RISK BASED INSPECTION

AS PART OF AN OVERALL INSPECTION MANAGEMENT PROGRAM

Rick Peterson, P.Eng., CET, NB, API, CGA
Metegrity Inc.
5715 – 76 Ave.
Edmonton, AB CANADA
T6B 0A7

ABSTRACT

This paper applies to plant integrity management and the inspection of pressure and non-pressure stationary equipment and systems. The principals and practices of Risk Based Inspection are demonstrated and explained. This approach may also be applied to the management of other types of equipment including, rotating equipment, conveying, etc.

Keywords: RBI – Risk Based Inspection, Probabilities, Consequences, Risk Assessment, Loss of Containment, NDE, Detection, Isolation, Mitigation, Safety, Environment.

INTRODUCTION

The purpose of Inspection is to:

- Maintain the integrity of an asset,
- Increase/maintain reliability,
- Maintain a safe workplace, operating area,
- Ensure fitness for service,
- Provide and prove due diligence,
- Do all the above at the lowest possible cost!

Inspection scopes (on-stream and off-stream) and inspection frequencies have traditionally been time-based and driven by Regulatory/Insurance requirements[5] and industry practices. The frequency was initially based on undocumented, conservative "gut" feelings. The inspections when completed were often unfocused and indiscriminate, resulting in large amounts or irrelevant or meaningless data contributing little to the assessment of the equipment[4]. These practices, although inflexible, have, on the whole, provided adequate safety and reliability. They just have not been cost effective or efficient.

Several organizations, such as the American Petroleum Institute (API), have developed recommended maximum inspection intervals (API – 510[3]) but there had not been a logical method of determining when these maximum intervals could be utilized.

RISK BASED INSPECTION

Risk Based Inspection (RBI) is a method for using risk as a basis for prioritizing and managing the efforts of an Inspection Management Program. Since a relatively large percentage of risk is associated with a small percentage of equipment, RBI permits allocating inspection and maintenance resources to provide higher level of coverage on the high-risk equipment and an appropriate effort on the lower-risk equipment.

The RBI methodology provides a logical, documented and repeatable system for making informed decisions on inspection frequencies, inspection scopes/details, types of NDE[(1)], etc. It is not intended for RBI to be any more complicated than this.

RBI is not to be confused with, or compared to, HAZOP[(2)] or Runtime-Between-Failure analyses. While RBI does not normally contribute in a significant manner to operational procedures, operational parameters (and excursions) can contribute greatly to the results of the RBI.

Organizations such as the API and the ASME[(3)], have recently developed Standards for Risk Based Inspection (ie. API – 581[1], API - 580[2]). But the RBI procedure/policy may also be developed in-house as long as the procedure takes into account all applicable aspects of the risks associated with the equipment and is logical, documented and repeatable.

PRINCIPALS OF …

The RBI process consists of:

- Performing a Risk Assessment of the equipment.
- Using the results of the Assessment to determine the inspection frequencies and scopes.

[(1)] Non-Destructive Examination
[(2)] Hazard & Operability Study
[(3)] American Society of Mechanical Engineers

To perform the Risk Assessment, the following three basic questions are considered:

1. What material degradation methods have been experienced or could be experienced?
2. What are the probabilities (likelihood) of these degradations occurring?
3. What are the consequences of these degradations?

RISK ASSESSMENT PROCESS

To conduct a risk assessment logically, systematically and methodically, the following process has been developed:

- Identify the hazards
- Frequency assessment
- Consequence assessment
- Risk evaluation and reporting
- Action forward

Hazard Identification. The main item to determine the hazards and material degradation (actual or expected) is the amount of information which is known about the equipment or conversely the identification of where there is a lack of information. Even when information appears to be known, the risk based approach requires the quality and veracity of the information be tested and validated. Risk increases when there is a lack of, or uncertainty in, the information required to assess the equipment integrity.

Information is gathered from the design specifications, fabrication records, operational experience, inspection records, the knowledge of material degradation methods and the rates at which material degradation will, or has, occurred.

Frequency Assessment. This is the probability of occurrence and is the mean frequency or rate at which the specified events would be expected to occur in a specified period of time.

Consequence Assessment. This can involve the use of analytical models to predict the effects of different scenarios. Information exists describing the toxic effects or materials on humans, fire and blast effects on buildings and structures, dispersion and environmental effects, etc. Assessments normally focus on business, safety and environmental consequences.

Risk Evaluation and Reporting. The simplest form of reporting the risk is by simply grading the equipment as high, medium or low. The preferred approach is to use a Risk Matrix to assign risk.

An example of a typical Risk Matrix is shown in Figure 1.
Each equipment will fall with a cell in the matrix corresponding to the likelihood and consequences of failure.

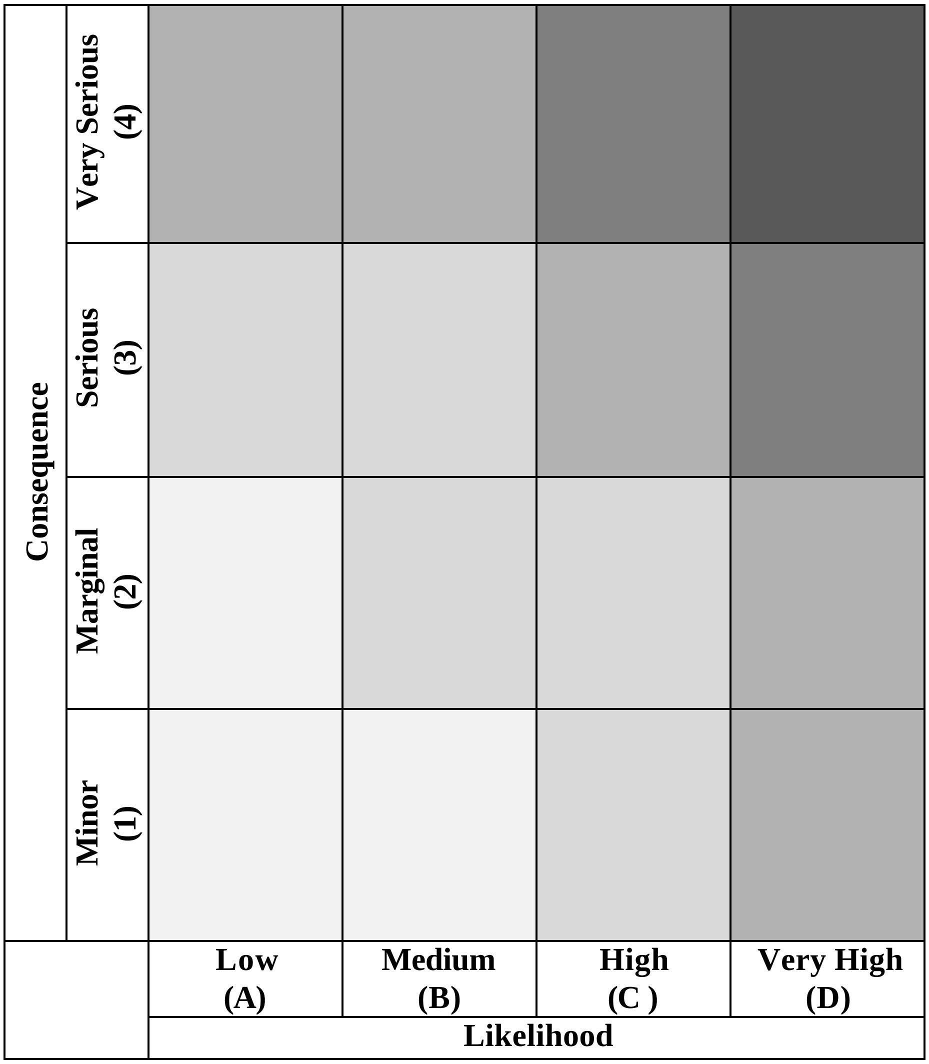

FIGURE 1 – Typical 4x4 Risk Matrix Grid

Table 1 and Table 2 shows sample definitions for Likelihood and Consequence for 4X4 Risk Matrix.
This can be take a step further by assigning a Code to each cell in the matrix as seen in Figure 2. The cell code numbers can be utilized to specify an inspection interval for the off-stream inspections. Table 3 illustrates sample assignment of Inspection Intervals.

TABLE 1
DEFINITIONS OF LIKELIHOOD FOR TYPICAL 4X4 RISK MATRIX

Likelihood Ranking	Likelihood Category	Definition
A	Low	Not likely
B	Medium	May occur
C	High	Probable occurrence
D	Very High	Occurred/occurring

TABLE 2
DEFINITIONS OF CONSEQUENCE FOR TYPICAL 4X4 RISK MATRIX

Consequence Ranking	Consequence Category	Impact
1	Minor	First aid, little/no response, minor equipment costs.
2	Marginal	Medical aid, limited response, equipment repairs, minor losses.
3	Serious	Serious injury(s), major response, major downtime, expenses.
4	Very Serious	Fatality(s), long term environmental, permanent shutdown

Consequence		Low (A)	Medium (B)	High (C)	Very High (D)
Consequence	Very Serious (4)	3	3	4	5
Consequence	Serious (3)	2	2	3	4
Consequence	Marginal (2)	1	2	2	3
Consequence	Minor (1)	1	1	2	3
		Likelihood			

FIGURE 2 – Typical 4x4 Risk Matrix Grid with Code Numbers

TABLE 3
RISK MATRIX GRID CODE DEFINITIONS

Cell Code Symbol	Off – Stream Inspection Interval
1	1 year
2	2 years
3	3 years
4	6 years
5	9 years

Action Forward. With the information resulting for the risk assessments, detailed inspection scopes and inspection scheduling can be developed.

Inspection scheduling is normally a function of the planned plant or unit shutdown intervals. It is not logical to have an inspection interval of five years for a piece of equipment which requires a unit outage and the unit outages are scheduled for every three years. In this case one of the values for the Cell Code Symbols would be equal six (6) years, to coincide with the planned outages.

RBI Parameters

Prior to conducting an RBI Assessment, Management or the Responsible Team, needs to define specific key parameters. This includes:

Objectives. In order to produce the necessary results, the objectives of the RBI process must be clearly defined. This can include: increase productivity and reliability, focus inspection resources, reduce inspection and maintenance costs, comply with Regulatory and/or Insurance regulations, improve outage planning, etc.

Scope. The scope of the program may include a facility, a specific plant or unit in the facility or several facilities. It may be a plant is to be assessed prior to an outage in order to determine the scope and duration of the outage

Resources. Conducting a risk assessment is a team based process. A team of people with the composite skills, background and experience typically conduct the activity. Departments normally involved in the assessments include Inspection, Operations, Engineering (process & mechanical), Maintenance and planning. One individual is identified as the focal point or leader of the project. Their duty is to keep the project focused and to ensure all relevant information is recorded.

It is very easy for the project to become side tracked and start solving all the problems of the world. It is the duty of the leader to keep the group focused and moving along.

Problem identification is necessary but problem solving would be conducted at another time.

Analysis Method. Risk Assessment can usually be described in one of three methods: Qualitative, Quantitative or Qualitative/Quantitative (semi-quantitative). The main difference between the approaches is the amount of information required to perform the analysis.

Qualitative – is the simplest of the approaches. The outcomes of each degradation method are much more generalized with respect to the safety, environmental and business impacts.

Quantitative – much more involved and the outcomes from each degradation method are deeply analyzed for method of release, quantity of release, specific effects of the release to operations, personnel safety, public safety, environmental impacts on and off site and detailed business impacts.

Semi-Quantitative – is a combination of the above. The outcomes are more detailed than the Qualitative approach but not as detailed as the Quantitative approach. This is probably the most common RBI approach utilized.

Measuring Factors. Clearly defined Objectives at the beginning of the RBI Assessments and accurate initial records can be utilized as a baseline at to measure the success of the program after implementation. Measurement factors can include items as: improved safety, reduced downtime, inspection and maintenance cost savings, increased intervals between forced outages, etc.

RBI AS PART OF AN EFFECTIVE INSPECTION MANAGEMENT PROGRAM

Implementing and RBI and Inspection Management Program can require gathering and analysis of vast amounts of data. This process then lends itself to being ideally suited for computerized data management software programs. Several programs have been developed to manage static and inspection data, analyze and calculate the risks associated with equipment and plan and schedule inspections.

Even with the latest computer software, there are philosophies which have to be adopted for the entire inspection management program to function effectively.

Probably the largest concept is the fact that the RBI process is dynamic and not static. When the initial RBI Assessment is completed, that is not the end of the process. When ever inspections are completed or information from other sources is obtained or if process conditions are varied, the RBI Assessment must be assessed again.

When inspections are completed, the results have the capability of changing the likelihood of the material degradations. For example, if the inspection results indicated much less degradation than anticipated, this would be a good thing and could result in a lower likelihood, lower risk values and potentially a decrease in inspection frequencies and/or a decrease in the inspection scope. A particular NDE[(1)] method may no longer be required.

Inspection results which indicate an increase in degradation or evidence of a new, unexpected degradation method would result in increased likelihood, higher risk values and potential an increase in inspection frequencies and scope.

In both the above cases, it is only the likelihood which could vary. The consequences remain the same. Only the likelihood would be assessed during the subsequent RBI Assessments.

If, however, there is a significant change in the operating or process conditions, the consequences of the outcomes of degradation methods could change significantly and the entire RBI Assessment would have to be completed on the equipment.

The flow chart in Figure 3 illustrates a working example of the dynamics of the RBI Process.

Step 1: Develop/Update Asset Register

All the static information, and some operational information, are entered into the database. This information is obtained from such varied sources as: Manufacturer's Data Reports, design specifications and drawings, operational procedures, etc. This information is continually updated as equipment is added, altered or removed from the site.

Step 2: Define Asset Strengths & Weaknesses

For each equipment, the following are defined, as applicable:

- Analysis of Inherent Design Strengths/Weaknesses
- Measures to control material degradation – coating, material specifications, excessive corrosion allowance, etc.
- Corrosion monitoring capabilities - coupons, on-line, etc.
- Operational Vulnerabilities
- Safety issues of product stream(s).
- Regulatory issues.
- Operation upsets/excursions.
- Proximity to populations.
- Environmental concerns.

Step 3: Corrosion Circuit Definition

Corrosion circuits are defined as process streams with similar metal loss/degradation mechanisms. It is possible for several process streams to be combined into one corrosion circuit. An example could be Steam. Even though there may be several different operating pressures in a plant, the expected or experienced degradations would be the same, pitting, corrosion, erosion, etc. From a metal loss/degradation aspect, all steam pressures are similar. The consequences of failure are different but this is covered during the actual risk analysis.

The plant is divided into corrosion circuits with each circuit being described and the metal loss/degradation mechanisms anticipated defined and described. Any conditions which contribute to the metal loss/degradation (operational, environmental, etc.) are described. Specific inspection and on-stream monitoring requirements are detailed.

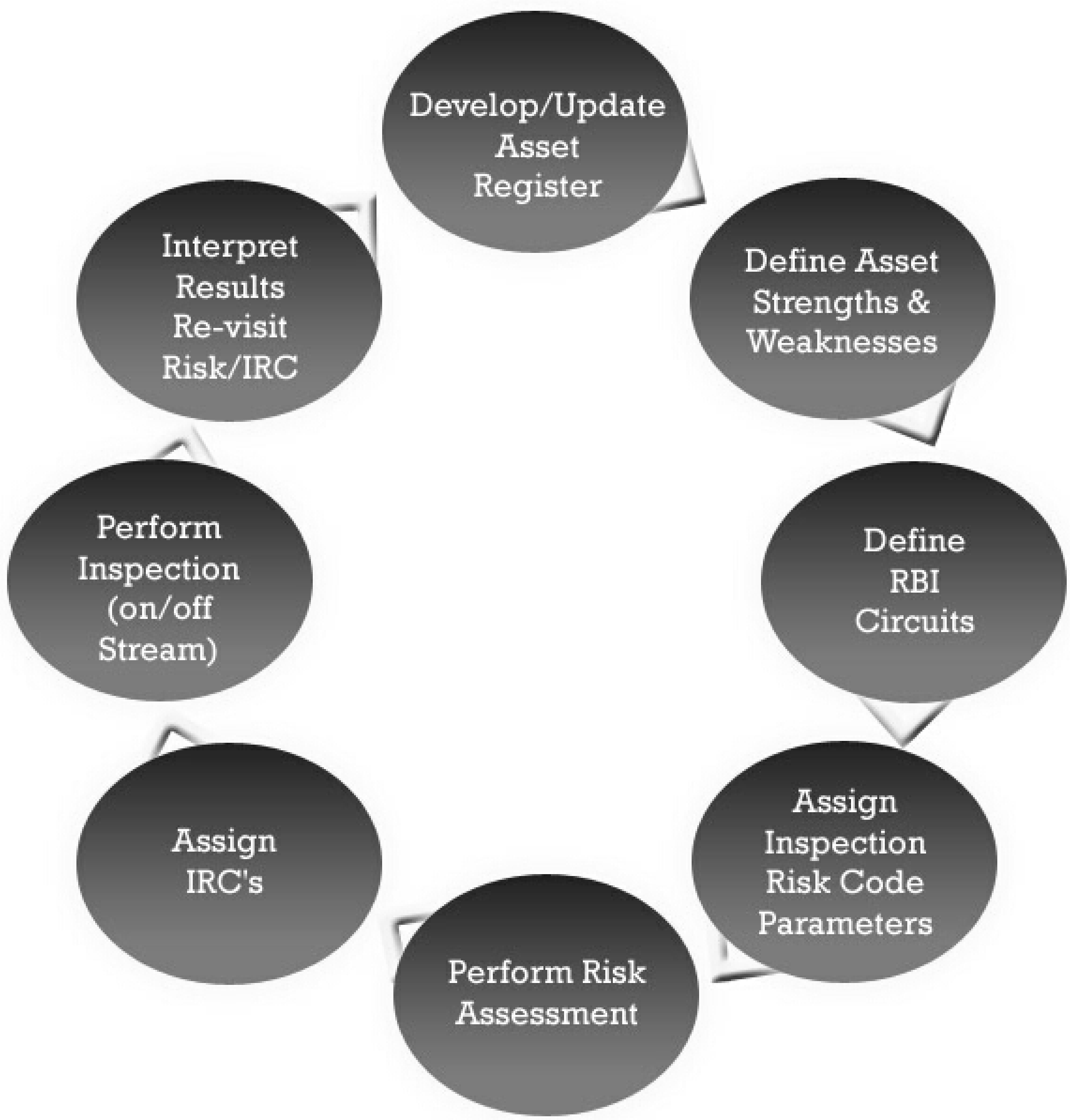

FIGURE 3 – Representation of RBI Dynamic Process

Step 4: Inspection Risk Code Parameters

The IRC's[(4)] are numeric codes (from 1 to 5) corresponding to an inspection interval (in years). These inspection interval values are selected to match the plant operating and shutdown intervals.

Step 5: Perform Risk Assessment

Using the accepted RBI Assessment approach each circuit and each piece of equipment is assessed as per the scope of the program and the results documented.

Step 6: Assign Inspection Risk Codes and Inspection Scopes

When the results of the risk assessment have been accepted, the correct IRC[(4)] is assigned to each circuit or equipment. This value is used to calculate the next inspection dates and long term inspection schedules.

The Inspector would also develop the individual inspection scopes for each piece of equipment based on the inspection requirements highlighted during the risk assessment. In order for inspection to be an effective part of integrity management, the techniques and procedures used must be capable of achieving reliable results. The techniques and procedures must therefore be matched to the potential deteriorations identified by the risk analysis.

Step 7: Perform Inspections (On/Off Stream)

As per the schedule/interval and the Inspection Plans developed from the risk assessment, the required inspections and examinations are completed and documented.

Step 8: Interpret Results, Revisit RBI and IRC's

With the results of the inspections (on and off stream) evaluations are completed regarding the actual state of the equipment compared to the anticipated states.

If the equipment is in better condition than anticipated, the risk assessment is completed again. With the new inspection results the outcome of the new risk assessment may give a higher IRC[(4)] value with a corresponding increase in the inspection intervals. Or, the new assessment may not change the IRC[(4)] but the scope of required inspections may be reduced. This is particularly important for TML's[(5)]. These are usually on-stream thickness locations. If the TML[(5)] inspections do not reveal problems, it should be possible reduce the number of the locations resulting in inspection cost savings.

[(4)] Inspection Risk Codes
[(5)] Thickness Monitoring Locations

If the equipment is in worse condition than anticipated, the new risk assessment may give a lower IRC[4] value with a decrease in the inspection interval. Again, even if the new assessment does not change the interval, the scope and/or methods of inspection and examination may be changed.

It is also possible to take the results of the inspection and apply them to the Risk Assessments of identical or similar equipment.

BENEFITS

There are several benefits to the RBI Program as opposed to a Time-Based Inspection Program:

Inspection intervals are based on the risks associated with the equipment and therefore inspection personnel will be spending most of their time on the higher risk areas and less time in the low risk areas.

Equipment with no history of problems or concerns and no anticipated problems is inspected on longer intervals rather than just inspecting every few years as is the case with a time-based program.

Information from inspections on one piece of equipment can be utilized in determining the inspection intervals and scopes for similar equipment. For example, if the inspections of an exchanger revealed problems on the cooling water side, it is easy for the Inspector to generate a listing of all exchangers with similar materials in cooling water service. Then the Inspector can make adjustments to the inspection intervals and/or inspection scopes for these equipment.

Or, if the inspections on a piece of equipment did not reveal any problems, this information can be used in the risk assessment to increase the intervals of similar equipment.

The methods used to determine the inspection intervals and inspection scopes are documented and repeatable. This is important with National Board Owner/User Inspection Programs, which are subject to audits by the Regulatory Authorities. This is also documented 'due diligence' which may be required in the future.

Efficiently reduce the risks (probabilities of occurrence) by focusing inspection efforts when and where they are required only.

Inspection no longer drives the scope of plant shutdowns. Most equipment would be shutdown for process or maintenance reasons (cleaning, overhauls, etc.) with inspection taking advantage of these opportunities.

CONCLUSIONS

Risk Based Inspection provides a logical, documented, repeatable methodology for determining the optimum combination of inspection frequencies and inspection scopes/methods. The equipment inspection priorities are determined by the perceived and actual risks associated with the operation of the equipment. RBI can result in significant inspection and maintenance cost reductions as efforts are focused on the higher risk equipment with the low risk equipment receiving correspondingly less, but adequate, inspection efforts. New inspection, nondestructive examination or monitoring technologies are easily incorporated into the RBI philosophy.

Operating a plant with a comprehensive risk based inspection program should also reduce the risks of releases from the facility and should provide benefits in complying with safety and environmental initiatives, without increasing the costs of the inspections.

Risk Assessment is an analysis of a great deal of information. Besides inspections and thickness monitoring, many other risk mitigation options are open to facilities. These include operational controls and limits, corrosion monitoring devices (real time and cumulative) and investigating alternative materials and technologies.

REFERENCES & BIBLIOGRAPHY

1. API Publication 581 – Risk Based Inspection, Base Resource Document – 1st edition 2000
2. API Publication 580 – Recommended Practice for Risk Based Inspection – 1st edition 2002
3. API Inspection Standard 510 – Pressure Vessel Inspection Code - 2000
4. Loss Prevention in the Process Industries, F.P. Lees, 1980
5. Inspection & Servicing Requirements for Pressure Equipment – Alberta Boilers Safety Association , 2002