



API 580 **Risk Based Inspection**

December 1-2, 2010

WHEN YOU NEED TO BE SURE

SGS

API 580 RISK BASED INSPECTION

- API 580 Risk Based Inspection provides guidance on developing a risk-based inspection (RBI) program on fixed equipment and piping in the hydrocarbon and chemical process industries. It includes:
 - What is RBI
 - What are the key elements of RBI
 - How to implement a RBI program

API 580 RISK BASED INSPECTION

- It is based on knowledge and experience of engineers, inspectors, risk analysts and other personnel in the hydrocarbon and chemical industry.
- API 580 is intended to supplement API 510 Pressure Vessel Inspection Code, API 570 Piping Inspection Code and API 653 Tank Inspection, Repair, Alteration and Reconstruction.
- These API inspection codes and standards allow an owner user to plan an inspection strategy and increase or decrease the code designated inspection frequencies based on the results of a RBI assessment.

1. PURPOSE

■ PURPOSE

The purpose of API 580 is to provide users with the basic elements for developing and implementing a risk-based inspection (**RBI**) program.

1. PURPOSE

Individual sections of this document describe the steps in applying these principles within the framework of the **RBI** process:

- Planning the **RBI** Assessment.
- Data and Information Collection.
- Identifying Deterioration Mechanisms and Failure Modes.
- Assessing Probability of Failure.
- Assessing Consequence of Failure.
- Risk Determination, Assessment and Management.
- Risk Management with Inspection Activities.
- Other Risk Mitigation Activities.
- Reassessment and Updating.
- Roles, Responsibilities, Training and Qualifications.
- Documentation and record-keeping.

1. PURPOSE

The **RBI** process is capable of generating:

- a) A Risk Ranking of all Equipment evaluated.
- b) A detailed description of the inspection plan to be employed for each equipment item, including:
 - 1. Inspection method that should be used (e.g. visual, UT, Radiography, WFMT).
 - 2. Extent of application of the inspection method (e.g. percent of total area examined or specific locations).
 - 3. Timing of inspections / examinations.
 - 4. Risk management achieved through implementation of the inspection plan.

1. PURPOSE

The **RBI** process is capable of generating:

- C) A description of any other risk mitigation activities such as repairs, replacements or safety equipment upgrades.**

- D) The knowable risk levels of all equipment after the inspection plan and other risk mitigation activities have been implemented.**

1. PURPOSE

■ Key Elements of a RBI Program

- a) Management systems for maintaining documentation, personnel qualifications, data requirements and analysis updates.
- b) Documented method for probability of failure determination.
- c) Documented method for consequence of failure determination.
- d) Documented methodology for managing risk through inspection and other mitigation activities.

1. PURPOSE

RBI Benefits and Limitations:

- **RBI** plans address ways to manage risks on an equipment level.
- Equipment plans highlight risks from a Safety, Health, Environment and or from an economic perspective.
- Cost-effective actions for risk mitigation

Implementation of these plans provides one of the following:

- a) An overall reduction in risk for the facilities and equipment assessed.**
- b) An acceptance/understanding of the current risk.**

1. PURPOSE

RBI is based on sound, proven risk assessment and management principles. However, **RBI** will not compensate for:

- a) Inaccurate or missing information.
- b) Inadequate designs or faulty equipment installation.
- c) Operating outside the acceptable design envelope.
- d) Not effectively executing the plans.
- e) Lack of qualified personnel or teamwork.
- f) Lack of sound engineering or operational judgment.

1. PURPOSE

Using RBI as a Continuous Improvement Tool

- **RBI** provides a vehicle for continuously improving the inspection of facilities and systematically reducing the risk associated with pressure boundary failures.
- **RBI** offers the added advantage of identifying gaps in the effectiveness of available inspection technologies and applications.
- **RBI** should serve to guide the direction of inspection technology development, and hopefully promote a faster and broader deployment of emerging inspection technologies

1. PURPOSE

RBI as an Integrated Management Tool

- **RBI** produces Inspection and Maintenance Plans for equipment that identify the actions that should be implemented to provide reliable and safe operation.
- The **RBI** effort can provide input into an organization annual planning and budgeting that define the staffing and funds required to maintain equipment operation at acceptable levels of performance and risk.

2. RBI SCOPE

SCOPE OF RBI

■ Industry scope

Risk management principles and concepts that **RBI** is built on are universally applicable but **API RP 580** is specifically target the application of **RBI** in the hydrocarbon and chemical process industry.

■ Flexibility in Application

Because of the broad diversity in organizations' size, culture, federal and/or local regulatory requirements, **RP 580** offers users the flexibility to apply the **RBI** methodology within the context of existing corporate risk management practices and to accommodate unique local circumstances

2. RBI SCOPE

SCOPE OF RBI

■ Flexibility in Application

API RP 580 offers users the flexibility to apply the **RBI** methodology within the existing risk management practices and to accommodate unique local circumstances.

RP 580 is intended to promote consistency and quality in the identification, assessment and management of risks pertaining material deterioration, which could lead to loss of containment.

This document is not intended to single out one specific approach as the recommended method for conducting a **RBI** effort.

2. RBI SCOPE

SCOPE OF RBI

■ Mechanical Integrity Focused

The **RBI** focused on maintaining the mechanical integrity of pressure equipment items and minimizing the risk of loss of containment due to deterioration.

2. RBI SCOPE

SCOPE OF RBI

- **Equipment Covered in API RP 580:**
 - a) **Pressure vessels:** All pressure containing components.
 - b) **Process piping:** Pipe and piping components.
 - c) **Storage tanks:** Atmospheric and pressurized.
 - d) **Rotating equipment:** Pressure containing components.
 - e) **Boilers and heaters:** Pressurized components.
 - f) **Heat exchangers:** Shells, Heads, Channels and Bundles.
 - g) **Pressure relief devices.**

2. RBI SCOPE

SCOPE OF RBI

■ Equipment Not Covered:

The following non-pressurized equipment is not covered by this document:

- a) Instrument and control systems.
- b) Electrical systems.
- c) Structural systems.
- d) Machinery components (except pump and compressor casings).

2. RBI SCOPE

■ TARGET AUDIENCE

Inspection and Engineering, Maintenance, Operations personnel who are responsible for the mechanical integrity and operability of equipment.

Others within the organization who are likely to be involved should be familiar with the concepts and principles in the **RBI** methodology.

4. DEFINITIONS

- **Absolute risk:** An ideal and accurate description and quantification of risk.
- **ALARP (As Low As Reasonably Practical):** A concept of minimization that suggest that feature (such as risk) can only be reduced to a certain minimum under current technology and with reasonable cost

4. DEFINITIONS

- **Consequence:** Outcome from an event. There may be one or more consequences from an event. Consequences may range from positive to negative. However, consequences are always negative for safety aspects.
- **Damage tolerance:** The amount of deterioration that a component can resist without failing.
- **Deterioration:** The reduction in the ability of a component to provide its intended purpose of containment of fluids.

4. DEFINITIONS

- **Event:** Occurrence of a particular set of circumstances. The event may be certain or uncertain.
- **Event tree:** An analytical tool that organizes and characterizes potential accidents in a logical and graphical manner.
- **External event:** Events resulting from forces of nature, acts of God or sabotage, or such events as neighboring fires or explosions, neighboring hazardous material releases. External events are usually beyond the direct or indirect control of persons employed at or by the facility.

4. DEFINITIONS

- **Failure mode:** The manner of failure. For risk based inspection, the failure of concern is loss of containment of pressurized equipment. Examples of failure modes are small hole, crack, and rupture.
- **Hazard:** A physical condition or a release of a hazardous material that could result from component failure and result in human injury or death, loss or damage, or environmental degradation. Hazard is the source of harm.

4. DEFINITIONS

- **Mitigation:** Limiting of any negative consequence or reduction in probability of a particular event.
- **Probability:** Extent to which an event is likely to occur within the time frame under consideration.
- **Qualitative Risk Analysis (Assessment):**

Methods that use engineering judgment and experience as the bases for the analysis of probabilities and consequences of failure.

4. DEFINITIONS

■ Quantitative Risk Analysis (Assessment):

Quantitative risk analysis integrates into a uniform methodology the relevant information about facility design, operating practices, operating history, component reliability, human actions, the physical progression of accidents, and potential environmental and health effects, usually very realistic.

4. DEFINITIONS

- **Relative risk:** The comparative risk of a facility, process unit, system, equipment item or component to other facilities, process units, systems, equipment items or components, respectively.
- **Residual risk:** The risk remaining after risk mitigation.
- **Risk:** Combination of the probability of an event and its consequence.
- **Risk acceptance:** A decision to accept a risk.

4. DEFINITIONS

- **Risk assessment:** Overall process of risk analysis and risk evaluation
- **Risk Based inspection:** A risk assessment and management process that is focused on loss of containment of pressurized equipment in processing facilities, due to material deterioration. These risks are managed primarily through equipment inspection.
- **Risk control:** Actions implementing risk management decisions.
- **Risk reduction:** Actions taken to reduce the probability, negative consequences, or both associated with a particular risk.

4. DEFINITIONS

- **Risk identification:** Process to find, list, and characterize elements of risk. Elements may include; source, event, consequence, probability.
- **Risk management:** Coordinated activities to direct and control an organization with regard to risk. Risk management typically includes risk assessment, risk mitigation and risk acceptance.
- **Risk mitigation:** Process of selection and implementation of measures to modify risk.

5. BASIC CONCEPTS

WHAT IS RISK?

- Risk is something that we as individuals live with on a day to day basis.
- Knowingly or unknowingly, people are constantly making decisions based on risk. Simple decisions such as driving to work or walking across a busy street involve risk.
- More important decisions such as buying a house, investing money and getting married all imply an acceptance of risk.

Risk is the combination of the probability of some event occurring during a time period of interest and the consequences associated with the event.

- In mathematical terms, risk can be calculated by the equation:

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

5. BASIC CONCEPTS

RISK MANAGEMENT AND RISK REDUCTION

- Risk reduction is only part of risk management.
- Risk reduction is the act of mitigating a known risk to a lower level of risk.
- Risk management is a process to assess risks, to determine if risk reduction is required and to develop a plan to maintain risks at an acceptable level.
- By using risk management, some risks may be identified as acceptable so that no risk reduction (mitigation) is required.

5. BASIC CONCEPTS

THE ADVANCEMENT OF INSPECTION INTERVALS

- In process plants, inspection and testing programs are established to detect and evaluate deterioration due to in-service operation.
- The effectiveness of inspection programs varies widely.
- One extreme of this would be the “don’t fix it unless it’s broken” approach. The other extreme would be complete inspection of all equipment items on a frequent basis.
- Time-based or “calendar based” intervals approach

5. BASIC CONCEPTS

THE ADVANCEMENT OF INSPECTION INTERVALS

- With advances in inspection approaches, and better understanding of the type and rate of deterioration, inspection intervals became more dependent on the equipment condition, rather than what might have been an random calendar date.
- Codes and standards such as **API 510, 570** and **653** evolved to an inspection philosophy with elements such as:
 - a) Inspection intervals based on some percentage of equipment life (such as half life).
 - b) On-stream inspection in lieu of internal inspection based on low deterioration rates.
 - c) Internal inspection requirements for deterioration mechanisms related to process environment induced cracking.
 - d) Consequence based inspection intervals

5. BASIC CONCEPTS

THE ADVANCEMENT OF INSPECTION INTERVALS

- **RBI** represents the next generation of inspection approaches recognizing that the ultimate goal of inspection is the safety and reliability of operating facilities.
- **RBI**, as a risk-based approach, focuses attention specifically on the equipment and associated deterioration mechanisms representing the most risk to the facility.
- **RBI** provides a better linkage between the mechanisms that lead to equipment failure and the inspection approaches that will effectively reduce the associated risks.

5. BASIC CONCEPTS

INSPECTION OPTIMIZATION

- In **RBI** each available inspection method can be analyzed and its relative effectiveness.
- In view of this information and the cost of each Inspection method, an optimization program can be developed to assess the risk associated with each item of equipment and the most appropriate inspection techniques for that piece of equipment.
- A conceptual result of this methodology is illustrated by the lower curve in Figure 1 in next slide. The lower curve indicates that with the application of an effective **RBI** program.

5. BASIC CONCEPTS

INSPECTION OPTIMIZATION

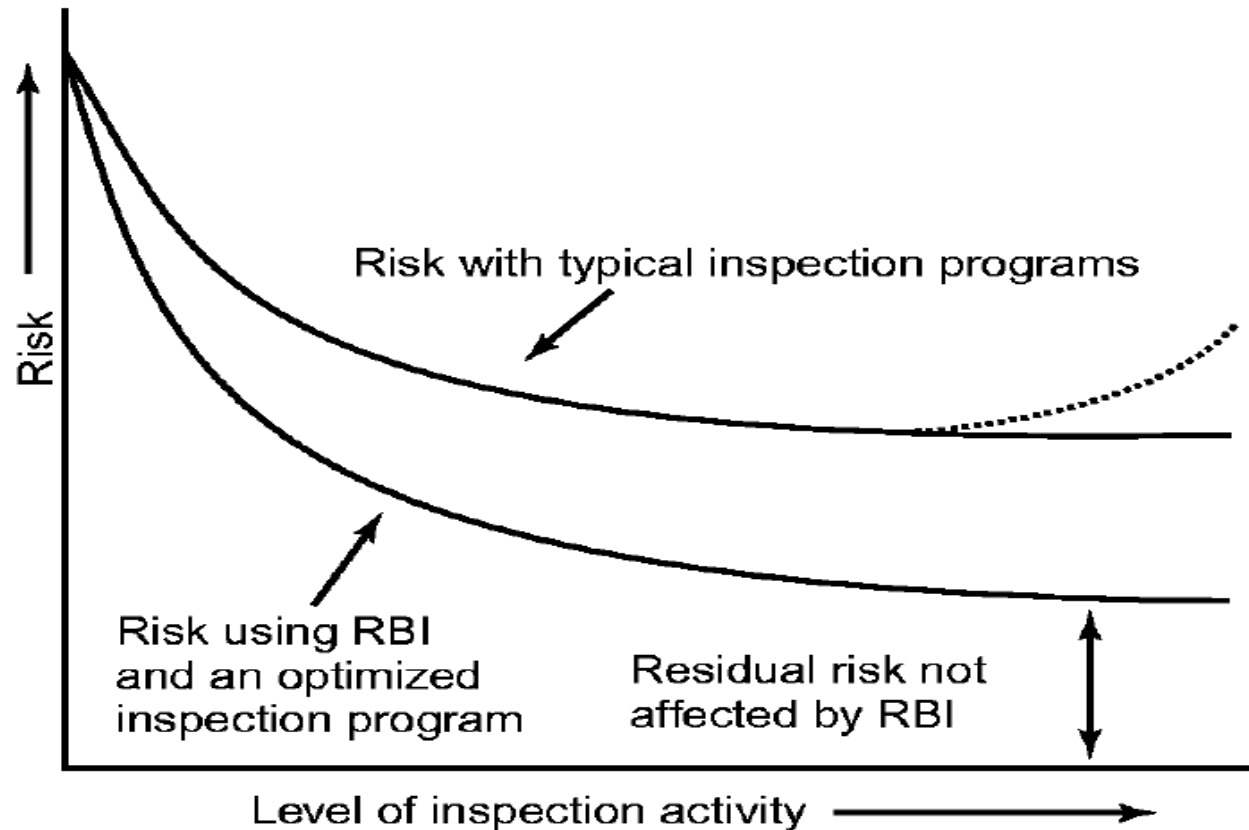


Figure 1—Management of Risk Using RBI

5. BASIC CONCEPTS

RELATIVE RISK VS. ABSOLUTE RISK

- The complexity of risk calculations is a function of the number of factors that can affect the risk.
- Many variables are involved with loss of containment in hydrocarbon and chemical facilities and the determination of absolute risk is often not cost effective.
- **RBI** is focused on a systematic determination of relative risks. In this way, facilities, units, systems, equipment or components can be ranked based on relative risk. This serves to focus the risk management efforts on the higher ranked risks.

6. INTRODUCTION TO RISK BASED INSPECTION

CONSEQUENCE AND PROBABILITY FOR RISK BASED INSPECTION

- The objective of **RBI** is to determine what incident could occur (consequence) in the event of an equipment failure, and how likely (probability) is it that the incident could happen.
- For example, if a pressure vessel subject to deterioration from corrosion under insulation develops a leak, a variety of consequences could occur. Some of the possible consequences are:

6. INTRODUCTION TO RISK BASED INSPECTION

- a) Form a vapor cloud that could ignite causing injury and equipment damage.
- b) Release of a toxic chemical that could cause health problems.
- c) Result in a spill and cause environmental deterioration.
- d) Force a unit shutdown and have an adverse economic impact.
- e) Have minimal safety, health, environmental and/or economic impact.

6. INTRODUCTION TO RISK BASED INSPECTION

- Combining the probability of one or more of these events with its consequences will determine the risk to the operation.
- Some failures may occur relatively frequently without significant adverse safety, environmental or economic impacts.
- Similarly, some failures have potentially serious consequences, but if the probability of the incident is low, then the risk may not warrant immediate action.
- However, if the probability and consequence combination (risk) is high enough to be unacceptable, then a mitigation action to predict or prevent the event is recommended.

6. INTRODUCTION TO RISK BASED INSPECTION

- Understanding the two-dimensional aspect of risk allows new insight into the use of risk for inspection prioritization and planning.
- Figure 2 displays the risk associated with the operation of a number of equipment items in a process plant.

6. INTRODUCTION TO RISK BASED INSPECTION

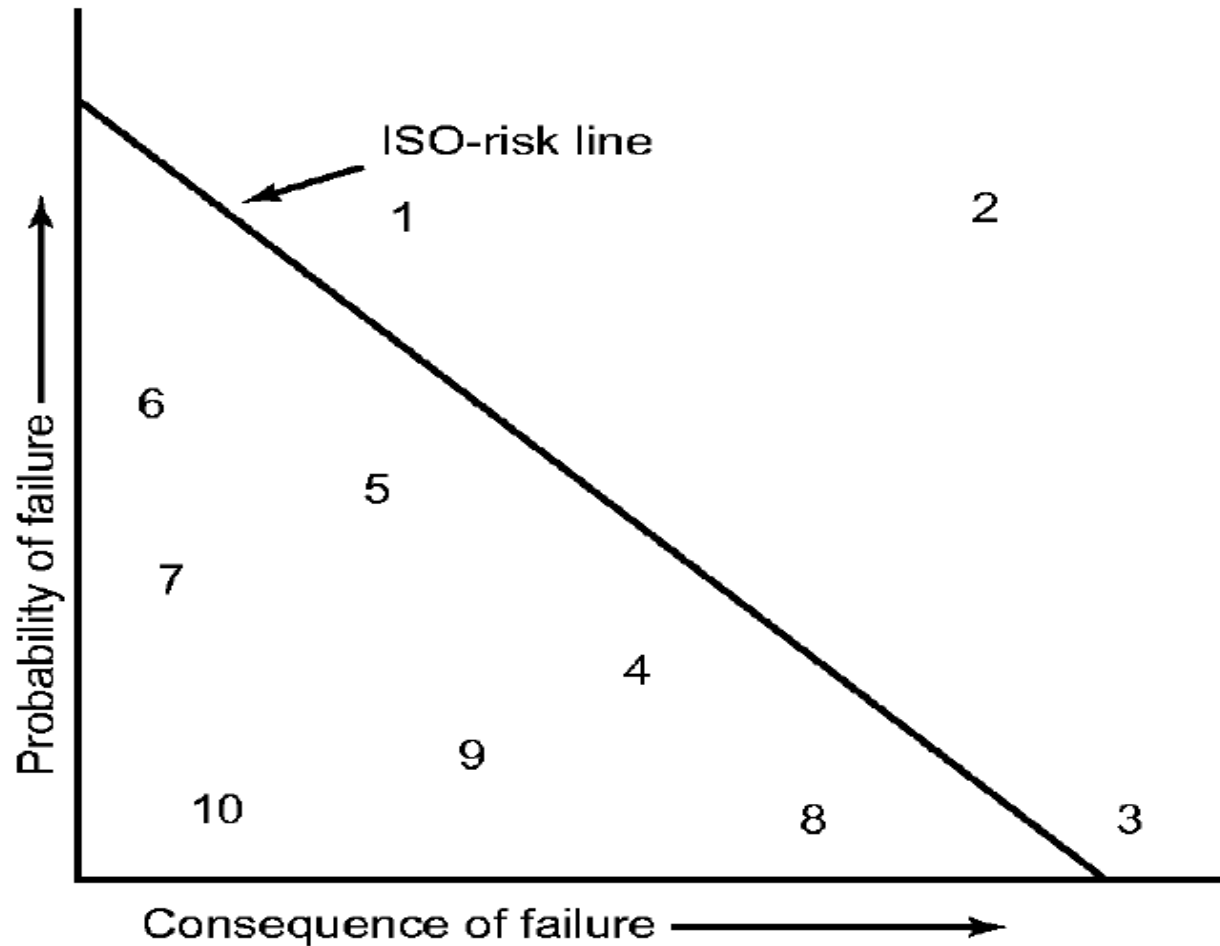


Figure 2—Risk Plot

6. INTRODUCTION TO RISK BASED INSPECTION

TYPES OF RBI ASSESSMENT

Various types of **RBI** assessment may be conducted at several levels. The choice of approach is dependent on multiple variables such as:

- a) Objective of the study.
- b) Number of facilities and equipment items to study.
- c) Available resources.
- d) Study time frame.
- e) Complexity of facilities and processes.
- f) Nature and quality of available data

6. INTRODUCTION TO RISK BASED INSPECTION

TYPES OF RBI ASSESSMENT

- Qualitative Approach
- Quantitative Approach
- Semi Quantitative Approach

6. INTRODUCTION TO RISK BASED INSPECTION

Qualitative Approach

- This approach using engineering judgment and experience for the analysis of probability and consequence of failure.
- Results are typically given in qualitative terms such as high, medium and low, although numerical values may be associated with these categories.
- The accuracy of results from a qualitative analysis is dependent on the background and expertise of the analysts.

6. INTRODUCTION TO RISK BASED INSPECTION

Quantitative Approach

- Quantitative risk analysis integrates into a uniform methodology the relevant information about facility design, operating practices, operating history, component reliability, human actions, the physical progression of accidents, and potential environmental and health effects.
- Quantitative risk analysis uses logic models representing combinations of events that could result in severe accidents and physical models representing the progression of accidents.
- Results using this approach are typically presented as risk numbers.

6. INTRODUCTION TO RISK BASED INSPECTION

Semi Quantitative Approach

- Semi-quantitative is a term that describes any approach that has aspects derived from both the qualitative and quantitative approaches.
- It is geared to obtain the major benefits of the previous two approaches (e.g. speed of the qualitative and rigor of the quantitative).
- Typically, most of the data used in a quantitative approach is needed for this approach but in less detail.

6. INTRODUCTION TO RISK BASED INSPECTION

Continuum of Approaches

- **RBI** study typically uses aspects of qualitative, quantitative and semi-quantitative approaches.
- These **RBI** approaches are not considered as competing but rather as complementary. For example:
- A high level qualitative approach could be used at a unit level to find the unit within a facility that provides the highest risk. Systems and equipment within the unit then may be screened using a qualitative approach with a more quantitative approach used for the higher risk items.
- Figure 3 illustrates this continuum concept.

6. INTRODUCTION TO RISK BASED INSPECTION

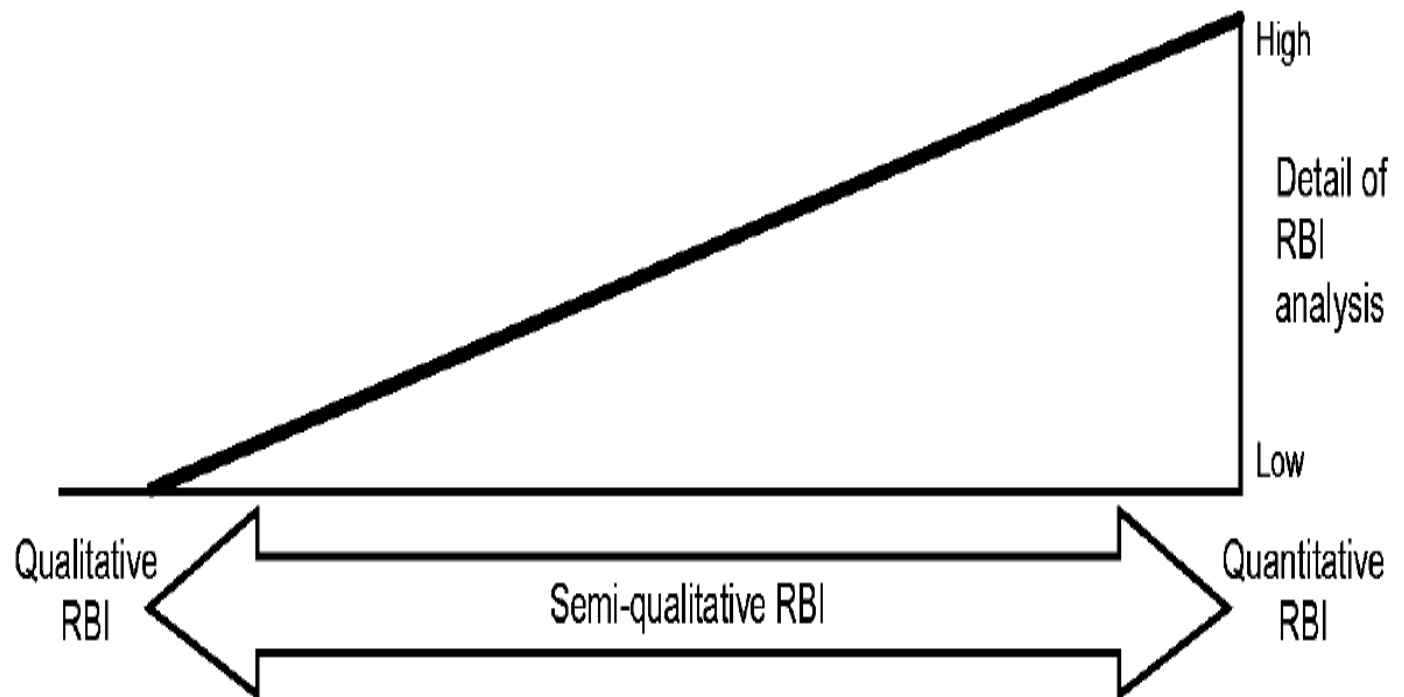


Figure 3—Continuum of RBI Approaches

6. INTRODUCTION TO RISK-BASED INSPECTION

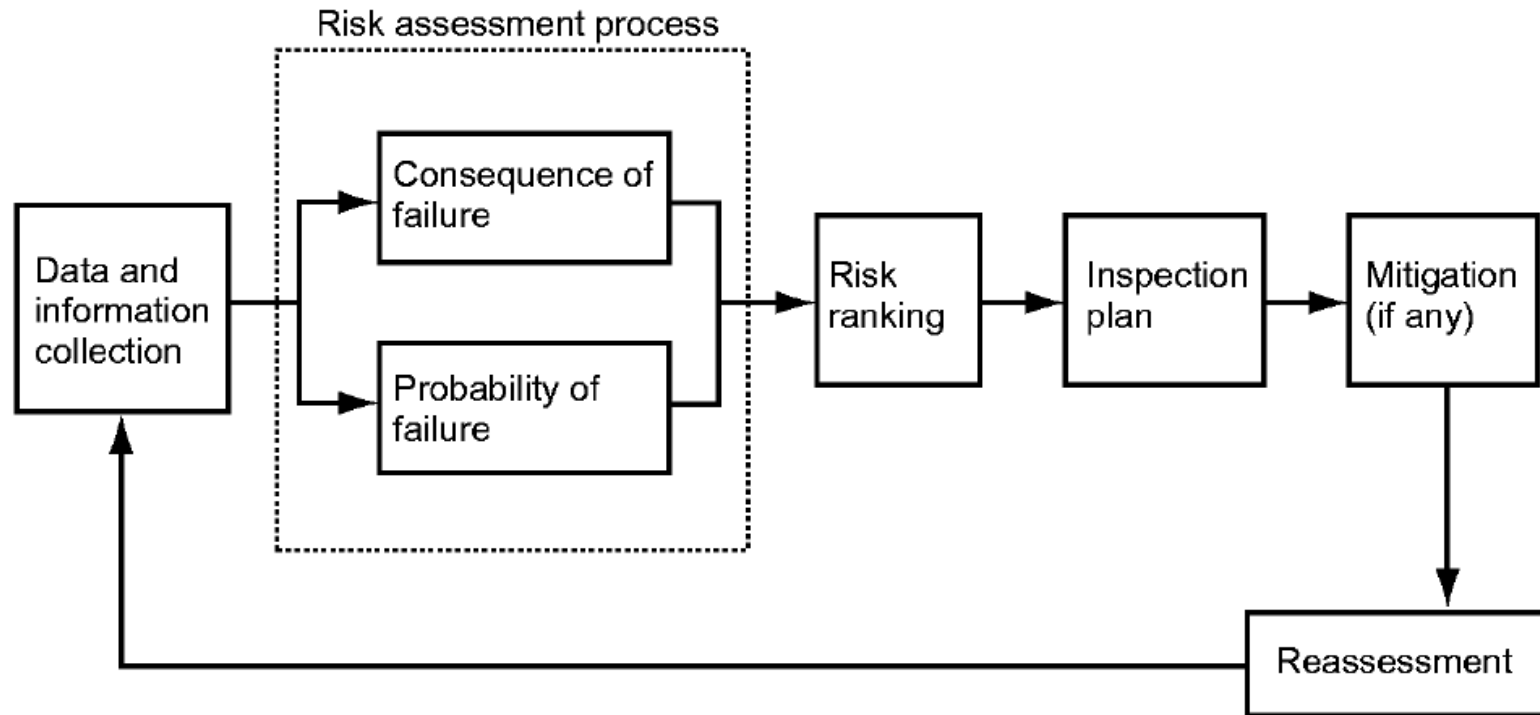


Figure 4—Risk-based Inspection Planning Process

6. INTRODUCTION TO RISK-BASED INSPECTION

■ Quantitative Risk Assessment (QRA)

The traditional QRA is generally comprised of five tasks:

- a) Systems identification.
- b) Hazards identification.
- c) Probability assessment.
- d) Consequence analysis.
- e) Risk results.

6. INTRODUCTION TO RISK-BASED INSPECTION

UNDERSTANDING HOW RBI CAN HELP TO MANAGE OPERATING RISKS

- In performing a **RBI** assessment, the susceptibility of equipment to deterioration by one or more mechanisms (e.g. corrosion, fatigue and cracking) is established.
- The suitability and current condition of the equipment within the current operating envelope will determine the probability of failure (POF) of the equipment from one or more deterioration mechanisms.
- This probability, when coupled with the associated consequence of failure (COF) will determine the operating risk associated with the equipment item.
- And therefore the need for mitigation, if any, such as inspection, metallurgy change or change in operating conditions.

6. INTRODUCTION TO RISK-BASED INSPECTION

MANAGEMENT OF RISKS

■ Risk Management Through Inspection

Although inspection does not reduce risk directly, it is a risk management activity that may lead to risk reduction.

In-service inspection is primarily concerned with the detection and monitoring of deterioration.

The probability of failure due to such deterioration is a function of four factors:

6. INTRODUCTION TO RISK-BASED INSPECTION

- a) Deterioration type and mechanism.
- b) Rate of deterioration.
- c) Probability of identifying and detecting deterioration and predicting future deterioration states with inspection technique.
- d) Tolerance of the equipment to the type of deterioration.

6. INTRODUCTION TO RISK-BASED INSPECTION

Using RBI to Establish Inspection Plans and Priorities

- The primary product of a **RBI** effort should be an inspection plan for each equipment item evaluated.
- The inspection plan should detail the unmitigated risk related to the current operation.
- For those equipment items where inspection is a cost-effective means of risk management, the plans should describe the type, scope and timing of inspection / examination recommended.
- Ranking of the equipment by the unmitigated risk level allows users to assign priorities to the various inspection / examination tasks.

7. PLANNING THE RBI ASSESSMENT

GETTING STARTED

A **RBI** assessment is a team-based process. At the beginning of the exercise, it is important to define:

- Why the assessment is being done.
- How the **RBI** assessment will be carried out.
- What knowledge and skills are required for the assessment.
- Who is on the **RBI** team.
- What are their roles in the **RBI** process.

7. PLANNING THE RBI ASSESSMENT

- Who is responsible and accountable for what actions.
- Which facilities, assets, and components will be included.
- What data is to be used in the assessment.
- What codes and standards are applicable.
- When the assessment will be completed.
- How long the assessment will remain in effect and when it will be updated.
- How the results will be used.

7. PLANNING THE RBI ASSESSMENT

■ ESTABLISHING OBJECTIVES AND GOALS OF A RBI ASSESSMENT

A **RBI** assessment should be undertaken with clear objectives and goals that are fully understood by all members of the **RBI** team and by management. Some examples are listed below:

1. Understand Risks
2. Define Risk Criteria
3. Management of Risks
4. Reduce Costs
5. Meet Safety and Environmental Management Requirements
6. Sort Mitigation Alternatives
7. New Project Risk Assessment

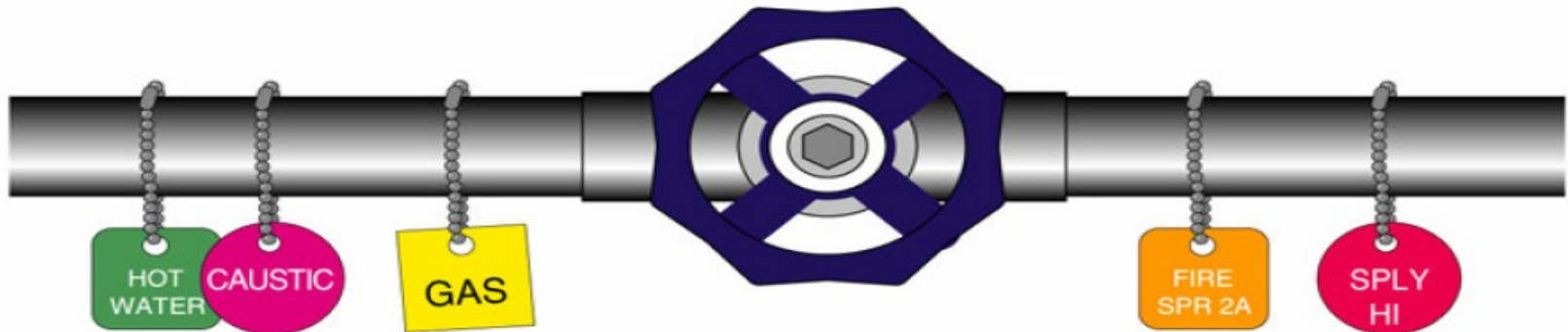
7. PLANNING THE RBI ASSESSMENT

INITIAL SCREENING

■ Establish Physical Boundaries of a RBI Assessment

The scope of a **RBI** assessment may vary between an entire refinery or plant and a single component within a single piece of equipment.

Typically, **RBI** is done on multiple pieces of equipment (e.g. an entire process unit) rather than on a single component.



7. PLANNING THE RBI ASSESSMENT

■ Facilities Screening

At the facility level, **RBI** may be applied to all types of plants including but not limited to:

- a. Oil and gas production facilities.
- b. Oil and gas processing and transportation terminals.
- c. Refineries.
- d. Petrochemical and chemical plants.
- e. Pipelines and pipeline stations.
- f. LNG plants.

Screening at the facility level may be done by a simplified qualitative **RBI** assessment.

7. PLANNING THE RBI ASSESSMENT

■ Process Units Screening

If the scope of the **RBI** assessment is a multi-unit facility, then the next step in the application of **RBI** is screening of entire process units to rank relative risk.

Priorities may be assigned based on one of the following:

- a) Relative risk of the process units.
- b) Relative economic impact of the process units.
- c) Relative COF of the process units.
- d) Relative reliability of the process units.
- e) Turnaround schedule.
- f) Experience with similar process units.

7. PLANNING THE RBI ASSESSMENT

■ Systems within Process Units Screening

It is often useful to group equipment within a process unit into systems or circuits where common environmental operating conditions exist based on process chemistry, pressure and temperature, metallurgy, equipment design and operating history.

By dividing a process unit into systems, the equipment can be screened together saving time compared to treating each piece of equipment separately.

7. PLANNING THE RBI ASSESSMENT

■ Equipment Item Screening

In most plants, a large percentage of the total unit risk will be concentrated in a relatively small percentage of the equipment items.

Potential high-risk items should receive greater attention in the risk assessment.

Screening of equipment items is often conducted to identify the higher risk items to carry forward to more detailed risk assessment.

7. PLANNING THE RBI ASSESSMENT

A **RBI** assessment may be applied to all pressure containing equipment such as:

- a) Piping.
- b) Pressure vessels.
- c) Reactors.
- d) Heat exchangers.
- e) Furnaces.
- f) Tanks.
- g) Pumps (pressure boundary).
- h) Compressors (pressure boundary).
- i) Pressure relief devices.
- j) Control valves (pressure boundary).

7. PLANNING THE RBI ASSESSMENT

■ ESTABLISH OPERATING BOUNDARIES

The purpose of establishing operational boundaries is to identify key process parameters that may impact deterioration.

The **RBI** assessment normally includes review of both POF and COF for normal operating conditions.

Start-up and shut-down conditions as well as emergency and non-routine conditions should also be reviewed for their potential effect on POF and COF.

7. PLANNING THE RBI ASSESSMENT

■ SELECTING A TYPE OF RBI ASSESSMENT

Selection of the type of **RBI** assessment will be dependent on a variety of factors, such as:

- a) Is the assessment at a facility, process unit, system, equipment item or component level.
- b) Objective of the assessment
- c) Availability and quality of data.
- d) Resource availability.
- e) Apparent or previously evaluated risks.
- f) Time constraints.

7. PLANNING THE RBI ASSESSMENT

■ ESTIMATING RESOURCES AND TIME REQUIRED

The resources and time required to implement a **RBI** assessment depends on a number of factors including:

- a) Implementation strategy / plans.
- b) Knowledge and training of implementers.
- c) Availability and quality of necessary data and information.
- d) Availability and cost of resources needed for implementation.
- e) Amount of equipment included in each level of **RBI** analysis.
- f) Degree of complexity of **RBI** analysis selected.
- g) Degree of accuracy required.

7. PLANNING THE RBI ASSESSMENT

- The estimate of scope and cost involved in completing a **RBI** assessment might include the following:
 1. Number of facilities, units, equipment items, and components to be evaluated.
 2. Time and resources required to gather data for the items to be evaluated.
 3. Training time for implementers.
 4. Time and resources required for **RBI** assessment of data and information.
 5. Time and resources to evaluate **RBI** assessment results and develop inspection, maintenance, and mitigation plans.

8. DATA & INFORMATION COLLECTION FOR RBI ASSESSMENT

RBI DATA NEEDS

Typical data needed for a **RBI** analysis may include but is not limited to:

- Type of equipment.
- Materials of construction.
- Inspection, repair and replacement records.
- Process fluid compositions.
- Inventory of fluids.
- Operating conditions.

8. DATA & INFORMATION COLLECTION FOR RBI ASSESSMENT

RBI DATA NEEDS

- Safety systems.
- Detection systems.
- Deterioration mechanisms, rates and severity.
- Personnel densities.
- Coating, cladding and insulation data.
- Business interruption cost.
- Equipment replacement costs.
- Environmental remediation costs.

8. DATA & INFORMATION COLLECTION FOR RBI ASSESSMENT

■ DATA QUALITY

The data quality has a direct relation to the relative accuracy of the **RBI** analysis.

It is beneficial to the integrity of a **RBI** analysis to assure that the data are up to date and validated by knowledgeable persons.

8. DATA & INFORMATION COLLECTION FOR RBI ASSESSMENT

■ SOURCES OF SITE SPECIFIC DATA AND INFORMATION

Specific potential sources of information include but are not limited to:

- a) Design and Construction Records/Drawings
- b) Inspection Records
- c) Process Data.
- d) Management of change (MOC) records.
- e) Off-Site data and information-if consequence may affect off-site areas.
- f) Failure data.
- g) Site conditions.
- h) Equipment replacement Cost.

9. DAMAGE MECHANISMS AND FAILURE MODES

■ INTRODUCTION

Identification of the appropriate deterioration mechanisms, susceptibilities and failure modes in a **RBI** study is essential to the effectiveness of the **RBI** evaluation.

A metallurgist or corrosion specialist should be consulted to define the equipment deterioration mechanisms, susceptibility and potential failure modes.

The deterioration mechanisms, rates and susceptibilities are the primary inputs into the probability of failure evaluation.

9. DAMAGE MECHANISMS AND FAILURE MODES

■ FAILURE AND FAILURE MODES FOR RISKBASED INSPECTION

The term failure can be defined as termination of the ability to perform a required function.

RBI is concerned with one type of failure, namely loss of containment caused by deterioration.

The term failure mode is defined as the manner of failure. Failure modes can range from a small hole to a complete rupture.

9. DAMAGE MECHANISMS AND FAILURE MODES

■ DETERIORATION MECHANISMS

The term deterioration mechanism is defined as the type of deterioration that could lead to a loss of containment. There are four major deterioration mechanisms observed in the hydrocarbon and chemical process industry:

- a) Thinning (includes internal and external).
- b) Stress corrosion cracking.
- c) Metallurgical and environmental.
- d) Mechanical.

9. DAMAGE MECHANISMS AND FAILURE MODES

- Appendix A provides tables describing the individual deterioration mechanisms covered by these four categories, the key variables driving deterioration, and typical process industry examples of where they may occur.
- These tables cover most of the common deterioration mechanisms. Other deterioration types and mechanisms may occur in specific hydrocarbon and chemical processing applications; however, these are relatively infrequent.

9. DAMAGE MECHANISMS AND FAILURE MODES

■ OTHER FAILURES

RBI could be expanded to include failures other than loss of containment. Examples of other failures and failure modes are:

- a) Pressure relief device failure - plugging, fouling, no activation.
- b) Heat exchanger bundle failure - tube leak, plugging.
- c) Internal linings -hole, disbandment.

10. ASSESSING PROBABILITY OF FAILURE

■ INTRODUCTION TO PROBABILITY ANALYSIS

The probability of failure analysis should address all deterioration mechanisms to which the equipment being studied is susceptible.

It should address the situation where equipment is susceptible to multiple deterioration mechanisms (e.g. thinning and creep).

10. ASSESSING PROBABILITY OF FAILURE

- It should be noted that deterioration mechanisms are not the only causes of loss of containment. Other causes of loss of containment could include but are not limited to:
 - a) Weather extremes.
 - b) Seismic activity.
 - c) Overpressure due to pressure relief device failure.
 - d) Operator error.
 - e) Inadvertent substitution of materials of construction.
 - f) Design error.
 - g) Sabotage.

These and other causes of loss of containment may have an impact on the probability of failure and may be included in the probability of failure analysis.

10. ASSESSING PROBABILITY OF FAILURE

■ UNITS OF MEASURE IN THE PROBABILITY OF FAILURE ANALYSIS

Probability of failure is typically expressed in terms of frequency.

Frequency is expressed as a number of events occurring during a specific time frame. For probability analysis, the time frame is typically expressed as a fixed interval (e.g. one year)

For a qualitative analysis, the probability of failure may be categorized (e.g. high, medium and low, or 1 through 5).

10. ASSESSING PROBABILITY OF FAILURE

TYPES OF PROBABILITY ANALYSIS

- Different approaches to the determination of probability.
- Qualitative” or “quantitative.
- Qualitative” and “quantitative” are the end points of a continuum rather than distinctive approaches. Most probability assessments use a blend of qualitative and quantitative approaches.

10. ASSESSING PROBABILITY OF FAILURE

Qualitative Probability of Failure Analysis

- A qualitative method involves identification of the units, systems or equipment, the materials of construction and the corrosive components of the processes.
- On the basis of the operating history, future inspection and maintenance plans and possible materials deterioration, probability of failure can be assessed.
- Engineering judgment is the basis for this assessment.
- Depending on the methodology employed, the categories may be described with words (such as high, medium or low) or may have numerical value.

10. ASSESSING PROBABILITY OF FAILURE

Quantitative Probability of Failure Analysis

- There are several approaches to a quantitative probability analysis.
- One example is to take a probabilistic approach where specific failure data or expert solicitations are used to calculate a probability of failure.
- These failure data may be obtained on the specific equipment item in question or on similar equipment items.
- Other approach, in this case, general industry, company or manufacturer failure data are used. A methodology should be applied to assess the applicability of these general data.

10. ASSESSING PROBABILITY OF FAILURE

■ DETERMINATION OF PROBABILITY OF FAILURE

Regardless of whether a more qualitative or a quantitative analysis is used, the probability of failure is determined by two main considerations:

- a) Deterioration mechanisms and rates of the equipment item's material of construction, resulting from its operating environment (internal and external).
- a) Effectiveness of the inspection program to identify and monitor the deterioration mechanisms so that the equipment can be repaired or replaced prior to failure.

10. ASSESSING PROBABILITY OF FAILURE

- Analyzing the effect of in service deterioration and inspection on the probability of failure involves the following steps:
 - a) Identify active and likely deterioration mechanisms that are reasonably expected to occur during the time period being considered.
 - b) Determine the deterioration susceptibility and rate.
 - c) Quantify the effectiveness of the past inspection and maintenance program and a proposed future inspection and maintenance program.
 - d) The failure mode (e.g. small leak, large leak, equipment rupture) should also be determined based on the deterioration mechanism.

10. ASSESSING PROBABILITY OF FAILURE

■ Determine Failure Mode

It is important to link the deterioration mechanism to the most likely resulting failure mode. For example:

- a) Pitting generally leads to small hole-sized leaks.**
- b) Stress corrosion cracking can develop into small, through wall cracks or, in some cases, catastrophic rupture.**
- c) Metallurgical deterioration and mechanical deterioration can lead to failure modes that vary from small holes to ruptures.**
- d) General thinning from corrosion often leads to larger leaks or rupture.**

Failure mode primarily affects the magnitude of the consequences.

10. ASSESSING PROBABILITY OF FAILURE

Quantify Effectiveness of Past Inspection

- Inspection programs vary in their effectiveness for locating and sizing deterioration, and thus for determining deterioration rates.
- The inspection program should be evaluated to determine the effectiveness in finding the identified mechanisms.

10. ASSESSING PROBABILITY OF FAILURE

- Limitations in the effectiveness of an inspection program could be due to:
 - a) Lack of coverage of an area subject to deterioration.
 - b) Inherent limitations of some inspection methods to detect and quantify certain types of deterioration.
 - c) Selection of inappropriate inspection methods and tools.
 - d) Application of methods and tools by inadequately trained inspection personnel.
 - e) Inadequate inspection procedures.
 - f) Deterioration rate under some extremes of conditions is so high that failure can occur within a very short time. Even though no deterioration is found during an inspection.

10. ASSESSING PROBABILITY OF FAILURE

- Determination of inspection effectiveness should consider the following:
 1. Equipment type.
 2. Active and credible deterioration mechanism.
 3. Rate of deterioration or susceptibility.
 4. NDE methods, coverage and frequency.
 5. Accessibility to expected deterioration areas.

The effectiveness of future inspections can be optimized by utilization of NDE methods better suited for the active / credible deterioration mechanisms.

10. ASSESSING PROBABILITY OF FAILURE

Calculate the Probability of Failure by Deterioration Type

- By combining the expected deterioration mechanism, rate or susceptibility, inspection data and inspection effectiveness, a probability of failure can now be determined for each deterioration type and failure mode.
- The probability of failure may be determined for future time periods or conditions as well as current.
- It is important for user to validate that the method used to calculate the POF is in fact thorough and adequate for the user needs.

11. ASSESSING CONSEQUENCES OF FAILURE

Assessing Consequences of Failure

■ INTRODUCTION TO CONSEQUENCE ANALYSIS

The consequence analysis in a **RBI** program is performed to provide discrimination between equipment items on the basis of the significance of a potential failure.

The consequence analysis is an aid in establishing a relative risk ranking of equipment items.

The consequence analysis should be a repeatable, simplified, credible estimate of what might be expected to happen if a failure were to occur in the equipment item being assessed.

11. ASSESSING CONSEQUENCES OF FAILURE

■ Loss of Containment

The consequence effects for loss of containment can be generally considered to be in the following categories:

- a) Safety and health impact.
- b) Environmental impact.
- c) Production losses.
- d) Maintenance and reconstruction costs.

11. ASSESSING CONSEQUENCES OF FAILURE

TYPES OF CONSEQUENCE ANALYSIS

- **Qualitative Consequences Analysis**
- **Quantitative Consequences Analysis**
- **Semi Quantitative Consequences Analysis**

11. ASSESSING CONSEQUENCES OF FAILURE

Qualitative Consequences Analysis

- A qualitative method involves identification of the units, systems or equipment, and the hazards present as a result of operating conditions and process fluids.
- The consequences of failure can be estimated separately for each unit, system, equipment group or individual equipment item.
- For a qualitative method, a consequences category (such as “**A**” through “**E**” or “high”, “medium” or “low”) is typically assigned for each unit, system, grouping or equipment item.
- It may be appropriate to associate a numerical value, such as cost with each consequence category.

11. ASSESSING CONSEQUENCES OF FAILURE

■ Quantitative Consequences Analysis

A quantitative method involves using a logic model describing combinations of events to represent the effects of failure on people, property, the business and the environment.

Quantitative models usually contain one or more standard failure scenarios or outcomes and calculate consequence of failure based on:

- a) Type of process fluid in equipment.
- b) State of the process fluid inside the equipment (solid, liquid or gas).
- c) Key properties of process fluid (molecular weight, boiling point, auto ignition temperature, ignition energy, density, etc.).

11. ASSESSING CONSEQUENCES OF FAILURE

- d) Process operating variables such as temperature and pressure.
- e) Mass of inventory available for release in the event of a leak.
- f) Failure mode and resulting leak size.
- g) State of fluid after release in ambient conditions (solid, gas or liquid).

Results of a quantitative analysis are usually numeric.

11. ASSESSING CONSEQUENCES OF FAILURE

UNITS OF MEASURE IN CONSEQUENCE ANALYSIS

The following provide some units of measure of consequence that can be used in a **RBI** assessment.

■ Safety

Safety consequences are often expressed as a numerical value or characterized by a consequence category associated with the severity of potential injuries that may result from an undesirable event.

For example, safety consequences could be expressed based on the severity of an injury (e.g. fatality, serious injury, medical treatment, first aid)

Or expressed as a category linked to the injury severity (e.g., A through E).

11. ASSESSING CONSEQUENCES OF FAILURE

■ Cost

Cost is commonly used as an indicator of potential consequences. Typical consequences that can be expressed in “cost” include:

- a) Production loss due to rate reduction or downtime.
- b) Deployment of emergency response equipment and personnel.
- c) Lost product from a release.
- d) Degradation of product quality.
- e) Replacement or repair of damaged equipment.
- f) Property damage offsite.

11. ASSESSING CONSEQUENCES OF FAILURE

- g) Spill / release cleanup onsite or offsite.
- h) Business interruption costs (lost profits).
- i) Loss of market share.
- j) Injuries or fatalities.
- k) Land reclamation.
- l) Litigation.
- m) Fines.
- n) Goodwill.

The above list is reasonably comprehensive, but in practice some of these costs are neither practical nor necessary to use in a RBI assessment.

11. ASSESSING CONSEQUENCES OF FAILURE

■ Affected Area

Affected area is also used to describe potential consequences in the field of risk assessment.

As its name implies, affected area represents the amount of surface area that experiences an effect (toxic dose, thermal radiation, explosion overpressure, etc.)

In order to rank consequences according to affected area, it is typically assumed that equipment or personnel at risk are evenly distributed throughout the unit.

11. ASSESSING CONSEQUENCES OF FAILURE

■ Environmental Damage

Environmental consequence measures are the least developed among those currently used for **RBI**. Typical parameters used that provide an indirect measure of the degree of environmental damage are:

- a) Acres of land affected.
- b) Miles of shoreline affected.
- c) Number of biological or human-use resources consumed.

The representation of environmental damage almost invariably leads to the use of cost, in terms of dollars per year, for the loss and restoration of environmental resources.

11. ASSESSING CONSEQUENCES OF FAILURE

■ VOLUME OF FLUID RELEASED

A key element in determining the magnitude of the consequence is the volume of fluid released.

The volume released is typically derived from a combination of the following:

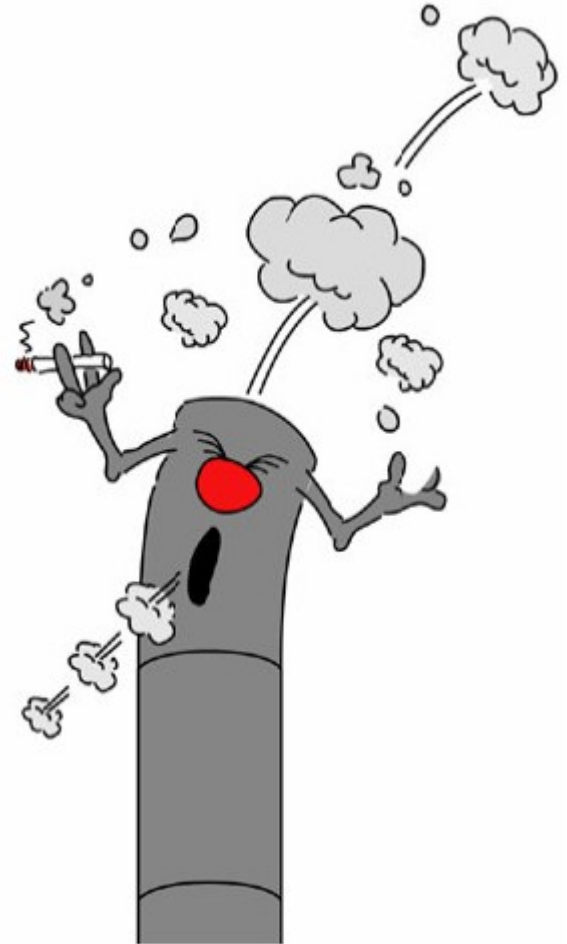
- a) Volume of fluid available for release - Volume of fluid in the piece of equipment and connected equipment items.
- b) Failure mode.
- c) Leak rate.
- d) Detection and isolation time.

11. ASSESSING CONSEQUENCES OF FAILURE

■ CONSEQUENCE EFFECT CATEGORIES

The failure of the pressure boundary and subsequent release of fluids may cause safety, health, environmental, facility and business damage.

The **RBI** analyst should consider the nature of the hazards and assure that appropriate factors are considered.



11. ASSESSING CONSEQUENCES OF FAILURE

■ Flammable Events (Fire and Explosion)

Flammable events occur when both a leak and ignition occurs.

Flammable events can cause damage in two ways: thermal radiation and blast overpressure.

Most of the damage from thermal effects tends to occur at close range, but blast effects can cause damage over a larger distance from the blast center.

11. ASSESSING CONSEQUENCES OF FAILURE

The flammable events consequence is typically derived from a combination of the following elements:

1. Inherent tendency to ignite.
2. Volume of fluid released.
3. Ability to flash to a vapor.
4. Possibility of auto-ignition.
5. Effects of higher pressure or higher temperature operations.
6. Engineered safeguards.
7. Personnel and equipment exposed to damage.

11. ASSESSING CONSEQUENCES OF FAILURE

■ Toxic Releases

Toxic releases, in **RBI**, are only addressed when they affect personnel (site and public).

These releases can cause effects at greater distances than flammable events.

The **RBI** program typically focuses on acute toxic risks that create an immediate danger, rather than chronic risks from low level exposures.

11. ASSESSING CONSEQUENCES OF FAILURE

The toxic consequence is typically derived from the following Elements:

- a) Volume of fluid released and toxicity.
- b) Ability to disperse under typical process and environmental conditions.
- c) Detection and mitigation systems.
- d) Population in the vicinity of the release.

11. ASSESSING CONSEQUENCES OF FAILURE

■ Environmental Consequences

The **RBI** program typically focuses on acute and immediate environmental risks, rather than chronic risks from low-level emissions.

The environmental consequence is typically derived from the following elements:

- a) Volume of fluid released.
- b) Ability to flash to vapor.
- c) Leak containment safeguards.
- d) Environmental resources affected.
- e) Regulatory consequence (e.g. citations for violations, fires, potential shutdown by authorities).

11. ASSESSING CONSEQUENCES OF FAILURE

- Liquid releases may result in contamination of soil, ground water and / or open water.
- Gaseous releases are equally important but more difficult to assess since the consequence typically relates to local regulatory constraints and the penalty for exceeding those constraints.
- The consequences of environmental damage are best understood by cost. The cost may be calculated as follows:

Environmental Cost = Cost for cleanup + Fines + Other costs

11. ASSESSING CONSEQUENCES OF FAILURE

The cleanup cost will vary depending on many factors. Some key factors are:

1. Type of spill-above ground, below ground, surface water etc.
2. Type of liquid.
3. Method of cleanup.
4. Volume of spill.
5. Accessibility at the spill location.

The fine component cost will depend on the regulations and laws of the applicable local and federal jurisdictions.

11. ASSESSING CONSEQUENCES OF FAILURE

■ Production Consequences

A simple method for estimating the business interruption consequence is to use the equation:

$$\text{Business Interruption} = \text{Process Unit Daily Value} \times \text{Downtime (Days)}$$

The Unit Daily Value could be on a revenue or profit basis.

The downtime estimate would represent the time required to get back into production.

11. ASSESSING CONSEQUENCES OF FAILURE

More exact methods for estimating business interruption consequences may take into account factors such as:

- a) Ability to compensate for damaged equipment (e.g. spare equipment, rerouting, etc.).
- b) Potential for damage to nearby equipment.
- c) Potential for production loss to other units.

11. ASSESSING CONSEQUENCES OF FAILURE

■ Maintenance and Reconstruction Impact

Maintenance and reconstruction impact represents the effort required to correct the failure and to fix or replace equipment damaged in the subsequent events (e.g. fire, explosion).

The maintenance and reconstruction impact should be accounted for in the RBI program.

Maintenance impact will generally be measured in monetary terms and typically includes:

- a) Repairs.
- b) Equipment replacement.

12. RISK DETERMINATION, ASSESSMENT AND MANAGEMENT

RBI defines risk as :

“The danger an undesirable event represent for people, environment and economic assets”



Risk = Probability X Consequence

12. RISK DETERMINATION, ASSESSMENT AND MANAGEMENT

■ PURPOSE

This section describes the process of determining risk by combining the results of work done as briefed in Section 9 and 10.

It also provides guidelines for prioritizing and assessing the acceptability of risk with respect to risk criteria.

This work process leads to creating and implementing a risk management plan.

11. RISK DETERMINATION, ASSESSMENT AND MANAGEMENT

DETERMINATION OF RISK

■ Determination of the Probability of a Specific Consequence

It is important to understand the linkage between the probability of failure and the probability of possible resulting incidents.

The probability of a specific consequence is tied to the severity of the consequence and may vary significantly from the probability of the equipment failure itself.

Probabilities of incidents generally decrease with the severity of the incident. For example, the probability of an event resulting in a fatality will generally be less than the probability that the event will result in a first aid or medical treatment injury. It is important to understand this relationship.

12. RISK DETERMINATION, ASSESSMENT AND MANAGEMENT

- Personnel inexperienced in risk assessment methods often link the probability of failure with the most severe consequences that can be envisioned.
- An extreme example would be coupling the POF of a deterioration mechanism where the mode of failure is a small hole leak with the consequence of a major fire.
- This linkage would lead to an overly conservative risk assessment since a small leak will rarely lead to a major fire.
- For instance, the consequences expected from a small leak could be very different than the consequences expected from a brittle fracture.

12. RISK DETERMINATION, ASSESSMENT AND MANAGEMENT

■ Calculate Risk

Referring back to the Risk equation:

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

it is now possible to calculate the risk for each specific consequence.

12. RISK DETERMINATION, ASSESSMENT AND MANAGEMENT

- If probability and consequence are not expressed as numerical values, risk is usually determined by plotting the probability and consequence on a risk matrix.
- When a risk matrix is used, the probability to be plotted should be the probability of the associated consequence, not the probability of failure.

12. RISK DETERMINATION, ASSESSMENT AND MANAGEMENT

RISK MANAGEMENT DECISIONS AND ACCEPTABLE LEVELS OF RISK

■ Risk Acceptance

Risk-based inspection is a tool to provide an analysis of the risks of loss of containment of equipment.

Many companies have corporate risk criteria defining acceptable and careful levels of safety, environmental and financial risks.

These risk criteria should be used when making risk-based inspection decisions. Because each company may be different in terms of acceptable risk levels.

12. RISK DETERMINATION, ASSESSMENT AND MANAGEMENT

■ Using Risk Assessment in Inspection and Maintenance Planning

Part of this planning process is the determination of what to inspect, how to inspect (technique), and the extent of inspection (coverage).

Determining the risk of process units, or individual process equipment items facilitates this, as the inspections are now prioritized based on the risk value.

12. RISK DETERMINATION, ASSESSMENT AND MANAGEMENT

■ SENSITIVITY ANALYSIS

Sensitivity analysis typically involves reviewing some or all input variables to the risk calculation to determine the overall influence on the resultant risk value.

Once this analysis has been performed, the user can see which input variables significantly influence the risk value.

Those key input variables deserve the most focus or attention.

12. RISK DETERMINATION, ASSESSMENT AND MANAGEMENT

■ ASSUMPTIONS

Assumptions or estimates of input values are often used when consequence and or probability of failure data are not available.

Even when data are known to exist, conservative estimates may be utilized in an initial analysis pending input of future process or engineering modeling information, such as a sensitivity analysis.

Presenting over inflated risk values may mislead inspection planners, management and insurers, and can create a lack of credibility for the user and the RBI process.

12. RISK DETERMINATION, ASSESSMENT AND MANAGEMENT

■ RISK PRESENTATION

Once risk values are developed, they can then be presented in a variety of ways to communicate the results of the analysis to decision-makers and inspection planners.

One goal of the risk analysis is to communicate the results in a common format that a variety of people can understand. Using a risk matrix or plot is helpful in accomplishing this goal.

12. RISK DETERMINATION, ASSESSMENT AND MANAGEMENT

■ Risk Matrix

Presenting the results in a risk matrix is a very effective way of communicating the distribution of risks.

Different sizes of matrices may be used (e.g., 5 x 5, 4 x 4, etc.).

Regardless of the matrix selected, the consequence and probability categories should provide sufficient discrimination between the items assessed.

An example risk categorization (higher, medium, lower) of the risk matrix is shown in Figure 6.

12. RISK DETERMINATION, ASSESSMENT AND MANAGEMENT

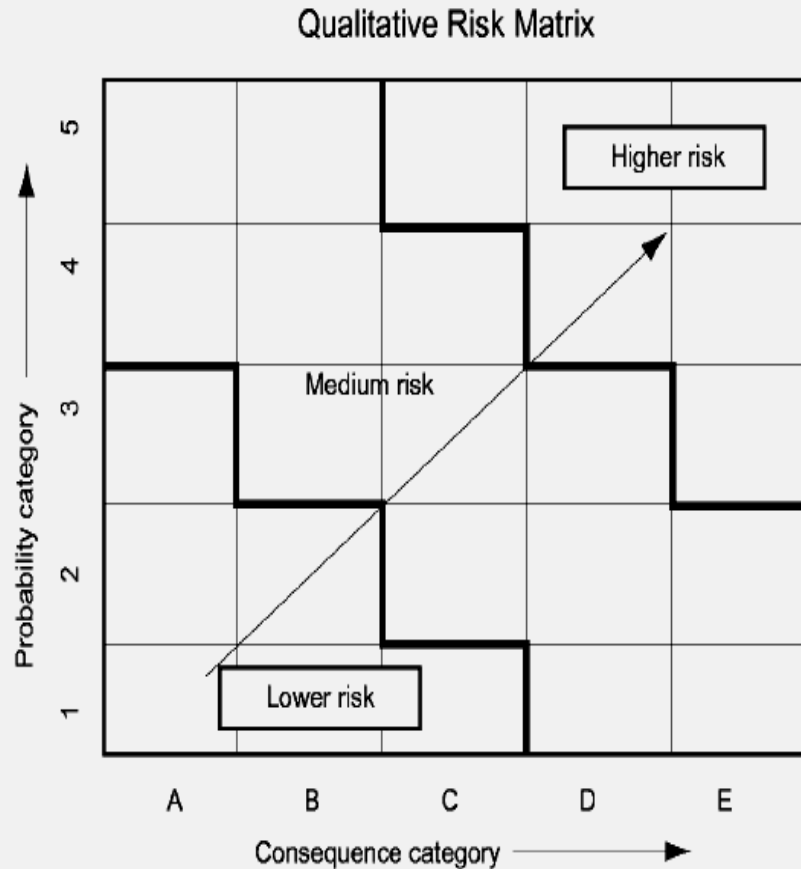


Figure 6—Example Risk Matrix Using Probability and Consequence Categories to Display Risk Rankings

12. RISK DETERMINATION, ASSESSMENT AND MANAGEMENT

■ Risk Plots

When more quantitative consequence and probability data are being used, and where showing numeric risk values is more meaningful to the stakeholders, a risk plot is used.

12. RISK DETERMINATION, ASSESSMENT AND MANAGEMENT

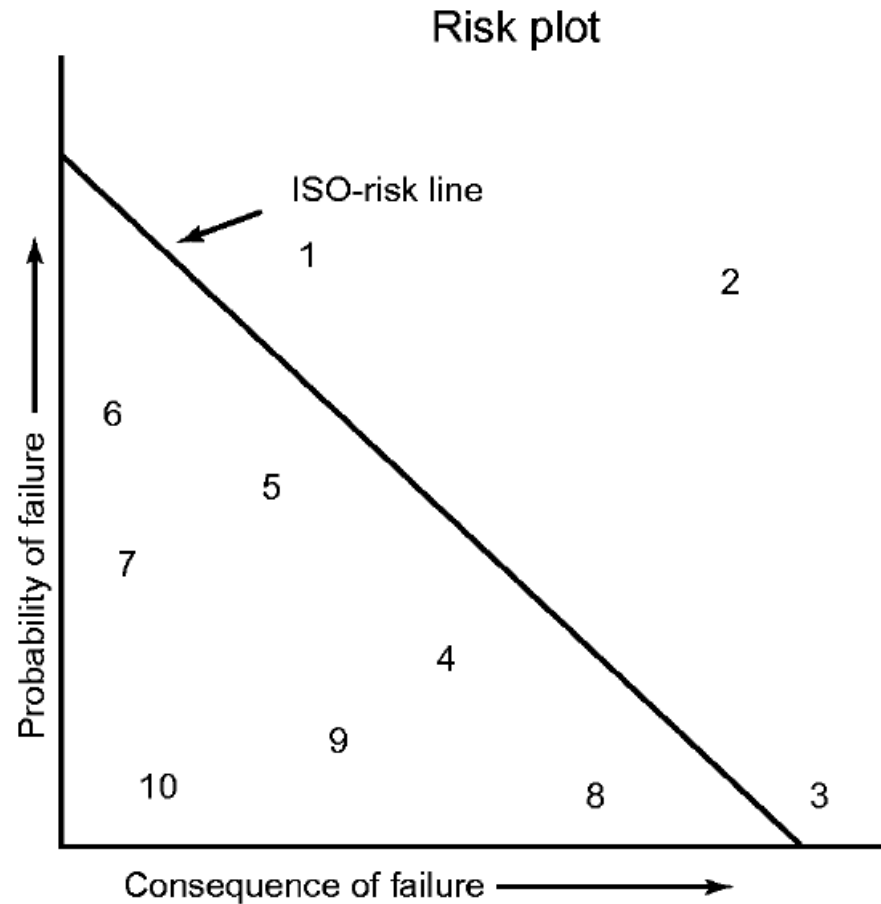


Figure 7—Risk Plot when Using Quantitative or Numeric Risk Values

12. RISK DETERMINATION, ASSESSMENT AND MANAGEMENT

■ Using a Risk Plot or Matrix

Equipment items residing towards the upper right-hand corner of the plot or matrix (in the examples presented) will most likely take priority for inspection planning because these items have the highest risk.

Similarly, items residing toward the lower left-hand corner of the plot (or matrix) will tend to take lower priority because these items have the lowest risk.

Once the plots have been completed, the risk plot (or matrix) can then be used as a screening tool during the prioritization process.

12. RISK DETERMINATION, ASSESSMENT AND MANAGEMENT

■ ESTABLISHING ACCEPTABLE RISK THRESHOLDS

Risk plots and matrices can be used to screen, and initially identify intermediate and lower risk equipment items.

The equipment can also be ranked (prioritized) according to its risk value in tabular form.

threshold that divide the risk plot, matrix or table into acceptable and unacceptable regions of risk can be developed.

Reduction of some risks to an acceptable level may not be practical due to technology and cost constraints.

An “As Low As Reasonably Practical” (ALARP) approach to risk management or other risk management approach may be necessary for these items.

12. RISK DETERMINATION, ASSESSMENT AND MANAGEMENT

■ RISK MANAGEMENT

Based on the ranking of items and the risk threshold, the risk management process begins.

For risks that are judged acceptable, no mitigation may be required and no further action necessary.

For risks considered unacceptable and therefore requiring risk mitigation.

12. RISK DETERMINATION, ASSESSMENT AND MANAGEMENT

There are various mitigation categories that should be considered:

- a) Decommission: Is the equipment really necessary to support unit operation?
- b) Inspection / condition monitoring: Can a cost-effective inspection program, with repair as indicated by the inspection results, be implemented that will reduce risks to an acceptable level?
- c) Consequence mitigation: Can actions be taken to lessen the consequences related to an equipment failure?
- d) Probability mitigation: Can actions be taken to lessen the probability of failure such as metallurgy changes or equipment redesign?

13. RISK MANAGEMENT WITH INSPECTION

■ MANAGING RISK BY REDUCING UNCERTAINTY THROUGH INSPECTION

Obviously, inspection does not arrest or mitigate deterioration mechanisms. Inspection serves to identify, monitor, and measure the deterioration mechanism (s). Also, it is invaluable input in the prediction of when the deterioration will reach a critical point.

Correct application of inspections will improve the user's ability to predict the deterioration mechanisms and rates of deterioration .

The better the predictability, the less uncertainty there will be as to when a failure may occur.

13. RISK MANAGEMENT WITH INSPECTION

Risk mitigation achieved through inspection presumes that the organization will act on the results of the inspection in a timely manner.

Risk mitigation is not achieved if inspection data that are gathered are not properly analyzed and acted upon where needed.

The quality of the inspection data and the analysis or interpretation will greatly affect the level of risk mitigation.

Proper inspection methods and data analysis tools are therefore critical.

13. RISK MANAGEMENT WITH INSPECTION

■ Identifying Risk management opportunities from RBI and probability of failure results



- Identify the risk driver
- Inspection opportunities through POF



13. RISK MANAGEMENT WITH INSPECTION

■ IDENTIFYING RISK MANAGEMENT OPPORTUNITIES FROM RBI AND PROBABILITY OF FAILURE RESULTS

Once a **RBI** assessment has been completed, the items with higher or unacceptable risk should be assessed for potential risk management through inspection. Whether inspections will be effective or not will depend on:

- a) Equipment type.
- b) Active and credible deterioration mechanism (s).
- c) Rate of deterioration or susceptibility.
- d) Inspection methods, coverage and frequency.
- e) Accessibility to expected deterioration areas.
- f) Shutdown requirements.

13. RISK MANAGEMENT WITH INSPECTION

■ ESTABLISHING AN INSPECTION STRATEGY BASED ON RISK ASSESSMENT

The inspection strategy should be designed in conjunction with other mitigation plans.

Users should consider risk rank, risk drivers, item history, number and results of inspections, type and effectiveness of inspections, equipment in similar service and remaining life in the development of their inspection strategy.

Inspection is only effective if the inspection technique chosen is sufficient for detecting the deterioration mechanism and its severity.

As an example, spot thickness readings on a piping circuit would be considered to have little or no benefit if the deterioration mechanism results in unpredictable localized corrosion

13. RISK MANAGEMENT WITH INSPECTION

The level of risk reduction achieved by inspection will depend on:

- a) Mode of failure of the deterioration mechanism.
- b) Time interval between the onset of deterioration and failure, (i.e., speed of deterioration).
- c) Detection capability of inspection technique.
- d) Scope of inspection.
- e) Frequency of inspection.

■ 12.4 MANAGING RISK WITH INSPECTION ACTIVITIES

RBI can be used to determine when, what and how inspections should be conducted to yield an acceptable future risk level. Key parameters and examples that can affect the future risk are:

- a) Frequency of inspection
- b) Coverage
- c) Tools and techniques
- d) Procedures and practices
- e) Internal or external inspection

13. RISK MANAGEMENT WITH INSPECTION

■ MANAGING INSPECTION COSTS WITH RBI

Resources can be applied or shifted to those areas identified as a higher risk or targeted based on the strategy selected.

Consideration for reduction of inspection activities in those areas that have a lower risk or where the inspection activity has little or no affect on the associated risks.

This results in inspection resources being applied where they are needed most.

13. RISK MANAGEMENT WITH INSPECTION

Another opportunity for managing inspection costs is by identifying items in the inspection plan that can be inspected non-intrusively on-stream.

If the non-intrusive inspection provides sufficient risk management, then there is a potential for a net savings based on not having to blind, open, clean, and internally inspect during downtime.

If the item considered is the main driver for bringing an operational unit down, then the non-intrusive inspection may contribute to increased uptime of the unit.

13. RISK MANAGEMENT WITH INSPECTION

■ ACHIEVING LOWEST LIFE CYCLE COSTS WITH RBI

The following examples can give a user ideas on how to lower life cycle costs through **RBI** with cost benefit assessments.

- a) RBI should enhance the prediction of failures caused by deterioration mechanisms. This in turn should give the user confidence to continue to operate equipment safely, closer to the predicted failure date. By doing this, the equipment cycle time should increase and life cycle costs decrease.
- b) Turnaround and maintenance costs also have an affect on the life cycle costs of an equipment item. By using the results of the RBI inspection plan to identify more accurately where to inspect and what repairs and replacements to expect.

14. OTHER RISK MITIGATION ACTIVITIES

Other Risk Mitigation Activities

■ GENERAL

Inspection may not always provide sufficient risk mitigation or may not be the most cost effective method. Therefore there may be the need of risk mitigation. These risk mitigation activities fall into one or more of the following:

- a) Reduce the magnitude of consequence.
- b) Reduce the probability of failure.
- c) Enhance the survivability of the facility and people to the consequence.
- d) Mitigate the primary source of consequence.

14. OTHER RISK MITIGATION ACTIVITIES

- **Equipment replacement and repair**
- **Evaluating flaws for fitness for service**
- **Equipment modification, redesign and rerating**
- **Emergency isolation**
- **Emergency depressurizing / de inventory**
- **Modify process**
- **Reduce inventory**

14. OTHER RISK MITIGATION ACTIVITIES

■ OTHERS

- a) Spill detectors.
- b) Steam or air curtains.
- c) Fireproofing.
- d) Instrumentation (interlocks, shut-down systems, alarms, etc.).
- e) Ventilation of buildings and enclosed structures.
- f) Piping redesign.
- g) Mechanical flow restriction.
- h) Ignition source control.

14. OTHER RISK MITIGATION ACTIVITIES

- i) Improved design standards.
- j) Improvement in process safety management program.
- k) Emergency evacuation.
- l) Shelters (safe havens).
- m) Toxic scrubbers on building vents.
- n) Spill containment.
- o) Condition monitoring.
- p) Improved training and procedures.

15. REASSESSMENT & UPDATING RBI

■ RBI REASSESSMENTS

RBI evaluations are based on data and knowledge at the time of the assessment. As time goes by, changes are expected and the results from the **RBI** assessment should be updated.

It is important to maintain and update a **RBI** program to assure the most recent inspection, process, and maintenance information is included.

The result of inspections, changes in process conditions and implementation of maintenance practices can all have significant effects on risk and can trigger the need to perform a reassessment.

15. REASSESSMENT & UPDATING RBI

■ WHY CONDUCT A RBI REASSESSMENT?

There are several events that will change risks and make it cautious to conduct a **RBI** reassessment.

It is important that the facility have an effective management of change process that identifies when a reassessment is necessary.

Some key factors that could trigger a **RBI** reassessment:

15. REASSESSMENT & UPDATING RBI

■ WHEN TO CONDUCT A RBI REASSESSMENT

■ After Significant Changes

Significant changes in risk can occur for a variety of reasons. Qualified personnel should evaluate each significant change to determine the potential for a change in risk.

15. REASSESSMENT & UPDATING RBI

■ After a Set Time Period

Over time many small changes may occur and cumulatively cause significant changes in the **RBI** assessment. Users should set default maximum time periods for reassessments.

The governing inspection codes (such as API 510, 570 and 653) and jurisdictional regulations should be reviewed in this context.

15. REASSESSMENT & UPDATING RBI

■ After Implementation of Risk Mitigation Strategies

Once a mitigation strategy is implemented, it is sensible to determine how effective the strategy was in reducing the risk to an acceptable level.

This should be reflected in a reassessment of the risk and appropriate update in the documentation.

15. REASSESSMENT & UPDATING RBI

■ Before and After Maintenance Turnarounds

As part of the planning before a maintenance turnaround, it could be useful to perform a **RBI** reassessment.

This can become a first step in planning the turnaround to insure the work effort is focused on the higher risk equipment items.

Since a large amount of inspection, repairs and modifications are performed during a maintenance turnaround, it may be useful to update an assessment after the turnaround to reflect the new risk levels.

16. ROLES, RESPONSIBILITIES, TRAINING & QUALIFICATIONS

■ TEAM APPROACH

RBI requires data gathering from many sources, specialized analysis, and then risk management decision-making.

Generally, one individual does not have the background or skills to single handedly conduct the entire study. Usually, a team of people, with the requisite skills and background, is needed to conduct an effective **RBI** assessment.



16. ROLES, RESPONSIBILITIES, TRAINING & QUALIFICATIONS

TEAM MEMBERS, ROLES & RESPONSIBILITIES

■ Team Leader

The team leader should be a full-time team member, and should be a stakeholder in the facility / equipment being analyzed. The team leader typically is responsible for:

- a) Formation of the team and verifying that the team members have the necessary skills and knowledge.
- b) Assuring that the study is conducted properly.
- c) Preparing a report on the **RBI** study and distributing it to the appropriate personnel.
- d) Following up to assure that the appropriate risk mitigation actions have been implemented.

16. ROLES, RESPONSIBILITIES, TRAINING & QUALIFICATIONS

■ Equipment Inspector or Inspection Specialist

The equipment inspector or inspection specialist is generally responsible for:

- a) Gathering data on the condition and history of equipment in the study.
- b) In conjunction with the materials and corrosion specialist, should provide predictions of the current condition.
- c) Assessing the effectiveness of past inspections.
- d) Implementing the recommended inspection plan derived from the **RBI** study.

16. ROLES, RESPONSIBILITIES, TRAINING & QUALIFICATIONS

■ Materials and Corrosion Specialist

The materials and corrosion specialist is responsible for:

- a) Assessing the types of deterioration mechanisms and their applicability and severity to the equipment.
- b) Providing guidance on deterioration mechanisms, rates or severity to be used in the **RBI** study.
- c) Evaluating the appropriateness of the inspections in relation to the deterioration mechanism.
- d) Providing recommendations on methods of mitigating the probability of failure.

16. ROLES, RESPONSIBILITIES, TRAINING & QUALIFICATIONS

■ Process Specialist

The process specialist is responsible for:

- a) The provision of process condition information. This information generally will be in the form of process flow sheets.
- b) Documenting variations in the process conditions due to normal occurrences (such as start-ups and shutdowns) and abnormal occurrences.
- c) describing the composition and variability of all the process fluid gases as well as their potential toxicity and flammability.
- d) should evaluate recommend methods of risk mitigation (probability or consequence) through changes in process conditions.

16. ROLES, RESPONSIBILITIES, TRAINING & QUALIFICATIONS

■ Operations and Maintenance Personnel

This person (s) is responsible for:

- a) Verifying that the facility equipment is being operated within the parameters set out in the process operating envelope.
- b) Providing data on occurrences when the process deviated from the limits of the process operating envelope.
- c) verifying that equipment repair, replacement, additions have been included in the equipment condition data supplied by the equipment inspector.
- d) Implementing recommendations that pertain to process or equipment modifications and monitoring.

16. ROLES, RESPONSIBILITIES, TRAINING & QUALIFICATIONS

■ Management

Management's role is to provide sponsorship and resources (personnel and funding) for the **RBI** study.

They are responsible for making decisions on risk management or providing the framework for others to make these decisions based on the results of the **RBI** study.

Finally, management is responsible for providing the resources and follow-up system to implement the risk mitigation decisions.

16. ROLES, RESPONSIBILITIES, TRAINING & QUALIFICATIONS

■ Risk Assessment Personnel

This person (s) is responsible for assembling all of the data and carrying out the **RBI** analysis. This person (s) is typically responsible for:

- a) Defining data required from other team members.
- b) Defining accuracy levels for the data.
- c) Verifying through quality checks the soundness of data and assumptions.
- d) Inputting data into the computer program and running the program.
- e) Quality control of data input / output.
- f) Manually calculating the measures of risk (if a computer program is not used).
- g) Displaying the results in an understandable way and preparing appropriate reports on the **RBI** analysis.

16. ROLES, RESPONSIBILITIES, TRAINING & QUALIFICATIONS

■ Environmental and Safety Personnel

This person (s) is responsible for providing data on environmental and safety systems and regulations.

He / she also is responsible for assessing / recommending ways to mitigate the consequence of failures.

■ Financial / Business Personnel

This person (s) is responsible for providing data on the cost of the facility / equipment being analyzed and the financial impact of having pieces of equipment or the facility shut down.

He / she also should recommend methods for mitigating the financial consequence of failure.

16. ROLES, RESPONSIBILITIES, TRAINING & QUALIFICATIONS

TRAINING AND QUALIFICATIONS FOR RBI APPLICATION

■ Risk Assessment Personnel

This person (s) should have a thorough understanding of risk analysis either by education, training, certification or experience.

He/ she should have received detailed training on the **RBI** methodology and on the procedures being used for the **RBI**.

16. ROLES, RESPONSIBILITIES, TRAINING & QUALIFICATIONS

■ Other Team Members

The other team members should receive basic training on **RBI** methodology and on the program (s) being used.

This training should be geared primarily to an understanding and effective application of **RBI**.

This training could be provided by the risk assessment personnel on the **RBI** Team or by another person knowledgeable on RBI methodology.

17. RBI DOCUMENTATION & RECORDKEEPING

■ GENERAL

This documentation should include the following data:

- a) The type of assessment.
- b) Team members performing the assessment.
- c) Time frame over which the assessment is applicable.
- d) The inputs and sources used to determine risk.
- e) Assumptions made during the assessment.
- f) The risk assessment results (including information on probability and consequence).
- g) Follow-up mitigation strategy, if applicable, to manage risk.
- h) The mitigated risk levels, residual risk after mitigation is implemented.
- i) References to codes or standards.

17. RBI DOCUMENTATION & RECORDKEEPING

■ RBI METHODOLOGY

The methodology used to perform the **RBI** analysis should be documented so that it is clear what type of assessment was performed.

■ RBI PERSONNEL

The assessment of risk will depend on the knowledge, experience and judgment of the personnel or team performing the analysis. Therefore, a record of the team members involved should be captured.

17. RBI DOCUMENTATION & RECORDKEEPING

■ TIME FRAME

The level of risk is usually a function of time. Therefore, the time frame over which the **RBI** analysis is applicable should be defined and captured in the final documentation. This will permit tracking and management of risk effectively over time.

17. RBI DOCUMENTATION & RECORDKEEPING

■ ASSUMPTIONS MADE TO ASSESS RISK

The assignment of failure mode and the severity of the considered event will invariably be based on a variety of assumptions.

To understand the basis for the overall risk, it is essential that these factors be captured in the final documentation.

Clearly documenting the key assumptions made during the analysis of probability and consequence will greatly enhance the capability to either recreate or update the **RBI** assessment.

17. RBI DOCUMENTATION & RECORDKEEPING

■ RISK ASSESSMENT RESULTS

The probability, consequence and risk results should be captured in the documentation.

Items that require risk mitigation, the results after mitigation should be documented as well.

■ MITIGATION AND FOLLOW-UP

The specific risk mitigation required to reduce either probability or consequence should be documented in the assessment.

The methodology, process and person (s) responsible for implementation of any mitigation should also be documented.

17. RBI DOCUMENTATION & RECORDKEEPING

■ **CODES, STANDARDS AND GOVERNMENT REGULATIONS**

Since various codes, standards and governmental regulations cover the inspection for most pressure equipment, it will be important to reference these documents as part of the **RBI** assessment.

This is particularly important where implementation of **RBI** is used to reduce either the extent or frequency of inspection.

END

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