



GUIDE FOR

SURVEYS USING RISK-BASED INSPECTION FOR THE OFFSHORE INDUSTRY

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**American Bureau of Shipping
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Foreword

This Guide contains the technical requirements and criteria employed by ABS to consider alternate Survey arrangements using Risk-Based Inspection (RBI) approaches for offshore installations. It is applicable to static pressure retaining equipment, and structures for offshore floating and fixed-base platforms.

ABS supports the implementation and use of RBI technologies as a means for optimizing inspection resources, while maintaining or perhaps lowering levels of risk. ABS recognizes the benefits that RBI can bring to an asset and makes provision within its rules for classification of assets, accordingly, thus allowing RBI to be utilized as an alternative for the Owner to maintain ABS classification for the asset. This Guide has been written for worldwide application and, as such, installation specific data, analyses and plans are generally required to demonstrate the adequacy of the RBI plan. It is not the intention of this Guide to impose requirements or practices in addition to those that have previously proven satisfactory in similar situations. This ABS Guide does not inhibit the use of any technological approach that can be shown to produce an acceptable service performance during the life of the structure with the risks understood and appropriately controlled.

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 cognizant administration or regulatory body is the final determining body for statutory or regulatory requirements under their jurisdiction. The Owner shall ensure that in developing the RBI plan, due consideration is given to Coastal and Flag State requirements.

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GUIDE FOR

SURVEY BASED ON RISK-BASED INSPECTION FOR THE OFFSHORE INDUSTRY

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SECTION 1 Introduction

1 General

The inspection of process equipment and offshore structural components play a significant role in preventing failures. Inspection and testing programs are established to detect and evaluate deterioration due to in-service operation. The methods, frequency and acceptance criteria used in inspections can affect the likelihood of component failure.

The inspection frequencies for pressure equipment and structures in the marine and offshore industry have traditionally been driven by prescriptive industry practices, usually at time-based or calendar-based intervals. This inspection practice, founded mainly on general industry experience for each type of component, has thus far provided an adequate level of reliability. However such a practice does not explicitly consider the likelihood of failure of a component under its operation and loading conditions, nor the consequences of a failure. Current inspection practices make it difficult to recognize if the same or improved service reliability can be achieved by varying inspection methods, locations or frequencies. Also, current practices do not easily identify if an inspection activity is excessive and provides no measure of increased assurance for the integrity of the component.

Certain sectors of industry have recognized that significant benefits may be gained from more informed inspection methods and have begun evolving into inspection program philosophies that combines factors such as satisfactory operating experience, low deterioration rates, minimal consequences of failure and condition-based inspection interval setting. Most operators have reached their current practice by an evolutionary process based upon experience, regulatory and classification society compliance. However, very few operators have developed their existing programs on the basis of a systematic process that seeks to achieve a balance between risk and the level of inspection effort.

In a facility with substantial production revenues, the cost of downtime can be significant. An effective inspection program is centered on knowing when, where and how to inspect. This enables the operator to not only control the integrity of the assets, but to control it with a focus on the economic value, while maintaining an acceptable service performance. Further, having a documentation trail for the inspection process allows for a focused and confident inspection plan updating should the operator undergo changes in operations, equipment, structures, personnel, contractors, company organization, etc.

Risk-Based Inspection (RBI), which focuses on the optimization of inspection programs for pressure retaining equipment and structures, is the subject of this Guide. RBI begins with the recognition that the essential goal of inspection is to prevent incidents that impair the safety and reliability of operating facilities. As a risk-based approach, RBI provides an excellent 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. RBI is a process that assures inspection resources are focused on the areas of greater concern, and provides a methodology for determining the optimum combination of inspection methods and frequencies. As a result of this there is a continuous improvement aspect to the RBI process that allows for recalculation of risk and subsequent refocusing of the inspections activities.

The recent trend towards RBI practices is being driven by factors such as:

- The increasing awareness and use of risk analysis in all aspects of the asset's operations
- The location of facilities in remote locations requiring highly effective inspection programs with limited resources
- Asset service life longer than designed and increased reuse of equipment in different services
- Increased emphasis on the justification of inspection frequency and practices required of the asset operators by financial venture partners.

The development and implementation of an RBI program requires the participation and coordination of groups within the operating organization, including process and hardware engineering, maintenance and operations personnel. The whole organization should commit and contribute to the RBI program. Inspections in themselves do not affect the actual failure likelihood of the components being inspected. The inspection process provides a means of gaining confidence in the service reliability of the component being inspected. When an inspection reveals an 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. Risk cannot be reduced to zero. There is always a "residual risk" associated with inspection. This is caused by factors such as operational errors, extreme weather, external events, process upsets, limitations of inspection methods and unrevealed deterioration mechanisms.

3 Purpose

The purpose of this document is to provide guidance to ABS Clients on the application of RBI programs to maintain class for an offshore 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 documentation, data requirements and analysis updates. It also describes the interaction between executing the RBI programs and how ABS will audit the plan and execute surveys for maintenance of class within the context of such a program. Specifically, it identifies the minimum elements that ABS requires to be considered in the development and implementation of an RBI program so that it can be considered in lieu of the conventional maintenance of class surveys.

This Guide is intended to clarify the elements involved in the development and implementation of an RBI program, but it does not intend to be a detailed technical reference of RBI methodologies, nor does it intend to single out or endorse any one specific RBI methodology. Appendix 1 lists some of the most commonly used RBI methodologies.

5 Scope

This Guide is specifically targeted for structures and production equipment for the offshore oil and gas industry. This Guide specifically covers:

- i) Static pressure retaining equipment, and
- ii) Structures for offshore floating and fixed-base platforms

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 Reliability-Centered Maintenance* provides guidance on a risk-based approach for such types of equipment.

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 cognizant administration or regulatory body is the final determining body for statutory or regulatory requirements under their jurisdiction. The Owner shall ensure that in developing the RBI plan, due consideration is given to Coastal and Flag State requirements.

7 Definitions

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

Catastrophic failure is a complete functional failure of a component.

Confidence is the analyst's certainty of an estimate.

Consequence is an unwanted 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, money lost or any other measure of negative impact for the quantification of risk.

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 of the component to provide its intended function (i.e., failure).

Event is an occurrence 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 defined as 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 expressed as events per unit time.

Hazards are conditions that can cause harm.

Likelihood is the possibility or frequency of a and 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 (e.g., \$1,000,000 per year).

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

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-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 a series of events that result in the occurrence of a potential consequence(s).

SECTION 2 Fundamentals of RBI

1 Definition of RBI

RBI 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. RBI combines risk assessment and risk management techniques with all inspection activities, such as planning, inspecting, documentation and data analysis, to develop inspection plans that direct inspections towards the areas of highest risk. RBI can be applied to all types of material deterioration processes that may cause loss of integrity for pressure retaining equipment and structures.

3 Risk Assessment and Inspection

Risk is defined as the product of the frequency with which an event is anticipated to occur and the consequence of the event's outcome. In mathematical terms, risk is calculated by:

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

Risk assessment is the process of identifying the sources of hazards, estimating the risk and evaluating the results. Appendix 1 provides a list of reference sources for risk assessment techniques.

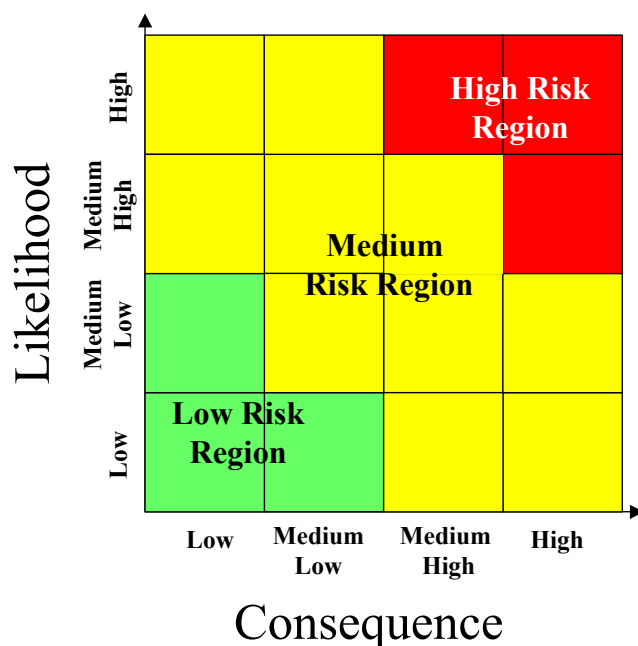
The risk assessment process answers the following three questions to determine the risk:

- i) What can go wrong?
- ii) How likely is it?
- iii) What are the consequences?

Risk can be expressed quantitatively as a measure of loss per unit of time, or presented qualitatively.

Presenting risk qualitatively is an effective means of illustrating risk. A qualitative risk matrix as exhibited in Section 2, Figure 1 below illustrates how risk is related to the likelihood and consequence. This matrix is simply a plot with likelihood on one axis and consequence on the other. The matrix shows the basic principles behind all evaluations of risk. A high likelihood combined with a high consequence results in a high risk, located in the upper right hand corner of Section 2, Figure 1. A low likelihood combined with a low consequence results in a low risk, located in the lower left hand corner of Section 2, Figure 1. These two extremes usually do not present any difficult decisions on the persons conducting the risk assessment. If the risk is "High", then the situation may not be acceptable and changes must be made to lower the risk. If the risk is "Low", then the situation is tolerable and no changes need to be made. The challenge lies in addressing risks in the central area of the matrix between "Low" and "High". In this "Medium Risk" range, the question arises as to how much risk is acceptable. An important concept to understand is that high consequence may not mean high risk, and similarly, high likelihood may not mean high risk. The level of risk can only be determined once both of these variables are known or estimated.

FIGURE 1
Risk Matrix



As previously defined, RBI is an inspection planning process using risk assessment and risk management. The setting of inspection frequency within RBI is not a rigid process with fixed, predetermined inspection intervals. Inspection intervals for any given component may change throughout the life of the asset as risk increases or decreases. The frequencies that RBI derives are aligned to the needs of the component or situation and the risks associated. There is, nonetheless, a general logic to the inspections and frequency of the inspections, namely:

- Higher risk systems/components generally have the shorter frequencies of inspection and have potentially larger inspection population requirements
- Lower risk systems/components often have extended inspection frequency (or even no inspection) and have reduced inspection population requirements

Risk for RBI is considered to be the product of the factors of consequence and likelihood:

- Consequence (i.e., the outcomes that would ensue should a catastrophic failure of the component occur); and
- Likelihood (i.e., the probability that a catastrophic failure for the component will occur)

In general, unless there is a major change in the use, service duty or service parameters for a given piece of equipment or structure, the consequence of failure from each type of degradation is likely to remain fixed for its service life. Given this fact, it is correct to assume that the type and frequency of inspection activity will have no impact in modifying the consequence factor values.

In comparison, inspection activities, specifically the actions/results derived from inspections, have a major influence on likelihood and, subsequently, the determined risk value for the component. Rates for degradation of components are the major time based factor that governs likelihood of failure. RBI usually relies on these time-based models of failure frequency, where the expected frequency of failure rises with ongoing degradation. Such time-based models are essential for setting specific inspection intervals that will allow detection of significant degradation before the likelihood of failure (and hence the risk of failure) reaches an unacceptable level. This process allows for enhanced monitoring of degrading components, implementation of mitigation measures to slow down the degradation or corrective actions such as repair or replacement.

5 The RBI Process

Typical standard inspection programs base the inspection techniques and frequencies mainly on manufacturer's recommendations, industry standards, classification society or regulatory requirements. The general belief is that a decrease in the level of inspection activities would bring an associated increase in failures and hence a risk increase. Conversely, an increase in inspection activities is thought to result in a safer installation, amid an increase in cost. This belief, though accurate in general, has exceptions:

- i) If failure of a component does not result in significant risk exposure, then any inspection activity for that component will result in additional costs without any risk reduction and further inspection may not be necessary.
- ii) Excessive inspection activities (i.e., too frequent) may not bring any additional risk decrease. The extra inspection could even cause a risk increase due to issues such as human error during inspection and damage to protective coatings.
- iii) Inspection activities that do not focus on the detection of the specific degradation mechanisms to which the component is subjected to will result in cost without benefit.

The conclusion is that not all inspection programs are equally effective in detecting degradation mechanisms and reducing risks, and they all have different costs. RBI provides the tools and processes to determine the optimum combination of inspection methods and frequencies.

The basic elements in the development of an RBI program are the following:

- i) The determination of the risk introduced by the potential failures of each component.
- ii) The identification of the degradation mechanisms that can lead to component failures.
- iii) The selection of effective inspection techniques that can detect the progression of degradation mechanisms.
- iv) The development of an optimized inspection plan using the knowledge gained in the three previous items.
- v) The analysis of the data obtained from the inspections and any changes to the installation in order to feed back into the RBI plan.

7 RBI Benefits

RBI programs address risks due to structural or equipment deterioration from a safety, environment and economic perspective. Implementation of RBI plans can provide and document the overall reduction in risk for the facilities assessed. RBI programs may identify risks of such low level that require little or no inspection as a means of mitigation, and consequently, improving management of inspection activities by directing resources to higher risk areas.

RBI ensures that maximum effectiveness and improved efficiency for inspection are gained by:

- i) Prioritizing the components based on risk to differentiate criticality.
- ii) Ensuring that the correct items within the system are selected for inspection (the "at risk" components).
- iii) Ensuring that the optimal inspection frequency is determined and met.
- iv) Ensuring that the correct inspection resources are selected for the job (skills set, competence).
- v) Selecting the correct inspection methods, since there is a thorough understanding of the potential failure modes.
- vi) Planning inspections to minimize business interruptions.

- vii) Providing greater focus for future inspection programs as inspection results are used to update the RBI program.

Where RBI is implemented, it is common to observe improvement in both the technical and economic performance of the equipment and installation. This improved performance is delivered through:

- i) Reduced installation outages due to unexpected failure of systems or components (reduction in the number of reactive repairs).
- ii) Safer operation due to higher level of integrity and reduction in failures.
- iii) Greater focus to planned maintenance activities through providing predictive replacement times from derived inspection data for critical components or structures.
- iv) Improved budgetary control and forecasting forward inspection planning and inspection survey execution.
- v) Reallocated inspection effort and resources to the items that would provide for the biggest impact on risk reduction.

It is important to recognize that seeking ways to relax inspection practices is not the goal of establishing an RBI program. Modifications to inspection plans are not achievable in all circumstances. Only when a relaxation of an inspection plan will not result in an unacceptable increase in risk can such a relaxation be made. This ensures that compromise to the integrity of the asset or component does not occur. The process of developing an RBI plan may uncover the fact that the operator of the asset has actually been operating, maintaining and inspecting some components in a manner which did not provide the most efficient use of inspection resources. RBI is specifically useful at matching the correct inspection frequency and methods to the level of risk posed by the inspectable item.

9 RBI Limitations

As with all inspection programs, RBI is subject to uncertainty in dealing with damage mechanisms, their progression rates and the response of equipment and structures to the damage. Some inspection specifications have developed over time in response to observed damage or failure, and these events tend to govern inspection plans for all such equipment or structures. While it is possible to improve inspection specifications (e.g., using more sophisticated predictive methods for measuring damage rates), it is unwise, without installation-specific or other pertinent data, to assume that inspections are excessive just because failures are rare.

Data used to support the RBI plan must be well characterized and include a clear understanding as to the uncertainties associated with such factors as corrosion rates, fatigue crack growth, material strength and toughness and stresses. Many RBI programs start with a period of data gathering and analyses, allowing the inspection plan to be fine-tuned over a period of time as confidence in the data grows.

It should be recognized that RBI does not eliminate risk. The likelihood and consequence of an event or failure is always present, RBI serves to help manage and control the risk to tolerable and sustainable levels by focusing the resources available towards the components that are recognizable as producing the highest risk to the asset. Within RBI, this consists of (1) ranking the components to be inspected according to risk and (2) devising a plan to proactively inspect these components at an appropriate level and frequency that provides the Owner confidence that such components' integrity remains acceptable. It follows that high-risk contributors deserve stricter management than the low risk contributors. It is this prioritization that allows for an efficient allocation of inspection resources.

SECTION 3 RBI Program Development

1 Main Steps in the Development of an RBI Program

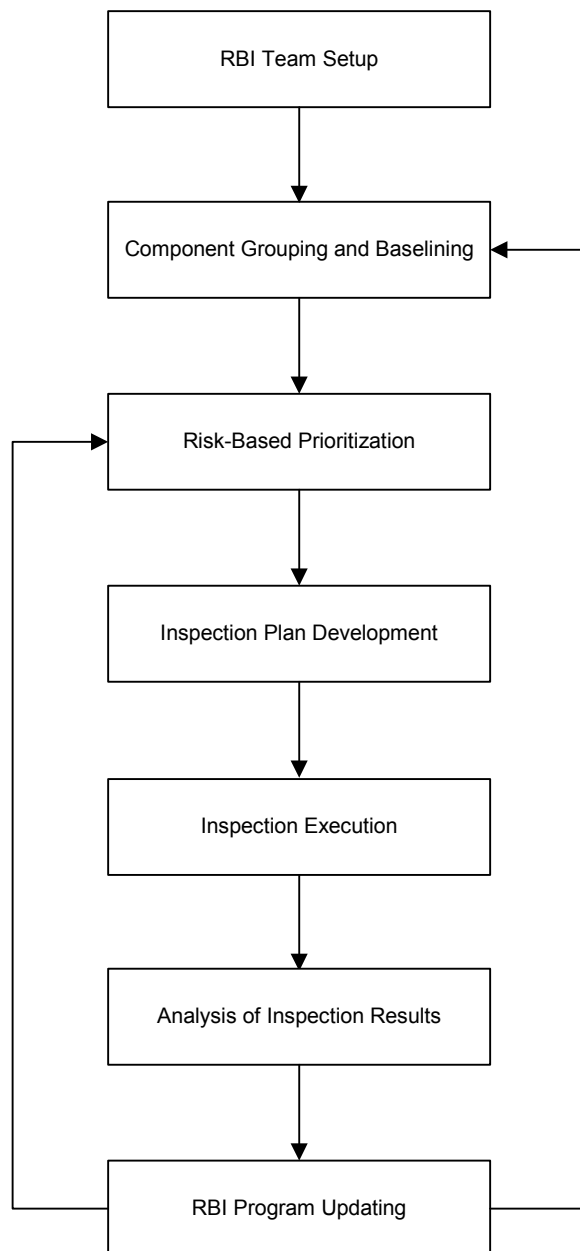
This section will describe a typical methodology used to develop an RBI program, but a variety of methodologies are accepted by ABS, provided that the steps in the development process as described in this section are included. If any of these steps are missing or they are considered in a substantially different way than common industry practice and standards, a suitable technical explanation on the adequacy of the methodology should be included with the submittal for ABS consideration and approval.

The typical procedural steps for the development on an RBI program are the following (Section 3, Figure 1):

- i) *RBI Team Setup.* The first step consists of the setup of an RBI team who will establish (or be given) the goals of the RBI program, and will carry out the RBI methodology to arrive at an inspection plan that achieves those goals.
- ii) *Component Grouping and Baselineing.* The program development begins with the identification and grouping of the components that are subject to the RBI program, and includes service, design and applicable inspection history data collection for those items. If new construction, then comparable service degradation data or reference material may need to be gathered to establish degradation concerns.
- iii) *Risk-Based Prioritization.* Perform a risk-based prioritization screening so that the components most critical to the safety of the installation can be identified. This requires a risk assessment to be initially performed that considers consequences of failure from the anticipated failure modes and degradation mechanisms and frequency based on expected degradation rates. If necessary, additional inspection data is specified if more data is needed to complete the risk assessment. The risk prioritization of the components occurs after the risk assessment is completed.
- iv) *Inspection Plan Development.* An inspection plan is developed based on the risk prioritization information so that the risk of failure is at or below acceptable levels.
- v) *Inspection Execution and Analysis of Inspection Results.* As the RBI program is executed and each inspection conducted, the results should be analyzed. This analysis should evaluate whether the assumptions made and data used to develop the RBI plan are valid and if the observed state of the component is acceptable for continuing operation until the next inspection.
- vi) *RBI Program Updating.* Finally, the observed degradation mechanisms and rates are used to update the RBI inspection plan.

Each step in this process will be described in more detail in the remainder of this Section.

FIGURE 1
Main Steps in the RBI Program Development



3 RBI Team Setup

An RBI program is best performed by a multi-disciplinary team that synergistically brings together different perspectives and technical strengths. A team approach ensures that all required information that is available within the facility and/or organization is considered in the RBI program, as well as providing a wider perception of the risks of failure.

The specific composition of an RBI team varies depending on the complexity of the facility, scope of the RBI program and any applicable regulatory requirements. Some of the disciplines will be called in as advisors, but a core team is essential for continuity.

RBI aims to prevent failures that lead to safety, environmental or economic concerns by planning inspections on the basis of information obtained from a risk analysis. The risk analysis for components needs to identify potential causes of failure, likelihood of failure, as well as determine the consequences arising from the failure. The RBI team should contain the expertise to identify and analyze all of the above factors and their implications to personnel safety, environment, property and production. If during the RBI risk prioritization, failure scenarios are inaccurately determined to have low risk, the RBI program could potentially reduce inspection efforts to related components, thus resulting in a hazardous situation. Personnel with technical and risk analysis knowledge are essential for the program to function effectively.

The RBI team will typically consist of individuals with experience and technical knowledge in the following disciplines:

- i) Maintenance and inspection
- ii) Degradation and failure mechanisms
- iii) Reliability
- iv) Operations
- v) Structural integrity
- vi) Risk analysis
- vii) Production process hazards
- viii) Safety and health
- ix) Materials of construction

Participation in the team of a representative with knowledge of RBI efforts in other similar facilities will ensure consistency throughout the organization and/or industry, as well as provide wider experience of risks and practices.

Among the duties of the RBI team members are to (a) participate and proactively contribute in all required risk analysis and RBI meetings to ensure their knowledge is easily tapped for the RBI purposes (b) validate the quality and veracity of the information available, and (c) perform their specific RBI tasks, keeping in mind the end goals of the RBI program.