



GUIDE FOR

**RISK-BASED INSPECTION FOR FLOATING OFFSHORE
INSTALLATIONS**

NOVEMBER 2018

**American Bureau of Shipping
Incorporated by Act of Legislature of
the State of New York 1862**

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Foreword

Risk-Based Inspection (RBI) provides an alternative means to Class rule-based or calendar-based inspection regimes. The essential goal of RBI is the prevention of incidents that impair the safety and reliability of the asset. A risk assessment and management process is used to develop and manage forward-looking inspection plans that direct inspections towards the areas of highest risk.

The focus of this Guide is on failure modes initiated by material deterioration or degradation mechanisms that can be controlled primarily through inspection of equipment and structures. It is tailored to specific asset features and associated modes of operation. It helps optimize inspection resources while maintaining or even lowering levels of risk through an optimum combination of inspection methods and frequencies.

This Guide provides guidance to Owner/Operators for the application of RBI programs to maintain class for an offshore floating installation. The Guide describes the minimum elements that ABS requires to be considered in the development and management of an RBI program for hull structures, mooring systems, riser systems and topsides process systems so that it can be considered in lieu of the conventional maintenance of class surveys. It also describes the necessary interactions between the Owner/Operator and ABS for a value-added RBI program.

A vessel that has been surveyed and commissioned to the satisfaction of the Surveyors in accordance with an approved RBI program may be classed and distinguished in the *Record* by the appropriate notation, namely **RBI(Hull)**, **RBI(Mooring)**, **RBI(Riser)**, **RBI(Topsides Facility)** or combinations thereof.

It is to be noted that this Guide is a complete re-write of the previous ABS *Guide for Surveys Using Risk-Based Inspection for the Offshore Industry* originally published in December 2003.

This Guide becomes effective on 1 November 2018.

For existing offshore floating installations with an ABS approved RBI plan or ISIP (updated with an RBI plan), appropriate notations are to be issued upon the completion of the next Annual Program Health Check or the next 5-Year Program Health Check and the RBI program found to be maintained satisfactorily.

Users are advised to check periodically on the ABS website www.eagle.org to verify that this version of this Guide is the most current.



GUIDE FOR
RISK-BASED INSPECTION FOR THE FLOATING
OFFSHORE INSTALLATIONS

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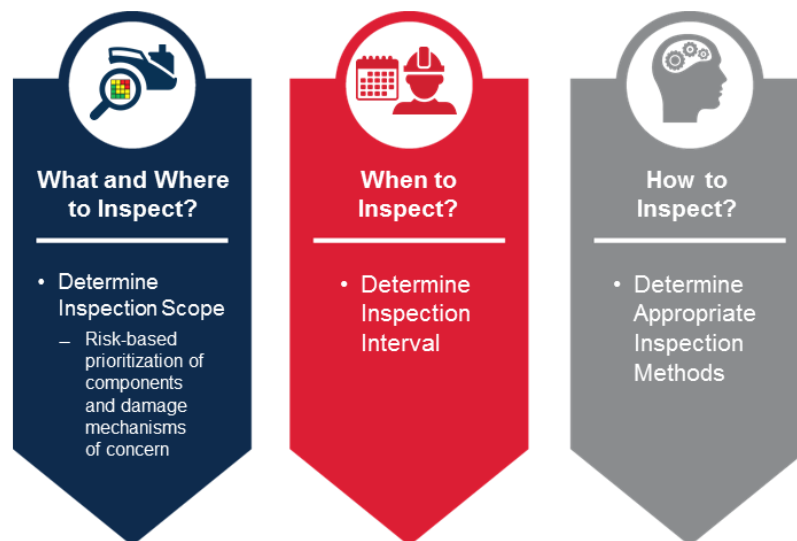
SECTION 1 Introduction

1 Overview

Risk-Based Inspection (RBI) provides an alternative approach to Class rule-based or calendar-based inspection regimes. It utilizes a risk assessment and management process to develop and manage forward-looking inspection plans that direct inspections towards the areas of highest risk. It focuses on failure modes initiated by material deterioration or degradation mechanisms that can be controlled primarily through inspection of equipment and structures.

RBI specifies which components to inspect (i.e. where), what degradation mechanism to inspect, when to inspect and how to inspect as shown in Section 1, Figure 1. RBI can be incorporated into the overall structural integrity management program for offshore structures and systems, as described in API RP 2SIM for fixed offshore structures, API RP 2FSIM for floating systems, API RP 2MIM for mooring systems, and the preliminary draft of API RP 2RIM for dynamic risers.

FIGURE 1
General Approach and Methodology of RBI



RBI begins with the recognition that the essential goal of inspection is to prevent incidents that impair the safety and reliability of the asset. It is tailored to specific asset features and associated modes of operation. As a risk-based approach, it provides means to evaluate the consequences and likelihood of component failure from specific degradation mechanisms and develop inspection approaches that will effectively reduce the associated risk of failure. The inspection process provides confidence in the service reliability of the component being inspected. When an inspection reveals excessive deterioration, actions are initiated, such as the repair or replacement of the affected component or a change to the operating conditions. By identifying potential problems in a timely manner, RBI increases the chances that mitigating actions will be taken, thereby reducing the frequency of failures.

RBI is a process that focuses inspection resources on the areas of greater concern, and provides a methodology for determining the optimum combination of inspection methods and frequencies. As a result, there is a continuous improvement aspect to the RBI process that allows for reassessment of risk and subsequent refocusing of the inspection activities. It is to be noted that risk is never reduced to zero through an RBI program and that there is always a residual risk associated with inspection. This is due to factors such as operational errors, extreme weather, external events, process upsets, limitations of inspection methods and unrevealed deterioration mechanisms.

3 Purpose

This Guide provides direction to Owner/Operators for the application of RBI programs to maintain Class for an offshore floating installation. This Guide describes the fundamentals of RBI, the essential steps in the development of an RBI program, and the management systems necessary for maintaining and updating documentation, data, and analysis. Specifically, it identifies the minimum elements to be considered in the development and management of an RBI program for hull structures, mooring systems, riser systems and topsides process systems so that such plans can be incorporated into the maintenance of class surveys. It also describes the interaction between the Owner/Operator that executes the RBI program and ABS that audits the program and performs surveys for maintenance of class.

This Guide does not intend to provide detailed technical references of RBI methodologies, nor does it intend to single out or endorse any one specific RBI methodology.

The RBI program described herein does not supersede the judgment of ABS during the design and approval process for classification of the hull structures, mooring systems, riser system and/or topsides process systems as required by the applicable ABS Rules such as:

- *ABS Rules for Building and Classing Floating Production Installations (FPI Rules)*
- *ABS Rules for Building and Classing Single Point Mooring (SPM Rules)*
- *ABS Rules for Building and Classing Facilities on Offshore Installations (Facilities Rules)*
- *ABS Guide for Building and Classing Subsea Riser Systems (Riser Guide)*

The application of this Guide does not cover any statutory survey requirements that may apply to the installation being considered (e.g., MODU code, SOLAS, MARPOL, coastal state regulations, etc.). Although ABS is authorized to perform statutory surveys on behalf of some authorities, ABS is not in a position to alter or waive them. The governing administration or regulatory body is the final determining body for statutory or regulatory requirements under their jurisdiction. The Owner/Operator is to consider the Coastal and Flag State requirements along with petitioning these bodies for approval to follow such approaches when developing the RBI plan.

5 Scope

This Guide is specifically targeted for structures and topside process systems for the offshore oil and gas industry. This Guide specifically covers:

- i) Static pressure retaining equipment, and
- ii) Structures for offshore floating installations, including hull structure, mooring system and production riser systems.

Items specifically excluded from the scope of this Guide are Instrumentation and Control (I&C) systems, electrical systems and non-static machinery components. For non-static machinery components, the *ABS Guide for Surveys Based on Machinery Reliability and Maintenance Techniques* provides guidance for a risk-based approach relevant to such types of equipment.

For existing offshore floating installations with an ABS approved RBI plan or ISIP (updated with an RBI plan), appropriate notations are to be issued upon the completion of the next Annual Program Health Check as per 5/9.7 or the next 5-Year Program Health Check as per 5/9.9 and the RBI program found to be maintained satisfactorily.

It is noted that while this Guide is primarily intended for offshore floating installations, the general methodology and related steps can be adapted for application to marine vessels and fixed-based platforms. In order to enroll in an RBI program for such assets, the Owner/Operator is requested to contact the responsible ABS Survey Office.

7 Class Notations

Offshore floating installations with an RBI program that complies with this Guide and have been surveyed and commissioned to the satisfaction of the Surveyors at the Implementation Survey (refer to 9.5/5 for details) in full compliance with this Guide may be classed and distinguished in the *Record* by the appropriate notation for the intended service as follows:

7.1 RBI(Hull) Notation

Offshore floating installations with an RBI program for its hull structure approved in accordance with applicable parts of Section 2, Section 3 and Section 5 of this Guide may be assigned a notation of **RBI(Hull)**.

7.3 RBI(Mooring) Notation

Offshore floating installations with an RBI program for its mooring system approved in accordance with applicable parts of Section 2, Section 3 and Section 5 of this Guide will be assigned a notation of **RBI(Mooring)**.

7.5 RBI(Riser) Notation

Offshore floating installations with an RBI program for its production riser system approved in accordance with applicable parts of Section 2, Section 3 and Section 5 of this Guide will be assigned a notation of **RBI(Riser)**.

7.7 RBI(Topsides Facility) Notation

Offshore floating installations with an RBI program for its topside static mechanical systems approved in accordance with Section 2, Section 4 and Section 5 of this Guide will be assigned a notation of **RBI(Topsides Facility)**.

Notes:

- 1 Offshore floating installations with an RBI program for a set of systems from above will be assigned a combination of appropriate notations. For example, **RBI(Hull, Mooring)** may be assigned if hull structure and mooring system both follow an RBI program.
- 2 The scope and extent of the systems covered under the RBI program for each of the above notations will be listed within the ABS approved In-Service Inspection Plan (ISIP) and noted in the vessel record.
- 3 For existing offshore floating installations with an ABS approved RBI plan or ISIP (updated with an RBI plan), appropriate notations are to be issued upon the completion of the next Annual Program Health Check as per 5/9.7 or the next 5-Year Program Health Check as per 5/9.9 and the RBI program found to be maintained satisfactorily.

9 Program Enrollment Conditions

In order for an RBI program of an offshore floating installations to be approved to satisfy the requirements of the Special Continuous Survey Hull and/or Machinery, the following conditions are to be met:

9.1 Age of Offshore Floating Installation

There is no limit to the age of an offshore floating installation when entered into the program. However, an installation applying for entrance into the program will be subject to a review of the Survey Status records to ascertain the historical performance of the relevant systems which could affect the RBI program. Provided there are no historical problems related to the maintenance of these systems (e.g., unscheduled repairs, significant stress fractures), the installation will be considered eligible. If a particular area of the system(s) is identified with unsatisfactory performance, the installation may still be considered eligible, provided more frequent surveys of that area are conducted, and/or a one-time change is made, resulting in satisfactory performance and confirmed by survey.

9.3 Status of Surveys

The relevant system(s) are to be on a Special Continuous Survey of Hull and/or Machinery cycle. If the installation is not on Special Continuous Survey, the Owner is to be advised to enter the installation into this survey cycle. Where an outstanding recommendation regarding the system(s) exists, the Owner is to be notified that an outstanding recommendation exists and will have to be addressed as part of the RBI plan. The initial RBI plan is to consider the risks of any existing outstanding recommendations and status of Special Survey items, and assign completion dates accordingly.

9.5 Program Review

Where enrollment of the offshore floating installation in the RBI program is requested, the RBI methodology document is to be submitted to ABS for approval prior to detailed work being carried out. Appendix 4, Table 1 lists the information to be included in this methodology document submittal. The submittal requirements for the RBI plan development and RBI program management for the relevant systems are listed in Appendix 4, Tables 3 and 4.

9.7 Program Management Software

If the RBI program is deployed and managed using an inspection and maintenance or integrity management software, then associated details are to be submitted to ABS for review.

9.9 Survey and Maintenance Intervals

ABS Surveys are to be performed as outlined in Section 5. In general, the intervals for the RBI plans are not to exceed those specified for Special Continuous Survey of Hull and/or Machinery. However, if an approved RBI program is in effect, and with appropriate technical justification and in-service monitoring of applicable degradation mechanisms in place, the survey intervals based on the Special Continuous Survey of Hull and/or Machinery cycle period may be extended.

9.11 Program Cancellation

The survey arrangement for an offshore floating installation under the RBI program may be cancelled by ABS if the attending Surveyor observes at the Annual Program Health Check and/or 5-Year Program Health Check that the program is not being satisfactorily maintained with respect to the following aspects:

- The maintenance records, or
- The monitoring and disposition of anomalies being logged as part of the RBI process, or
- The general condition of the covered system(s), or
- The agreed intervals between inspections are exceeded.

Sale or change of management of the offshore floating installation or transfer of class is to be cause for reconsideration of the approval. The Owner/Operator may at any time cancel the survey arrangement for the offshore floating installation under the RBI program by informing ABS in writing.

In case of cancellation, the prescriptive survey regime contained in the relevant ABS Rules is to be followed, items which have been inspected under the program since the last Annual Survey may be credited for class at the discretion of the Surveyor. However, ABS will determine future survey requirements for an offshore floating installation formerly enrolled in the RBI program.

11 Definitions

Acceptable Risk is the risk considered tolerable for a given activity.

Anomaly is an in-service survey measurement, which is outside the threshold considered acceptable from the design and most recent fitness-for-service assessment.

Catastrophic failure is a complete functional failure of a component.

Confidence is the analyst's certainty of an estimate.

Consequence is an unwanted outcome of an event that can negatively affect subjects of interest. It can be expressed as number of people affected (injured or killed), property damage, amount of a spill, area affected, outage time, mission delay, dollars lost or other measure of negative impact.

Degradation or deterioration is the degradation of materials due to various mechanisms (e.g., corrosion, cracking, embrittlement, fatigue) that causes a detrimental effect on the material's physical properties, eventually resulting in the inability/reduced ability of the component to provide its intended function (i.e., failure).

Event is an occurrence or change of a particular set of circumstances that has an associated outcome. There are typically a number of potential outcomes from any one initial event that may range in severity from trivial to catastrophic, depending upon other conditions and subsequent events.

Failure Mode is the manner of failure (e.g., complete rupture of a pipe, buckling of a side shell).

Frequency is the expected number of occurrences of an event or outcomes defined per unit time.

Hazards are conditions or sources that can cause potential harm.

Likelihood is the possibility or frequency of an event's occurrence.

Qualitative Risk Assessment is a risk assessment that expresses the risk in terms of quality or kind (e.g., low, high, very high).

Quantitative Risk Assessment is a risk assessment that expresses the risk in terms of risk impact per unit time.

Residual Risk is the acceptable risk remaining after all risk control options are implemented.

Risk is a measure of loss; mathematically, it is the product of frequency with which an event is anticipated to occur and the consequence of the event's outcome.

Risk Analysis is the process of understanding (1) what undesirable things can happen, (2) how likely they are to happen and (3) how severe the effects may be. More precisely, it is an integrated array of analytical techniques (e.g., reliability, availability and maintainability engineering, statistics, decision theory, systems engineering and human behavior) that can successfully integrate diverse aspects of design and operation in order to assess risk.

Risk Assessment is the overall process of risk identification, risk analysis and risk evaluation.

Risk-Based Inspection is a risk assessment and management process that is focused on failure modes initiated by material deterioration, and controlled primarily through equipment and structure inspection.

Risk Controls are the measures taken to prevent hazards from causing consequences. Controls can be physical (safety shutdowns, redundant controls, conservative designs, etc.), procedural (written operating, maintenance, or inspection procedures) or can address human factors (employee selection, training, supervision).

Risk Evaluation is the process used to compare the estimated risk against given risk evaluation criteria to determine the significance of the risk. Risk evaluation may be used to assist in acceptance decisions.

Risk Management is a set of coordinated activities directed to control risks within an organization. These activities usually include risk analysis, risk assessment, risk control, risk acceptance and risk communication.

Scenario is an event or series of events that result in the occurrence of a potential consequence.

13 Abbreviations

ABS	American Bureau of Shipping
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
CFD	Computational Fluid Dynamics
COF	Consequence of Failure
CUI	Corrosion Under Insulation

CVI	Close Visual Inspection
DLA	Dynamic Load Analysis
DM	Direct Measurement
FEA	Finite Element Analysis
FFS	Fitness for Service
FM	Fracture Mechanics
FMEA	Failure Mode and Effects Analysis
FMECA	Failure Mode Effects and Criticality Analysis
HAZID	Hazard Identification
HAZOP	Hazard and Operability
ISIP	In-Service Inspection Plan
LNG	Liquefied Natural Gas
MPI	Magnetic Particle Inspection
NDE	Non-Destructive Examination
NDT	Non-Destructive Testing
P&ID	Piping and Instrumentation Diagram
PFD	Process Flow Diagram
POD	Probability of Detection
POF	Probability of Failure
PMI	Positive Material Identification
PSD	Process Safety Diagrams
QRA	Quantitative Risk Analysis
RBI	Risk-Based Inspection
RP	Recommended Practice
RT	Radiographic Testing
SRB	Sulfate-Reducing Bacteria
SFA	Spectral Fatigue Analysis
UT	Ultrasonic Testing
VI	Visual Inspection
VIV	Vortex-Induced Vibration



SECTION 2 RBI Program Overview

1 Overview

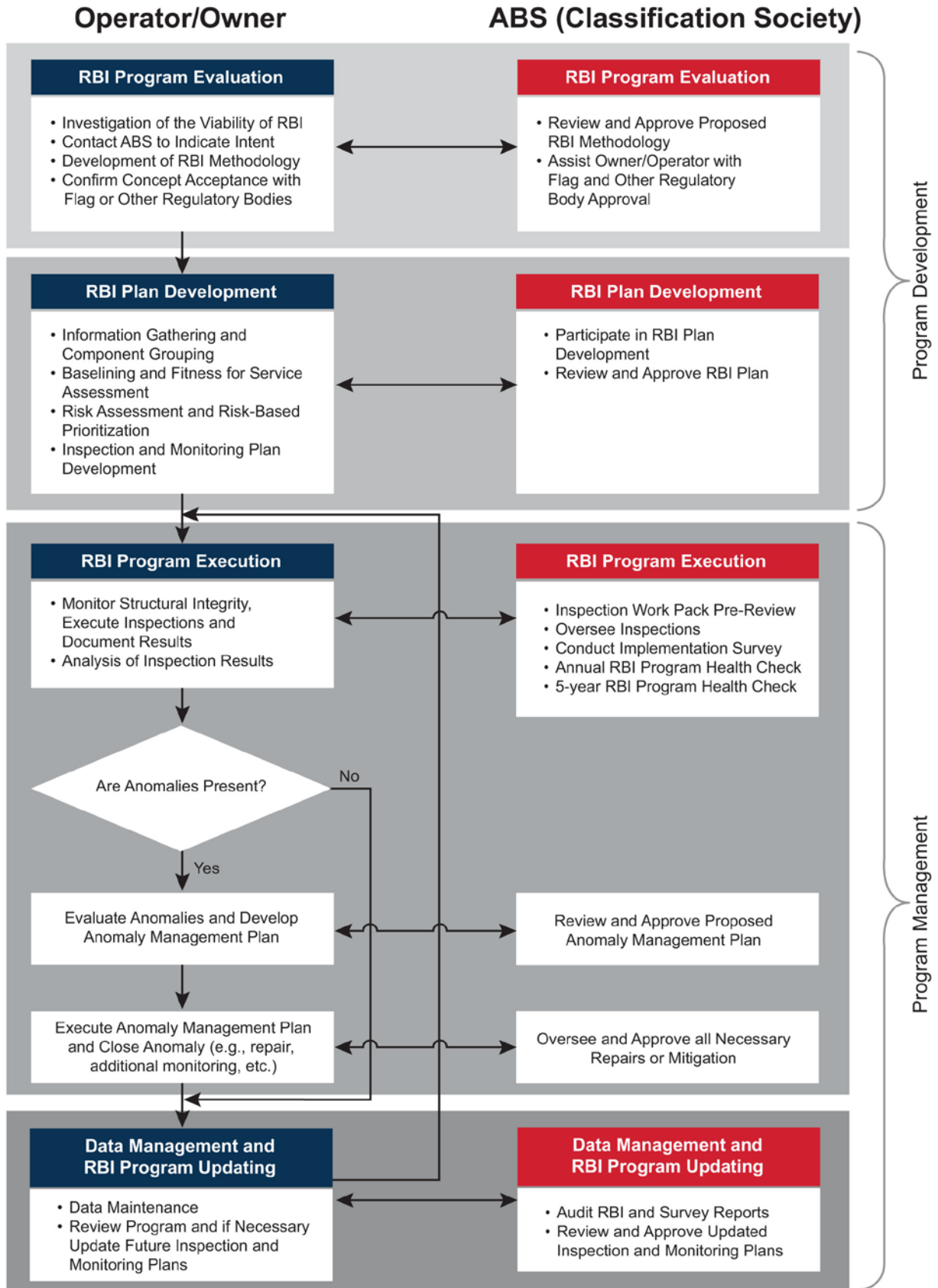
This Section describes the typical methodology and steps involved in developing an RBI program. Other methodologies are also accepted by ABS, provided that the steps in the development process as described in this Section are included. If any of the steps are absent or they are considered in a substantially different way than common industry practice and standards, a suitable technical explanation on the adequacy of the methodology is to be included with the submittal for ABS consideration and approval.

The development process and submittal requirements in this Section are common to hull structures, mooring systems, riser systems and topsides process systems. Additional details specific to hull structures, mooring systems, and riser systems are described in Section 3, and specific to topsides process systems in Section 4.

Section 2, Figure 1 shows the overall process of developing and managing an RBI program divided into four stages and associated steps. The figure also shows how the Owner/Operator and Class interact with each other. A brief summary of each stage is described below. These are further detailed later in this Section.

- 1) *RBI Program Evaluation* – This is the starting point for enrolling in an RBI program. The Owner/Operator investigates the viability of applying RBI and discusses this intent with ABS. The key points for discussion include the applicability of RBI to the specific offshore floating installation, the proposed systems to be considered within the scope, the objective (inspection scope and/or frequency adjustment), proposed methodology and identification of the required submittals. In this stage, a general methodology document along with a letter of intent will be submitted by the Owner/Operator to ABS with these details for review. Upon satisfactory completion of review by ABS, the concept is discussed with the flag State and other relevant regulatory bodies for preliminary agreement.
- 2) *RBI Plan Development* – This stage includes various steps for developing an asset-specific inspection and monitoring plan. During the development activities, Class interface points include participation in risk assessment workshops as well as reviews of interim submittal documents. At the completion of this stage, the Owner will submit the proposed RBI plan to ABS for review and approval. The RBI plan will outline the proposed inspection scope and schedule for a predefined service period. The document will also provide guidance on key inspection locations, RBI scope (i.e., systems and components covered by RBI) as well as threshold limits and required actions for anomalies.
- 3) *RBI Program Execution* – This entails the execution of the program including the monitoring and inspection activities, recording of related data and management of inspection work packs that outline the inspection scope and associated inspection techniques, as well as the follow-up and disposition of anomalies. The Class interface points will occur throughout the process, similar to Rule-based inspection programs. The RBI plan will be part of the vessel survey record, accessible by the Class Surveyor. The Owner/Operator follows the inspections per the RBI plan and contacts the appropriate ABS office to request an attending Surveyor for the inspection. The Surveyor will oversee the inspections as well as confirm the general health of the RBI program. Additionally, if any anomalies are observed during the inspections this will be brought to the attention of the attending Surveyor. As part of the anomaly management process, the Owner/Operator will inform Class of the plan of action to address anomalies, obtain approval for the proposed resolution as well as request appropriate Class oversight and inspection of any repairs.

FIGURE 1
RBI Program Overview



- 4) *Data Management and RBI Program Updating* – One of the features of RBI is a formal review of the inspection and monitoring data to determine if updates to the program are warranted. This provides a forward-looking inspection program for the installation based on a foundation of analysis results, historical information and knowledge, risk assessment results and anticipated operating conditions. However, when the inspection results deviate from the anticipated condition or pass a predetermined threshold or trigger, updates to the RBI program may be warranted. As part of the updating process the Owner/Operator will inform Class of the updates, describing the proposed changes as well as identifying the reasons.

Section 2, Figure 1 assumes the program development is conducted during the design and construction stage. ABS will allow the Owner/Operator of an offshore floating installation operating under the Rule-based inspections to transition to a risk-based program. The process is essentially the same as shown in Section 2, Figure 1, but depending on when the last special survey was conducted, there may be additional baselining inspection requirements to confirm the current condition and transition over to the risk-based program. Also, it is envisioned that some Owners/Operators may have completed the RBI Program Evaluation Stage prior to contacting ABS. In such cases, ABS would perform an assessment of the current stage of RBI program development and endorse the RBI program based on this assessment. The RBI program can then proceed starting at that stage and continue to the subsequent stages.

3 RBI Program Evaluation

In the initial development stages, the Owner/Operator should investigate whether an RBI approach is viable as compared to a traditional time-based approach. This may involve a cost benefit analysis by the Owner/Operator to evaluate the benefits of applying an RBI program to the installation as well as investigating eligibility considering the requirements of applicable ABS Rules and Subsection 1/9 of this Guide. Also, the Owner/Operator should consider the Coastal and Flag State requirements and preliminary acceptance from relevant authorities for applying an RBI program to the installation. ABS can facilitate these discussions between the Owner/Operator and the Coastal and Flag Authorities at the appropriate time.

Once it is determined that an RBI program is to be pursued, a letter of intent along with a methodology document should be submitted to ABS for review. Appendix 4, Table 1 lists the detailed information that should be included as part of the methodology document submittal. The methodology that will be used to develop the RBI plan is to be submitted, including a clear definition of the scope of the components that are proposed to be covered within the RBI program. The typical scope that can be covered in the RBI program for hull structures, mooring systems, and riser systems are provided in Section 3, and the typical scope for topsides process systems are provided in Section 4.

The RBI approach requires significant initial effort to determine the inspection methods, scope and frequency based on the risk assessment and risk prioritization results. Therefore, a multi-disciplinary team that synergistically brings together different perspectives and technical strengths should be assembled. The specific composition of an RBI team may vary depending on the complexity of the installation, RBI methodology and scope.

5 RBI Plan Development

5.1 Information Gathering and Component Grouping

5.1.1 Information Gathering

All RBI plans require an adequate amount of data for the assets in question. Typically, this data is stored in various forms (e.g., original design and construction data including design analysis reports, inspection and maintenance records, information on repairs and modifications, and operational records and histories). Having this information in hand is essential to the development of the RBI plan. It should be noted that the lack of data/information and/or the level of accuracy should have a bearing on the amount of conservatism and initial assumptions made when developing the RBI plan.

This information is usually collected, stored and retrieved in an electronic database that is also used to handle the day-to-day inspection and maintenance tasks. This database will contain unique tag numbers and identifications for all aspects of the process, most often down to the subcomponent level. This classification is sometimes known as the asset hierarchy. A complete asset hierarchy is essential to developing and sustaining a viable RBI plan.

One aspect that should be included when gathering the information needed for an RBI plan development is the novel or unique attributes of the particular asset. Often the experience from the performance of other similar assets is drawn upon to gauge the anticipated performance of the asset for which the RBI plan is being developed. If the operating conditions or features are outside the existing bounds of experience, the information needed to accurately predict the performance may not be available. In these cases, the inspection plan will need to identify this and ultimately be structured such that a steady stream of information is collected on the performance of the unique attribute(s).

5.1.2 Component Grouping

The objective of this step in the RBI plan development is to delineate the equipment or components within the asset hierarchy into manageable logical groupings, hereby referred to as “inspectable units”. Offshore hull structures, mooring systems, riser systems, and topsides process systems consist of many components, and each has a role/function in the overall integrity of the asset. These components may involve complex interactions and dependencies. One goal of RBI is to use risk assessment to establish a priority order for components to be inspected from the highest risk to the lowest risk. The selection of the component or system of components to be considered in the risk assessment is essential for effective RBI inspection planning. The RBI priority is usually set based on the risk associated with failure of a major component or system of components. Therefore, the consequence evaluation is to be performed on a component or sub-system of components that has meaning in the context of inspection. It has to be a large enough inspectable unit that has significant consequences upon failure, but small enough to have similar load and degradation mechanism exposures.

A consequence evaluation for a floating structure or the entire topsides would not be meaningful to an inspection plan since each involves hundreds of disparate components. Also, a consequence evaluation of a single bracket in a highly redundant and complex structural system may not have a meaningful consequence of failure. The inspectable units for structural components are difficult to identify because of the redundancy of the load paths within the structure. Selection of the components to perform consequence evaluation should be limited to major components with significant function and represent large inspectable units.

This is an essential step since developing an RBI plan at too broad a level would be overly vague whereas at the individual component level, it would be very time consuming and difficult to manage. Grouping components together in a consistent manner will make the RBI risk prioritization easier to complete and document.

5.3 Baseline and Fitness for Service (FFS) Assessment

In some instances, existing equipment and structure may have no or limited data available to gain an understanding of its present condition. In such cases, the initial step towards developing an RBI plan includes some form of inspection for data gathering (baselining) coupled with a FFS assessment using the collected data.

Methodologies for conducting gauging surveys and FFS assessments of existing hull structures (ship-shape and non-ship-shape hulls), and mooring systems, are available in other ABS Guidance Notes such as the *ABS Guidance Notes on Life Extension Methodology for Floating Production Installations*, and for topsides process systems in other industry codes and standards such as API 579-1/ASME FFS-1.

The goal of such data gathering and FFS assessment is to review the available information on the installation to identify and execute an inspection scope that can then be used to perform a FFS assessment on the various components that make up the system in question. The FFS assessment should accomplish the following:

- i) Identify the type and magnitude and possible cause of deterioration present in each component.
- ii) Trend or track deterioration versus the initial as-built condition using tools such as remaining life calculations.
- iii) Assess other anomalies and defects (such as crack-like flaws) for suitability for continued operation in terms of the operating environment (e.g., pressure, temperature, cyclic loading, stress field).
- iv) Gather information on unknown or unidentified material properties (positive material identification).
- v) If applicable, assess existing anomalies and damages such as deformation, cracking, coating breakdown, and local failures caused by accidental events such as collision, dropped objects, fire, or explosion.

Conducting a baseline assessment on the installation will enable information to be gathered on the present condition of the installation, such that data informed decisions can be made for risk prioritization and in the setting of the RBI plan. FFS may be needed for the installation depending on the installation's current condition as requested by ABS.

The types of data to be collected and reviewed for the components within the scope of the RBI plan in order to facilitate the baselining or FFS assessment may include:

- i) *Original Design and As-Built Information.* Covers the initial data point against which all subsequent information can be compared. This includes data on original materials of construction, initial thickness, degree of NDT used during fabrication, initially assumed design and operating envelope, and design analysis reports (if available).
- ii) *Operational history.* Covers knowledge of how systems and components were operated from the time of construction. Information on loading versus design intent or extent of fatigue related loading can be ascertained from this information.
- iii) *Inspection records and inspection methods/frequencies.* Enables identification of prevalent damage and trending of that damage versus the initial as-built condition. The effectiveness of prior inspections and confidence in results can also be verified compared with anticipated damage mechanisms.
- iv) *Repair and Modifications Records.* Repairs should be investigated in terms of their cause (i.e., was damage greater than anticipated or was a damage mechanism identified which had not been considered in the RBI program?). Modifications should also be noted to verify that any required upgrade/change is assessed in terms of how this modification affects the original design/operating parameters (management of change).
- v) *Mitigation strategies.* Covers strategies such as chemical injection and corrosion inhibition, insulation and coating.

For a new build asset, many of the data sources listed will be available with the exception of historical data. Where the new asset is of similar design to one already managed by an Owner/Operator, it may be appropriate to apply the knowledge gained from the existing asset (including degradation rates and repair history) to the new asset. In this instance, the parallels drawn between the two assets will require appropriate justification.

5.5 Risk Assessment and Risk-Based Prioritization

Prioritization of the components subject to inspection is a critical step in the development of an RBI plan and helps optimize resources. The prioritization process within RBI is largely governed by the derived risk rankings for systems and components established through a risk assessment. In the case of a mature RBI program, prioritization may also be influenced by additional factors such as anomalies, repairs or scheduled shutdown programs. ABS participation in the risk assessment is recommended.

In general, the RBI prioritization is performed using risk as the ranking parameter, which gives an equal weight to the likelihood and consequence components in the risk equation. Using consequence or likelihood alone for prioritization purposes can prove problematic and may not accurately reflect the worst potential scenario, resulting in dissimilarities for priority of inspection. Using overall risk rank confirms that the

most critical components (higher consequence, higher likelihood) are easily distinguishable and, as such, are prioritized accordingly. For high and medium consequence scenarios, special attention should be paid when assigning the likelihood values to avoid an inaccurate estimation of the overall risk. The use of conservative likelihood values is recommended so as not to screen out potentially high-risk scenarios.

The risk assessment for the prioritization step in the development of an RBI plan is limited in scope to the accident scenarios resulting from deterioration mechanisms of the components within the scope of the analysis, and which can potentially be detected by inspection.

The risk prioritization of the inspectable units within an RBI plan is performed by evaluating the results of the component identification and grouping discussed in 2/5.1.2. As much as possible, the components identified through that process are to be followed when determining appropriate likelihood and consequences of failure. If, when working through the prioritization process, it is found that the system identification is too broad or too narrow to accurately describe the risks, the system identification and grouping should be revisited and, where appropriate, refined sets of components identified. Thereby, the risk assignments developed can match the components inspected under the RBI plan.

An in-depth analysis of degradation mechanisms and frequencies for all the units within the scope of an RBI plan can be very time-consuming. Therefore, depending on the scope of components within the RBI plan, at this stage, it is acceptable to use conservative values for the frequency of failure of each inspectable unit for screening purposes. A more detailed analysis can be performed more efficiently later during the Inspection and Monitoring Plan Development step, once high priority items have been identified using screening estimates.

Once all inspectable units are analyzed and risk estimates for each failure mode are assigned, a prioritized list of the inspectable units can be obtained, which will constitute the input to the next step in the RBI plan development.

5.5.1 Risk Assessment Methodology

Selection of the most appropriate risk assessment method is dependent on several factors such as:

- Whether the installation is a new build or an existing asset
- Number of facilities/components/structure items to study
- Available resources
- Complexity of facilities and processes
- Nature and quality of available data
- Purpose of analysis (e.g., to support company policy, to satisfy a regulatory, legal or stakeholder requirement)

Once the above items have been evaluated, the method best suited to the particular case may be selected and applied. There are three basic groups of methodologies:

- i)* Fully qualitative
- ii)* Fully quantitative
- iii)* Semi-quantitative

In the fully qualitative approach, competent personnel may make expert judgments or subjective review within a formal evaluation process (e.g. risk assessment workshop) for assessment of the severity and likelihood of failure of each component under review. The process typically involves personnel who are involved with the daily management of the installation and can provide input on the condition of the installation and any potential scenarios that may occur. The process is facilitated by an individual experienced in risk assessment evaluation, thus focusing the study outcomes. Both factors of likelihood and consequence are assessed. A final value for risk is derived by placing the components' derived likelihood and consequence assessments within a risk matrix, thus delivering a final component risk score or rank. The risk matrix is a plot with likelihood on one axis and consequence on the other. Section 2, Figure 2 shows a sample risk matrix with three regions of risk: Low, Medium, and High.

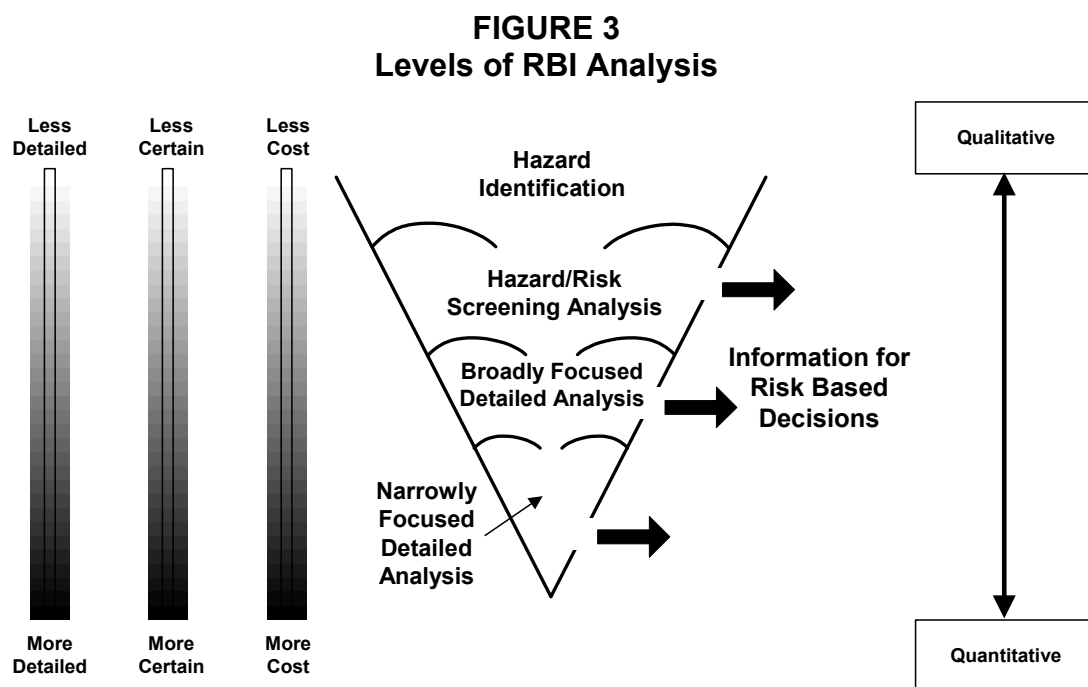
Qualitative analyses normally use descriptive ranges for inputs and outputs that are intended to be broad enough to cover the ranges of uncertainty involved. The most typical use of this technique is for the purpose of “screening” out low risk items for which the time and cost of a quantitative study cannot be justified. As an aid to solicitation of input, it is common to establish pre-defined categories or ranges for likelihood and consequences.

FIGURE 2
Sample Risk Matrix

Frequent Incident is likely to occur at this facility within the next 5 years.	4	L I K E L I H O O D	High Risk					
			Occasional Incident is likely to occur at this facility within the next 15 years.	3	Medium Risk			
					Seldom Incident has occurred at a similar facility and may reasonably occur at this facility within the next 30 years.	2	Medium Risk	
							Unlikely Given current practices and procedures, incident is not likely to occur at this facility.	1
			C O N S E Q U E N C E					
			1	2	3	4		
			Incidental	Minor	Serious	Major		
<i>Personnel</i>			Minor or no injury, no lost time.	Single injury, not severe, possible lost time.	One or more severe injuries.	Fatality or permanently disabling injury.		
<i>Community</i>			No injury, hazard or annoyance to the public.	Odor or noise complaint from the public.	One or more minor injuries.	One or more severe injuries.		
<i>Environmental</i>			Environmentally recordable event with no Agency notification or permit violation.	Release which results in Agency notification or permit violation.	Significant release with serious offsite impact	Significant release with serious offsite impact and likely to cause immediate or long term health effects.		
<i>Facility</i>			Minimal equipment damage at an estimated cost less than US\$100K, negligible downtime.	Some equipment or structural damage at an estimated cost greater than US\$100K, 1 to 10 days of downtime	Major damage to installation at an estimated cost than US\$1 MM but less than US\$10 MM, 10 to 90 days of downtime	Major or total destruction to installation estimated at a cost greater than US\$10 MM; downtime in excess of 90 days.		

The fully quantitative method uses formulas, algorithms, engineering analysis or event modeling to provide a direct numerical value for each factor of consequence and likelihood, rather than making use of experience or subjective decision making to assess risk. This method is more objective (i.e., mathematically calculating risk rather than subjectively evaluating it). An RBI plan based only on a quantitative method can be resource intensive and has potential to overlook the value that is gained from the input offered by experienced operations personnel.

In practice, it is doubtful that any RBI approach could be termed wholly qualitative (without use of any analytical tools) or wholly quantitative (without use of judgment). Almost all approaches are “semi-quantitative”, although some are at the qualitative end of the spectrum while others are at the analytical side. Thus, the qualitative and quantitative approaches do not compete with each other, but complement each other. Section 2, Figure 3 illustrates this concept. When utilizing this method, the objective is to get the best of the qualitative and quantitative methods. This combined methodology can often provide the most favorable and practical results for risk ranking and optimize the time expended on the assessment.



There are certain limitations with quantitative and qualitative methods. For qualitative methods of RBI, the main issue that may undermine the results of the RBI analysis is that this method is largely an expert scoring process. As a result, the outcomes of such a study could be considered to be overly judgmental and wholly reliant on the expertise of the individuals who evaluate the risks. Qualitative RBI in certain cases may not be fully adequate to accurately evaluate the worst-case as certain key factors (e.g., failure degradation/propagation rates) may have critical importance. By comparison, quantitative analysis in support of RBI plan requires considerable quantities of detailed data and as such can be exceptionally labor-intensive. For this reason, quantitative risk assessment is most commonly used as an enhancement to the qualitative method – a first pass qualitative analysis in advance of the quantitative to pre-screen for components where use of quantitative methods would neither be technically appropriate nor cost-effective due to low risk. More detailed descriptions of specific risk assessment methodologies to use in RBI plan development can be found in the ABS *Guidance Notes on Risk Assessment Application for the Marine and Offshore Oil and Gas Industries*.

It is noted that an RBI plan based on only a qualitative method can serve the objective of refining/adjusting the inspection scope but for refining/adjusting the inspection frequency, a quantitative approach is oftentimes necessary. It is also important to note that any major change in the use, service, process parameters or location of the equipment would affect both the likelihood of failure and the consequences of failure. If and when such change events occur, a reassessment of risk study is required as triggered by a Management of Change (MoC) program.

The risk assessment for an offshore floating installation is to be site-specific. If the installation is to be relocated, the risk assessment is to be reviewed by the Owner and resubmitted to ABS for approval.

5.7 Inspection and Monitoring Plan Development

Once a risk-prioritized list of inspectable items is generated as discussed in 2/5.5, those items with higher associated risk should be assessed for potential risk reduction by an appropriately selected inspection and monitoring strategy. This is the objective of the “Inspection and Monitoring Plan Development” step of the RBI program. The setting of the inspection strategy involves the establishment of the most appropriate inspection methods, scope and frequency. This strategy aims to deliver timely inspections that bring valuable information in the form of inspection and monitoring results. The reduction in component condition uncertainty and increase in predictability of deterioration rates translate directly into a reduction in the likelihood of failure. The RBI plan should be integrated with the overall In-Service Inspection Plan (ISIP) to address the following aspects:

- What is the objective and scope of the RBI plan?
- What structures or systems will remain under the Class rule-based inspection?
- Which items are susceptible and where are they located?
- What inspection methods or tools should be adopted in order to deliver the required inspection result?
- How effective are the selected inspection methods at detecting the perceived degradation mechanisms?
- How much inspection is required in order to confirm the target inspection effectiveness.
- What frequency of inspection is required for each inspectable unit or component?
- Have inspection specifications as required by the applicable ABS Rules and industry design codes and standards been considered?
- How will the data be managed and the RBI plan updated?
- What are the thresholds or triggers that would initiate activities such as engineering assessments or updates to the RBI plan?

When available, the RBI plan should consider and build upon the knowledge gained during baselining and FFS assessment, as discussed in 2/5.3.

5.7.1 Degradation Mechanisms and Inspection Methods

Potential failure modes are to be estimated before inspection methods are selected. For each failure mode, the potential degradation mechanisms that can cause those failures are to be identified. The evaluation of such mechanisms should consider the type and rate (time dependency) of degradation that may be likely. Typical degradation mechanisms to be considered for the hull structure, mooring systems, riser systems and topsides process systems include:

- Uniform corrosion
- Localized corrosion
- Galvanic corrosion
- Pitting corrosion
- Crevice corrosion

- Erosion
- Fatigue cracking
- Environmentally induced cracking
- Overstress due to metal loss
- Creep
- High temperature oxidation and metallurgical changes
- Brittle fracture
- Mechanical damage

API RP 571 and API RP 581 provides detailed guidance on the damage mechanisms to be considered for topsides process systems, determination of degradation rates and inspection planning.

A preliminary evaluation of the applicable degradation mechanisms and deterioration rates may have been performed during the likelihood estimation in the risk prioritization step. During this step, those evaluations should be reconsidered for the higher risk items, and perhaps a more detailed assessment may be necessary. Once the degradation mechanisms have been accurately assessed, the selection of an inspection method can be successfully achieved.

It is important to consider that there are many inspection techniques and testing methods available to accurately assess component integrity. Section 2, Table 1 provides a listing of inspection methods available to assess common degradation mechanisms. Some methods available have inherent limitations that may impair at least the accuracy of reported results. Many inspection methods are subjective and as such provide an assessment tool rather than a quantification tool (e.g., visual inspection can only provide a qualitative assessment of the condition of the component), whereas NDT methods provide values in the form of thickness measurements or crack dimensions (length/depth). Even with NDT methods, an error band on the measured values exists and should be recognized and accounted for. The level of error for some NDT methods is often directly associated with the level of cleaning and preparation performed prior to the recording of the resultant value for degradation. This may be a problem if not managed by procedures, and could lead to an inaccurate prediction of the integrity, which in turn may impact inspection intervals.

RBI uses the same types of inspection techniques as traditional inspection planning methods, the main difference being the prioritizations applied and the feedback of results into future plans. As with all inspection plans, RBI requires the use of appropriate inspection technology performed by competent practitioners. Each type of inspection has its limitations, and these should be accounted for within the RBI plan. For example, when considering which inspection technique to use for detecting a certain type of damage, the probability of detection (POD) of the inspection technique should be also considered. The POD depends on the size and extent of the damage. The POD may drive the confidence in the selection of inspection techniques and associated conservatism in the development, updating, and calibration of the RBI plan.

Typical types of inspections for either structural components or pressure system components include:

- External Visual
- Internal Visual
- External Gauging
- Internal Gauging
- Flaw Detection
- Material Characterization

The level of confidence gained from the results of an inspection is an important factor for RBI and all steps available to improve the effectiveness of an inspection should be taken. This would include preparation of the component for inspection including the provision of a safe working environment for the inspector.

Section 2, Table 2 describes inspection conditions that may affect confidence of inspection results for typical inspection methods.

**TABLE 1
Degradation Mechanisms, Causes and Inspection Methods**

<i>Degradation Mechanism</i>	<i>Causes</i>	<i>Inspection Methods</i>
Uniform and localized corrosion	Exposure to corrosive material such as mineral or carbonic acids or aqueous environments, seawater and humid or condensing environments. Damage can be localized over an area and is accelerated by exposure to alternating wet/dry conditions, increases in corrosive specie concentration, temperature, oxygen content of the fluid and the large cathodic/anodic surface area ratios in contact with the fluid	Visual Inspection (VI), Direct Measurement (DM) and Ultrasonic Testing (UT)
Pitting	Exposure to corrosive material such as mineral or carbonic acids or aqueous environments, seawater and humid or condensing environments. Damage can be localized over an area or uniform distributed surface in contact with the aqueous phase. Corrosion rates can be much higher than uniform or localized corrosion	VI, DM
Crevice corrosion	Electrochemical concentration cell set up associated in crevice areas with stagnant aqueous phase fluids, such as under sludge, sand, biological materials or corrosion products, failed coatings, gasket surfaces, bolt heads and riveted lap joints. Damage is usually found within the crevice area	VI, DM, UT and Radiography Testing (RT)
Erosion	High fluid velocity in piping or impingement on a surface, accelerated by solids in the stream	VI, UT and RT
Erosion-corrosion	Corrosion contributes to erosion by removing protective films or scales, or by exposing the metal surface to further corrosion under the combined action of erosion and corrosion	VI, UT and RT
Fatigue cracking	Cyclic loading coupled with an initiating location caused by a stress riser, weld defect, arc strike, mechanical, corrosion damage or environmentally-induced cracking (e.g., thermal fatigue)	VI, Surface flaw detection, UT flaw methods, RT, Magnetic Particle (MP), Eddy Current (EC)
Environmentally induced cracking	Exposure to specific agents that cause environmentally-induced cracking such as caustic and aqueous phases with hydrogen sulfide	VI, Surface flaw detection, UT flaw methods, RT, MP, EC
Creep	Temperature exposure coupled with stress damage is exposure time dependent, for most steels short term exposure generally above 1200°F is of concern	VI and DM
High temperature oxidation and Metallurgical Changes	Prolonged temperature exposure generally above 1000°F, damage is exposure time dependent, or rapid cooling from above 1300°F in a fire situation	VI, DM and metallography, Positive Material Identification (PMI)
Mechanical damage	Impact or abrasive loading	VI, RT, UT

TABLE 2
Inspection Types, Techniques and Factors Affecting Confidence

<i>Type of Inspection</i>	<i>Inspection Method</i>	<i>Inspection Conditions Affecting Confidence of the Results</i>
External Visual	General VI	Surface condition, lighting and close access to surface
	Close VI	
Internal Visual	General VI	Surface condition, lighting and close access surface
	Close VI	
External Gauging	VI	Thickness of reference surface for pit gauging
	Ultrasonic Technique (UT)	Surface preparation and surface condition relative to transducer diameter. Component temperature and metal composition
	Radiographic Technique (RT)	Access to both sides and relative position of source and film
Internal Gauging	VI	Thickness of reference surface for pit gauging
	Ultrasonic Technique (UT)	Surface preparation and surface condition relative to transducer diameter. Component temperature and metal composition
Flaw Detection	VI	Surface condition, lighting and close access to surface
	Ultrasonic Technique (UT)	Surface preparation and surface condition relative to transducer diameter. Access to location relative to beam path. Component temperature and metal composition
	Radiographic Technique (RT)	Access to both sides and relative position of source and film. Material thickness and film resolution
	Surface Flaw Detection	Correct surface preparation for the method
	Liquid Penetrant	The penetrant color, dwell time, materials to be tested, surface condition, lighting and close assess to surface
	Magnetic Particle	The ferromagnetic of the materials, surface condition, UV lighting and close access to surface
	Eddy Current	The permeability of the material, thickness, and diameter
Material Characterization	Positive Material Identification (PMI)	Access to surface
	In-Place Metallography	

5.7.2 Scope of Inspection (Sample Population Size, Location and Extent of Inspection)

This topic in the inspection and monitoring plan development addresses the questions of where to inspect and how much to inspect. These elements together are largely driven by the likelihood assessment.

It should be recognized that the likelihood of loss of integrity increases as the number of components affected by the same degradation mechanism increases. Risk is observed to increase as inspectable units degrade. As likelihood is time-dependent, older and more frequently used systems generally are more likely to fail.

5.7.2(a) Sample Population Size and its Relationship to Degradation Mechanisms. The objective of setting of inspection scope is to measure the levels of activity for the degradation processes. The sample population size (number of test locations) that is selected should reflect the nature and type of degradation and criticality of the location under investigation. An example of this may be where overall uniform corrosion is identified as the likely cause of failure of a system.

In this scenario, the factors that govern where and how much to inspect are less complicated than with other degradation scenarios where isolated failure would be the main feature. For a uniform corrosion example, failure of any given part of the inspectable unit should (in theory) be as likely as any of the other locations. Uniformity of degradation may allow the inspections to be less specific and focused when considering where and how much of the system requires inspection. This method would provide an answer to the basic question “is degradation present?” Where a measurement of degradation rate is required, the sample population (number of test points) should be large enough to be collectively representative. Although one or two test points and results may well answer the questions as to whether uniform corrosion is present, this sample population size would be too small to accurately define a corrosion rate.

Ideally, the sample inspection is to be of a sufficient size and population spread to accurately reflect the system make-up as a whole, both geometrically (i.e., for piping systems, this would cover all of the different types of piping geometric features such as “tees”, “bends”, “reducers” as well as straight line pipe) and as representative of the size of the system (i.e., a more extensive piping system requires a larger number of tests than a smaller system). Consideration should be given to the possibility that no other deterioration mechanism, such as erosion, may be influencing the outcome of the inspections. Were such a case encountered, then the inspection plan should be modified in recognition of this influence and the scope be modified to investigate a combined failure scenario.

Localized isolated or dispersed (non-uniform) degradation mechanisms, as exemplified by pitting events or cracking, are more complicated to assess and would more likely require a much greater sampling population, and increased spread/density of test locations across the system in order to effectively assess them.

5.7.2(b) Test Point Location Selection. The degradation mechanism, critical areas and stress patterns will dictate the locations to inspect. However, sampling of common features within the inspectable unit is a proven approach for inspection location selection.

All of the major surfaces of the component may be targeted for inspection, as are other features. These may include:

- Weld seams and heat-affected zones
- Connections to piping or adjacent structural members
- Process internals, phase boundaries
- Vapor spaces
- Internal structural members
- Heat-affected zones from weldments attached to the component surface (e.g., welded pipe supports)
- Stagnant and low flow areas
- Areas subject to impingement

When available, knowledge gained from baselining and fitness for service assessment (2/5.3) will allow the inspection plan to focus on the areas known historically or through analysis to be prone to failure or degradation.

5.7.2(c) Extent of Inspection. The extent of the inspection identifies how much, in terms of surface area, is required to be inspected for each given component. For smaller components, this may involve inspecting the whole component. For larger components such as pressure vessels or large structural members, this may be restricted to smaller representative areas often known as ‘grids’ or to localized areas that are at risk from degradation (e.g., the upper area of a web frame uniquely exposed to atmospheric interaction).

Often complex or multiple degradation effects may be observed. In such cases, the areas to be inspected for these larger components should be wholly representative of the service duty seen by the whole component (e.g., for a process separator, there may be three distinct process phases: a wet gas phase, and oil phase and a produced water phase, all within the one pressure vessel). With this example, risk from failure for each of these phases may be very different in value, but all three potential risks should be addressed within the inspection program. Degradation to a point of failure and loss of containment within any of the phase areas of the pressure vessel will likely produce an unacceptable consequence.

5.7.3 Frequency of Inspection

Inspection frequency is the time interval between planned inspections. The inspection frequency to be selected, in general, is directly related to the identified degradation rate and the determined condition of components following each inspection.

Inspection frequencies set by the initial RBI plan should have a realistic time period so that adequate inspections are performed to assess the ongoing integrity of the components and produce reliable measurements for degradation rates. The initial inspection frequency set by the RBI plan is likely to be more conservative than those that may ultimately be achieved. In general, and specifically for high-risk items, these initial frequencies should reflect the typical intervals that are presently established within existing industry codes and standards commonly in use. These frequencies are likely to remain a feature of the RBI until the factors predicted by the RBI such as trends for degradation and rates are recognizable. Once validated, the RBI plan may provide for optimization of frequencies, as discussed in 2/7.3, “Evaluation of Inspection Results” and Subsection 2/9, “Data Management and RBI Program Updating”.

The inspection interval, in terms of RBI, is the time span for estimating the likelihood of an undesirable consequence or condition occurring based on the component’s current condition and degradation rate. The inspection interval should be planned for the component reaching a damage condition, rather than failure, which permits development of mitigation options in which the timeliness and scope can be evaluated with risk assessment tools.

Several methods or concerns are listed below that may establish inspection plan interval or change a planned inspection interval:

- Default maximum intervals in industry-accepted inspection codes
- Corrosion rate or condition-based to an appropriate technical evaluation condition
- Probabilistic methods based on variations in degradation rates and in loads to an appropriate technical evaluation condition
- Fixed time schedule for condition, to meet jurisdictional requirements, or to meet a sequential inspection sampling plan (a different component every inspection so all components are inspected over the life of the asset)
- Run to failure (no interval)
- In response to an extreme event or the presence of an overt condition below the technical evaluation condition
- Changes in process conditions or load-state, such as increased temperature and or the advent of persistent cyclic loading
- Sampling of multiple tanks with similar operating service and structural details can be used to justify extending inspection frequencies.

5.7.4 Monitoring

In addition to the inspection plan described above, monitoring the condition of certain structures, process system parameters and protective systems (e.g., coatings and cathodic protection) is to be taken into consideration for maintaining the overall integrity of the asset. This may involve either a system including electronic devices (e.g., sensors) and its associated recording systems, or manual recording of a parameter, stored in a file (electronic or paper). Additional guidance on the use of monitoring systems can be found in the *ABS Guide for Hull Condition Monitoring Systems* and *ABS Guidance Notes on Equipment Condition Monitoring Techniques*.

Certain threshold values are usually used to provide alerts for anomalies. The threshold values are limits associated with potential integrity issues, such as a high corrosion rate, that require some action to be taken. The load condition of the structures (e.g., tank fill levels) should be monitored to check that no loading patterns will lead to an overstress of the structures. The parameters of the process systems (e.g., fluid composition) should also be monitored to check that the analytical models used to develop the RBI plan are still valid.

When a crack or corrosion is found, some monitoring activities may be required to check the crack propagation and the corrosion condition, especially when the crack or corrosion occurs at critical locations. Generally, the RBI plan will remain unchanged unless specific thresholds are passed during the monitoring activities or inspections. The Owner/Operator is to be responsible for reviewing the results and confirming they do not exceed any defined RBI thresholds.

5.7.5 Compiling the Inspection and Monitoring Plan

Compilation of the overall RBI plan itself is the final step/deliverable task within the development of the RBI Plan Development step. With all the elements now established and quantified, this task is achieved by distilling them into a format or framework that constitutes a recognizable plan. The plan is to be organized in a logical fashion based on identified inspectable units so that it is easily understandable and easily applied, and should clearly identify the associated risk analysis. A sample RBI plan for hull structures can be found in Appendix 2.

This plan is to be integrated within an overall In-Service Inspection Plan (ISIP) for the offshore floating installation that clearly outlines where, when, what and how the asset will be inspected both for structures and systems covered under the RBI plan as well as those covered under Class rule-based inspections.

7 RBI Program Execution

RBI not only attempts to inspect the asset in a risk-prioritized manner, but also seeks to utilize the data gathered during inspections to the maximum benefit, thus maintain the highest level of integrity for the asset. The effective and efficient execution of the ISIP is a prerequisite for a successful RBI. The inspections themselves are one of the primary data gathering sources of an RBI program and the results of each inspection has a significant impact on both the perceived integrity of the asset and the accuracy of the RBI plan updates.

If the execution of the inspection fails to deliver quality results, then a resultant negative impact on the RBI will ensue. This could undermine the RBI program, regardless of the quality of the RBI assessments and inspection planning processes employed. The success or failure of the whole RBI program largely hinges on this particular activity. If inaccurate, spurious or incomplete results are the outcome of inspections, it follows that subsequent analysis, assessment of integrity and the updating of the RBI program could be flawed, impacting the integrity of the asset.

Measures to maintain the inspection execution in a controlled manner are to be devised as part of the RBI program development. These measures are to be introduced prior to implementation of the inspections. Furthermore, an MoC program should be established so that if deviations to the initial plan are required, they will not detract from the overall objective of the RBI program. Additional guidance on developing and managing an MoC can be found in the *ABS Guidance Notes on Management of Change for the Marine and Offshore Industries*.

7.1 Controlling the Inspection Execution

Simple control mechanisms can be applied so that a successful outcome of inspections and collection of accurate and comparable inspection data can be obtained. These may include:

- Forward preparation of clear and concise inspection work scope
- Clear inspection control procedures that should be followed
- Standardization of reporting formats
- Use of qualified and competent personnel
- Use of quality inspection equipment with controlled calibration
- Clear anomaly acceptance criteria and reporting mechanisms
- Clear MoC program that allows flexibility to respond to findings on a real time basis
- Responsibilities matrix with appointed roles
- Clear safety guidelines and policies

One commonly employed method of exerting improved control over the inspection program is to compile and issue the planned inspection work scope as formal inspection work packs. These work packs are then issued to the inspection technicians who will perform the inspections. The format of the inspection work packs should be designed in a way that is easy to understand and follow, and should be self-contained. Included within should be copies of all of the necessary information such as drawings, procedures, test locations, inspection methods, reporting sheets, calibration logs and required anomaly reporting forms. These work packs act as the inspection instruction, specifying the goals set for the inspection program and how to affect the program in the safest, controlled manner.

The inspection work packs should fully reflect the inspections as dictated by the plan and it is essential that this program be followed in full.

There may be instances that require deviation from the initial planned work scope (i.e., where results of inspection dictate a change in emphasis, such as severe anomalies or unexpected findings). In such a case, the developed inspection work packs should have sufficient flexibility and provide instructions to allow for further inspection to assess the condition of the defective components. However, where such deviations occur, the method specified is to be to the same standard of quality and control as those applied to the initial work scope. If such anomaly-driven events occur, these additional activities are not to be at the expense of cutting short the original inspection plan. It is essential that once these unplanned anomaly assessment inspections are completed, the inspection plan returns to the original RBI inspection scope. Any additional inspections performed in support of anomalies are to be captured and documented after they are completed and fed back into the RBI update process.

7.3 Evaluation of Inspection Results

Once inspection activities for a given set of components is complete, an evaluation is to take place to determine whether anomalies are potentially significant to the integrity of structures or process systems and whether any action is required to address anomalies, revisit assumptions on degradations and modify future inspection scope, frequencies or methods.

7.3.1 Anomalies

Anomalies are of immediate concern since they may represent a deficient condition. When anomalies are found, an assessment is to be conducted to determine which of the following actions are required:

- Re-inspection to resolve data capture, measurement or input errors
- Additional inspections including broader coverage and possibly more invasive techniques to refine the scope of the anomaly
- Technical analysis of the system or component to determine its suitability for continued service
- Modification of the RBI plan to include increased inspection intensity with respect to scope and/or frequency (e.g., examination of similar items earlier than previously planned).
- Design of repairs to restore the system or component to safe operation
- Repair prioritization based on the risk assessment results

Once the anomaly has been resolved, the RBI plan is to be updated. Similar components are to be reviewed for susceptibility to the same anomaly, inspection frequencies may need to be modified, and operational changes may be appropriate to reduce the likelihood of future occurrences.

Sometimes, more sophisticated analysis methods are required to evaluate severe anomalies. The selection of which method to apply will vary. The analysis method to be applied will usually be specific to the type and nature of the defect under evaluation. Software and engineering tools such as fracture mechanics (FM), finite element analysis (FEA), corrosion modeling/prediction, FFS, spectral fatigue analysis (SFA) and dynamic loading assessment (DLA) are all acceptable methods that may be applied. The above range of analysis tools, although not comprehensive, would likely cover most deterioration mechanisms encountered within offshore oil and gas production.

7.3.2 Trending of Results

One important function of a sustaining RBI program is the identification and use of observed trends. This is particularly useful for degradation mechanisms such as corrosion and fatigue. The following are to be considered when analyzing the trending information:

- How do these trends compare to previous inspections of the same components?
- How do these trends compare to similar systems or components?
- Are degradation mechanisms proceeding more quickly or more slowly than anticipated?
- Are damage mechanisms occurring that were not part of the original RBI program development?

This trending information should be reviewed after each inspection is completed.

The methods by which data may be processed prior to investigation of trends should be considered. In many cases, pre-processing data such as averaging of values may be detrimental and may effectively mask otherwise observable trends. Caution should be applied when other than raw values are analyzed or trended.

9 Data Management and RBI Program Updating

All the relevant data obtained from the inspection and monitoring activities are to be recorded and managed appropriately. Computer software and the use of virtual models and digital twins are common tools in use for managing such programs and are recommended to store and analyze the data.

In order to be an effective risk management program, the RBI program is to be dynamic. Continuous feedback loop to improve the program will increase the confidence levels in the condition of the installation and the RBI effectiveness.

Because the data around which the RBI is based changes over time, the RBI program is to be updated periodically and at relevant stages in the life of the installation. The updating may include re-confirmation of the risk assessment, risk ranking and inspection plan.

Consideration of increased inspection history, observed industry advances/ knowledge and experienced trends for degradation will add value to the updating process. If quantitative approach is used, a Bayesian updating approach can be used to update the probability of failure taking into account the findings from the inspection and monitoring activities.

Examples of changes to be considered to the RBI program are:

- Revised prioritization of the risk-based on frequency changes or additional failure mechanisms
- Revised or different inspection techniques to increase confidence in results
- Revised inspection frequency and/or scope



SECTION 3 RBI Plan Development for Hull Structures, Mooring Systems and Riser Systems

1 General

This Section provides additional details on the development of an RBI plan for hull structures, mooring systems and production riser systems. Topsides processing systems are discussed in Section 4. It is important to note that the development of an RBI plan for hull structure is often influenced by both likelihood and consequence of failure by proximity to various topside process equipment and systems and should be considered during the development process.

Details on how RBI can be incorporated into an overall integrity management program for offshore structures and systems is further described in relevant industry publications such as API RP 2SIM for fixed offshore structures, API RP 2FSIM for floating systems, the *ABS Guidance Notes on Mooring Integrity Management*, API RP 2MIM for mooring systems, and the preliminary draft of API RP 2RIM for dynamic risers.

3 RBI Program Specifications

3.1 RBI Scope

A clear definition of the structure components covered by the RBI program is to be developed. The focus for the RBI program in this section are the hull structures as well as the associated mooring and riser systems.

The hull structures include the structure from the bottom plate up to the main deck and including major interfaces with the main hull such as interfaces with the mooring system, riser system, topside modules, deck mounted equipment/machinery, et al. Full consideration for the scope of Class surveys is to be accounted for in the ISIP and the Owner/Operator may decide upon the extent of hull structure to be covered within the RBI program and its impact, if any, on the approach to achieving Class credit. For example, the Owner/Operator of a floating production storage and offloading (FPSO) installation may wish to manage the integrity of cargo block tanks using a RBI program while the remainder of hull remains on an inspection interval and scope as defined by the standard prescriptive rules for survey.

The mooring systems extend from the anchor/pile to the connection to the offshore floating installation (e.g., chain stoppers) including the equipment on deck (e.g., sheaves and winches). The riser systems extend from a subsea structure on the seabed to the boarding valve or pig trap on the installation. The scope of the RBI program will be noted in the vessel record.

Static equipment associated with ship systems (e.g., ballast, bilge, etc.) typically found within hull structure compartments may also be considered within an RBI program. The RBI program development can follow similar methodology for the topsides process systems as discussed in Section 4.

3.3 Information Gathering and Component Grouping

3.3.1 Information Gathering

As mentioned in 2/5.1.1, an RBI program requires appropriate and adequate data to be collected. Without adequate data, a complete understanding of the relevant system expected responses cannot be developed. The objective of the data gathering is to identify factors that will affect the loading, capacity, and ultimately the criticality of the various components that make up the hull structures and the mooring and riser systems. The data collected includes structural drawings, design and analysis reports, operational data, and as-built survey/inspection reports. These documents provide information on the general arrangement of the hull structures, the mooring and riser systems. The design and analysis reports contain vital information relating to the design philosophy, the operational environment, the safety factors used, and the previous service life (if the vessel is already operating).

The operational data may include manuals or other documents indicating how the vessel is to be run, what parameters are to be followed in the operation, and how certain systems or components are intended to perform and/or have performed during its service life. Note that in cases where a vessel is being converted (i.e., has past history) or is in operation when developing the RBI program, the conversion and modification details and analyses, past survey/inspection reports and prior gauging and NDE reports are to be collected and reviewed. The actual conditions of the structure are the key data for RBI program. In addition, as mentioned in 2/5.1.1, if the operating conditions or structural features are outside the existing bounds of experience, the RBI plan is to identify this information and describe how the plan will address these novel or unique attributes.

3.3.2 Component Grouping

A typical hull structure consists of many components and each of them play a different role. For hull structural components, structural drawings and analyses that detail the design are used in the selection of appropriate groupings. In the case of marine and offshore structures, the ability to group structures into like components depends on a combination of the function of the structure and its ability to be isolated from other parts of the structure during inspection. For example, tank service similarity and loading similarity are usually considered for component grouping of hull structures.

- i) Examples for the component grouping of ship-type hull structures could include:
- Deck
 - Void spaces
 - Pump rooms
 - Engine rooms
 - Slop tanks
 - Storage tanks
 - Ballast tanks
 - Miscellaneous tanks (i.e., fuel, lube oil, fresh water, etc.)
 - Water tight compartments
 - Major interfaces to the main hull (e.g., brackets, gussets, doubler plates, and porches.)
- ii) Examples for the component grouping for offshore column-stabilized installation or tension leg platform (TLP) could include:
- Topside deck/deck box
 - Pontoon water ballast tanks
 - Pontoon void tanks
 - Pontoon miscellaneous tanks (i.e. fuel oil, fresh water etc.)

- Topside module supports
 - Pontoon access tunnels
 - Column water ballast tanks (if any)
 - Column storage tanks (if any)
 - Column void tanks
 - Column access trunks
 - Chain lockers
 - Other major foundations
 - Horizontal braces, Vertical braces, (if any)
 - Tendons and tendon connections (for TLP)
- iii)* Examples for the component grouping of Spar installations could include:
- Topside deck
 - Hard tank
 - Ballast tanks
 - Void spaces
 - Center well
 - Miscellaneous tanks (i.e., diesel oil, drill water, methanol storage, etc.)
 - Truss
 - Soft tank
 - Strake
 - Fairlead
 - Heave plates
 - Major interfaces (e.g., SCR porches.)
- iv)* These components of hull structures can be further divided into major structure elements for inspection:
- Bulkheads
 - Side structures
 - Bottom structures
 - Girders
 - Stringers
 - Web frames
 - Stiffeners
 - Plate panels
- v)* For the mooring systems, typical component grouping could include:
- Mooring line
 - Chain, wire rope, synthetic rope, or a combination
 - Clump weight
 - Spring buoy

- Connecting hardware (shackle, swivel, other connectors)
- Chain jewelry
- Winching equipment
 - Windlass
 - Chain jack
 - Winch
 - Fairlead and stopper
- Anchoring system
 - Drag Embedment Anchors
 - Pile Anchors (driven, jetted, drilled and grouted)
 - Dynamically installed piles
 - Suction pile and Suction Caisson
 - Gravity Anchor
 - Plate Anchor (drag embedded and direct embedded)
- vi) For production riser systems, typical component grouping could include:
 - Riser pipe
 - Riser joint
 - End fitting (for flexible risers) / connector
 - Bend stiffener (for flexible risers)
 - Tensioning system and special joints
 - Flexible joint
 - Stress joint
 - Tensioner/air can (for top tensioned risers)
 - Tensioning joint (for top tensioned risers)
 - Telescopic joint (for top tensioned risers)
 - Buoyancy tank (for hybrid riser systems)
 - Tether chain (for hybrid riser systems)
 - Goose neck assembly (for hybrid riser systems)
 - Top riser assembly (for hybrid riser systems)
 - Bottom riser assembly (for hybrid riser systems)
 - Attachments and supports, if any
 - Buoyancy/ballast module
 - Vortex Induced Vibration (VIV) suppressor
 - Riser guide
 - Deadweight support
 - Mid-water arch and its associated anchor and anchoring line or tether
 - Pigging system, if any
 - Pig launcher/receiver

3.5 Establishing Baseline and Fitness for Service Assessment

For existing vessels that have no or limited data, the initial step towards developing an RBI plan will include some form of inspection data gathering (baselining), coupled with a FFS (on a facility coming into Class) assessment using the data to confirm the current condition (e.g., type of corrosion, remaining thickness, crack location and size, coating breakdown, and other damage mechanisms) so as to eliminate unknowns.

Methodologies for conducting gauging surveys and FFS assessments on existing structures such as ship-shape and non-ship-shape hulls and mooring systems are available in *ABS Guidance Notes on Life Extension Methodology for Floating Production Installations* and *ABS Guidance Notes on Mooring Integrity Management*. For the baseline and FFS assessments of riser systems, reference may be made to the preliminary draft of API RP 2RIM.

3.6 Design Analysis (Global and Local Strength and Fatigue Analysis)

The results from both strength and fatigue structural analyses are necessary to develop a comprehensive RBI program regardless if it is qualitative-based or quantitative-based. These results can be obtained from the original design analysis reports or the fitness for service assessment (if required). Like the data collection effort, these results form an essential segment of the program foundation.

The results of structural analysis allow the identification of specific critical components of the structures that are more prone to high stress levels or high fatigue damage, so that they can be targeted in the inspection plan. In addition, the structural analysis facilitates the development of reliability models used to predict future response and select appropriate inspection intervals.

For the qualitative risk assessment, remaining strength and fatigue are the two primary factors influencing the likelihood of a failure. For the quantitative approach, the analysis results are typically used to identify the most critical components and connections. Once these locations are identified, loadings and their induced stresses are extracted from the analysis results to conduct the structural reliability calculations.

Due to the importance of the design analysis, a summary of the key results is to be provided in the RBI documentation. The results are to clearly identify the most critical locations for strength and fatigue.

3.7 Risk Assessment and Risk-Based Prioritization

As mentioned in 2/5.5, both qualitative and quantitative methods can be used for the development of RBI programs. Both methods use similar information; however, the quantitative approach has additional steps which typically utilize structural reliability techniques to further enhance the program capabilities and guidance, such as providing additional details on inspection frequency, scope, methods of inspection, and scope expansion when anomalies are identified.

The quantitative-based approach tends to represent the more rigorous method, providing a first principles basis for the integrity program. Generally, as the rigor of the method increases, there is less reliance on Rule-based guidance. Which approach is the best alternative is dependent on the installation particulars, site specific requirements and overall needs of the Owner/Operator.

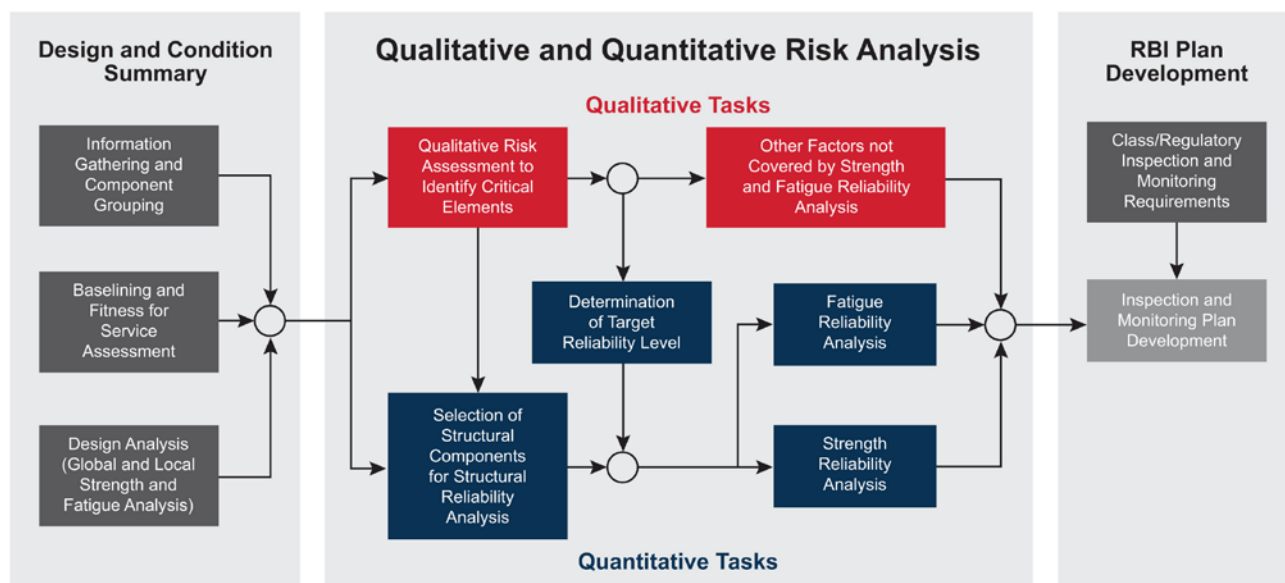
3.7.1 Risk Assessment of Hull Structures

Section 3, Figure 1 shows the typical “building blocks” of a typical Quantitative-based approach for hull structures. The only difference between the quantitative and qualitative approaches is the strength and fatigue structural reliability tasks. A typical Qualitative approach generally would not include structural reliability analysis.

ABS recognizes that Owner/Operators may include other building blocks or tasks not shown in the figure, such as trending data or cost benefit analysis that may enhance the basis and guidance for an RBI program. While various techniques/methods may be applied, the suitability and appropriateness of any selected method is to be agreed upon by ABS. If the methodology used deviates from common industry practice or standards, a suitable technical explanation on the adequacy of the methodology is to be included in the submittal for ABS consideration and approval.

Note that ABS does not endorse any particular method or approach. As a result, each RBI plan application may be unique and will be reviewed and approved accordingly.

FIGURE 1
Typical Building Blocks for Quantitative-based RBI Development for Hull Structures



The following sections provide information on the qualitative and quantitative risk analysis, shown in Section 3, Figure 1. These tasks form the basis for the inspection scope and frequency as well as to provide adequate instruction to the personnel executing the plan.

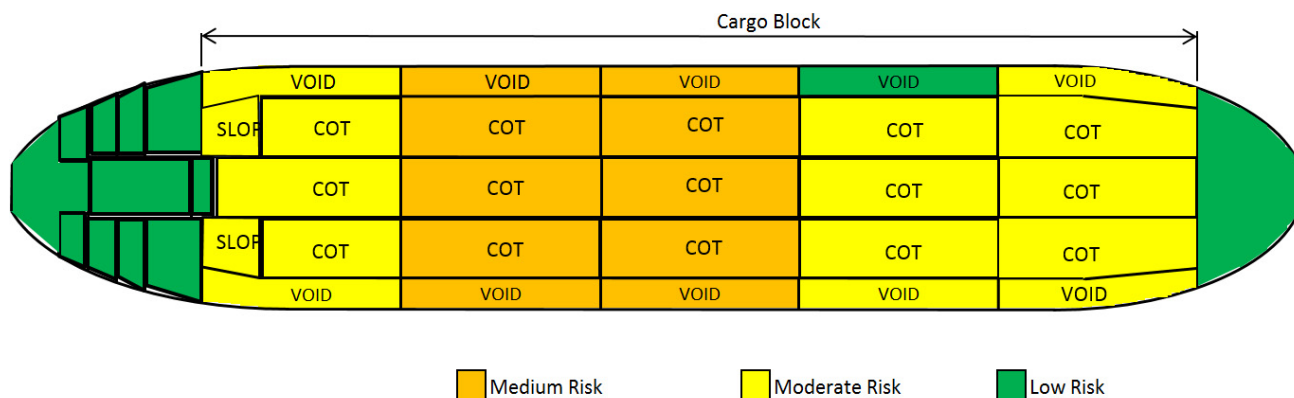
3.7.1(a) Qualitative Risk Assessment. Typically, the qualitative risk assessment is conducted similar to a hazard identification (HAZID) exercise in which a team of subject matter experts and personnel familiar with the installation step through the system identifying deterioration scenarios and risk ranking. The focus of the assessment is on the inspection-preventable hazards.

The qualitative risk assessment serves four objectives:

- i) Identify critical elements within the structure. This is a key objective of the qualitative risk assessment.
- ii) Identify the potential consequences related to damage. In cases where quantitative analysis is being conducted, the consequences are typically used to set the structural reliability targets or thresholds, which will influence the required inspection intervals.
- iii) 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.).
- iv) Identify other factors that may impact integrity not necessarily covered by the fatigue and strength analysis (e.g. potential local failures such as leak potential).

The qualitative risk assessment captures information related to features of the installation, potential deterioration scenarios, potential consequences, safeguards, and risk ranking. The risk ranking can be performed by using a pre-defined acceptable risk matrix agreed upon by the analysis team. An automated or semi-automated scoring method may be used to rank the structure components. Scoring factors and weighting used in the scoring method should be clearly defined and documented. Essentially, the risk assessment identifies what to inspect and why to inspect. It also provides a process to catch inspection-preventable scenarios that could impact the hull integrity in the plan development, as complete as possible. Due to the importance of this task, the level of detail and quality of the assessment are critical. Appendix 3 shows a sample risk assessment worksheet for hull structures. Section 3, Figure 2 shows a sample result of risk ranking for hull structure components.

FIGURE 2
Sample Result of Risk Ranking for Hull Structure Components



3.7.1(b) *Quantitative Risk Assessment.* In addition, a structural reliability analysis may be carried out as an enhancement to the qualitative-based approach. Structural reliability analysis uses the strength/fatigue analysis results, coupled with degradation mechanisms (e.g., corrosion rate, crack propagation parameters, etc.), to calculate time-varying structural reliability index of the selected structures. The results are compared to the reliability targets or thresholds to identify how often specific components should be inspected.

Typical reliability analysis defines a limit state function in the form of difference between the structural capacity and the load. The failure probability is calculated as the probability when the limit state functional value is negative. The capacity term can be the hull girder strength, plate panel buckling strength, or allowable crack size. The load term can be the hull girder bending moment, plate panel stress, or stress ranges for crack growth. The fatigue reliability analysis of structures may use probabilistic fracture mechanics.

The capacity terms (e.g., buckling strength for a plate panel) should be taken from recognized sources, such as ABS Rules and Guides, industry standards and industry common practices. For example, the capacity term for the buckling strength of a plate panel is a probabilistic quantity because of plate thickness variation due to corrosion. In addition, appropriate modeling uncertainties should be applied to reflect the accuracy of capacity equations.

The acceptance criteria (target reliability) for the calculated reliability for structural components can be derived from a risk study on the considered structure based on their consequences of failure identified as part of the qualitative risk assessment. In general, higher target reliability is assigned for structural components with high consequence of failure. For the hull structures, the target reliability generally applies to the reliability of specific types of structural components and their associated failure modes, with the largest component being the overall hull girder and the smallest component relating to an individual unstiffened plate. For the largest component (i.e., hull girder), failure would result in catastrophic consequences and thus a high reliability target value should be assigned. For smaller and less critical components lower reliability target values are tolerable since the resulting consequences are significantly less severe.

Then, the results from the structural reliability analysis can be combined with the results from the qualitative risk assessment to determine the inspection scope and frequency.

3.7.2 Risk Assessment of Mooring Systems

Similar to the hull structures, both qualitative and quantitative methods can be used for the development of mooring RBI programs. The risk assessment approach for the mooring systems can follow the same process as described for the hull structures. The selection of the risk assessment approach depends on the complexity of the mooring system and the quality of the available data. Section 3, Figure 1, which shows the key tasks that take place as part of the RBI development of the hull structures, is also applicable to mooring systems.

For the qualitative risk assessment of mooring systems, the main objective is to (1) identify mooring components that have high failure rates, (2) identify mooring components that can result in high consequences, and (3) increase the inspection scope/location for those components, while reduce for the others. For example, if top chain link is found to be of high failure rate, then the scope of inspection may be expanded to include every single top chain link. In addition, the information obtained from the qualitative risk assessment helps in identifying appropriate inspection methods based on deterioration scenarios and experience.

In case additional quantitative analysis is deemed 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. The reliability analysis uses the mooring design analysis and degradation models to forecast a reliability index for the mooring lines. The reliability index is related to the probability of failure based on reduction in strength or fatigue life.

Mooring strength reliability analysis involves the uncertainties associated with chain or line capacity, corrosion rate, the load from the wind, current and wave, as well as the model uncertainty. The capacity calculations involve the minimum break strength considering the annual corrosion rate for mooring chains. The load calculations involve the metocean criteria, their annual maximum distributions, and their relationship to the maximum mooring line tension. Fatigue reliability analysis involves the uncertainties associated with the S-N or T-N fatigue curve, stress range, and the model used.

The reliability results are used to provide guidance on inspection intervals as well as inspection thresholds or triggers. Inspection thresholds provide guidance on actions or activities, such as additional inspections or monitoring, when specific deterioration or damage is observed or loading conditions are experienced.

3.7.3 Risk Assessment of Risers

The risk assessment approach for production riser systems can follow the same process as described for the hull structures. Both qualitative and quantitative risk analysis shown in Section 3, Figure 1 are acceptable.

Risk assessment of risers includes identifying failure modes along with their consequences of failure and likelihood of occurrence. Risk matrix can be set up to estimate the risk level for an individual riser or a group of similar risers. Additional guidance on carrying out risk assessments for risers can be found in the preliminary draft of API RP 2RIM.

3.9 Inspection and Monitoring Plan Development

The final stage is to develop an initial RBI plan for the relevant systems. The RBI plan for hull structures, mooring systems and riser systems can be developed in parallel using a similar process. One key element of the RBI plan is the development of a general rule set for combining the results of the structure analyses, qualitative risk assessments, and structure reliability analyses. How this information is aggregated to provide a defensible basis for the inspection plan is to be clearly documented. The main contents that should be included in the RBI plan can be found in 2/5.7.

For qualitative approaches, the initial inspection and monitoring plan for the structure components can be developed based on the risk assessment and the risk ranking results.

For quantitative approaches, the strength and fatigue reliability analysis results provide the primary basis for setting the inspection intervals and scope. For some components, the RBI plan may be driven by strength reliability and in others by fatigue reliability. These drivers are then coupled with the qualitative risk assessment results. In addition, other factors such as sampling inspections, outstanding issues, and general class requirements may be used to adjust the inspection intervals and scope. Similar to the scoring method, the method is to be clearly defined to prove that the approach provides justifiable results. Note that for both examples, engineering judgment is required in setting the rules and relationships of the methods.

Note that this is an initial plan as subsequent inspection results may warrant changes/updates to the plan over the life of the asset. Generally, this inspection and monitoring plan (i.e., the RBI plan) is intended to be the primary working document used to plan the inspection and monitoring activities. Detailed inspection work packs are then developed as a supplement to the inspection and monitoring plan to provide guidance on executing the inspection and monitoring activities.

5 Submittal Requirements

A description of the approach and methodology to be used for the development and implementation of the RBI program is to be submitted to ABS for review prior to detailed work being carried out.

Appendix 4, Table 1 lists the detailed information that should be included in the methodology document submittal. The submittal requirements for the RBI plan development and RBI program management for hull structures, mooring and riser systems are listed in Appendix 4, Table 2.



SECTION 4 RBI Plan Development for Topsides Process Systems

1 General

The RBI of topsides process systems focuses on maintaining the integrity of pressure equipment and minimizing the risk of loss of containment. This Section is intended to provide additional guidance on the development of an RBI plan for the topsides process systems to supplement the RBI program development process described in Section 2. It is noted that a similar methodology can also be applied to the static equipment associated with ship systems (e.g., ballast, bilge, etc.) typically found within hull structure compartments.

The guidance provided in this Section is compatible with industry standards such as API RP 580 and API RP 581 which are widely applied to specify RBI for process systems. API RP 580 outlines the basic principles and general guidelines to develop and maintain a RBI program; and API RP 581 provides detailed quantitative methods to determine a RBI plan that is in line with API RP 580. Although the general principles introduced in API RP 580 and API RP 581 can be applied to offshore topsides process systems, the estimation of likelihood and consequence of equipment failure needs to be adjusted since API RP 581 focuses on onshore refinery plants.

3 RBI Program Specifications

3.1 RBI Scope

This Section is specifically targeted at topsides process systems on floating offshore installations. This section specifically covers:

- Pressure vessels
- Pipe and piping components
- Heat exchangers
- Storage tanks
- Boilers and heaters
- Pressure relief devices
- Pump and compressor casings

Note that the scope of the RBI plan may vary from the entire process unit to a single piece of equipment (e.g., pressure relief valve). The Owner/Operator may select specific parts of the process systems that will be covered by RBI while the other parts remain covered by pertinent rules for survey.

3.3 Information Gathering and Component Grouping

3.3.1 Information Gathering

The topsides processing systems for offshore installations are defined and presented by means of Process Flow Diagrams (PFDs) and Piping and Instrumentation Diagrams (P&IDs). These systems are sub-divided into sub-systems, components and, as applicable, various levels of sub-components. The various tiers of sub-components to systems are known collectively as the Asset Hierarchy. In addition to the Asset Hierarchy, the design reports, the operating and processing data, materials of construction, and the inspection and maintenance records all provide useful information to estimate the potential damage mechanisms and failure modes, the probabilities of failure, and the consequence of failure.

Typically, the following information is to be prepared for developing the RBI plan:

- i)* Design and fabrication information
 - Equipment list
 - Design basis for the equipment
 - Process Flow Diagrams (PFDs)
 - Piping and Instrumentation Diagrams (P&IDs)
 - Process and Safety Diagrams (PSDs)
 - Emergency shutdown (ESD) logic diagrams
 - Piping data sheets
 - Vessel sheets
 - Materials of construction
 - Detection and monitoring systems
 - Damage mechanism rate estimate
 - Coating, cladding, and insulation data (as built)
- ii)* Process and operating data
 - Operating procedures
 - Process fluid composition and quantity
 - Operating parameters, like pressure, temperature, etc.
 - Operating logs and process records (if applicable)
- iii)* Past inspection records
 - Amount and type of inspection
 - Past repairs and replacements history
 - Coating, cladding and insulation condition
 - Estimated corrosion rate (if applicable)
- iv)* Past risk assessment studies (if available)

In addition to the information mentioned above, the Owner/Operator may also consider other factors when developing the RBI plan, such as the business interruption cost and equipment replacement cost. The amount of data needed depends on the RBI approach used. For a qualitative RBI approach, only a high-level broad range of data are required. More detailed information and data are needed for a quantitative RBI approach to simulate the physical model of the hazard scenarios.

3.3.2 Component Grouping

The inspectable units for topsides equipment are individual pressure vessels and portions of piping systems with similar metallurgy, nearly constant fluid conditions, environmental and degradation conditions. These are easy to define since the equipment is usually discrete, their load conditions are well known and the consequences from the release of the fluids are handled routinely with a variety of commercially available consequence assessment models. The Asset Hierarchy can be used as a starting point for grouping common equipment into Inspectable Units.

For process systems, there are many ways to establish the basis for component grouping. One of the simplest methods is to establish groupings based upon similarity of service. This may be relatively simple to achieve, as operational information and practices such as isolation and lock down philosophy are usually readily available. By using data from the asset hierarchy and related safety management schemes, many of the issues that RBI will seek to establish, such as high/low pressure interfaces, safety relief and process phase interactions (process flow diagrams), will already be available, as will many of the component relationships.

Inspectable Units may be determined based on some or all of the factors including but not limited to:

- Operating conditions (operating temperatures and pressures)
- Service conditions and composition of conveyed fluid
 - May also include corrosion rates if corrosion predominates
- The major accident potential of conveyed fluid
 - Flammability, explosiveness, toxicity, etc.
- Internal pressure, and the ratio of diameter to nominal wall thickness
- Materials of construction,
- Location on the installation such as within hull tanks or confined spaces

For liquefied natural gas (LNG) process equipment, cryogenic service conditions may be a driving factor in the definition of the associated piping circuits. When considering susceptibility to corrosion for example, stainless steel process piping at cryogenic temperatures may not be expected to be susceptible to external atmospheric corrosion. However, austenitic stainless steels may for example be susceptible to Corrosion Under Insulation (CUI).

3.5 Baselineing and Fitness for Service Assessment

For existing process systems that have no or limited data, the initial step towards developing an RBI plan will include some form of inspection data gathering (baselineing), coupled with a FFS assessment using the data to confirm the current condition (e.g., type of corrosion, remaining thickness, crack location and size, coating breakdown, and other damage mechanisms) and eliminate unknowns. A number of industry codes and standards for conducting FFS assessments on process systems are available. The most widely applied industry codes for FFS assessment are API 579-1/ASME FFS-1.

3.7 Risk Assessment and Risk-Based Prioritization

Risk assessment is a critical component of RBI planning and has the objective of prioritizing the most susceptible equipment by assigning a higher or lower risk value to the equipment. The risk value is assigned based on the assessed risks of failure of the equipment caused by the different predominating degradation mechanisms.

The risk assessment begins with the identification of equipment damage mechanisms, failure modes and the associated accident scenarios. Then, the probability of failure (POF) and the associated consequence of failure (COF) are estimated. The POF and COF can be estimated by a qualitative or quantitative approach, or by using a semi-quantitative approach. The risk associated with a damage mechanism can be estimated by the combination of POF and COF.

If any risk studies have been previously carried out for the topsides process systems [e.g., Quantitative Risk Analysis (QRA)], the COF may be still valid and can be re-used. However, the POF needs to be changed based on the specific degradation mechanisms since generic failure rate data may be used in these studies.

3.7.1 Damage Mechanisms, Failure Modes, and Process Accident Scenarios

Identification of damage mechanism and failure modes for the process equipment is a critical step in the risk assessment. Individuals with experience and technical knowledge in materials and corrosion should be involved in this process. The process conditions and the materials of construction should be combined together to identify the potential damage mechanisms. The main damage mechanisms for process systems include corrosion, erosion, cracking, mechanical and metallurgical damage.

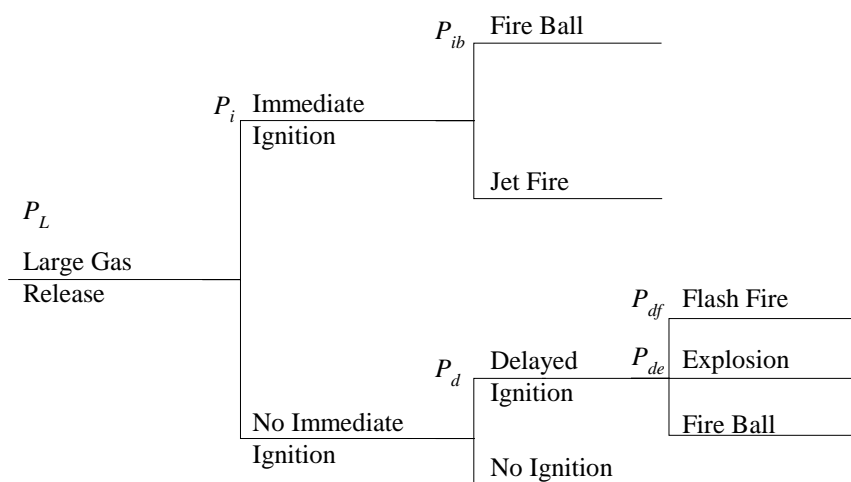
Once the damage mechanisms are identified, the associated failure mode can be identified. For example, localized corrosion may result in a pinhole type leak. As mentioned earlier, the main focus of the RBI for process systems is the loss of containment due to deterioration. Therefore, the risk assessment for the process systems should consider the following failure modes:

- Pinhole/small leak
- Medium leak
- Large leak
- Rupture

Before consequences and risk can be evaluated, a specific *event* should be described. It is common in risk assessment to describe the consequences of a leak as initiating with the leak itself, which produces a chain of events that may or may not lead to fire or explosion, along with the “ultimate” consequences of injuries, equipment or structural damage, environmental impact, and economic loss.

An event tree approach can be used to show the chain of events starting with the initiating event and ending in a final event, usually called the *end state*. Section 4, Figure 1 is an example of an *event tree* for a large gas release. These events should consider operating conditions and individual process section characteristics; and should include various leak sizes used as initiating events. Hazard Identification (HAZID), Failure Mode and Effect Analysis (FMEA), Hazard and Operability (HAZOP) analysis may be used to identify the relevant events.

FIGURE 1
Example Event Tree for a Large Gas Release



P_L – Probability of a large hole (large leak)	P_i – Probability of immediate ignition
P_{ib} – Probability of a fire ball	P_{de} – Probability of an explosion
P_d – Probability of delayed ignition	P_{df} – Probability of a flash fire

Note that there are many possible end states than can result from an initiating event. Each end state has a unique likelihood of occurrence that depends on the frequency of each of the initiating events and the probability of *intermediate events* that lead to that particular end state. The example event tree is much simplified from a “real world” case where other intermediate events can occur.

For example, there is the early detection of the leak, the activation of water sprays, the activation of an emergency isolation and blowdown system, each with its own probability of occurring or failing to occur. The event tree could also be extended to other end states resulting from escalation and evacuation.

The entire set of events beginning at the initiating event and ending at a specific end state is called a *scenario*. For special applications such as RBI, it is common to refer to the risk of a collection of scenarios. For example, if the risk of a corrosion-induced leak is to be determined, then all the scenarios that can occur from all leak sizes are needed to fully describe the risk.

The risk of the individual scenarios can be summed to determine the total risk. One by-product of the use of RBI is the identification of intermediate events that offer potential for risk reduction by reducing the likelihood or consequence of one or more end states, such as gas detectors that automatically trip the emergency shutdown system and close isolation valves.

3.7.2 Probability of Failure Assessment for Process Systems

POF is likelihood that a piece of equipment will fail at a given time. POF is one of the most important factors that affects the selection of inspection frequency. POF is assessed for individual pieces of equipment by looking at the potential damage mechanisms it could be susceptible to. As previously discussed, both qualitative (judgmental) and quantitative (analytical) risk assessment approach can be used to set the RBI plan.

For a qualitative approach, the probability of failure may be developed based on engineering judgment. The probability of failure of equipment under consideration may be categorized by several groups (e.g., high, medium, and low or scores from one to five). The qualitative approach also provides a way to qualitatively and quickly “screen” equipment to identify those that need a more detailed quantitative analysis.

Depending on whether sufficient data exists, there are mainly two quantitative approaches to estimate the POF: based on available data or based on analytical degradation models. The available data can come from the following sources:

- Past inspection data
- Laboratory and/or in situ testing
- In-service monitoring
- Data from similar equipment
- Generic industry data

There are several databases of equipment failures in the oil and gas industries (e.g., OREDA). Data from such sources is referred to as “generic” failure data, and is often used in risk assessments to describe the failure rate of a “typical” component. For a particular installation, there may be reason to believe the failure rates may be higher or lower than those reported in databases. In such cases, this “generic” data needs to be adjusted to the particular equipment by increasing or decreasing the failure rates based on equipment-specific information.

The “generic” failure frequencies are averages of the failure frequencies of all members of a population, and the data do not provide information regarding any individual component. In addition, such databases rarely record the cause of failure. A model of the damage mechanism can be created for each type of failure that can help identify which components are more subject to one or more mechanisms.

The actual amount of equipment damage can also be estimated by analytical models (from rate and age). Many engineered structures such as pipes, tanks and pressure vessels all have a maximum allowable amount of corrosion, called a “corrosion allowance” or “wastage allowance”. These allowances can be used to set up a limit state function to calculate the probability of failure.

The time anticipated for the wastage allowance to be consumed (or a crack to grow to a critical size) is often referred to as the “remaining life”. Note that this indicates that at some time the equipment or structures will no longer conform to the design requirements, and not that they will fail at the end of the “life” determined by this method. Generic or specific degradation models may be adopted to predict the remaining life for a given component. A distribution rather than a deterministic value of degradation rates may be provided by these models.

It should be noted that confidence in the values used for analysis is always to be included. In highly quantitative analyses, this “confidence” may be quantified as a standard deviation or some form of scatter in the distribution of values used. Accounting for possible errors in evaluations is one of the keystones of RBI.

3.7.3 Consequence Assessment for Process Systems

Consequence is the outcome of the failure of the process equipment. Consequence analysis should address different failure modes (i.e., leak hole size). The distribution of hole size depends on the damage mechanisms. Usually separate event trees are developed for different hole sizes. Every installation has its own unique characteristics, and when developing an RBI program, these characteristics should be considered.

In order to assess the consequences of each accident scenario, the severity or impact should be determined for each case. An important step in the analysis is to identify what consequences are to be evaluated and measured, either qualitatively or quantitatively. These might be harm to people, property loss, environmental damage, business interruption or all of these. Through consequence analysis, the lowest ranked items can be partially or fully screened out from the inspection program. This is an acceptable practice, as those items that have negligible consequence, irrespective of their probability of failure, do not have a significant impact on the asset’s integrity.

Qualitative consequence analysis are usually based on engineering judgment. A consequence category may be assigned for the equipment (e.g., high, medium, and low or scores from one to five). There may be a need for more categories so that any one category is not too broad to be useful. Qualitative consequence analysis can be assessed by performing hazard analysis activities such as HAZID, FMEA, HAZOP analysis, or function failure analysis. If the purpose of the study is to simply “screen” the equipment or structures by risk category, then it may be sufficiently accurate to group production areas together with respect to consequence of an equipment failure.

If a more detailed consequence analysis is needed, then quantitative models can be used. Some of the analytical studies typically employed are gas dispersion analysis, fire and explosion analysis, radiation and thermal impacts analysis, cryogenic spill analysis, etc. Analysis tools such as Computational Fluid Dynamics (CFD) and/or FEA models may be utilized as part of the assessment process.

Tools used are to be documented, utilized appropriately, and analysis performed by qualified personnel. Documentation should include inputs, assumptions, boundary conditions, results, sensitivity, etc. For the example case of fire and explosion, the impact of these can be quantified using sophisticated modeling software to determine, for example:

- The rate and velocity of release of a given gas or liquid through a given hole size at a particular pressure and temperature
- The dispersion of gas in the atmosphere depending on the properties of the gas and a given set of weather conditions
- The spread and evaporation rate of liquids that leak, and also the effects of a gas condensing in the air and raining out as fluid
- The tendency of the leaking fluid to ignite upon encountering an ignition source

- Whether a fire or explosion or both result from ignition and the type of fire or explosion
- The heat produced by a fire as a function of distance from the fire, or the overpressure from an explosion given as a function of distance from the explosion source

Once these calculations have been made, the impact of the failure can be expressed in terms of three consequence types:

- Safety
- Environment
- Economic

Safety consequences include immediate harm to asset personnel or immediate surrounding public.

Environmental consequences can be defined as damage to the immediate ecosystem or landfill. The extent of environmental impact and ultimate rectification costs is directly associated with the consequence of the release or failure of a major system or component. The combination of cleanup costs, regulatory fines and loss of public relations may be evaluated as a factor within the RBI consequence evaluation, as well as the long-term impact on the environment for each release scenario. Relevant information that is needed to determine consequence includes fluid type, phase, release rate, inventory release, toxicity and flammability.

Economic consequences include property protection, damage to or loss of critical capital equipment, production outage or reduced availability of systems. Equipment availability has a very high influence over the economic factor of the consequence determination. Business interruption is usually the costs that are associated with failures of equipment on an offshore installation. The amounts of downtime and equipment repair are costs that all offshore facilities seek to reduce. If businesses have an effective inspection plan, that helps to reduce shutdown frequency and reduce costly repairs or replacements.

Consequences may vary significantly, ranging from almost inconsequential to totally catastrophic. It is important to highlight that the evaluation of the consequences for the asset should consider all of its potential modes of operation or states, such that the worst consequence scenario has been identified and accounted for.

Once consequences have been determined for a component or system, they remain relatively static. Only where a major change in the use, service, process parameters or location of the equipment is enacted would the consequence factor change. If and when such change events occur, a reassessment of this factor is required.

Examining all of the above calculations, the analysis appears to be very quantitative, but clearly a great deal of judgment (qualitative) should be used in every step along the way. To recap some of these judgments, consider some of the inputs that cannot be known with great certainty:

- The size and shape of the hole
- The likelihood of each size of hole
- The likelihood of ignition
- The effectiveness of detection, isolation and mitigation measures
- The conditions of weather affecting dispersion
- The number of persons within an affected area
- The potential for escalation from equipment/structures in the damaged area
- The impact of escalation on evacuation

It is this mixture of analytical tools with human judgment that results in an analysis that can never be said to be fully quantitative. As mentioned before, most studies can be considered to be “semi-quantitative”. Given the uncertainties listed above, it can be seen that a qualitative study to screen out low risk items from further analysis is often justified.

3.9 Inspection and Monitoring Plan Development

The final stage is to develop an initial RBI plan for the process systems. The inspection strategies should be developed in conjunction with mitigation measures so that all equipment have an acceptable level of risk. One key element of the RBI plan is the development of a general rule set for combining the results of the damage mechanisms, failure modes, and process accident scenarios analyses, probability of failure analyses, and consequence analyses. Methodologies denoting how this information is aggregated to provide a defensible basis for the inspection plan are to be clearly documented. The main contents that are to be included in the RBI plan can be found in 2/5.7.

If a qualitative approach is used to develop the RBI plan, once the risks (i.e., probabilities and consequences) are assessed, the ranking is performed using the risk matrix. The risk matrix allows distinguishing different risk levels which are then used for inspection frequency attribution. In cases where significant variation exists in the safety, environment, and economic consequence categories, separate risk matrices can be used. The inspection interval is chosen based on the minimum inspection interval across the separate risk matrices.

If a quantitative approach is used to develop the RBI plan, the detailed quantitative probability of failure and consequence analyses results provide the primary basis for setting the inspection intervals and scope. Other factors such as sampling inspections and outstanding issues may be used to adjust the inspection intervals and scope. The method is to be clearly defined to verify the approach provides justifiable results. Note that for both examples, engineering judgment is required in setting the rules and relationships of the methods.

5 Submittal Requirements

A description of the approach and methodology to be used for the development and implementation of the RBI program is to be submitted to ABS for review prior to detailed work being carried out.

Appendix 4, Table 1 lists the detailed information that should be included in the methodology document submittal. The submittal requirements for the RBI plan development and RBI program management for the topsides process systems are listed in Appendix 4, Table 3.



SECTION 5 RBI Plan Execution and Updating

1 General

The successful implementation of any integrity management scheme requires the proper execution of inspections and monitoring in the field as well as the review and evaluation of the data. Both aspects are critical to maintain the quantity and quality of the information necessary to inform the RBI program.

The Owner/Operator is responsible for preparing and executing the program, while class is responsible for reviewing whether the program meets the requirements of this guide and its relevancy to assisting in crediting Class requirements, and to confirm that the plan is executed as written in the ABS approved ISIP. The ISIP is to include the structures or systems covered by the RBI plan as well as those covered by the Class rule-based inspections.

In general, the program management entails:

- i)* Monitoring asset integrity and executing inspections as per RBI plan,
- ii)* Coordination and common understanding of inspection scope or work pack and role of Surveyor in the process
- iii)* Reviewing results and evaluating the data,
- iv)* Evaluating anomalies and their resolution (as required),
- v)* Complying with applicable ABS Survey requirements
- vi)* Managing data, reviewing and updating program when inspection results warrant change or when significant changes to the installation occur.

3 Monitoring Asset Integrity and Executing Inspections

The quality of the inspections is dependent on the experience and knowledge of the personnel conducting and supervising the inspection as well as the detailed inspection guidance that is provided to them. Typically, the inspections will incorporate third party inspection companies to execute the specific inspections, such as thickness measurements, CVI, NDE, etc.

These personnel will be supervised by the installation operations personnel and/or Owner/Operators' representatives. They will verify that the inspections are carried out safely and per the inspection guidance that is provided typically in the form of inspection work packs. The Owner/Operator's representative should have a basic understanding of the RBI program, know the predefined thresholds that initiate additional inspections, and be able to communicate these observations to any technical support personnel while the inspection is being conducted. These personnel are also ultimately responsible for making sure the inspections are adequately documented (i.e., all checklists, NDE reports and anomaly reports are completed with ample photos and diagrams).

Detailed inspection guidance is a critical item for those who execute the inspection work. They should also provide the means to document the observations in a complete and repeatable manner. The more guidance provided to the on-site inspection personnel, the lower the likelihood of inadequate data collection or poor/inconsistent quality data. This is important since personnel involved in the management of the program will change over the life of the installation. Clear and consistent guidance is necessary to prevent potential gaps in the data collection.

5 Evaluation of Inspection Results

Monitoring identified by the RBI program is conducted during the operation of the installation. The Owner/Operator are responsible for reviewing the results and confirming they do not exceed any defined RBI thresholds. If they do, appropriate action as per the RBI program is to be taken. Similarly, as inspections are carried out and the data is compiled the Owner/Operator is responsible for reviewing the results as well as identifying and recording any anomalies in an anomaly register which is to be used by the Owner/Operator to track and manage open anomalies.

Records of the items being monitored, and any action taken as a result are to be submitted to the attending Surveyor during the Annual Confirmation Survey.

7 Anomaly Management Plan

The Owner/Operator is to submit an anomaly management plan to ABS for approval both for findings made by ABS as well as those identified by the Owner/Operator. Submission is to be done through the local ABS Survey Office. Anomaly management plans accompanied by engineering justification or modifications will be forwarded to ABS Engineering for review and approval.

The Owner/Operator is to keep current an anomaly register which will be used to track and manage open anomalies. The register is also a useful tool for reviewing past or recurring anomalies in the search for trends and insight into potential future issues, which may warrant updates to the RBI program. The anomaly register is to be made available to the Class Surveyor prior to any scheduled inspections. The register is to indicate which anomalies are open and which ones have been closed and provide the related backup information on how the anomaly was addressed. The Owner/Operator anomaly register will generally correspond with the Class anomalies listed in the installation's survey record.

For example, an installation's RBI program defines the presence of anodes within a cargo oil reception tank as critical to the overall corrosion protection of the tank bottom structure. As a result, an RBI threshold was set, stating if anodes are observed to have wastage greater than 50% then the technical support team should be contacted to evaluate if mitigation is required (e.g., more frequent inspections, installation of additional anodes, etc.). The concern being that if service conditions are very severe, the coatings may be approaching their anticipated service life (i.e., may begin to flake or blister). If the anodes become completely wasted before the next inspection, no back up protection will be present and the potential for excessive local corrosion exists.

Based on the RBI plan, this would be an anomaly warranting entry into the anomaly register. However, this condition would not necessarily warrant a recommendation by Class to conduct some form of mitigation, since at the time of the inspection anodes were present and the coatings were generally in good condition. For an RBI program, Class would record the amount of anode wastage as an Observation, but it would require no specific action since no corrosion issues were observed and the structure remained within Rule-required limits.

Section 5, Table 1 describes the Class anomaly types and how certain types of anomalies are to be addressed under an RBI program. The table describes the three Class anomaly types, the Owner/Operator's responsibilities for each anomaly type as well as example anomalies. All of the described anomalies would be recorded in the Owner/Operator's anomaly register. They may be organized and prioritized as per the Owner/Operator's quality system.

TABLE 1
Class Anomaly Types

<i>Anomaly Type</i>	<i>Description</i>	<i>Owner/Operator Responsibilities</i>	<i>Examples⁽¹⁾</i>
Recommendation	This is an anomaly that is entered into the vessel recorded as a condition of class and should be addressed by the Owner/Operator. <u>Immediate action is required by Owner/Operator.</u>	The Owner/Operator should address the anomaly. The proposed modifications or repairs by the Owner/Operator should be reviewed by the ABS Surveyor and if requested approved by ABS Engineering Office.	[RBI/Class] – Cracks observed within side shell longitudinal bracket to forward water tight bulkhead [RBI/Class] – Corrosion is greater than the renewal wastage criteria
Additional Requirement	This is an anomaly that is in accordance with class rules but requires additional attention at future surveys to maintain class. The anomaly is entered into the vessel recorded and it may be addressed by the Owner/Operator or changes to the inspections may be required. <u>Action may be required by Owner/Operator or inspections may need to be changed.</u>	The Owner/Operator may choose to repair the anomaly. However, if no repairs/mitigation initiated more frequent inspections and/or refined scopes may be required. Additionally, for RBI programs “health checks” may indicate potential gaps in the management of the program that may require changes of the RBI monitoring and inspection plan.	[RBI/Class] – Substantial corrosion (i.e., wastage is 75% of the renewal wastage) [RBI/Class] – Ballast tank coatings in Poor condition [RBI] – SRB bug count monitoring was above the defined RBI thresholds and no indication Owner/Operator has taken necessary actions as per RBI program
Observation	This is a generally a note in the recorded information of the Owner/Operator and the Survey report of something for which no recommendation nor repair need be carried out. Over time, the anomaly may increase in severity if left in current state or the issue continues to occur. <u>No immediate action required by the Owner/Operator.</u>	The Owner/Operator may choose to address the issue but at this time it is not a requirement or condition of class. However, over time it may become a more significant issue requiring action (i.e., become an Additional Requirement or Recommendation).	[Class] – Narrative report describing that scale was noted on the deck plating but no substantial corrosion was found upon removal hence no immediate action needed by Owner/Operator. [RBI] – Surveyor was informed SRB bug count monitoring was once again above the defined RBI thresholds for a period of time and Owner/Operator has taken necessary actions (e.g., increased biocide doses); and since then mitigation bug counts have been below defined RBI threshold.

Note: The examples are intended to illustrate some of the anomaly types that may occur for a typical Rule-based program [Class] or an RBI program [RBI]. For the “Recommendation” anomaly type, generally the anomaly will be covered by both Class requirements and the RBI program.

9 ABS Survey Requirements

9.1 General

9.1.1 Pre-Survey Meeting

Prior to commencing any survey, a pre-survey meeting is to be held. The RBI Plan including the anomaly management plan are to be made available onboard for the purpose of carrying out an on-board survey pre-planning meeting with the attending Surveyor. The following topics are to be discussed during the meeting at a minimum:

- Any variations from the inspection work pack scope made as a result of previous inspections.
- Any findings or anomalies identified by the Owner/Operator or Class that needs to be reviewed.

9.1.2 Survey Execution

Establishment of proper preparation and close co-operation between the attending Surveyor(s) and the Owner/Operator's representatives onboard prior to and during the survey is an essential part of the safe and efficient execution of the survey. The survey execution should follow the *Surveys After Construction* of the pertinent ABS Rules.

9.1.3 Post Survey Meeting

At the post-survey meeting, the following items are to be discussed:

- Any actions required as a result of findings made
- The general health of the RBI program
- Any changes to the RBI program that needs to be evaluated as a result of conditions found
- Surveys completed, and structures/equipment credited towards the Continuous Survey Program

The attending ABS Surveyor is to submit a report confirming the above.

All Class and Statutory surveys and outstanding requirements or deficiencies are available to the Owner/Operator through the ABS Eagle portal. The Owner/Operator may further discuss any Class or Statutory survey requirements with the local ABS Survey Office at any time.

9.3 Baseline Survey

Where an existing offshore floating installation enters into an RBI program, a baseline survey may be required to confirm the structural or topsides condition (refer to 2/5.3, 3/3.5 and 2/5.3 for details). When required, the scope and extent of the baseline survey is to be included in the RBI plan submitted for review and approval.

The baseline data may be drawn from the existing survey status. The baseline data will be used to verify the initial assumptions related to the condition. If there are significant variations between the assumed condition and the actual, adjustments to the program may be required.

If baselining is built into the RBI plan and is intended to be carried out during the initial years of the RBI plan implementation, completion of the baseline survey and a revisit of the RBI plan is required within 3 years from the plan commencement. The objective of revisiting the RBI plan is to revalidate assumed condition and degradation made during the initial study. Any exceptions are to be requested and approved by ABS.

9.5 Implementation Survey

The implementation survey is to be carried out by the attending Surveyor within one year from the date of the letter approving the RBI plan, as issued by the responsible ABS Engineering Office. The Surveyor is to verify the following:

- i) The RBI plan is implemented according to the approval documentation.
- ii) The RBI plan is producing the documentation required for the Annual Program Health Check and the requirements of surveys and testing for retention of class in accordance with the approved plan are complied with.
- iii) The onboard personnel responsible for inspection, maintenance and repairs (IMR) are familiar with the RBI plan.

When this survey is carried out and the implementation found to be in order, a report confirming the implementation of the RBI plan is to be submitted by the attending ABS Surveyor, and the plan may be put into service. Upon satisfactory completion of the Implementation Survey, appropriate class notations will be assigned and distinguished in the Class Record.

9.7 Annual Program Health Check

In addition to the Owner/Operators review, the Surveyor will review results during the scheduled inspections similar to typical Rule-based inspections. These health checks could be conducted by the Surveyor during the time of the onboard inspections. However, in some cases the checks may be conducted onshore through workshops/meetings between Class and the appropriate Owner/Operator representatives. The checks are a confirmation that the Owner/Operator is keeping the program up to date and providing adequate support.

If the program does not appear to be working as it was intended and/or equipment or structures covered by the RBI plan are not functioning satisfactorily, based on the information gathered from the on-site personnel and correspondence with Owner/Operator support personnel, the Surveyor will record their concerns in the survey record. The recorded Class anomaly type (See Section 5, Table 1) and necessary Owner/Operator action will depend on the severity of the finding and the discretion of the attending Surveyor.

The following provides some indicators that can be used to confirm an RBI program is managed adequately.

- Verification of the qualification scheme of inspectors and other relevant personnel
- Adequate information is available to on-site personnel regarding the scope covered by the RBI program and what is covered by Rules.
- During the inspection execution activities
 - There is a support system in place to respond to anomaly findings (e.g., On-site Owner/Operator representative familiar with the inspection program overseeing the inspection plus technical support personnel/engineers off-site that can be reached via phone or email to provide advice and guidance).
 - The inspection company conducting the inspection has been given clear guidance and instructions on what is to be inspected and by what method.
 - The inspection company has clear guidance on how to document the inspection (e.g., pictures, completed checklists, etc.)
- Anomalies observed during previous inspections or monitoring activities have been captured in the Owner/Operator anomaly register and it is current.
- The Owner/Operator anomaly register is available to the Surveyor prior to the scheduled inspection.
- An anomaly management plan is available to the Surveyor. All RBI and Class anomalies are addressed in a timely manner and there are no overdue repairs.
- Description of repairs as well as any component which has been replaced is to be examined.
- The program inspection and monitoring data is being stored either electronically or in hardcopy and it is easily retrieved for reference for future inspections.
- All data from prior inspections and monitoring activities is included in the electronic or hardcopy data repository.
- RBI program required monitoring is being conducted, recorded and is up to date.
- The RBI program is being reviewed to determine if any changes are required based on past anomalies. Modifications and update to the RBI plan, if any, with justification of the change as supported by inspection data and the RBI methodology subject to the approval of the appropriate ABS Engineering Office and verification by attending ABS Surveyor.
- At the discretion of the Surveyor, function tests, confirmatory surveys and random check readings, such as gauging, are to be carried out as far as practicable.

Note that the RBI program management is intended to be a collaborative effort between the Owner/Operator and Class, with the ultimate objective of confirming the fitness of the installation for continued operation. However, management is a critical aspect of a successful RBI program and the primary responsibility of the management resides with the Owner/Operator. As a result, the management of the RBI program becomes a condition of Class, because it can ultimately impact the integrity of the installation.

The RBI program may be subject to cancellation if not being satisfactorily maintained. Refer to 1/9.11.

9.9 5-Year Program Health Check (Special Confirmation Survey)

In coordination with the fifth annual confirmation survey, a special review of the RBI program is to take place called a “program health check”. This review meeting is also sometimes referred to as the special confirmation survey. It involves a meeting held between Owner/Operator and ABS to review a report detailing the previous 5 years of inspection results, anomalies, variations from assumed conditions, and changes made to the program as a result. Based on this review, a plan for the next 5-year cycle is to be developed. This revised plan is to be submitted and approved by ABS.

It is noted that the RBI program is part of the Special Survey and the Special Survey cannot be credited if the RBI program is not found to be satisfactory by ABS.

11 Data Management and RBI Plan Updating

11.1 Data Management

The monitoring and inspection data are to be kept and made available for review by the attending Surveyor. The data are to be reviewed to establish the scope and content of the required Annual and Special Surveys which are to be carried out by a Surveyor. During the service life of the asset, the data are to be updated on a continuing basis. A computerized system for performing calculations (e.g., remaining life, inspection intervals) and maintaining data related to the RBI plan and inspections is recommended, but not required. The database should contain unique tag numbers and identification for all aspects of the asset, most often down to the subcomponent level. However, the ability to perform trending and calculations as new data is collected and to apply this to RBI plan updates is required. If the software utilized is not widely used in the industry, ABS may require submitting more detailed information about the software package.

11.3 RBI Plan Updating

The review and updating of the RBI plan is conducted by the Owner/Operator. The review of the inspection and monitoring results as well as the observed anomalies and occurrences where RBI thresholds were exceeded will dictate whether modifications to the program are necessary. If modification or updates are deemed warranted, the program is updated by the Owner/Operator. If the modifications or updates only impact the inspection scopes (e.g., more refined inspection techniques or inspection of more structures), Class will not need to be informed until the time the Class Surveyor is requested to attend the next scheduled survey. However, if the modifications or updates warrant changes in inspection frequencies or changes in compartment inspection sequences, the Owner/Operator is to submit a request to Class outlining the proposed inspection schedule changes. Class will review and approve each schedule change request.

Completion of the program review ends the program management loop until the next monitoring and inspection activities. The knowledge gained from each inspection cycle is incorporated into the next set of inspections and monitoring, thus building upon the understanding of the particular installation’s performance.

Generally, the RBI plan will remain unchanged unless specific thresholds are passed during the monitoring activities or inspections. The thresholds are limits associated with potential integrity issues, such as a high corrosion rate, that requires some action to be taken.

Note also that thresholds may be reached by design and/or service changes that could influence the RBI program. For example, if there are plans for tank service changes (e.g., void to be used as a ballast tank), a review by Class of the identified risks of the effected tanks or hull structure will be required. The review is intended to check any new risks associated with the proposed modifications are accounted for and whether or not the program in its current form will address these risks or if adjustments to the program are required.

The RBI program should include a structured and documented process to incorporate new experience and improved knowledge into their risk assessment, risk prioritization and inspection plan. Such a process should state conditions where a revision and update of parts of the RBI program are warranted. Changes or events that should explicitly be indicated as triggers for a revision of the RBI program may include:

- Operational events such as excursions above maximum parameters
- Improved inspection and integrity knowledge
- Unanticipated degradation rates or increased failures

11.3.1 Operational Events

Events or changes in the operation of the installation (even very small ones) can have significant effect on the integrity of an RBI covered item. One example may be where previously unused equipment such as chemical injection is brought into service without consideration of the impact on the RBI program. In this case, a possible localized failure threat may be introduced without identifying this new potential failure within the RBI. Significant events or changes to the operation of an installation that would likely warrant a review of the risk assessment and/or RBI program may include:

- Significant process or operational upsets
- Movement of phase boundaries for process systems (e.g., loss of dew point control)
- Failure of a component within an equipment or system
- Changes in parameters of operations and type of fluids
- Changes in process chemistry
- Changes in the level of experience and knowledge of operators
- Changes of usage of tanks (e.g. void tank to ballast tank)
- Changes of variable loads
- Changes in environmental data through condition monitoring
- Major structural changes

If the installation does not have a formal program for Management of Change (i.e., review and approval of the change, as well as communication of the change to all parties that may be impacted), the RBI team should introduce measures to verify that change processes are managed within the RBI program.

11.3.2 Improved Inspection and Integrity Knowledge

All acquired knowledge with respect to the integrity of the components (i.e., degradation mechanisms, results of inspection, repairs, new technology) is to be incorporated in the RBI Program in order to review and revalidate the assumptions. This may be acquired from inspections, repairs and through published industry sources. Events that may justify re-assessment of the RBI program include:

- Unanticipated degradation or failure mechanisms
- Results from anomaly assessment and data trending
- Increased or decreased degradation rates for anticipated failure mechanisms
- Repairs/modifications/replacements or other mitigation actions taken as a result of inspection
- New inspection technology
- Updated information gathered from industry databases

Decisions to change inspection frequencies will be highly dependent on several aspects of the degradation mechanisms. These include:

- Specific characteristics of the deterioration mechanism
- Inspection methods employed
- Time dependency of failure

In many cases, the justification to increase the interval between inspections may be easy to justify, but for some degradation mechanisms, caution should be used prior to resetting.

In the case where corrosion of a component is the dominant factor in the likelihood of failure, positive evidence that the corrosion observed is not as severe as that initially perceived may be easy to gather and substantiate. In this case, actual correlation and trending may be established and modified frequencies can be calculated and implemented.

For other mechanisms of failure, evidence of the deterioration may not be detectable or verifiable until some critical point within the deterioration process' profile has been reached. Such scenarios are exemplified by fatigue and 'work/service hardening' deterioration mechanisms. In these cases, crack propagation within a component may be occurring without obvious indication. Only where the surface-breaking phase of the crack is reached will the crack be recognizable. This is especially relevant where the inspection methods selected (such as visual or MPI) rely on this feature. In such a case, changing the inspection frequency would be unwise until the predicted time to failure is confidently established.

In all cases, the setting of inspection frequencies should be performed in a responsible manner so that systems assessed as having undesirable consequences will not face imminent potential failure. All changes to the RBI frequencies (other than minor changes for low risk systems) would require being processed within a Management of Change program and may ultimately require validation.

11.3.3 Unanticipated Failures

Upon occurrence of unanticipated failures, an investigation should be undertaken to verify any lessons that may be learned can be gathered. Even where the failure does not impact safety, business or the environment, it should be investigated. Many major accidents were preceded by smaller or indicative incidents. Significant damage could be prevented if these smaller incidents are investigated and lessons learned implemented.



APPENDIX 1 References

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APPENDIX 2 Sample RBI Plan for Hull Structures

Inspection Key	General Visual (GVI)	Yellow
	Close Visual (CVI)	Green
	NDE	Pink
	UT / Thickness Measurement	Blue
	Thickness Measurement (Girth Belt)	G
	Thickness Measurement (Enhanced Gauging)	E
	CP Measurement / Anode Grading	Light Green
	Function Test / Observe (e.g., bilge pump)	Grey
	ROV/Diver/UWILD	Red
	Conduct Repairs	Black
	Inspection Completed	White

Anomaly Codes			
Corrosion	C1	Light	<10% wastage
	C2	moderate	10-25% wastage
	C3	Heavy	>25% wastage
Other	STB	Sounding tube blocked	
	SW	Standing water present	
	CSB	Coating system blistered	
	CK	Cracklike indication	
	PL	Pipe leak or deterioration	
	AD	Anode depletion	
	PD	Physical damage (dent, abrasion, etc.)	
	DB	Debris	

Inspection History / Results																																		
Hull Components							Inspection Year																											
Tank	Service / Duty Type	Risk Index			Historical Condition		Panel	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035							
		S	F	L	Last Insp.	Anomaly		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20							
1P VOID	VOID	4	3	4			Deck																											
							Bottom																											
							Inner Bottom																											
							Side Shell																											
							OLBHD																											
							FTBHD																											
15 VOID	VOID	4	3	4			Deck																											
							Bottom																											
							Inner Bottom																											
							Side Shell																											
							OLBHD																											
							FTBHD																											
1P SCOT	Cargo	4	3	4			Deck																											
							Inner Bottom																											
							ILBHD																											
							OLBHD																											
							FTBHD																											
							ATBHD																											
15 SCOT	Cargo	3	3	3			Deck																											
							Inner Bottom																											
							ILBHD																											
							OLBHD																											
							FTBHD																											
							ATBHD																											



APPENDIX 3 Sample Risk Assessment Worksheet for Hull Structures

Facility:		System: Hull Deck Structure				Study Date:						
TANK / DESCRIPTION	FEATURES	Damage Type	POTENTIAL DETERIORATION SCENARIOS	FACTORS INFLUENCING SCENARIO LIKELIHOOD	EXISTING SAFEGUARDS	POTENTIAL CONSEQUENCES (SAFETY, REPAIRS, OPERATIONAL IMPACT)	#	C	L	R	SEF	COMMENTS (ACCESS, REPAIR ISSUES, CRITICAL INSPECTION POINT)
1P SCOT Deck	Service: Cargo Storage Tank Interior Features: Deck head hard coated during refurbishment Exterior Features: Flare tower piping support	S	<input checked="" type="checkbox"/> Interior coating failure with potential of excessive corrosion of deck plating, stiffeners and top of transverse frames <input checked="" type="checkbox"/> Exterior coating failure and excessive wastage of plating <input checked="" type="checkbox"/> Dents, gouges or holes from movement of equipment and activity on deck	<input checked="" type="checkbox"/> Results of analysis conducted on this tank not available but anticipate stresses to be similar to or lower than tank 2P SCOT stresses which are approximately 43% yield in the deck plate	<input checked="" type="checkbox"/> Deterioration of deck exterior (coatings, dents, etc.) will be observed by operators and maintenance / prevention program in place to prevent exterior corrosion. <input checked="" type="checkbox"/> Topside housekeeping policies and maintenance <input checked="" type="checkbox"/> Exterior corrosion protection maintenance program <input checked="" type="checkbox"/> Deck head is fully coated	<input checked="" type="checkbox"/> Excessive wastage of top of the transverse web frames, deck plate and deck longitudinals resulting in repairs that must be conducted within the tanks.	1	III	D		F	<input checked="" type="checkbox"/> Loss of cargo tank can put in other tank or slop. <input checked="" type="checkbox"/> Tanks interconnected with others for short term storage.
		F	<input checked="" type="checkbox"/> Fatigue cracking of deck longitudinal connections or transverse web frames.	<input checked="" type="checkbox"/> Remaining fatigue lives (>> 50 years) are found on the deck structure (Reference [1]).		<input checked="" type="checkbox"/> Loss of local strength causing local buckling, cracking into deck plating, or cracking requiring deck connection repair (DL's). <input checked="" type="checkbox"/> Propagation of WF cracking into deck and subsequent crack growth (WF cracking).	2	III	D		F	
		L	<input checked="" type="checkbox"/> Excessive localized corrosion of deck plate	<input checked="" type="checkbox"/> Possibility of high humidity, high sulfur, or high temperature in vapor space.	<input checked="" type="checkbox"/> Fully hard coated	<input checked="" type="checkbox"/> External pitting and holing of deck requiring minor repair which can be repaired without entering the tanks (internal corrosion would tend to be general loss – see strength above).	3	IV	C		F	<input checked="" type="checkbox"/> Expected maximum crude temperature is 140 F, which is close to the design limits for the coating.



APPENDIX 4 RBI Program Submittal Requirements

1 General

This Appendix provides details on the submittal requirements for the first two steps in the RBI process. The first step is the development of an RBI methodology as part of the RBI Program Evaluation and the second step is the actual program development. Also, it is envisioned that some Owners/Operators may have existing ABS approved RBI programs and a similar methodology will be utilized. In such cases, the first step RBI methodology submittal requirements may be waived. If the new methodology has significant differences, it should be submitted to ABS for review.

3 RBI Methodology Submittal Requirements

The starting point for an RBI program is the development of a methodology document. The methodology document and associated letter of intent provide a formal means for the Owner/Operator to inform ABS of their intent to maintain all or part of a hull structure, mooring systems, riser systems or topsides process systems using RBI methodologies.

Prior to initiating the formal development process, it is recommended that the Owner/Operator contact one of the regional ABS Survey offices to discuss their plans and expectations of implementing RBI. These initial discussions are helpful for the Owner/Operator to understand the approval process, the responsibilities of implementing the program as well as possible additional flag State and/or other regulatory requirements or submittals.

Once the initial discussions have been conducted the next step is the development of a RBI methodology document which will outline the approach the Owner/Operator will follow. The document will provide a road map for the development of the RBI which ABS can review and approve. Appendix 4, Table 1 lists the information that should be included in the methodology document submittal for hull structures, mooring systems, riser systems, and topsides process systems. The RBI methodology development for these systems generally follows similar process as described in Section 2 of this Guide.

The methodology document submittal is to include a cover letter (letter of intent) indicating the Owner/Operator's intent to use RBI methodologies for the specific installation. Prior to submitting the document, the Owner/Operator should contact one of the regional ABS offices to confirm number of required copies, submittal format (hardcopy and electronic) and distribution.

ABS will confirm receipt of the documents and provide an estimated time to complete the review. Once the review process is complete, ABS will provide the client with a letter indicating preliminary acceptance of the proposed methodology.

TABLE 1
Methodology Document Requirements

<i>ID</i>	<i>Required Information</i>	<i>Description</i>
M1	Describe anticipated development submittals	<ul style="list-style-type: none"> • Provide general description of the anticipated RBI deliverables and supporting documentation that will be submitted
M2	Installation description and general arrangement	<ul style="list-style-type: none"> • Indicate flag state as well as other regulatory authorities the installation will operate under • Installation particulars (mooring and riser systems, water depth, production, location, etc.) • Intended design life and upgrades/modifications • Novel features (This could include unique structural or operational features)
M3	Planned operation	<ul style="list-style-type: none"> • Anticipated tank service conditions, if relevant. • Mooring and riser systems in service data (e.g., vessel position, heading, mooring line and riser tensions, etc.), if relevant • Process and operating data (e.g., procedures, fluid composition, pressure, temperature, etc.), if relevant • Corrosion protection systems • Design environment
M4	Operating history and inspection status	<ul style="list-style-type: none"> • Description of installation history (how long operating, any additions or major modifications, any observed anomalies, etc.) • Provide current Rule-based inspection status (i.e., when hull structures, mooring systems, riser systems or topsides process systems were last inspected) • Provide past inspection records
M5	RBI program scope	<ul style="list-style-type: none"> • Describe hull structures, mooring systems, riser systems or topsides process systems that will be covered by proposed RBI program • Describe any key interface points (e.g., structures not within the scope that could influence integrity of hull structures within RBI scope)
M6	Proposed approach	<ul style="list-style-type: none"> • Indicate the intended approach (i.e., Qualitative or Quantitative) • Overview of proposed RBI development process (e.g., flow charts, diagrams, or tables showing proposed development steps)
M7	Information basis	<ul style="list-style-type: none"> • General design information (Structural drawings, mooring and riser systems design drawings, design reports, process flow diagrams (PFDs), piping and instrumentation diagrams (P&IDs), etc.) • Baseline information (Available data on present condition) and any additional inspections planned to collect baseline data • Description of structural analysis that will be conducted or that is readily available, if relevant
M8	Risk assessments	<ul style="list-style-type: none"> • Describe the process that will be used to evaluate hull structures, mooring systems riser systems or topsides process systems risks • Provide proposed risk matrix with likelihood and consequence definitions • Provide past risk assessment studies if applicable
M9	For Quantitative-based approaches only	<ul style="list-style-type: none"> • General description of the quantitative process and development • Description of how the results will be used in the overall RBI program development process
M10	Data management and RBI plan updating	<ul style="list-style-type: none"> • Describe the plan for executing the RBI program • Describe anticipated requirements and guidance that will be in place for updating the program • Describe the plan for reviewing and managing the inspection and monitoring data • Describe any technical support mechanisms that will be in place (e.g., corporate integrity management group, etc.)

5 RBI Program Submittal Requirements for Hull Structures and Mooring Systems and Riser Systems

Regardless of the approach, the primary objective of the RBI program submittals is to provide adequate basis and documentation to justify the proposed inspection/monitoring scope and frequencies. In general, the submitted documents are to:

- Provide adequate information basis for the RBI program (i.e., describe “how” the conclusions were formed) as well as information on “why” the selected hull structures and/or mooring and riser systems are inspected.
- Clearly state the initial inspection scope and frequencies.
- Provide adequate guidance to those who will manage and execute the plan, such that these personnel know what is expected with regards to inspection scopes, techniques, monitoring, and documentation. There should also be guidance on when changes are warranted to the program.
- Describe the management system and team that will support and oversee the program.

This Subsection describes in general the RBI development submittal expectations and key information that should be provided within the deliverables for hull structures, mooring and riser systems. The number of submittal documents necessary to convey these objectives as well as form the program foundation will be at the discretion of the Owner/Operator. The documents should as a minimum provide adequate understanding for ABS to approve the program as well as provide clear instructions to the Owner/Operator’s personnel and contractors who will implement the program. If an outstanding recommendation regarding anomalies/repairs exist, the outstanding recommendation will have to be addressed as part of the RBI plan. Refer to 1/9.3.

To provide general guidance on the type of information and supporting documentation expected for the RBI approval process, Appendix 4, Table 2 has been provided. This table is divided into six sections which generally follow the RBI building blocks described previously in Section 3. Note that for existing vessels with no or limited data, a baselining and FFS assessment also needs to be done and submitted to ABS for review. The table is intended for general guidance only and the Owner/Operator may develop the program using other “building blocks” or steps not shown in the table.

TABLE 2
Required RBI Submittal Information for Hull Structures, Mooring Systems
and Riser Systems

<i>ID</i>	<i>Key Information/ Deliverable</i>	<i>Description</i>
<i>Information Gathering & Component Grouping</i>		
Information used to understand and develop the RBI program including past history and existing condition of the hull structures, mooring systems, riser systems as well as the component grouping information.		
IG1	Structural drawings	Provide information on the applicable drawings that were used in the development of the program. This should include not only the hull structures within the scope of the RBI but also the structures that interface with the RBI structures as well as the mooring and riser systems design drawings, if applicable.
IG2	Design and analysis reports	Provide information on the available design and analysis reports used in the development of the RBI as well as how this information was used.
IG3	Operational data	This should describe tank service conditions (e.g., ballast, cargo, etc.), mooring and riser systems service conditions (e.g., metocean data, mooring line and riser tensions, etc.), corrosion protection systems, design environment, design life, as well as any other loading conditions or protection systems.
IG4	Operating history and structural performance of similar vessels	This information provides insight into the operating experiences of the specific hull structure type as well as potential critical structures and the associated mooring and riser systems.
IG5	Construction monitoring information and/or previous gauging and inspection data	These data provide key information into the as-is or current condition of the hull structures, mooring or riser systems. This is critical information for a transitioning from Rule-based to Risk-based approach. The amount and quality of this information will impact the need for baselining inspections. Also, this information provides insight into areas or structures where there is limited information or knowledge on the actual condition. This can then be addressed as part of the risk assessment process.
IG6	Failures, anomaly, past repair/replacement records	This generally relates to an installation that is transitioning from Rule-based to Risk-based or in the case where the installation is being “converted” for a site specific offshore application. Information on the past hull structure and mooring and riser systems performance should be documented as well as any repairs or modifications. If an outstanding recommendation regarding anomalies/repairs exist, the outstanding recommendation will have to be addressed as part of the RBI plan.
IG7	Operational history of installation	Similar to IG6, this relates to facilities transitioning to a Risk-based approach or being converted for site specific application. This information should include a summary of operations history of the structure including information such as previous offshore sites or trading route history if originally a trading ship.
IG8	Codes and standards	The selection and type of codes and standards should be described.
IG9	Unique or novel structures or loading conditions	The novel or unique attributes of hull structures, mooring or riser systems should be provided for a RBI program development. Often the experience from the performance of other similar assets is drawn upon to gauge the anticipated structural performance of an installation for which the RBI plan is being developed (similar designs or sisters). If the operating conditions or structural features are outside the existing bounds of experience, the information needed to accurately predict the performance may not be available. In these cases, the inspection program will need to be structured such that a steady stream of information related to the performance of the unique attribute is collected.
IG10	Component grouping	This provides information on how the hull structure components and mooring and riser components are grouped for inspection.

**TABLE 2 (continued)
Required RBI Submittal Information for Hull Structures, Mooring Systems
and Riser Systems**

ID	Key Information/ Deliverable	Description
<i>Baselining and Fitness for Service Assessment (if required)</i>		
For existing structures with no or limited data, a baselining inspection and fitness for service assessment may be required to gain an understanding of their present condition.		
BF1	Baselining inspection	The scope and extent of baselining inspection should be based on the review of existing information and focused on the items that have no or limited data. The inspection scope and inspection technique should be discussed with ABS and specified if built into the RBI plan The baseline data collected will be used to verify the present condition or any initial assumptions made regarding the condition.
BF2	Fitness for service assessment report	For structures, the fitness for service assessment may include strength, fatigue, and stability analysis. The fitness for service assessment is to incorporate the results of the baselining. Specifically, deck loads, wastage, marine growth, and any modifications and damages are to be incorporated into the analysis. Where available, the original fabrication materials and fit-up details are to be established such that proper material characteristics are used in the analysis and any stress concentrations are accounted for.
<i>Design Analysis (Global and Local Strength and Fatigue Analysis)</i>		
Strength and fatigue analysis results used to understand the anticipated hull structures, mooring or riser systems performance and critical components as well as support the risk evaluations and overall development of the RBI program. The design analysis results can be obtained from the original design reports or the fitness for service assessment (if required)		
SA1	Structural analysis	The results from both fatigue and strength structural analyses are necessary to develop a comprehensive RBI plan, as these results form the foundation for the plan. The submittal documents should include details on the type of analysis conducted (e.g., simplified/longitudinal strength and fatigue model or complete installation model/dynamic load analysis and spectral fatigue analysis, etc.) used in the program development. General information on the results should be included in the submittals describing the calculated strength and fatigue characteristics.
SA2	Critical connections and components	Based on the strength and fatigue analysis, critical fatigue connections and strength components should be clearly identified within the submittal documents.
SA3	Loading conditions	A description of the loading conditions that were considered as well as information on the observed correlation between the various load cases and the structural performance. Load cases that cause the most severe stress conditions should be highlighted. The submittal documents should provide an indication on which factors lead to the most severe stress (e.g., global loading, connection detailing, etc.).
<i>Risk Assessment and Risk-Based Prioritization (Qualitative)</i>		
Process of identifying potential degradation or deterioration scenarios, probability of failure, potential consequences of failure, safeguards and risk ranking. Critical locations/structures are identified based on the risk assessment.		
QA1	Process used to determine the risk	A description of the process used to risk rank the structure is to be included within the submittals. Include the inputs used in the risk process (e.g., gathered condition data, structural analysis, anecdotal information, etc.) If the process includes any workshops (e.g., HAZID) the makeup of the participating team and associated worksheets should be provided with the submittals.
QA2	System identification and hull structures, mooring and riser systems breakdown and interfaces	This is a description of the level to which the structure is broken down and evaluated. Additionally, any key interface points between structures within and without the RBI scope that could influence integrity of structure within RBI scope should be described.
QA3	Risk matrix	The risk matrix to rank the likelihood and consequence is to be included within the submittal documents. The basis of the proposed risk matrix categories should be discussed. The question that should be answered is, “Do the risk ranking likelihoods and consequences match published risks such as those found in the offshore industry?” This exercise verifies the “correctness” of the risk matrix and its applicability to hull structural risk or mooring and riser systems risk.
QA4	Risk evaluation	Evaluates the risk of the hazardous scenario by measuring it against the acceptable risk criteria agreed upon by the analysis team

Appendix 4 RBI Program Submittal Requirements

<i>ID</i>	<i>Key Information/ Deliverable</i>	<i>Description</i>
QA5	Risk control	Identifies and evaluates the need for any recommendations to lower the risk to acceptable levels through risk control measures
QA6	Critical loading/or unique features	Presentation of risk results regarding identified critical load cases or unique features of the installation that influence the risk rankings.
QA7	Risk drivers	Description of risk drivers based on the risk assessment. Essentially, this information provides key insight into the “why” certain structures have higher risks than others.
QA8	Critical inspection locations/structures	Identification and description of the critical inspection locations and structures based on the risk assessment.
QA9	Hazard Register	Risk assessment worksheets and supporting calculations as necessary.
<i>Risk Assessment and Risk-Based Prioritization (Quantitative)</i>		
Process of quantifying the risks using degradation models and reliability analysis or other methods to forecast the structural condition to refine the inspection/monitoring scope and frequencies. For the quantitative approach, in addition to the submittal information required above for the qualitative approach (i.e., QA1 to QA9), the following information should be submitted for review.		
QR1	Method	A description of the process used is to be included within the submittals. Include the inputs used in the process as well as all appropriate references.
QR2	Degradation models	Descriptions of the degradation models and distributions are to be included in the submittals.
QR3	Assumptions	All assumptions and key variables are to be described in the submittals.
QR4	Scope of evaluation	Submittals should provide a clear description of what structures and/or connections the quantitative evaluations cover. For example, the evaluations may only include a select representative cross section of the entire hull structure. The basis for this selection should be described in the submittals.
QR5	Targets/threshold definitions	Any thresholds or targets used to make a distinction between different risks or acceptance levels (e.g., high, medium, low, acceptable, not acceptable, etc.) should be clearly defined within the submittal documents.
QR6	Results	The results of the evaluations should be clearly presented and associated to the different hull structures, mooring or riser systems.
<i>Inspection and Monitoring Plan and Program Management</i>		
The inspection and monitoring plan provides the necessary guidance on what, where, when and how to inspect and the monitoring activities as well as an understanding on why these structures need to be inspected. The program management document provides guidance on how the RBI program will be managed and updated.		
PD1	RBI Plan (usually integrated within the ISIP)	The document should include a clear description of the general scope and frequency of inspections and monitoring activities. The scope and frequencies should be reflective of the results from the various buildings blocks (e.g., analysis, risk results, etc.) and include all identified critical inspection locations/structures.
PD2	Inspection Work Packs	A detailed description that outlines the inspection scope and associated inspection technique for each component due for inspection for each year.
PD3	Interfaces	The document should describe any key interfaces not covered within the RBI program scope that may impact the integrity of the structures covered within the RBI program.
PD4	Anomaly Management	The Owner/Operator is to submit an anomaly management plan for findings made by ABS or the Owner/Operator to ABS for approval. Anomaly management plans accompanied by engineering justifications or modifications will be forwarded to ABS Engineering for review and approval.
PD5	RBI program updating guidance	The document should provide guidance on potential update of the RBI program, as needed, as future inspection results become available.
PD6	Rule-based & Risk-based	The document should clearly state what is covered by RBI and what will remain within the Rule-based requirements.
PD7	Program management	The document should provide general guidance on how the program will be managed and what the anticipated Owner/Operator support mechanisms will include.

7 RBI Program Submittal Requirements for Topsides Process Systems

This Subsection describes in general the RBI development submittal expectations and key information that should be provided within the deliverables for topsides process systems. The number of submittal documents necessary to convey these objectives as well as the form of the program foundation will be at the discretion of the Owner/Operator. The documents should as a minimum provide adequate understanding for ABS to approve the program as well as provide clear instructions to the Owner/Operator’s personnel and contractors who will implement the program. If an outstanding recommendation regarding anomalies/repairs exist, the outstanding recommendation will have to be addressed as part of the RBI plan. Refer to 1/9.3.

To provide general guidance on the type of information and supporting documentation expected for the RBI approval process, Appendix 4, Table 3 has been provided. The table generally follows the RBI development process described previously in Section 4. Note that for existing process systems with no or limited data, a baselining and FFS assessment also needs to be done and submitted to ABS for review. The table is intended for general guidance only and the Owner/Operator may develop the program using other information not shown in the table.

**TABLE 3
Required RBI Submittal Information for Topsides Process Systems**

<i>ID</i>	<i>Key Information/ Deliverable</i>	<i>Description</i>
<i>Information Gathering & Component Grouping</i>		
Information used to understand process systems and develop the RBI program including past history and existing condition of the equipment as well as the component grouping information.		
IG1	Drawings	Provide information on the applicable drawings that were used in the development of the program, such as Process Flow Diagrams (PFDs) and Piping and Instrumentation Diagrams (P&IDs).
IG2	Design and fabrication information	Provide information on the available design and fabrication used in the development of the RBI as well as how this information was used.
IG3	Operating and processing data	This should describe operating data (e.g., pressure, temperature), corrosion protection systems, design environment, design life, as well as any other protection systems.
IG4	Operating history and performance of similar vessels if applicable	This information provides operating logs and process records which provide insight into the operating experiences of the specific equipment.
IG5	Construction monitoring information and/or previous inspection data	This information provides key information into the as-is or current condition of the equipment. This is critical information for an equipment transitioning from Rule-based to Risk-based approach. The amount and quality of this information will impact the need for baselining inspections. Also, this information provides insight into areas where there is limited information or knowledge on the actual condition. This can then be addressed as part of the risk assessment process. To address unknowns related to the process system condition, a baselining effort may be required. The baseline effort may be conducted over the first 2-3 years of the RBI, depending on the extent of data required and its importance to the plan basis. The baselining data will be used to verify the initial assumptions related to the process system condition. If there are significant variations between the assumed condition and the actual, adjustments to the initial program may be required.
IG6	Failures/anomaly/repair records	This generally relates to an equipment that is transitioning from Rule-based to Risk-based inspection. Information on the equipment past performance should be documented as well as any repairs or modifications. If an outstanding recommendation regarding anomalies/repairs exist, the outstanding recommendation will have to be addressed as part of the RBI plan.
IG7	Codes and Standards	The selection and type of codes and standards should be described.

TABLE 3 (continued)
Required RBI Submittal Information for Topsides Process Systems

<i>ID</i>	<i>Key Information/ Deliverable</i>	<i>Description</i>
IG8	Unique or novel attributes	Another aspect that should be included when gathering the information needed for a RBI program development is novel or unique attributes. Often the experience from the performance of other similar assets is drawn upon to gauge the anticipated performance of an equipment for which the RBI plan is being developed (similar designs or sisters). If the operating conditions or structural features are outside the existing bounds of experience, the information needed to accurately predict the performance may not be available. In these cases, the inspection program will need to be structured such that a steady stream of information related to the performance of the unique attribute is collected.
IG9	Component grouping	This provides information on how the topsides process system components are grouped for inspection.
<i>Baselining and Fitness for Service Assessment (if required)</i>		
For existing equipment with no or limited data, a baselining inspection and fitness for service analysis are required to gain an understanding of their present condition.		
BF1	Baselining inspection	The scope and extent of baselining inspection should be based on the review of existing information and focused on the items that have no or limited data, especially the non-accessible pipes and valves. The inspection scope and inspection technique should be discussed with ABS and specified if built into the RBI Plan. The baseline data collected will be used to verify the present condition or any initial assumptions made regarding the condition.
BF2	Fitness for service assessment report	The fitness for service (FFS) assessment is to incorporate the results of the baselining. The FFS assessment should consider the inspection findings that may impact the operation of the system, such as metal loss, dents, misalignment, cracking, blisters, laminations, etc. Specifically, any modifications, upgrades, and changes are to be incorporated into the analysis.
<i>Risk Assessment and Risk-Based Prioritization</i>		
Process of identifying potential degradation or deterioration scenarios, probability of failure, potential consequences of failure, safeguards and risk ranking. Critical locations/equipment are identified based on the risk assessment..		
RA1	Risk assessment methods	A description of the qualitative or quantitative risk assessment methods to be used and description if using a non-standard method.
RA2	Assumptions	All assumptions and key variables are to be described in the submittals.
RA3	Scope of the risk assessment	Submittals should provide a clear description of what equipment and/or connections the risk assessment cover. For example, the risk assessment may only include a select representative sections of the entire topsides process systems. The basis for this selection should be described in the submittals
RA4	Degradation models, damage mechanisms, and process accident scenarios	Descriptions of the degradation models, damage mechanisms and the associated accident scenarios are to be included in the submittals.
RA5	Probability of failure assessment	The methods and data sources used to estimate the probability of failure of various damage mechanisms should be submitted.
RA6	Consequence assessment	The consequence of each of the accident scenarios including the harm to people, property loss, environmental damage and business interruption should be documented. For quantitative approach, the physical models used to calculate the consequence of the process accident scenarios should be submitted for review.
RA7	Risk matrix	The risk matrix to rank the equipment as well as the likelihood and consequence definitions are to be included within the submittal documents. The basis of the proposed risk matrix categories should be discussed. The question that should be answered is, "Do the risk ranking likelihoods and consequences match published risks such as those found in the offshore industry?" This exercise verifies the "correctness" of the risk matrix and its applicability to the equipment risk.
RA8	Risk evaluation	Evaluates the risk of the hazardous scenario by measuring it against the acceptable risk criteria agreed upon by the analysis team
RA9	Risk control	Identifies and evaluates the need for any recommendations to lower the risk to acceptable levels through risk control measures

TABLE 3 (continued)
Required RBI Submittal Information for Topsides Process Systems

<i>ID</i>	<i>Key Information/ Deliverable</i>	<i>Description</i>
RA10	Critical inspection locations/equipment	Identification and description of the critical inspection locations and equipment based on the risk assessment.
RA11	Risk drivers	Description of risk drivers based on the risk assessment. Essentially, this information provides key insight into the “why” certain structures have higher risks than others.
RA12	Hazard Register	Risk assessment worksheets and supporting calculations as necessary (e.g., fault trees and event trees)
<i>Inspection and Monitoring Plan and Program Management</i>		
The inspection and monitoring plan provides the necessary guidance on what, where, when and how to inspect and the monitoring activities as well as an understanding on why the equipment needs to be inspected. The program management document provides guidance on how the RBI program will be managed and updated.		
PD1	RBI plan (usually integrated within the ISIP)	The document should include a clear description of the general scope and frequency of inspections and monitoring activities. The scope and frequencies should be reflective of the results from the risk analysis and include all identified critical inspection locations/equipment.
PD2	Inspection Work Packs	A detailed description that outlines the inspection scope and associated inspection technique for each equipment due for inspection for each year.
PD3	Anomaly Management	The Owner/Operator is to submit an anomaly management plan for findings made by ABS or the Owner/Operator to ABS for approval. Anomaly resolution plans accompanied by engineering justifications or modifications will be forwarded to ABS Engineering for review and approval.
PD4	RBI program updating guidance	The document should provide guidance on potential update of the RBI program, as needed, as future inspection results become available.
PD5	Rule-based & Risk-based	The document should clearly state what is covered by RBI and what will remain within the Rule-based requirements.
PD6	Program management	The document should provide general guidance on how the program will be managed and what the anticipated Owner/Operator support mechanisms will include.