



RBI in Major Plants

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Risk Based Inspection

An Overview

Introduction:-

Risk Based Inspection, or RBI, is increasingly being promoted in the process industries as a means of optimising the costs of complying with statutory and other HSE obligations.



What is the Purpose of Inspection?

- ◆ Check the plant is ‘fit for purpose’
- ◆ Monitor the deterioration of vessel or piping thickness
- ◆ Assess the REMAINING SAFE OPERATING LIFEsay 5 years left
- ◆ Retire plant which is deemed not usable
- ◆ Examine failure mode

The Inspector Must Be/Have



- ◆ Able to undertake his/her work without interference
- ◆ Competent
- ◆ Tools
- ◆ Records
- ◆ Able to trend thinning
Or tolerances



Why use RBI ?

Focus on Critical Plant to ensure the business is in a safe and profitable state



Inspection Methods

Visual	Penetrant Dye Testing – finds surface flaws	Magnetic Particle – Flux – Field Distorted
Eddy Current - AC – near surface flaws	Radiography - volumetric	Ultrasonic Testing – planar and volumetric
ACFM/ACPD – size of flaw - Alternating Current Field Measurement or Potential Drop	Ultrasonic Testing - size of flaw	TOFD Time of Flight Diffraction – all details from 2 probes ultrasound from upper and lower extremes of flaw



Failure Modes

Corrosion/Erosion, Water, Chloride, High Temperature Sulphidation, V/L Impingement	Creep $> 350^{\circ}\text{C}$ High Temp Damage $> 450^{\circ}\text{C}$ - Cracks grow	Fatigue Cracking – Cyclic stressing - e.g. Toe of welds
Embrittlement – Caustic with $T > 70^{\circ}\text{C}$, H_2 Partial $P > 5$ bar, H_2S Partial $P > 0.05$ psia HCN/HF promotes	Stress Corrosion Cracking – Ammonia, Chlorides	Brittle Fracture OK if $T > 0^{\circ}\text{C}$ But not if $T < 0^{\circ}\text{C}$



Can use RBI to focus on:

◆ Corrosion/Erosion

- If conditions are severe e.g. high PP of contaminant
- Thereby eliminating “lower” risk areas?
- Ignore systems where conditions are outside concern range? E.g. low T and no or low Contaminant PP

◆ Condition Monitoring

- Machine reliability not adequate
- Critical to production/safety
- Mechanical failure could lead to VCE?
- Ignore safe systems such as potable water pumping?



Objective

The main aim of RBI, if properly carried out, is to manage the “**Risk**” of plant failure at an acceptable level.

“Risk” = Likelihood x Consequence



If the risk of failure of a component has an effect:

Assess the Risk in terms of:

- Safety (Personnel? Fire? Toxicity?.....)
- Loss of Production?
- Failure to meet Legislation?

Then cost the risk of failure and its probability
Or likelihood

- Set Inspection Requirement and Frequency



Then we can :

- ◆ Eliminate unnecessary work?
- ◆ Reduce inspection work load
- ◆ Increase/Decrease Frequency of Inspection
- ◆ Save Time and Money



The HSE will accept:

- ◆ Goal setting safety legislation (UK in 1989 & 2000) has enabled a move towards inspection strategies based on the risk of failure. This legislation allowed a user/owner together with a nominated “Competent Person” the flexibility to decide a “suitable” written inspection regime based on system information and good engineering practice.



Application:

- ◆ The evolution to a **risk-based** approach has been supported by specific process plant operating experience together with better knowledge of material degradation mechanisms and availability of fitness-for-service assessment procedures.

Also, developments in **NDT technology** have improved inspection ability, performance and consistency.



Major Plants

- ◆ Industry considers there are benefits from more informed inspection, particularly in refining & petrochemicals where they are now setting inspection priorities on the specific risk of failure. Benefits include:-
- ◆ Improved inspection screening for high risk areas;
- ◆ Prioritising inspection based on measured risk;



- ◆ Cost savings by stopping ineffective inspection, extending inspection intervals and greater plant availability;
- ◆ Systematic management of risks associated with equipment failures.



But!

- ◆ Inspection is usually only **one part** of a site's integrated integrity management strategy which **also** normally includes **routine and preventative maintenance** and they are usually linked within a common framework.



What is Risk Based Inspection?

“Risk Based Inspection” is a systematic process that involves planning an inspection on the basis of the information obtained from a Risk Analysis of the equipment concerned.

The purpose of the “Risk Analysis” is to identify the potential deterioration mechanisms and threats to the integrity of the equipment and to assess the consequences and risks of failure.



Risk Analysis

Risk Analysis usually contains the following 6 stages:-

- ◆ Identification of equipment failure scenarios
- ◆ Identification of potential deterioration mechanisms and modes of failure
- ◆ Assessment of the probability of failure from each mode/mechanism



Risk Analysis

- ◆ Assessment of consequences resulting from failure
- ◆ Determination of the risks from failure
- ◆ Risk ranking and categorisation.



Types of Risk Analysis

- ◆ Qualitative;
- ◆ Semi-Quantitative;
- ◆ Fully Quantitative.



Measuring Risk

- ◆ **Qualitative** risk analysis is based primarily on objective engineering judgements made by an RBI “team”. The Likelihood and Consequences of Failure (**LoF** & **CoF**) are expressed in relative terms, as below:-
- ◆ Risks are usually expressed within a Risk Matrix.



Measuring Risk

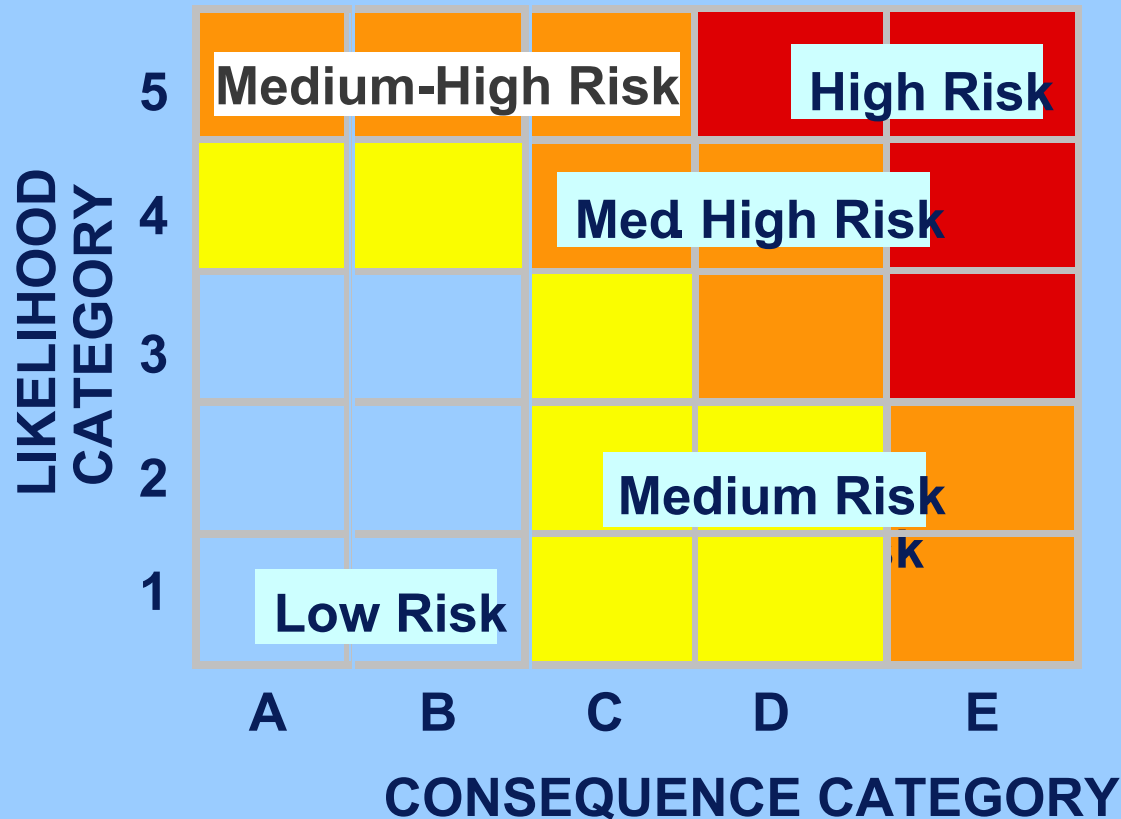
L.o.F:-

- ◆ Very unlikely
- ◆ Possible
- ◆ Reasonably probable
and
- ◆ Probable

C.o.F:-

- ◆ High
- ◆ Moderate or
- ◆ Low

Typical Risk Matrix



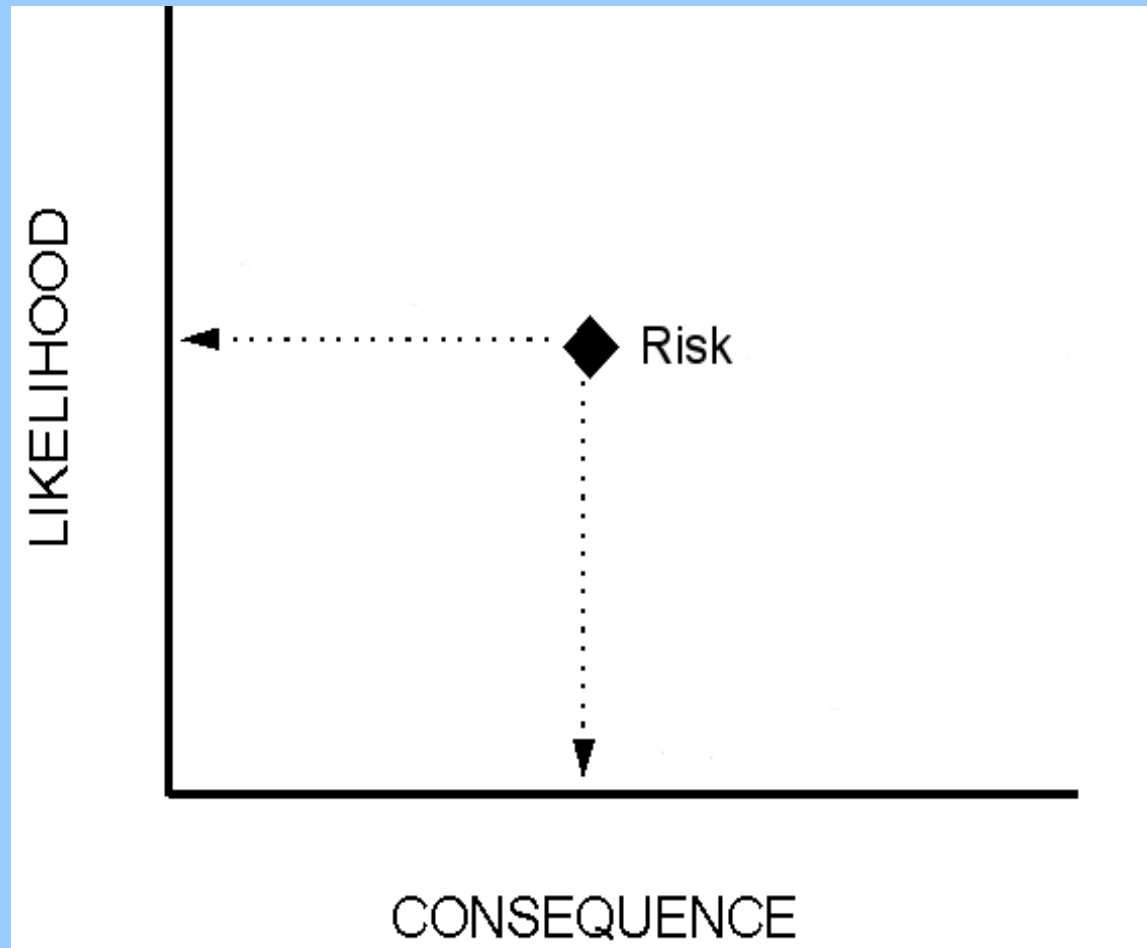


Measuring Risk

- ◆ **Semi-Quantitative** risk analysis determines single numerical values for the probability of failure and the consequences from every cause and effect. Analysis of failure is more numerically based and detailed than the Qualitative approach, but may still include a large element of engineering judgement.



Likelihood and Consequence X-Y Plot

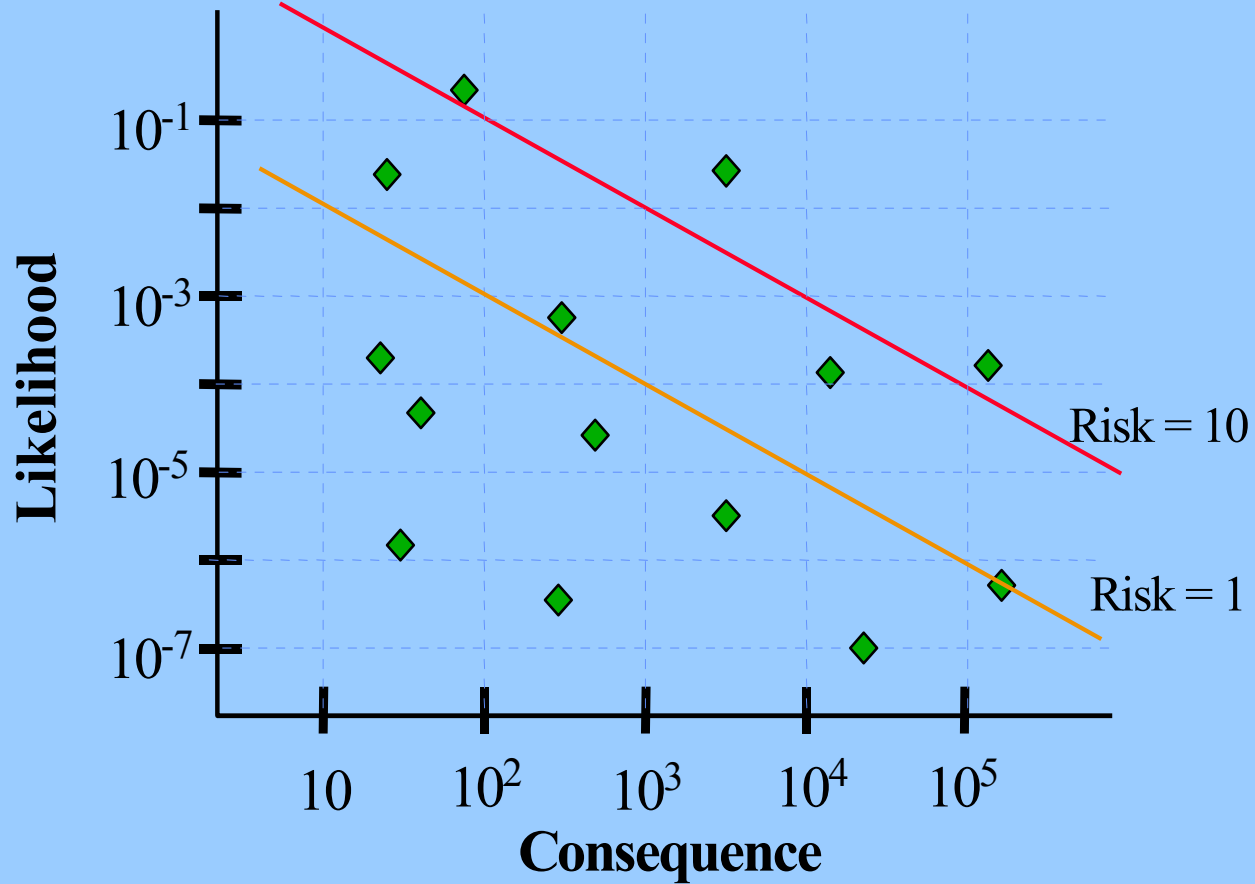




Measuring Risk

- ◆ For a fully **Quantitative** risk analysis, the likelihood and consequences of failure are determined for each scenario using standard reliability analysis methods with the total probability of failure evaluated using methods such as survival statistics. Results are normally presented on logarithmic probability-consequence plots.

Iso Risk Lines





Measuring Risk

- ◆ Whilst all these approaches to Risk Analysis may be valid, the **process** and the **data** needs to be transparent and the use of non-validated software may be restricted. The risk analysis & measuring process must be consistent and able to be **independently assessed**.



Definitions

“Risk” – The risk of failure of an item combines the probability or likelihood of failure with a measure of the consequences of that failure:-

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

The “Consequence” of failure through the unintentional release of stored energy and/or hazardous material is the potential for injury, damage, lost production, pollution, reputation etc. These can be measured in a variety of ways – fatalities, fines and compensation payments, bankruptcy, higher insurance premiums.....



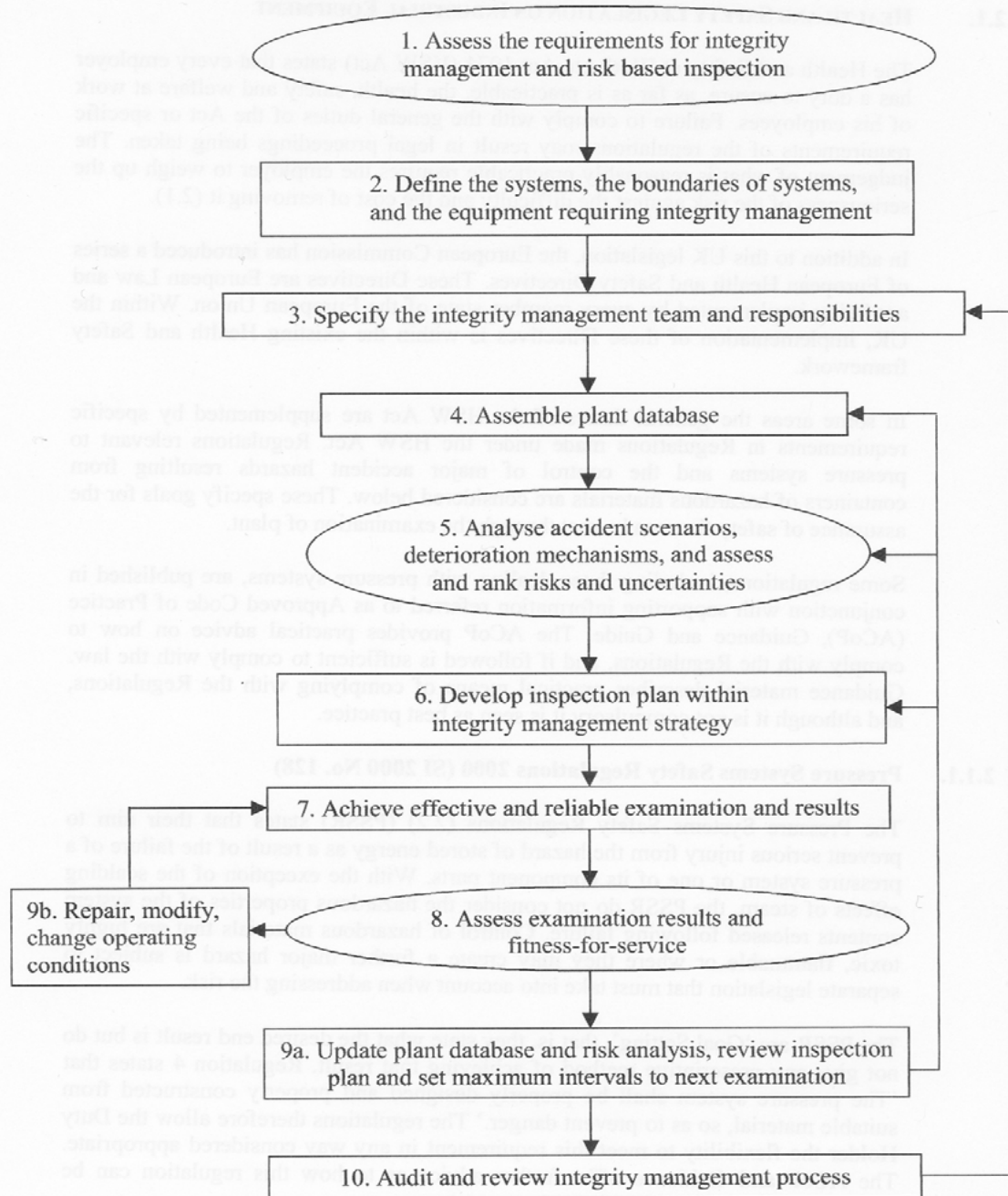
Definitions cont.

“Inspection” in RBI is the planning, implementation and evaluation of examinations to determine the physical and metallurgical condition of equipment or a structure in terms of fitness-for-service. It is usually part of a company, site or facility “Integrated Integrity Management Strategy” for managing risk of failure which should still include conventional routine and preventive maintenance.



Process of Risk Inspection

- ◆ **Risk Based Inspection** is defined as a logical and structured process of planning and evaluation as shown in the following flow chart for plant integrity management by RBI:-





Definitions etc

“In-service” inspection is most valuable where there is uncertainty about the process operating conditions, their effect on materials, particularly where the conditions are such as to promote “deterioration”.

“Deterioration” is defined as damage, defects or degradation from the design intent or the as-manufactured condition.



Guidelines on Inspection Frequency

Guidelines have been published by various organisations giving guidance on good practice for setting intervals between statutory inspection of pressure equipment, 3 of these are:-

- ◆ SAFeD (SafeD (Safety Assessment Federation)) - In 1997 SAFeD produced guidelines on extension of existing intervals.



Guidelines on Inspection Frequency

- ◆ CEOC (European Confederation of Organisations for Testing, Inspecting, Certification and Prevention) - recognised inspection intervals varied significantly within the EEC and basis is not one of risk and that it would be desirable to inspect on a variable throughout cycle life.



Guidelines on Inspection Frequency

- ◆ **Institute of Petroleum** – In the IP Code of Safe Practice proposed two interrelated concepts – Grade Allocation and Sampling examination procedures. - allocation of grading depends upon assessment following 1st examination – if rapid deterioration item is allocated a low grade (i.e. high failure risk). If reasonable deterioration and predictable then given less severe grade.



Guidelines on Inspection Frequency

This is a semi-quantitative method for assessment of risk and recognises the importance of good information. The periodicity (in months) between inspections is set according to type of vessel and allocated grading as follows:-



IoP Guidelines on Inspection

Equipment	Grade 0	Grade 1	Grade 2	Grade 3
Pressure Vessels & Heat Exchangers	36	48	84	144
Pressure Storage Vessels	60	72	108	144
Protective Devices	24	36	72	~



Guidelines on Risk Assessments

- ◆ The UK **HSE** published a Guide to Risk Assessment Requirements in 1996 intended for employers which set down 5 steps:-
 1. Look for Hazards;
 2. Decide who might be harmed and how;
 3. Evaluate risks and review precautions;
 4. Record findings;
 5. Review assessment & revise if necessary.



Guidelines on Risk Assessments

- ◆ In 1999 the UK **HSE** published a discussion document which described the assessment of risk process adopted by the HSE.
- ◆ It also introduced the important concept of **tolerability** – i.e. the willingness of society to live with a risk etc



Guidelines on Risk Assessments

- ◆ CEOC produced guidelines* on a Qualitative & Quantitative approach including **historical** and **analytical** approaches to estimating probability of failure – they noted weaknesses of both methods and concluded improvement of both methods should continue and also building of data bases required.



Guidelines on RBI

- ◆ The UK HSE Hazardous Installations Directorate issued an internal circular in 1999 as guidance for HSE inspectors for auditing plant inspection systems which adopt RBI.



Guidelines on RBI

- ◆ ASME issued an overview of RBI principles in 1991 recommending a four-part process:-
 1. Definition of the System;
 2. A Qualitative Risk assessment;
 3. A Quantitative Risk Analysis;
 4. Development of inspection programme



Guidelines on RBI

This ASME document mainly considered the theoretical approach to the problem detailing actual analysis methods i.e. FMECA (Failure Modes Effects Criticality Analysis), Structural Reliability & Risk Assessment (SRRA) and Probabilistic Risk Analysis (PRA).



Guidelines on RBI

- ◆ API 581 designed for the petroleum and chemical industries was published in draft form in May 2000. It followed the same overall approach as ASME, aiming to:-
 1. Define & measure level of risk;
 2. Evaluate safety, environmental and Business Interruption risks;
 3. Reduce risk of failure by effective use of inspection resources.



Guidelines on RBI

The level of risk is assessed following the same procedure as ASME – quantitative analysis applied after initial qualitative analysis.

The qualitative analysis assesses each plant item in a 5 x 5 risk matrix.

The likelihood of failure is determined from the sum of 6 weighted factors viz:-



Guidelines on RBI

- ◆ Amount of equipment within item;
- ◆ Damage mechanism;
- ◆ Usefulness of inspection;
- ◆ Current equipment condition;
- ◆ Nature of process;
- ◆ Safety design and mechanisms.



Guidelines on RBI

The consequence of failure is divided into only two factors:-

1. Fire/Explosion;
2. Toxicity



Guidelines on RBI

Risk is then calculated as the product of each consequence and likelihood for each damage scenario, the total risk for an item equated as the sum of all the scenario risks:-

$$\text{Risk}_s = C_s \times F_s$$

where:-

S = Scenario

C_s = Consequence of Scenario

F_s = Failure frequency of Scenario



Guidelines on RBI

$$\text{Risk}_{\text{Item}} = \Sigma \text{Risk}_s$$

The inspection programme is then developed to reduce that risk. To do that one needs to establish:-

1. What type of damage to look for;
2. Where to look for damage;
3. How to look for damage;
4. When to look for damage.



Guidelines on RBI

What and **Where** is established from design & process data and equipment history. **How** to look for damage by reviewing the damage density and variability, sample validity, sample size, detection capability of method and validity of future based on past observations. **When** to look for damage is related to estimated remaining life of item.



Software Packages for RBI

There are many commercial software packages which vary in complexity but generally follow the **semi-quantitative** risk assessment methodology. 5 of these packages are listed below but a report prepared for the UK HSE **did not specifically endorse any one and noted none of the methods used have been validated.**



Software Packages for RBI

They also noted their practical application is limited and they should **only** be used as a guide and **not** to replace risk assessment and inspection planning.

- ◆ Akzo Nobel;
- ◆ Det Norsk Veritas (DNV);
- ◆ The Welding Institute (TWI);
- ◆ Tischuk;
- ◆ LMP Technical Services.



RBI Team

In all but the simplest situations, RBI is best undertaken as a team activity similar to Hazop. Technical knowledge and experience should encompass;-

- ◆ Risk assessment;
- ◆ Process hazards and failure consequences;
- ◆ Plant safety and integrity management;
- ◆ Mechanical engineering/metallurgy/design;
- ◆ Plant operation, maintenance & inspection history;
- ◆ Inspection methods/NDT effectiveness etc.



RBI Team

- ◆ Where there are significant Health & Safety implications arising from equipment failure, the qualifications and competence of team members needs to be to a recognised professional standing. Where not available in-house “duty holders” will need to take advice from appropriate external experts and consultants.



RBI Team

- ◆ Ideally, the Team Leader should be independent from the direct pressures of the site production function and should have appropriate seniority and authority.
- ◆ Good records need to be kept on how qualitative judgements and decisions were kept.
- ◆ In many cases the information required for a quantitative risk assessment either does not exist, or is not sufficiently accurate.



Assessing Requirements for RBI

- ◆ What reference has been made to published information?
- ◆ What are the reasons/drivers for the risk-based approach?
- ◆ Is the availability and accuracy of information sufficient?
- ◆ Does the approach reflect the plant complexity and potential catastrophes?
- ◆ How do Integrity Management & Inspection link to plant operations?
- ◆ How is the documentation managed & controlled?



Auditing the RBI Process

- ◆ How often is the Management Process audited and reviewed?
- ◆ Who carries out the audit and review?
- ◆ What aspects of the Management Process are covered;
- ◆ Is documentary evidence available to support each aspect?
- ◆ How has the Integrity Management process changed?



RBI should not be used to:

Reactively spot check a system which has just been involved in a major accident

Try to satisfy the Authorities

Purely extend the period between maintenance turnarounds without good reason

Just produce computer output which is not relevant to the job



RBI will not solve:

Inadequate
Design/Operation beyond
intention/incorrect
manufacture – these are
under Quality Assurance

Deliberate
damage/External factors
such as storm, hurricane
which exceed the design
case

Failures caused by
presence of unforeseen
presence of contaminants
or pollution (perhaps
intermittent occurrence)

Wrong selection of
materials or PMI failure

No Plant May Implement RBI if:

They have no records
They cannot display the trends of the last inspections

They have a poor loss record

They are looking to save money only

Their Maintenance is inadequate



RBI is useful:

In work prioritisation – to focus on areas where business outage could be significant

Feedback in industry to highlight failure modes and educate other plants before failure

As a tool to help the company focus its resources

To assess the risk to the business (in terms of loss of production)