		Likelihood of Failure		

Figure 3—Risk Categorization Matrix Example

Risk categories are typically assigned to the boxes on the risk matrix. For the example matrix, symmetrical risk categories have been assigned. They can be asymmetrical where, for instance, the consequence category can be given higher weighting than the likelihood category.

4.4.3.3.3 Using a Risk Matrix

Risk categories may be used for setting inspection intervals and work scopes as part of a risk-based IM strategy. For example, a 3×3 risk matrix, as shown in Figure 3, may be used to categorize the mooring as follows:

- Risk Level 1: major focus of resources, which can include an increased inspection frequency and intensity of inspection and/or more detailed engineering.
- Risk Level 2: moderate focus of resources.
- Risk Level 3: less focus of resources, which can include a reduced inspection frequency and scope of inspection.

4.4.3.3.4 Consequence of Mooring Failure

Mooring components are categorized by the risks of their failure. This allows for:

- determining criteria for a fitness-for-service assessment, and
- developing inspection strategies.

An important consideration is a test of the as-built design condition for the one-line broken condition to be within riser design envelope, and interface with riser engineer for API 2RIM assessment.

The consequence of failure should account for possible effect on safety and environmental as well as possible economic losses to the owner (particularly lost production).

Annex A includes descriptions of factors that serve as a basis for determining the appropriate category for the mooring consequence of failure. More rigorous risk assessment tools may be used to determine the range of consequences for a particular mooring failure mode.

4.4.3.3.5 Likelihood of Mooring Failure

If the mooring owner/operator chooses to adopt a risk-based mooring IM strategy, the IM data should be evaluated to determine the likelihood of mooring failure. The likelihood that a mooring will fail because of loading, whether that is an extreme storm load, ice load, earthquake, or some other foreseeable design load is a function of the robustness of the mooring.

Each mooring has a likelihood of failure based on key characteristics. Damage or deterioration can indicate that the strength of a mooring has reduced, increasing the likelihood of failure. Annex C provides a summary of industry mooring failure rates.

4.4.4 Requirement for Mooring Assessment

4.4.4.1 General

A mooring fitness-for-service assessment is part of a detailed evaluation (Figures 1 and 2) that compares the estimated strength of a mooring against performance criteria. A fitness-for-service assessment of the mooring shall be performed if the evaluation of IM data determines that an assessment initiator has been triggered (e.g. API 2I).

The assessment should determine whether a mooring is fit-for-service or whether risk reduction measures should be performed.

NOTE The bibliography provides a list of references that outline assessment techniques for determining residual capacity of mooring components.

4.4.4.2 Triggers for Reassessment

The owner/operator should develop a list of triggers for the mooring system as part of the IM Plan. Annex C provides a summary of triggers.

4.4.4.3 IM Process Assessment

The mooring IM process itself should be assessed annually. The self-assessment may consider items such as:

- recent failures in similar mooring systems;
- additions to infrastructure in close proximity to the FPS (e.g. pipelines, other FPS's);
- new research that makes the original design assumptions less valid;
- changes in metocean definition and/or geotechnical conditions at site.

4.5 Strategy

4.5.1 General

The IM strategy defines the overall inspection and mitigation philosophy for the mooring. This RP provides guidance for the development of an IM strategy based on the mooring probability of failure and exposure categories with specific recommendations for inspection planning and risk reduction options.

4.5.2 Inspection Plan and Strategy

The inspection plan defines the frequency and scope of the inspection, the tools and techniques to be used, and the deployment methods. The inspection plan should be developed for the mooring and should cover the anticipated remaining service life. The plan should be periodically updated throughout the mooring's service life following receipt and evaluation of IM data, e.g. inspection data, results of mooring assessments, etc. The following basic elements should be included in the inspection plan:

- baseline inspections;
- routine above-water inspections;
- routine underwater inspections;
- special inspections in response to identified anomalies, and events such as an extreme event or mechanical damage.

An inspection strategy shall be developed for the moorings. This strategy should account for the interdependence between the mooring IM phases. The inspection strategy should be a "living" document, meaning that inspection requirements can change due to new information from inspection results or due to changes to the FPS (e.g. changes in topsides, discovery of damage to mooring system, addition of new risers). See 5.2.2 for the inspection requirements.

4.5.3 Risk Reduction

4.5.3.1 General

Exposure mitigation and likelihood reduction options should be addressed at all stages of the IM process.

4.5.3.2 Exposure Mitigation

Exposure mitigation is defined as changes that reduce the risk of the mooring. Mitigation includes measures that reduce the consequence of mooring failure (e.g. increased number of mooring lines, spare mooring components).

4.5.3.3 Likelihood Reduction

Likelihood reduction is defined as modifications that reduce the likelihood of structural failure. It includes measures such as load reduction and/or an increase in system strength through global and or local strengthening and/or repairing known damage.

4.5.4 Monitoring

In-service monitoring for mooring systems should be considered. Monitoring provides real-time data that may be evaluated to confirm that the mooring is still fit-for-service. Active monitoring data should be recorded and managed within the DMS.

4.5.5 Emergency Response

Mooring system emergency response plan should address unexpected failures as well as incidents arising from known degraded/degrading mooring components. Commentary on incident response planning is provided in Annex D.

A range of possible mooring conditions should be considered as part of an incident response plan. Such a plan should incorporate the following elements:

- defined means of identifying occurrence of a failure;
- defined response procedures for different types of incidents;
- site-specific ranges and combinations of metocean conditions;
- consideration of SIMOPS;
- mooring line replacement plan/procedures.

Based on the time horizon of the failures/incidents, a range of responses that should be addressed are: immediate/operational, short-term, mid-term, or long-term (see Annex D for more information).

4.5.6 Related Systems

During the evaluation process, other systems which mooring integrity is dependent on should be identified. Examples include:

- thruster systems for thruster assisted moorings;
- position monitoring systems used to determine the integrity of the mooring system (i.e. position-based line breakage detection systems);
- Swivel/bearing systems for weathervaning moorings (e.g. turret-moored systems).

4.6 Process

4.6.1 General

The IM process represents the execution of the detailed work scope and should be conducted to complete the activities defined in the IM strategy. The IM process includes inspections as well as modification or repair activities.

All data collected during the process should be incorporated back into the IM data management system. Consistency, accuracy, and completeness of inspection records are important since these data form an integral part of the IM process.

4.6.2 Implementing a Mooring IM Process

4.6.2.1 Initiation

A mooring IM process that is consistent with the owner/operator's corporate IM process should be defined early in the design phase. If no IM philosophy is in place for an existing mooring, one should be established as soon as possible.

4.6.2.2 Identify Potential Failure Causes

To reduce the risk of a mooring system failure, events which could lead to such a failure should be identified using techniques such as FMEA, FMECA, HAZID, and HAZOP. A technique should be selected to identify and record potential mooring failure modes. Annex C should be referred to for details on causes of failure.

4.6.2.3 Identify Risk Control Measures

Once the potential causes of mooring system failure have been identified, risk control measures (i.e. means of mitigating these failure causes) shall be identified. See C.2, which provides causes of mooring failure and potential control measures.

4.6.2.4 Risk

The mooring should be assigned to a risk category based upon the product of its consequence and likelihood of failure.

4.6.2.5 Risk Controls

Measures to control risk should be identified so that they can be monitored during the life of the mooring system. An example of a risk control is the jacketing of wire rope to inhibit corrosion.

4.6.2.6 Process Setup for Existing Facilities

4.6.2.6.1 General

The fundamental difference between mooring IM implementation for an existing mooring and a new mooring design is that risk is present in the existing mooring, while it can be reduced in an ongoing design process.

4.6.2.6.2 Mooring Baseline Condition Assessments

4.6.2.6.2.1 Objectives

A baseline condition assessment should be performed to determine:

- current mooring system condition;

- criticality of the mooring system;
- identification of possible threats across the preceding life cycle phases.

4.6.2.6.2.2 Assessment Phases

When performing a baseline condition assessment, the assessment should include the following phases:

- initiation;
- data collection;
- risk assessment;
- baseline condition assessment.

4.6.2.6.3 Methodology

- a) Initiation: The objectives of the condition assessment should be defined.
- b) Data collection: Information collated in the data management system should be reviewed in the integrity assessment of an existing mooring. This should include the following:
 - 1) Original and as-built information, providing baseline data by which successive inspections can be measured. This includes design, construction, and installation phase information and records.
 - 2) Operational history, records of ongoing monitoring, and using the actual loading vs design intent to understand fatigue-related degradation.
 - 3) Inspection records collated since deployment and pre-deployment inspections.
 - 4) Repair and modification records, to understand infantile failures, and changes in the design baseline due to component replacements, substitutions, or modification.
- c) Risk assessment: A risk assessment should be performed based on the known make-up of the mooring system to:
 - 1) Identify the type, magnitude, and possible cause of deterioration present in each component.
 - 2) Track deterioration from the as-built/baseline condition against the predicted rates of deterioration used in the original design.
 - 3) Identify anomalies and defects.
- d) Baseline condition assessment: The baseline condition assessment should address the design and operational aspects of the integrity of the mooring system. The various threats and associated degradation mechanisms applicable to the mooring system should be identified, and their nature (event or rate-based) should be specified. The key components and locations that present risk to the integrity of the mooring system should be identified.

The baseline condition assessment should form the basis for the mooring condition dataset that should be upgraded after inspections, incidents, or changes of state.

5 Inspection and Monitoring

5.1 General

Inspection and monitoring are elements of the IM process. Inspection and monitoring essentially encompass the collection of data to understand the condition of the mooring as it changes over time. Results of inspection and monitoring activities should be evaluated against the design envelope to determine if there are changes outside of the envelope. If changes are outside the envelope, then assessment initiators should be triggered.

The IM plan should address all threats to mooring integrity and include a means for determining the current condition. The IM plan should ensure that inspection and monitoring are in place to allow evaluation and assessment of the mooring.

This may be by continual measurement, periodic measurement, visual inspection, or other means of inspection. This may include inferences made from indirect measurements. For example, regular monitoring of line tension, metocean data, and platform motions can provide useful data from which to infer aspects of the condition of a mooring. Absent of measurements, it can be difficult to substantiate the condition of a mooring. Trends in inspection and monitoring data over time as well as data from similar moorings can provide information useful for developing inspection/monitoring plans. Annex C provides mooring component degradation mechanisms experienced in the industry.

5.2 Inspections

Mooring IM strategy should include baseline, periodic, and special inspections. The main objective of inspection is to determine the present condition of the mooring to support fit-for-service assessment of the mooring system.

Offshore mooring inspections typically include a rope access team (RAT) for above-water inspection (e.g. top chain above water), diver for near surface/splash zone inspection (e.g. top chain in water, connector, etc.), and ROV for deeper depth/subsea inspection (wire rope, polyester line, connectors, bottom chain, pile/anchor, etc.).

Annex E provides additional information on inspection methods and objectives.

The inspections should:

- a) identify potential failure modes associated with the as-built mooring system, including:
 - 1) likely means of detecting these failure modes;
 - 2) likely timeframe for revealing these failure modes; and
- b) develop an inspection process suitable for identifying the presence and progression of potential failure modes.

5.2.1 Inspection Strategy

Depending on the overall mooring IM strategy, mooring inspection strategies can be categorized into two main groups: (1) prescriptive inspection and (2) risk-based inspection (RBI).

5.2.1.1 Prescriptive Inspection

Owner/operator may use class default program as the prescriptive approach to setting an inspection strategy.