GUIDANCE NOTES ON

MOORING INTEGRITY MANAGEMENT

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Foreword

These Guidance Notes provide technical recommendations and guidance on the integrity management of mooring systems used on floating production installations (FPIs) that produce and/or store hydrocarbons. Mooring integrity management actively evaluates and manages the mooring system and thus reduces the risk of failure, and maintains the mooring system's fitness-for-service throughout the life of the FPI. These Guidance Notes are relevant to mooring systems for FPIs of varying shapes, ranging from semi-submersibles to ship-type FPIs. They are applicable to both new and existing installations.

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SECTION 1 Introduction

1 Background

The mooring systems for floating production installations (FPIs) remain in service for years without retrieval from the water. Deterioration of the lines due to corrosion, wear and other unfavorable conditions can increase the likelihood of single or multiple line failures which could result in loss of position of the FPI, possibly causing damage and hydrocarbon release if the riser is pressurized.

HSE JIP FPS Mooring Integrity [1] and Deepstar mooring integrity management (MIM) Guidelines [2] summarized serious mooring system incidents and failures of FPIs [3]. These documents show that even for modern designs, deterioration of some parts of the mooring systems may be more rapid than expected. The data collected demonstrates that mooring system failures tend to occur in regions of highly dynamic behavior (i.e., at or near the fairlead) at the interfaces with other components (mooring support buoys, subsea connectors), and in the touch down area [4]. Most incidents reported are related to chain, connectors and wire rope. This highlights the importance of a proper MIM system for FPIs.

2 Objectives

These Guidance Notes provide recommended integrity management procedures of mooring systems for FPIs. The mooring integrity management is to actively evaluate and manage the mooring system, and hence reduce the risk of failure and maintain the mooring system's fitness-for-service throughout the life of the FPI.

They should be used in conjunction with the following ABS Rules, Guides and Guidance Notes.

- ABS *Rules for Building and Classing Floating Production Installations (FPI Rules)*
- ABS *Guide for the Certification of Offshore Mooring Chain*
- ABS *Guidance Notes on the Application of Fiber Ropes for Offshore Mooring*
- ABS *Guidance Notes on Life Extension Methodology for Floating Production Installations*

3 Scope and Application

These Guidance Notes are relevant to mooring systems for FPIs of varying shapes, ranging from semi-submersibles to ship-type FPIs. They are applicable to new and existing installations. The mooring system extends from the anchor to the connection to the FPI, including mooring line, winching equipment and anchoring system. These Guidance Notes are not intended for:

- Mooring systems of Mobile Offshore Drilling Units (MODUs)
- TLP tendons

SECTION 2 Mooring Integrity Management (MIM)

1 General

1.1 MIM Philosophy

MIM philosophy should be defined before commencing the design a mooring system. The MIM philosophy should include the following:

i) Corrosion protection approach

ii) Degree of redundancy to single and multi-line failure

iii) Availability of back up station keeping systems (e.g., thrusters, main engines, etc.)

iv) Inspection philosophy

v) Design for replacement philosophy

vi) Approach to safety factors/ margins

vii) Approach to the management of uncertainty,

viii) Approach to the management of technology risk

ix) Approach to sparing and redundancy

The MIM philosophy affects the design of the mooring, and usually forms part of the design basis for the mooring system.

1.2 Design Basis

Mooring design basis contains the baseline requirements for the design of a mooring system. It usually includes the following functional specifications and performance standards [2]:

i) Whether the mooring is dis-connectable

ii) Watch circle requirements

iii) Design service life

iv) Geotechnical conditions

v) Location as it pertains to availability/cost of mooring installation vessels

vi) Mooring design standard or Recommended Practice

vii) Owner specified design guidelines and philosophies

This section introduces the MIM process and its role in the lifecycle of a new mooring design.

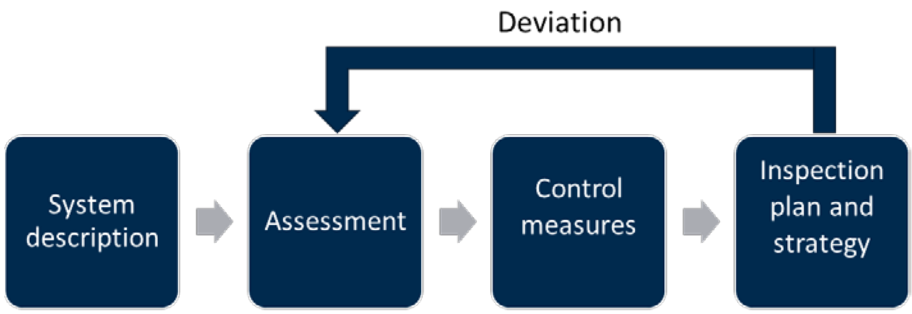
2 MIM Process

As shown in Section 2, Figure 1, the MIM process includes:

- *System Description.* The collection of mooring data at installation and during its lifetime.
- *System Assessment.* The assessment of the impact of new data on the fitness-for-service or MIM strategy of a mooring system, and the risk associated with one or more causes of failure.

- *Control Measures.* The development of risk control measures and verification that the intended risk mitigation measures have been successfully implemented.
- *Inspection Plan and Strategy.* Capture of suitable records to facilitate ongoing management by means of inspection and monitoring, and future re-reassessment if there is deviation from the as designed mooring design basis.

FIGURE 1
MIM Process



3 Implementation of MIM in New Design

For a typical mooring design, the MIM process is applied across the entire lifecycle of the mooring system. A number of key activities continue through the project lifecycle, as shown in Section 2, Table 1.

Section 2, Figure 2 shows a recommended practice for applying the MIM process to a new FPI from design phase to installation and commissioning, and finally the operation phase.

3.1 System Description

A description of the mooring system should be developed to include the following elements:

i) Mooring line

- Chain, wire rope, synthetic rope, or a combination
- Clump weight
- Spring buoy
- Connecting hardware (shackle, swivel, other connectors)
- Chain jewelry

ii) Winching equipment

- Windlass
- Chain jack
- Winch
- Fairlead and stopper

iii) Anchoring system

- Drag Embedment Anchor
- Pile Anchor (driven, jetted, drilled and grouted)
- Dynamically Installed Pile

- Suction Pile and Suction Caisson
- Gravity Anchor
- Plate Anchor (drag embedded and direct embedded)

iv) Monitoring system

- Tension and position monitoring

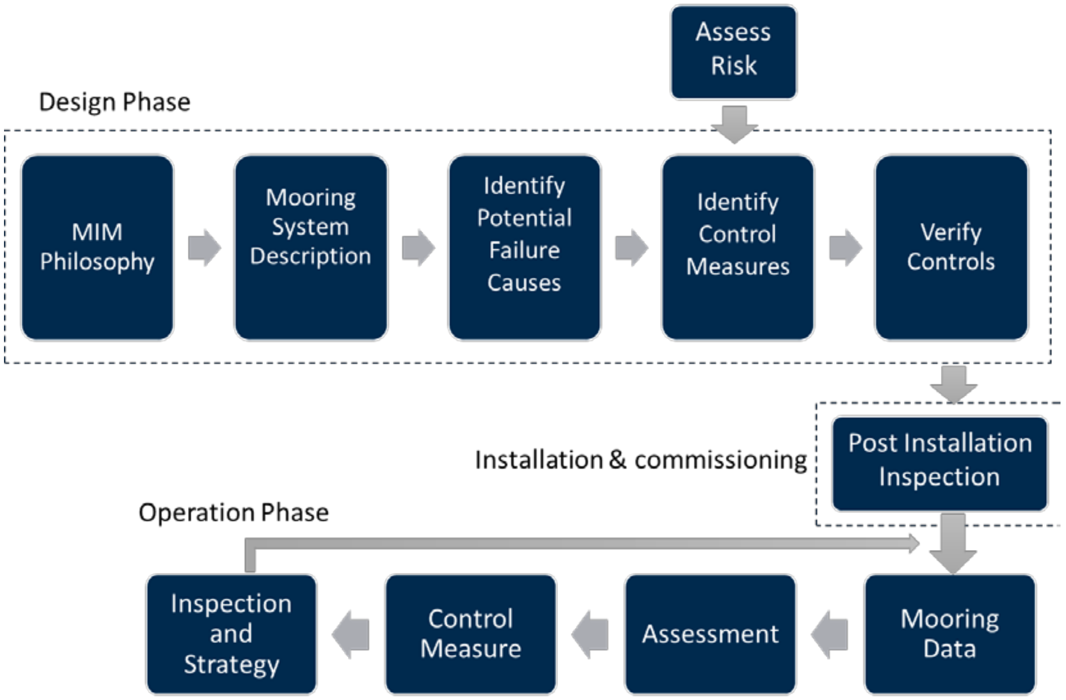
Up to date mooring information should be kept and maintained for the MIM process throughout the life of a FPI with the goal of capturing data about the mooring's characteristics, including design data, installation data and fabrication data. It also includes the in-service monitoring data (e.g. vessel position, heading, metocean data, and mooring line tension), in-service inspection data, modification/repair data, corrosion data, and operational incident report etc. In developing a description of the mooring system, the typical states and conditions should be considered such as connected/disconnected, intact, transient and damage states.

MIM data should be collected and maintained in a data management system such that the state of the mooring system is always readily available. The monitoring/inspection data should be stored so as to facilitate the quantification of the degradation rate of the system.

TABLE 1
MIM Implementation Activities

Activity	*Ref.*	*Design*			*Fabrication*	*Install-ation*	*Commiss-ioning*	*Operations*	*Operation-State Change*	*Life Extension*	*Decomiss-ioning*
		Feasibility Concept	*FEED*	*Detail*							
Develop/Update MIM Philosophy	2/1.1	X	X							X	
Develop/Update Design Basis	2/1.2	X	X	X					X	X	
Develop/Update Mooring Risk Assessments	5/5	X	X	X	X	X	X		X	X	
Develop/Update Numerical Models	2/3.4	X	X	X		X		X	X	X	
Develop/Update System Controls and Control Verification Plan	2/3.5		X	X							
Develop/Update Control Test & Verification Records	2/3.5			X	X	X	X			X	
Develop/Update Emergency Response Plan	5/6		X	X	X	X		X	X	X	
Develop/Update Mooring Inspection Plan	2/3.6		X	X			X	X	X	X	
Compile Mooring Inspection Records	4/2.3						X	X	X	X	X

FIGURE 2
MIM Process for New Installation



3.2 Identify Potential Failure Causes

Mooring failures are divided into three categories [2] as follows. Section 2, Table 2 shows some sample causes of mooring system failure.

- *Design/Fabrication.* A latent defect passed through from the design, fabrication, or installation.
- *Degradation.* Deterioration of the system.
- *Individual Event.* Occurrence of an event-based failure.

TABLE 2
Sample Causes of Mooring System Failure

Design/Fabrication Based	*Degradation Based*	*Event Based*
• Calculation Error • Incorrect Environmental Conditions • Incorrect Geotechnical Data • Incorrect Material Specification • Modeling Error • Fabrication Error • Drafting Error • Inadequate Allowance for Clashing • Inadequate Marine Growth Allowance • Inadequate Corrosion Allowance • Unsuitability of mooring accessories • Inadequate consideration of mooring line movement in dynamic zone	• Wear • Corrosion • Failure of Locking Arrangements • Fatigue • Excessive Marine Growth • Structural damage of mooring line in dynamic zone	• Installation Damage • Vessel Impact • Dropped Object • Exceeded Design Condition

A suitable technique should be selected to identify and record potential mooring failure modes. Also, consideration should be given to each of the states and modes of the system. While failures or significant degradation may eventually become evident during the operation phase, the rate of progression should be documented, and any deviation may be a trigger for reassessment.

3.3 Assessment

The assessment process evaluates the impact of new data on the fitness for service or MIM strategy of a mooring system. It is performed during the design stage when the MIM program is set up for a new FPI or during the life of a mooring system in response to new data. Also, reassessment of a mooring's continuing fitness for service is necessary if there are significant changes in mooring properties, metocean criteria, vessel's motion characteristics, mooring system response, offloading procedures, failure/damage/degradation of mooring system, or life extension. Refer to Section 5 for more details on assessment methodology and process.

The frequency of the system assessment should be based on the risk and criticality of the factors influencing the MIM system, and it should be performed at least once every five years.

3.4 Numerical Models

Numerical simulation is one of the key methodologies used for the design and reassessment of mooring systems. The development, updating and maintenance of numerical models allows for the timely assessment of mooring system behavior in the event of mooring damage or state change. For example, the vessel may be operated at different drafts and trims compared to those assumed during the design stage.

In assessing the consequence of particular component failures to a mooring system (single line failure, multi-line failure), numerical simulation can be very effective. The maintenance of an accurate numerical model of a mooring system allows for prediction of behavior under degraded conditions.

Numerical models may also play a role in the overall verification of system global response where real-time monitoring of the environment, vessel position and mooring system parameters are used to benchmark the numerical models.

Access to current numerical models are especially important for emergency response considerations. In addition, numerical models allow rapid evaluation after abnormal inspection findings.

Both frequency domain and time domain analyses methods can be used for mooring dynamic analysis. Numerical analysis techniques are addressed in mooring system design standards such as API RP 2SK and the ABS *FPI Rules.*

3.5 Control Measures

Once the potential degradation/failure causes of the mooring system have been identified and recorded, control measures should be implemented to prevent or mitigate the possible failures during operations. These control measures could be applied at different project phases (e.g., design, fabrication, installation and operation stages). The effectiveness of control measures should be verified through design reviews and subsequently testing/inspection/monitoring programs of the mooring systems. The following are possible strategies to apply to a mooring system:

i) Design and Fabrication:

- Third Party Verification
- Design Redundancy

ii) Installation:

- Installation Tolerances and Procedures
- As-Installed Inspection
- Assembly/Materials Substitution Procedures

iii) Operations:

- Line Tension Monitoring
- Inspection Program
- Marine Growth Removal
- Vessel Approach Procedures
- Lifting Procedures
- Corrosion Control Procedures

These control measures should be applied at different points of the project lifecycle to provide multiple layers of protection. The control measures should be documented in a data management system. The effectiveness of a mooring system should be periodically verified through inspection to confirm that potential failure causes are being successfully prevented or mitigated during operations.

The overall installation and commissioning activity for an FPI will include an extensive test and verification program. It is important that mooring system control measures are included in this program. The records of tests and verification activities should be collected, collated and retained in a document management system.

3.6 Inspection Plan and Strategy

In order to maintain Class, ABS has specific inspection requirements for survey during installation and commissioning, annual survey and periodic survey of mooring system, per the *FPI Rules*. Detailed recommendations on inspection and monitoring are provided in Section 4.

These inspections may identify failure or degradation of the mooring system. Typical deviations during operations include, but are not limited to:

- Degradation of mooring line due to excessive marine growth or corrosion
- Damage to buoys
- Breakage of mooring lines
- Missing or loose retaining pins
- Trenching in front of anchor

Once the deviation is addressed, assessment may be taken to determine the effect of the anomaly by re-running the numerical simulations. Necessary control measures should be provided, and further inspections be specified, to mitigate any possible increase in the risk of mooring system failure.

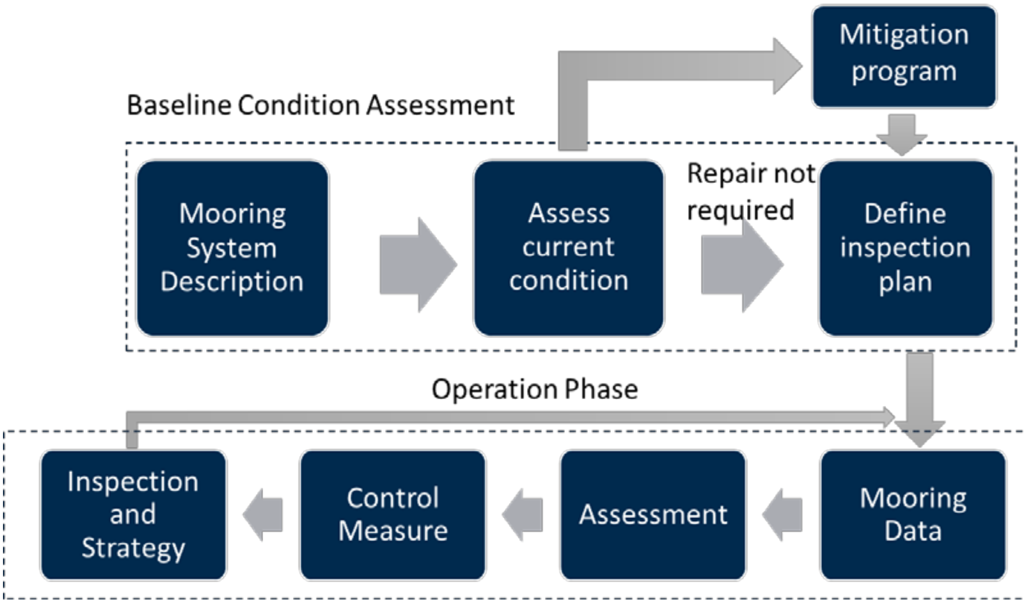
SECTION 3 Baseline Condition of Existing Mooring Systems

1 Introduction

When assets are sold or when there has been a change in the system state, the current condition of the existing mooring system should be established. In addition, the known risks and associated causes arising from each of the earlier lifecycle phases should be addressed as well. It is essential to possess the original design reports, documents, original and as-is plans, specifications, survey records from fabrication, installation and past service. The operator should confirm that any assumptions made are reasonable and information gathered is both accurate and representative of actual conditions at the time of the assessment.

Section 3, Figure 1 shows the recommended process for implementing a MIM program for an existing FPI. This section focuses on the baseline condition assessment. Once the baseline condition is understood, effective integrity management plans can be implemented.

FIGURE 1
MIM Process for Existing Installation



2 Data Collection

It is important to understand the current condition of an existing mooring system compared to the original "as-designed" condition and the original "as-built" baseline installation. As such, a number of documents and reports should be reviewed, including:

- Original design, construction and installation reports
- Monitoring and inspection reports taken during operation
- Repair and modification reports in which any changes in the design baseline due to component replacements, substitutions or modification are specified

3 Baseline Condition Assessment

The following procedure should be applied for the assessment of the baseline condition:

i) Review completeness and extent of original design analyses and determine need for further analyses

ii) Identify the various risks and associated degradation mechanisms applicable to the mooring system

iii) Specify mitigation program and plan for future monitoring/inspection activities

The baseline condition assessment should be upgraded regularly after inspections, incidents or changes of state.

SECTION 4 Mooring Inspection and Monitoring

1 General

Inspection and monitoring are effective means of identifying damage or degradation of the mooring system. These activities support operational integrity through collection of data to understand the condition of the mooring system as it changes over time. They are differentiated by frequency of inspection, inspected objects and type of feedback.

2 Inspection

A rigorous inspection protocol typically includes a combination of:

- Inspection team for above-water inspection
- Diver inspection on near surface/splash zone
- ROV inspection of the subsea and touch down area

Accordingly, inspections should be well planned with clear objectives and target deliverables. Depending on the overall MIM strategy, mooring inspection strategies can be categorized into two main groups, calendar-based inspection and risk-based inspection.

2.1 Calendar-based Inspection

Calendar-based inspection strategies specify inspection frequencies at fixed intervals using accepted techniques for all locations of a particular component type.

The following programs should be followed for the mooring inspection:

i) Perform inspection in accordance with applicable sections of 7-2-4/5 and 7-2-6/5 of the ABS *FPI Rules*, ABS *Guide for the Certification of Offshore Mooring Chain*, ABS *Guidance Notes on the Application of Fiber Ropes for Offshore Mooring*, and/or API RP 2I as reference.

ii) Baseline the current mooring condition in accordance with Subsection 4/5 of the ABS *Guidance Notes on Life Extension Methodology for Floating Production Installations*.

iii) Carry out general visual inspection (GVI) on:

- Mooring lines, components and connectors
- Fairleads and mooring equipment (i.e., windlasses, chain jacks, chain stoppers, etc.)
- Turret bearings, bogies, and wear pads
- Anode condition, anchor scour, trenching, marine growth, CP protection (for anchors and connectors), wire rope sheathing and bird caging, etc.

iv) Carry out measurement on:

- Chain diameter/abrasion
- Chain interlink grip
- Connector size & shackle diameter
- Tension if available
- Chain hull clearance between chain and hull

- Pretension angle (Change to departure angle in operating conditions)
- Trench size

Non-inspectable areas are to be considered and agreed upon between Class and Owner/Operator.

2.2 Risk-Based Inspections (RBI)

The primary objective of developing the RBI plan for the FPI mooring system is the implementation of an optimized mooring system inspection plan tailored to the system’s condition, service environment, and planned operating life. The inspection plan should be developed by gaining an in-depth understanding of the mooring system’s risks and the risk drivers. This helps target inspections specifically at the critical areas which warrant special attention. It also allows the identification of the best preventative measures which can then be included in the FPI maintenance program, to avoid unnecessary damage or deterioration of the mooring system.

Both qualitative and quantitative methods can be used for the development of RBI plan. The selection of the risk assessment approach depends on the complexity of the mooring system and the quality of the available data. For the qualitative risk assessment of mooring systems, the main objective is to:

- Identify mooring components that have high failure rates,
- Identify mooring components that can result in high consequences, and
- Increase the inspection scope/location for those components, while reducing it for the others.

In case additional quantitative analysis is deemed necessary, a structural reliability analysis may be carried out. The results from the mooring design analysis can then be combined with those from the risk assessment to determine the inspection scope and frequency.

2.3 Inspection Documentation

Inspections should have documentation to support inspection activities, such as inspection plans, objectives for each inspection, procedures, inspection methods and key findings. Documentation assists inspection operators to clearly identify anomalies, be aware of criticality to the system, and enable appropriate actions to be taken by responsible technical personnel.

3 Mooring Monitoring

The main objective of monitoring is to establish the condition of the mooring system, so as to assess integrity and guide day-to-day operational decisions. Considerations should be balanced between the parameters being recorded, logistics of monitoring and recording equipment, system operation, and storage and transfer of data.

For mooring systems where the mooring line length can be adjusted or the chain links shifted, a mooring monitoring system should be in place during those operations so that the mooring line tension is well controlled. Other operational activities that may affect the mooring line tension should also be monitored.

For a thorough mooring system strength analysis verification, the mooring monitoring parameters should include:

- Anchor position
- Vessel motion
- Vessel position
- Relative rotation between FPSO hull and turret
- Vessel draft and trim
- Wind speed and direction
- Wave height, period and direction
- Current speed and direction

- Mooring line pre-tension or top angle
- Mooring line tension

The position monitoring system can be used to verify that the performance of the mooring system corresponds with the original basic design. The mooring system can provide timely alarms when the specified bounds are exceeded. This may be due to loss of mooring line tension, shift in equilibrium position, change in line angle or position. The environmental monitoring of wind, waves and currents could help to verify if the metocean data in the original analysis is representative of the actual site. The motions, offsets, and headings of the FPI can be compared to what has been derived from the original design phase and be used to calibrate the numerical model. If a significant deviation from the original design is observed, a reassessment of the mooring system is necessary to confirm the safe operation of the system under actual conditions.

SECTION 5 Assessment

1 General

An anomaly or change in mooring conditions will trigger the assessment process. Examples of anomalies or changes include

- Mooring component updates
- Metocean environmental condition variations
- Changes to the seabed
- Any other possible changes affecting the mooring responses

The initial assessment aims to understand the potential influence of the anomaly or change on the mooring system performance and, if required, better define the specific mooring system analysis that may be needed to demonstrate fitness-for-service. The effectiveness of the MIM program should be checked if the MIM process is being followed. If the initial simple assessment does not pass, a detailed mooring analysis is needed.

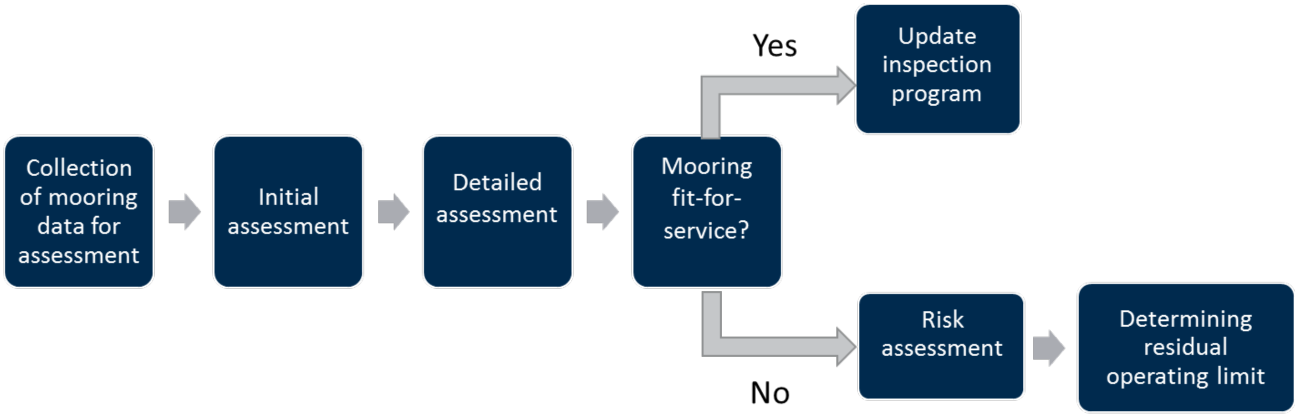
Risk assessment could be performed in parallel or towards the end of the assessment process to quantify the residual risk associated with the mooring and determine whether it has changed based on the anomaly or event that triggered the assessment.

As shown in Section 5, Figure 1, this process is continued until the mooring system is determined to be either:

1. Fit-for-service, or
2. Not fit-for-service

If a mooring system is determined as being unfit for service in its current condition, it is recommended that the residual capacity of the mooring system and offsets limits be determined, so that suitable operating limitations and emergency response procedures can be put in place.

FIGURE 1
Mooring Assessment Process



2 Assessment Information

Prior to performing a mooring assessment, the mooring data should be collected and reviewed to understand the current conditions of the mooring, including:

- Initial mooring design data / analyses
- Mooring upgrade / repair design data
- In service inspection and monitoring data
- Geotechnical data

The mooring system should be assessed based on its present condition, accounting for any damage, repair, changes or other factors that may affect its fitness-for-service. The owner/operator should confirm that the data is accurate and representative of actual conditions at the time of the assessment, or the data is representative of future planned updates to the mooring system.

3 Assessment Process

If the actual site-specific environmental conditions are more severe than the original design environmental conditions, the actual site-specific environmental conditions are to be applied.

Global performance/mooring analysis should be conducted with updated metocean data and any other changes. Global performance responses such as motion, acceleration, offset, or air gap should be within the original design criteria.

Detailed calculations for individual components should be carried out using as-is conditions and actual loads.

The Safety Factors for fatigue life and minimum breaking strength of mooring lines should comply with 6-1-1/Table 1 of the *FPI Rules* using measured or estimated component degradation rates.

The offset limits of the moored floating structures should be established based on the clearance requirements and limitations on the equipment such as umbilicals, risers and gangways.

The mechanical components of single point mooring systems should follow the procedures specified in 5/11.1 of the ABS *Guidance Notes on Life Extension Methodology for Floating Production Installations*.

The holding capacity of the anchoring point should be reevaluated if the mooring line loads increase, or scouring or trenches develop around the anchors.

Major considerations for nearshore jetty mooring include bending fatigue of chain and wire rope, rope creep and degradation, and operational switching of lines during their lifetime. Industry guidelines, such as OCIMF MEG, can be used as reference for each specific application.

4 Life Extension of Mooring System

4.1 Assessment

The ABS *Guidance Notes on Life Extension Methodology for Floating Production Installations* provides the procedures for the life extension of mooring systems. Appendix 1 gives an example of a mooring system life extension.

Life extension is part of the MIM process. The focus is on continuous service through the integrity management. A baseline condition assessment, in accordance with Section 3 of these Guidance Notes, should be undertaken.

In calculating accumulated damage or remaining fatigue life, the original safety factors for fatigue life may be reduced provided that the technical justifications submitted by the Owner/Operator reflect a reduction of the uncertainty in the original design, and are subject to the following conditions:

- No past findings
- Corrosion rate to be within the original design assumption
- Reliable load/metocean history

However, the safety factors for fatigue life for accumulated damage should be not less than 3. If the safety factors for fatigue life and minimum breaking strength of mooring lines do not comply with the ABS *FPI Rules* Section 6-1-1/Table 1, the risk assessment and risk reduction plan may be required to reduce the risk of mooring failure. See Subsection 5/5 for more details.

Alternative methodology may be accepted on a case-by-case basis, such as fatigue testing of mooring chain.

If survey shows that anode replacement is required, a replacement plan should be submitted for review and approval.

If an alternative to anodes is selected (such as impressed current), the system details should be submitted for review.

4.2 Documentation to be Collected

The documentation listed below should be provided for the life extension process.

- Drawings for the mooring system and all components, including ropes, chains, connectors and anchoring system (piles or anchors) and mechanical components
- Design basis containing an assessment of existing design, additional engineering analysis performed in service, and proposed future plan/schedule for life extension, including equipment change out (e.g., mooring chains replacement)
- Existing mooring analyses including strength analyses and fatigue analyses
- Existing in-service inspection program (ISIP) or survey plan and results/findings, including revision history
- Survey and gauging reports
- Owners/Operators reports covering repairs, replacements and operational history
- Record of modifications, including updated drawings
- Records of installation (piles orientation, inclination, etc.)
- Updated metocean data of site (if available), metocean history (normal and extreme events) from monitoring system or hindcast analysis
- Measured mooring load history

The procedure for a life extension is based on availability and quality of the submitted documentation.

5 Risk Assessment

Risk assessment methods are dependent on the complexity of the mooring system and the quality of the available data. A risk assessment should conform to the guidance found in ISO 31000 [5] and API RP 2SK [6]. The ABS *Guidance Notes on Risk Assessment Applications for the Marine and Offshore Oil and Gas Industries* also provide the guidelines for defining the concept of risk, describing the methods available to assess risk, and in performing successful risk studies. Since the objective of the risk assessment is to demonstrate the fitness of the mooring system and the associated structure or systems of interest via risk, the assessment should clearly define the risk categories (e.g., risk matrix) and acceptable risk levels.

Typically, the qualitative risk assessment is conducted similar to a hazard identification (HAZID) exercise in which a team of subject matter experts identifies the potential hazards associated with the mooring systems. The objectives of the risk analysis are to:

- Identify the potential consequences related to the failure and provide recommendations to eliminate or mitigate the effects of common mode failures
- Demonstrate effective redundancy
- Identify potential "hidden" failures and determine the effects of a second failure
- Identify conditions or factors that will influence the likelihood of structural damage (e.g., loading conditions, service conditions, condition of protection systems, past experiences of similar facilities, etc.).

If additional quantitative analysis is necessary, a structural reliability analysis may be carried out. The structural reliability analysis will provide input on strength and fatigue performance of the mooring systems based on probabilistic methods. Note that in the absence of design information, or where previous analytical rigor was inadequate, additional numerical modeling may be required to provide a sound understanding of the mooring system response and resultant residual capacity.

6 Consequence Mitigation

Section 5, Table 1 summarizes the possible mooring risk control measures with different risk levels. A mooring contingency plan should be in place to enable a quick response to any integrity concerns or line failure. Contingency plan may be required in terms of short, medium or long-term remediation actions to partially or fully restore mooring system capacity as follows.

- Immediate reactions include repairs/actions to prevent total loss of station keeping capacity or damage to other critical elements such as the riser system.
- Medium-term plans to repair/refurbish the degraded components such that the mooring system is returned to good condition and meet its required performance standards.
- Longer-term plans where the mooring system may be re-engineered to eliminate/minimize the impact of the observed degradation mechanisms.

As a part of the plan a set of critical mooring spares should be stored and maintained in country, available for immediate use if required. This includes large diameter chain, wire/fiber rope, connectors or anchors. Mooring line and anchor replacement procedures should be developed with a generic anchor handling vessel. Installation/construction vessels are unlikely to be readily available at short notice. In addition, emergency response plan should be laid out which includes procedures to be implemented after detecting a line failure based on position monitoring and predetermined offset zones.

For a mooring system that does not pass a fitness-for-service assessment, the residual capacity, offset limit and operating limit should be determined, see Section 5 Table 1. Risk reduction measures should be taken to reduce the risk of failure, including modifications of operational procedures that reduce loads, increase capacity, or reduce exposure. Also, inspection and monitoring programs should be updated in a timely manner so as to identify potential future deterioration.

TABLE 1
Mooring Risk Control Measures with Different Risk Levels

Control Measures	*Low Risk*	*Medium Risk*	*High Risk*	*Very High Risk*
Annual inspector team, mooring ROV and diver inspections, In-service monitoring	x	x	x	x
In-country critical mooring spares		x	x	x
Mooring line replacement procedures		x	x	x
Emergency response plan		x	x	x
Risk assessment and risk reduction plan			x	x
Determine residual capacity, offset and operating limit of mooring system				x

Notes:

- Low risk – meet both intact and damaged safety factor (SF) or minimal mooring integrity concern
- Medium risk- meet intact or damaged SF, not both or some mooring integrity concern
- High risk - does not meet intact or damaged SF or considerable mooring integrity concern
- Very high risk- intact or damaged SF<1 or significant mooring integrity concern

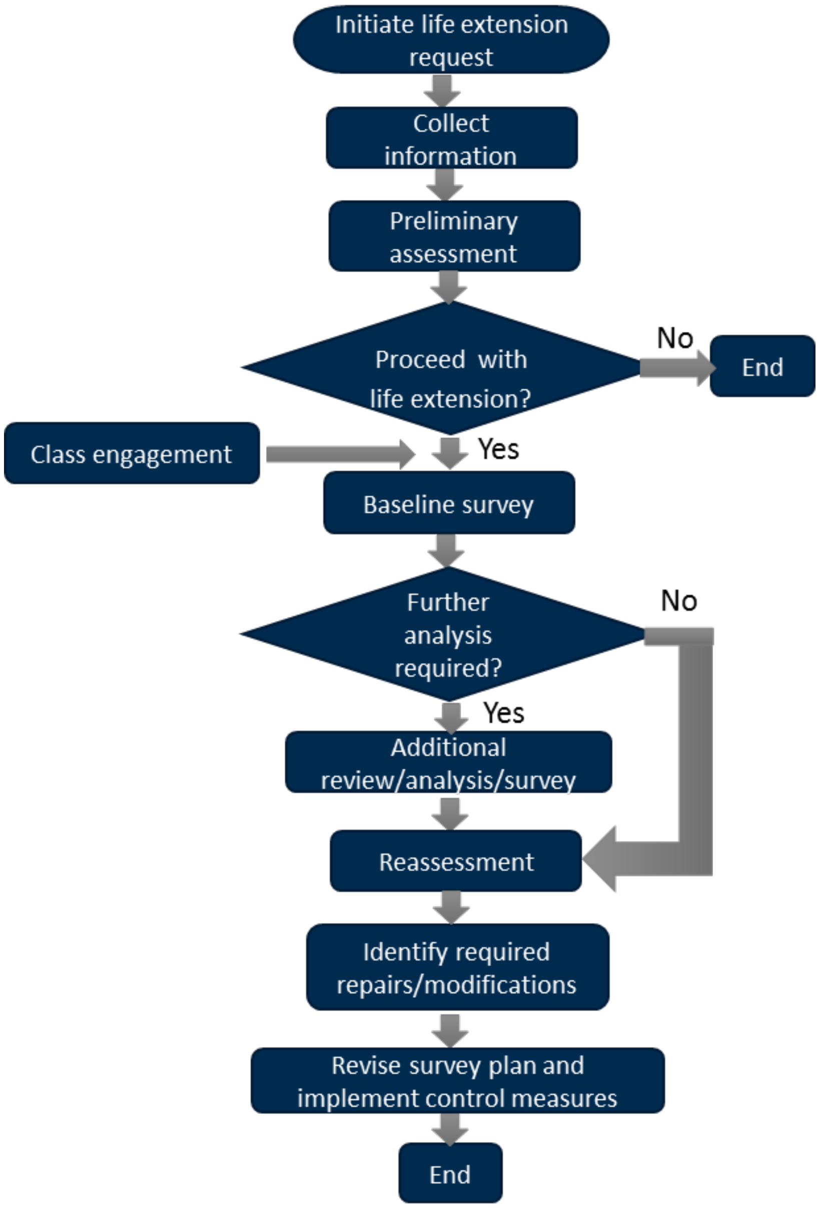
APPENDIX 1 Example of Mooring System Life Extension

APPENDIX 1 Example of Mooring System Life Extension

1 General

This Appendix provides guidance for the assessment of FPI mooring systems when the intended period of operation at the original site or the cumulated operating time at both the original and relocated sites is extended beyond the original design life. An example is given below to demonstrate the procedures for mooring system life extension, as shown in the flow chart in Appendix 1, Figure 1.

FIGURE 1
Flow Chart for Mooring System Life Extension



2 Information Collection

The design and operational information of the mooring system should be collected to allow an engineering assessment of an installation's overall structural integrity. The key events affecting the mooring system should be collected chronologically, such as the original design reports and drawings, the original installation, survey and risk mitigation decision, replacement plan of mooring line/wire, and forensic testing of hardware, if any.

3 Baseline Survey According to Survey Plan

A survey of an existing installation by an ABS Surveyor is necessary to determine the baseline condition upon which justification of continued service can be made. The baseline Survey will include:

- Review of reports of previous surveys and maintenance
- Development of an inspection procedure
- Complete inspection (including underwater inspection) to verify that an accurate assessment of the installation's condition is obtained

Baseline survey information can be collected from the surveys leading up to the expiration of the design life. All survey items should be up to date and examined within the previous 5 years. Any anomalies should be resolved or accounted for in the life extension plan. For details of the baseline survey, see 4/2.1.

4 Additional Review/Analysis/Survey

Any additional scope of survey and analysis should be determined based on a review of data from existing engineering analyses and surveys, and discussion between Class and Owner/Operator.

Any additional analysis to be performed at this stage should address changes in the original design conditions (loading, structural modifications or significant condition changes such as material loss).

Each request for life extension should be treated on a case-by-case basis and the final extent of the analysis should be clarified for each specific project.

5 Reassessment

The scope of assessment includes, but is not limited to:

- Review design reports of baseline strength and fatigue requirement of existing mooring system
- Review of mooring integrity program to identify gaps and provide recommendations to enhance effectiveness
- Evaluation of data from historical inspection surveys to identify anomalies and estimate degradation rate, where available
- Estimate the present condition using measured or estimated component degradation rates and evaluate the strength and fatigue performance in the extended life period against the ABS *FPI Rules* or API RP 2SK
- Estimate the operational risk associated with continued service of the mooring system

See Subsection 5/4 for more details.

6 Implementation of Risk Control Measures

In order to mitigate any detected mooring integrity issues and manage operational risks, in addition to the inspection regime, a rigorous mooring response plan should be in place, including but not limited to:

- Emergency response plan
- Mooring line and anchor replacement procedures
- In-country critical mooring spares, including chains, shackles, links, swivels, and mud-rope
- In-service monitoring

The above response plans should be modified based on the assessment results. Repairs/replacement should be available for the critical components.

APPENDIX 2 Acronyms

CP:	Cathodic Protection
DP:	Dynamic Positioning
FEED:	Front End Engineering and Design
FLNG:	Floating Liquefied Natural Gas vessel
FMEA:	Failure Modes and Effects Analysis
FMECA:	Failure Modes, Effects and Causes Analysis
FPI:	Floating Production Installation
FPS:	Floating Production System
FPSO:	Floating Production, Storage and Offloading
GVI:	General Visual Inspection
HAZID:	Hazard Identification
HAZOP:	Hazard and Operability Study
ISIP:	In-Service Inspection Program
MIM:	Mooring Integrity Management
MODU:	Mobile Offshore Drilling Units
RBI:	Risk-based inspection
SEPLA:	Suction Embedded Plate Anchor
SF:	Safety Factor
TLP:	Tension Leg Platform

APPENDIX 3 References

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