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Risk Based Inspection

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ABSTRACT

The concept of risk analysis has been around for a long time and Risk Based Inspection (RBI) programs have generated considerable interest in industry. Effective implementation of a Risk Based Inspection program extends the operating life of equipment and piping, safely and cost effectively. RBI is accepted as good engineering practice for the implementation of inspection and maintenance programs and has its roots in Process Safety Management and Mechanical Integrity programs. The objective, principals and practices of Risk Based Inspection are demonstrated and explained.

The target audience for this paper is engineers, inspectors and managers who want to understand what Risk Based Inspection is all about, what are the benefits and limitations and how inspection practices can be changed to reduce risks, save costs without impacting safety risk.

INTRODUCTION

We know that there are two extremes of inspection, both undesirable. One extreme is very little inspection replacing pressure equipment and piping when it leaks or fail. The reason why this extreme is unacceptable is obvious. On the other extreme is inspection of all pressure equipment so often and so thoroughly that it becomes uneconomic to compete in the marketplace.

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

RBI is a method for using risk as a basis to prioritize and manage the efforts of an inspection program**.** In any operating plant, a relatively large percentage of the risk is usually associated with a small percentage of equipment. RBI methodology permits the shift of inspection and maintenance resources to provide a higher level of coverage on the high-risk equipment and an appropriate effort on lower risk equipment. RBI provides a methodology for determining the optimum combination of equipment inspection methods, scopes and frequencies. i.e. Risk Based Inspection is an inspection optimization technique.

RBI is not to be confused with, or compared to, HAZOP. RBI integrates very well with PHA (Process Hazards Analysis). PHA's focus primarily on process hazards and not as well on mechanical integrity hazards (which are what RBI focuses on). So integrating the results of RBI with PHA's can significantly increase the quality of your PHA risk assessments.

RBI covers only the breach of pressure containing members, i.e. vessels, columns, exchangers, piping, furnace tubes, tanks, etc. It does not cover the functional failure of non-pressurized equipment, e.g. instruments, electrical gear. Control systems, etc.

RISK BASED INSPECTION

RBI is a system used to determine the **likelihood** of failure, and the **consequences** of failure. The likelihood and consequences are combined to produce an estimate of risk.

Risk = Likelihood of failure X Consequence

Key point:

- Likelihood
  - failure per year
  - need to understand failure cause (at what point it fails).
- Consequence
  - fatalities or cost.
  - need to understand failure mode (how it fails, what will result from failure).

It groups static equipment (piping system, vessels and tanks) into High, Medium and Low inspection risk. This permits the elimination of unnecessary inspections, the postponement of certain inspections, and prioritization of essential inspections.

Purpose of Risk-Based Inspection

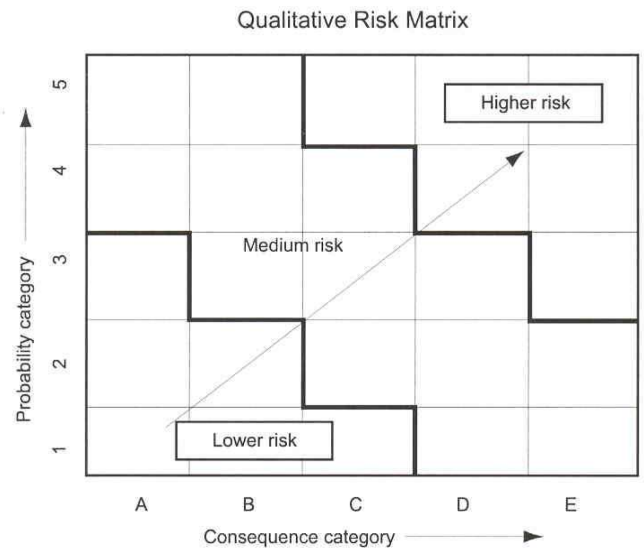
- Screen operating units within a plant to identify areas of high risk.
- Estimate a risk value associated with the operation of each piece of equipment
- Prioritize the equipment based on the measured risk
- Design an appropriate inspection program
- Systematically manage the risk of equipment failures.

Types of RBI Assessment

RBI is both a qualitative and quantitative process for systematically combining both the likelihood of failure and the consequence of failure to establish a prioritized list of pressure equipment basis total risk.

Three levels of risk based inspection have been developed by API for prioritizing risk levels associated with individual pieces of pressure equipment.

Level I Qualitative RBI which utilizes a simple, single-screen format to risk rank process equipment into a five by five risk matrix . Because of its simplicity, Level I is quick and easy, but results in fairly conservative risk rankings. Level I analysis is meant for initial pre-screening of risk, and is a good tool for demonstrating API RBI methodology.



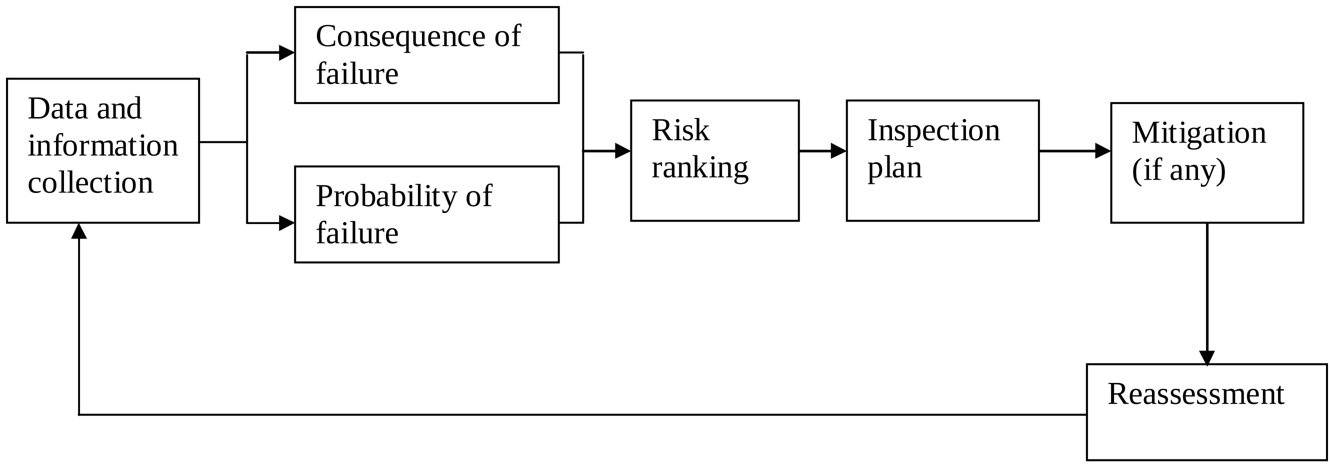
•Likelihood 1 to 5 [m10^{-n} leak/year]
•Consequence A to E [sq.ft. damage area]
•Risk Rank (Low, Medium or High)
•Inspection priority = Risk Rank

Level II Semi-quantitative RBI, which is an intermediate method of quantitative RBI (Level III), for risk ranking individual pieces of equipment in a process unit. Level II also uses a 5 X 5 risk matrix for displaying risk analysis results. Level II RBI analysis asks more questions, and therefore takes more time to accomplish, but results in more accuracy and avoids overly conservative risk ranking that may result from simpler methods.

Level III Quantitative RBI which is more detailed (and more accurate) method of risk ranking individual pieces of equipment in a process unit. Level III calculates a specific consequence score, a specific likelihood of failure score and a specific risk score for each piece of equipment in a process unit. Typically, the user is expected to utilize Level III analysis for equipment that ranked up into the higher risk categories when prioritized by Level II analysis.

RBI Process

Simplified block diagram of RBI process showing essential elements of inspection planning based on risk analysis regardless of approach (qualitative, semi-quantitative or quantitative) is as below:



The RBI process consists of performing a risk assessment of the equipment, then determining inspection frequencies and scopes. Many types of RBI methods exist and are currently being applied throughout industry.

A risk assessment involves first establishing the current and anticipated condition of the equipment, by asking the following questions:

- What material degradations have been experienced or could be experienced?
- What are the likelihood (probabilities) of these degradations occurring?
- What are the consequences of these degradations?

The next step is to determine the risk of operating equipment as the combination of two separate terms: the **likelihood** of failure and the **consequence** of failure.

The **likelihood** analysis assesses the probability and effects of specific failure mechanisms based on:

- The history of the equipment
- The history of similar or identical equipment in identical service conditions

The **consequence** analysis of a release (instantaneous or continuous) is calculated by:

- Estimating the release rate and release amount based on:

    - Pressure differentials
    - Size of opening
    - Leak detection methods
    - Isolation capabilities

- Predict the outcome of the release based on:

    - Amounts released
    - Composition of released material
    - Impact area of released material
    - Environmental impact
    - Business interruption effects

The data from likelihood and consequences analysis can then be combined to produce an estimate of risk for each equipment item and piping system. The risk factor can then be ranked and used to determine inspection schedules.

RBI Steps

Scope and Plan

1. What is RBI? – Manage risk through equipment inspection, it is Predictive Maintenance.
2. Why RBI? – Regulatory driven, Liability driven, Profit driven, Safety driven

    Achieve necessary and sufficient inspections.
    Necessary = Inspect everything that must be inspected.
    Sufficient = Do not inspect what does not need to be inspected.
    It is a tool to prioritize inspection budgets, using the experience of the whole industry.

3. How is it implemented?
4. Who is involved?-roles and responsibilities, Expertise – Inspection, Design, Material and corrosion, Operations, Safety
5. How long does it take?
6. How much does it cost and save?

    - Costs are REAL <u>and</u> readily QUANTIFIED

        - Cost of personnel time, training, reference documents, inspections, documentation, FFS analysis of inspection results, analysis of stable construction flaws, new inspections or shorter inspection intervals

    - Savings are REAL <u>but</u> difficult to QUANTIFY

        - Avoidance of failure (leak or rupture) of high safety consequence (fire, environmental remediation, toxic release, etc.),
        - Avoidance of loss of production.
        - Early warning for planning repairs or replacements.
        - Early detection of process upsets (unusual flow, unusual contaminants in process fluids, unusual temperatures, unusual fatigue, accelerated corrosion, etc.), leading to improvements in operations to extend life.
        - Extension of inspection intervals, and – in some cases – elimination of unnecessary inspections.
        - Better material selection, design and construction for future projects, through understanding of risk and inspection data.

- Choice of less expensive inspection techniques if justified by risk analysis (visual internal vs. volumetric, etc.).

Likelihood Assessment

- Design Margins : Design margin to failure (loss of pressure boundary) of equipment.
- Material Deterioration: Material deterioration mechanisms that will reduce the original margin to failure. (Wall thinning, cracking, high temperature, microbiological effects, mechanical damage)
- Overload: Operating loads that will reduce the margin to failure.
- Probability of Leak: Establish method to quantify likelihood.

For the quantitative method in API BRD 581 the likelihood evaluation process starts with a generic failure frequency for the type of equipment in question. This value is then modified by factors relating to: the specific equipment (F_E) and the safety management regime (F_M). F_E takes account of items such as damage type, inspection effectiveness, condition, design and fabrication, process control and safety management and F_M addresses the potential impact on mechanical integrity of all process safety management issues from API RP 750. The factors F_E and F_M are obtained from an exhaustive scoring system based on questionnaires or workbooks.

Likelihood (failures / year) = Generic failure frequency X Equipment specific factor(FE) X Management specific factor(FM)

Equipment factor(FE) = function of score S

S = -2 + technical factor + universal factor + mechanical factor + process factor

- Technical factor depends on P, flow stress, wall loss, critical factor Kc etc.
- Universal factor depends on Plant condition, Weather, Seismic
- Mechanical factor depends on complexity, construction code, life cycle, operating pressure, operating temperature, vibration monitoring
- Process factor depends on planned shutdown, unplanned shutdown, process stability, relief valve maintenance, relief valve fouling, corrosion service, clean service

Management System factor(FM): depends on Management System points(Leadership and administration, process safety information, process hazard analysis, operating procedure, safe work practices, mechanical integrity, audits etc.)

Consequence assessment

The quantitative assessment of failure consequence within API BRD 581 is based on a systematic multi-stage process to determine costs relating to explosive release, toxic consequences, environmental clean-up and business interruption.

- Failure Mode: leak or break, size crack opening area
- Fluid Discharge: rate, inventory
- Quantitative RBI(Establish method to quantify consequence) : phase, duration, fire and fatality areas

Risk Ranking

- Prioritize risk
- The process follows a logical progression, where system and equipment specific data is superimposed to generic equipment reliability data to determine a likelihood and consequence of failure, which together determine a risk ranking.

The final report on each RBI contains, not only the prioritized risk ranking (combined likelihood and consequence of failure), but also contains a prioritized list of equipment by both likelihood of failure only and consequence of failure only. This allows the user to focus on the specific issues that drive up total risk, and to understand whether total risk is driven primarily by likelihood of failure or primarily by consequence of failure. That understanding is vital to user decision making about how to reduce risk levels associated with each piece of equipment.

Inspection techniques, Frequency and Acceptance criteria

- How to inspect?
- When and how often?
- RBI is Predictive maintenance – Inspection interval based on analysis of previous inspection results and requires expertise in corrosion engineering and Fitness-for-Service analysis
- Original construction or fitness-for-service acceptance?

Management Process

- Engineering, operations, maintenance.
- Management.
- Strategic decisions on operations, projects.

Documentation: Clear, complete, concise and elegant documentation to

- Recreate the basis and conclusion
- Usable to make practical decision
- Link to equipment maintenance history
- Retrievable

RBI is Risk Based Management

RBI is really RBM (Risk-Based Management); though RBI is focused on risk mitigation through inspection activities, its application is much broader. Since RBI is a fully integrated methodology, the user also has the opportunity to reduce risk by means other than changing the inspection program. There may be a number of opportunities to strengthen process safety management systems and procedures. The user can also lower risk by installing safety systems, leak detection systems, isolation valves, and anything else that might mitigate consequences, once a release has occurred. So RBI is a management tool for risk reduction that goes beyond inspection activities.

Relationship of RBI to Mechanical Intergrity Standards and Regulations

Risk-based inspection integrates well with current editions of industry inspection codes/standards like: API-510, the Pressure Vessel Inspection Code, API-570, the Process Piping Inspection Code, and API-653, the Storage Tank Inspection Standard. API accepted recognition of RBI in both API-510 and API-570. Though each of these standards sets forth minimum practices for inspection frequencies and many recommended practices for inspection activities associated with pressure equipment, each now allows inspection plans and strategies (including frequency) to be established by following the principles of a quality RBI program. These codes now offer the user much flexibility and many options relative to the frequency, scope and extent of inspection options to optimize the inspection program for the purpose of reducing risk.

Benefits

- Improved health and safety management
- Avoiding unnecessary inspection – Inspection intervals are based on the risks associated with the equipment and therefore inspection personnel can spend most of their time on the high risk areas and less time in the low risk areas.

- Cost saving – Equipment with no history of problems and no anticipated problems is inspected on longer intervals rather than just inspecting every few years as is the case with a time-based inspection program.
- Information from inspections on one piece of equipment can be utilized in determining the inspection intervals and scopes for similar equipment.
- The RBI program is totally dynamic: risks are updated after inspections or even the inspection of similar equipment, changes to process conditions or even if new information becomes available. Any of the above may result in a change in inspection frequencies or changes to the inspection scopes.
- The methods used to determine the inspection intervals and inspection scopes are documented and repeatable.
- Reliability and compliance with applicable Codes/Standards
- Increasing plant availability and optimum repair and replacement scheduling
- Extended plant and equipment life.

RBI APPROACH AT QATAR GAS

RBI Methodology has been implemented in Qatar Gas since start-up and therefore was prior to release of API 580. The RBI methodology considers both Likelihood and Consequence of failure. A matrix approach was not implemented but instead a numeric value is obtained and the Risk ranking (Criticality) is based on this value within a given range of values (eg > 15 = High, 10 - 15 = Medium, 5 - 10 = Low, <5 = Very Low). Inspection frequencies are based on the Criticality. Written schemes of examination were prepared for all static equipment. Inspection Grades are applied to equipment based on the as found condition and credit taken for the scope of inspection. By applying a Grade factor to the Risk number, the Likelihood of failure value is affected, resulting in a lower or higher score. Reviewing the Inspection Grade after each Inspection ensures that the Risk score is reviewed after each inspection. Implementation of this approach is consistent with RBI Methodologies, differing only in the absence of the Matrix. Existing RBI Program has been easy to manage and highly transparent in that management and asset owners can easily see the impact of inspection results by the assigned Inspection Grade i.e. are things getting better or worse, and have the inspection frequency increased or decreased.

CONCLUSION

RBI provides a logical, documented, repeatable methodology for determining the optimum combination of inspection frequencies and inspection scopes. RBI objective is to ensure focus of inspection to areas with high risk, while inspection in areas with low risk will be reduced or excluded from the normal inspection program and therefore result in significant inspection and maintenance cost reduction.

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REFERENCES

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 510 – *Pressure Vessel Inspection Code – 2000.*
4. API 570 – *Piping Inspection Code – 2001.*
5. Stephen Anderson, "*Risk Based Inspection Case Studies",* Annual PSM Symposium, 2001.
6. Rick Peterson, "*Risk Based Inspection as part of an overall Inspection Management Program".*
7. John T. Reynold, " *The API Methodology for risk-based inspection analysis for the petroleum and petrochemical industry",* Texas, 1998.
8. Julian B Speck and Abdolreza T M Iravani, " *Industry survey of risk-based life management practices"*ASME PVP 2002 Conference, Canada, 2002.
9. George Antaki, "*Risk Based Inspection in Refineries, Petrochemical Plants and Oil/Gas Plants".*