Risk Based Inspection (RBI) Best Practice: The Technical Specification for Ensuring Successful Implementation

Ron Selva B.Sc, C.Eng, F.I.Mech.E

PP SIMTECH Solutions Limited, Enterprise Centre Buildings, Washington Street, Bolton BL3 5EY, United Kingdom.
ronselva@ppsimtech.com

13th International Conference on Pressure Vessel & Piping Technology, 20-23 May 2012, London
Keynote Paper – Technical Session: Managing Risk

Abstract

This Keynote Paper is written to help plant sites wishing to implement Risk Based Inspection (RBI) for the first time to enhance their equipment integrity management practice as well as for those plant sites not satisfied with their existing Risk Based Inspection (RBI) process at site and considering a change. It is also considered of immense value for plant sites wishing to set up a Risk Based Inspection (RBI) audit programme to review their existing RBI technology process and site practices and make the necessary improvements. The technical specification provided in this paper for ensuring successful implementation of Risk Based Inspection (RBI) is based on current knowledge of RBI technology, best practices, industry experience and feedback particularly from Inspection and Operations engineers at a variety of plant sites.

Guidance is also provided to plant sites on key technical aspects which they must include when writing their Technical Specification for Risk Based Inspection (RBI) Project Tender enquiry, together with various criteria which must be satisfied when they finally evaluate and select the Risk Based Inspection (RBI) Service Provider. Any plant site following these guidelines will ensure achievement of its site strategic goals, whilst help minimise the serious inconsistencies exist between Risk Based Inspection (RBI) service providers with respect to the 5 critical aspects mentioned below.

As a background, Risk Based Inspection (RBI) is a technology process which, when correctly implemented, is used to formally optimise the inspection efforts for each equipment item of plant within the boundaries of appropriately defined integrity operating limits, whilst minimising equipment failure risks caused by the relevant Damage Mechanisms (DMs). Risk Based Inspection (RBI) driven integrity management is relevant to static equipment, piping, storage tanks, pipelines and pressure relief valves operating in the oil, gas, petrochemical, fertilizer manufacturing & power generating plants.

The management process is also evergreen as the initial Risk Based Inspection (RBI) study of each of these items requires reviews and updates after inspection or when operational changes are made. As such the integrity management responsibilities involve not just the Inspection Engineers but also the Operations and Process Engineers at a plant site.

As Risk Based Inspection (RBI) is still a developing technology, there are various RBI methodologies are available in the marketplace, including API 581. Each has its own merits and weaknesses. As such, those companies who have already implemented Risk Based Inspection (RBI) at plant sites have reported varying outcomes from implementation.

It is emphasized therefore, only through proper implementation of a robust and user-friendly Risk Based Inspection (RBI) technology process, the perceived substantial safety & financial benefits can be achieved by plant sites. As such, the following critical aspects must not be compromised as these are the ‘bottom line’ for implementing Risk Based Inspection (RBI) successfully. The plant site must ensure:-

1. Selected Risk Based Inspection (RBI) <u>Technology is reliable</u> (in assessing Probability of Failure [PoF] for each identified DMs and their Risks), <u>incorporates best practices</u> and is <u>technically practical and user-friendly for Inspection Engineers</u> at plant site.

2. Risk Based Inspection (RBI) Team Study of each item and each piping corrosion loop (PCL) is comprehensive, in particular the study process for identifying potential DMs & evaluating of PoF and risk profile, optimising inspection interval, defining inspection scope/method for each DM and defining integrity operating limits – *there is no shortcut to this task, <u>the study time must not be compromised</u>*.

   With respect to Risk Based Inspection (RBI) study data, ensure all damage causing chemicals including their actual compositions/temperatures at various locations in the plant are correctly established, including relevant past operational changes. Samples must be taken and analysed where such compositions are uncertain.

3. In addition to Risk Based Inspection (RBI) Specialist Engineer and Corrosion Specialist, the Risk Based Inspection (RBI) Study Team includes Inspection, Operations and Process engineers from plant site.

4. Risk Based Inspection (RBI) Team Study Output is reliable, addresses all integrity related aspects (e.g. Optimum Inspection Interval, Integrity Operation Limits & Critical Maintenance Activities, etc) and matches site strategic goals.

5. Risk Based Inspection (RBI) software comprehensively supports 1-4, future updates of study and is fully auditable.

With this mindset, following important aspects are discussed to provide an overall appreciation of the requirements:-

1. Industry Status on Risk Based Inspection (RBI) Technology
2. Plant Site Risk Based Inspection (RBI) Objectives and Project Deliverables
3. Risk Based Inspection (RBI) Implementation – Best Practice Risk Based Inspection (RBI) Technology
4. Risk Based Inspection (RBI) Implementation – Risk Based Inspection (RBI) Team Study and Study Time
5. Risk Based Inspection (RBI) Implementation – Study Output/Deliverables + example
6. Plant Site Management Commitment & Obligations
7. The role of supporting Risk Based Inspection (RBI) Software system
8. Writing a Technical Specification for an Risk Based Inspection (RBI) Project Enquiry
9. Selecting the Risk Based Inspection (RBI) Implementation Service Provider

When the above important aspects are correctly addressed and followed, it has been shown to deliver the plant site Risk Based Inspection (RBI) strategic goals in terms of substantial improvement in safety, reliability and financial benefits:-

1. Enhanced integrity for each plant item (improved safety & reduction in lost production days) through better understanding of potential DMs and respective damage susceptible locations.
2. More focused inspection strategies with reliably optimised interval and inspection activities for each equipment item, based on identified ‘active’ and ‘potential’ DMs. Reduction in inspected items during each TA, through extended inspection intervals for items which are found to be over inspected. Replacement of intrusive inspections with non-intrusive methods for items where this is feasible.
3. Reduction in equipment failure risks due to better defined Integrity Operating Limits & Critical Maintenance Tasks.
4. Formally justified opportunities with recorded evidence to increase plant run-length time between TAs and optimise maintenance / inspection TA times. Reduction in unexpected deteriorations usually found during TA inspections which in turn lead to reduction in unplanned repairs, thus avoiding over-run of TA period.
5. Improved ‘working together culture’ between inspection, process and operation departments and proactive ‘asset care’ at plant site and improved self-assurance on equipment reliability.

The Senior Management at plant site must therefore appreciate that, for implementing Risk Based Inspection (RBI) successfully at a plant site, it is the reliability of this technology process, its user-friendliness to inspection engineers plus the accuracy of the data, comprehensiveness of the team study and the people involved in this from the plant site which deliver the set objectives & goals and not the software. i.e. do not buy an Risk Based Inspection (RBI) software where the responsible plant inspection engineers cannot fully understand the Risk Based Inspection (RBI) technology behind it, as implementing such a technology can lead to an increase in equipment risk rather than a reduction in risk.

Keywords: Risk Based Inspection; RBI; RBI team study; study time; RBI software; Damage Mechanisms; DMs; Piping Corrosion Loop; API 581; API 580; Integrity Operating Limits; Selecting RBI Service Provider; Writing Technical Specification for RBI Project Enquiry;

---

1. Industry Status on RBI Technology

A word of ‘caution’, RBI is still a developing technology and therefore various Risk Based Inspection (RBI) methodologies are available in the marketplace, including API 581. Each has its own merits and weaknesses. As such, those companies who have already implemented Risk Based Inspection (RBI) at plant sites have reported varying outcomes from implementation. For these reasons, UK Health & Safety Executive (HSE) and API 580 issued some guidance for RBI implementation to help minimise inconsistencies.

1.1. Status of API 580 / API 581

The original versions of API 580 and API 581 were published in May 2002 and May 2000 respectively. After approximately 8 years, API has revamped both API 580 and API 581 and these were issued in November 2009 and September 2008 respectively.

In the latest versions, API 580 gives guidance for key aspects which should be considered for implementing RBI at a plant site, using either Level-1 (Qualitative) or Level-2 (Semi-Quantitative) or Level-3 (Quantitative) methods. Whereas, API 581 was developed only to deal with Level-3 Quantitative RBI.

1.2. API 581 Concerns

In theory, the accuracy, detailed nature of Risk Based Inspection (RBI) study and confidence in the results are supposed to increase with the increased Level of assessment. Unfortunately, it is not the case in this instance if API 581 (Level-3 quantitative RBI methodology) is selected. Noting that Risk Based Inspection (RBI) is still a developing technology, there are a number of technical and procedural issues in the latest API 581 which are questionable with regard to their validity, applicability and scope of application. Critical issues regarding these include but are not limited to:-

- Validity of “generic failure frequency data” in relation to Damage Mechanisms (DMs) & equipment types.
- Validity of “Probability of Failure [PoF]” assessment method for each identified DMs.
- Assessment of “Consequence of Failure [CoF]” in relation to a “DM” vs. its “failure mode”.
- Assessment of “Management Factor” does not adequately address accuracy/quality of Risk Based Inspection (RBI) study data with respect to damage causing chemicals, applied loads and environment. Neither does it address the impact of failure to identify or incorrect identification of applicable DMs in equipment or piping. *i.e. Management Factor needs to address specific aspects which affects, for example, DMs induced risk, inspection interval, etc, rather than generic aspects.*
- Does not provide a robust process to identify existence of relevant damage causing chemicals, applied loads & environment for correct identification of active and potential DMs in equipment or piping.
- Many of the DMs applicable to petrochemical, fertilizer and gas processing plants are not covered. Only most of the DMs applicable to refineries are covered.

All these concerns will have a direct impact on the confidence that can be placed on the Risk Based Inspection (RBI) study output, particularly the risk profile of the DMs, overall risk ranking of the equipment, optimum inspection interval, inspection requirements and Integrity Operating Limits.

Some of these issues are addressed by Helle in his paper, ‘Five fatal flaws in API RP 581’, presented at the NACE Middle East Corrosion Conference Feb 2012 (Ref. 5).

1.3. Which Risk Based Inspection (RBI) Method is Acceptable?

As per API-580:2009, any of the 3 Assessment Levels is acceptable; but plant site must ensure that the Risk Based Inspection (RBI) methodology and RBI team study method provided by the service provider is defendable, user-friendly, detailed, documented, transparent and auditable with the facility for future updates of the initial implementation, whilst it is also imperative to ensure that the methodology matches the output requirements of the plant site & end user. Additionally, the selected Assessment Level must be user friendly to the engineers at plant site (end user), in order to ensure success after initial implementation. i.e. **do not buy into a Risk Based Inspection (RBI) methodology where the responsible plant inspection engineers or operations engineers cannot fully understand the technology behind it,** as such technology can lead to an increase in equipment risk rather than a reduction in risk.

It is also emphasised that the chosen Risk Based Inspection (RBI) technology method (whether it is Level-1, Level-2 or Level-3) must be robust, in particular **the selected Level must have the methodology to <u>reliably</u> assess the ‘Probability of Failure’ & the ‘risk profiles’ of <u>each</u> of the DMs** applicable to an item.

Failure to satisfy this important criterion, the confidence in the optimum inspection interval derived for each item is fundamentally questionable. This is simply because the optimum inspection interval is derived from the risk profile of each of the applicable DMs. It must also be **supported by a comprehensive and consistent team study method** that ensures identification of all active & potential DMs as well as integrity related operating limits, maintenance activities, together with other risk mitigation measures.

Based on the foregoing, the wider industry experience clearly shows that a Level 2 Semi-Quantitative RBI methodology, which satisfies the technical criteria outlined above (regarding PoF and DMs risks) plus API 580:2009 and UK HSE guide, supported by an experienced multi-discipline team study which includes plant inspection, operation and process engineers proves to deliver the required output and the confidence in the results. A Semi-Quantitative methodology is also 'User-Friendly' for the inspection engineers at plant site.

With respect to API-581:2008 (Level-3 quantitative Risk Based Inspection (RBI) method), API need to address the critical concerns outlined in section 1.2 above as well as make this technology 'easy to understand' & 'user-friendly' for inspection engineers at plant site, whilst ensuring that the assessment of all the relevant DMs applicable to petrochemical, fertilizer & gas processing plants are included in it. For these reasons and that API is believed to be considering revamping this methodology, by incorporating technologies based on structural reliability theories, its current use must be treated with caution, until this Quantitative Risk Based Inspection (RBI) methodology is stabilised and approved by all major global operating companies, wider RBI service providers/Experts and relevant industry sectors. However, the current API-581 document is still useful for obtaining damage rates and other relevant information on DMs which are addressed in it, when using a Level-2 (semi-quantitative) Risk Based Inspection (RBI) methodology.

2. Plant Site Management Commitment & Obligations

The Risk Based Inspection (RBI) cash challenge, in terms of financial benefits (see Ref. 9), has become one of the key site strategies for many progressive plant sites. However, it is emphasised that only the implementation of best practices in RBI (see Section 3) together with a robust Risk Based Inspection (RBI) technology (see Section 1.3) will deliver these benefits. As such, there are no shortcuts to this process.

For example, **compromising integrity of the Risk Based Inspection (RBI) technology process OR quality of Risk Based Inspection (RBI) team study by not providing sufficient study time in order to reduce project costs / timescales will have a detrimental effect on the confidence that can be placed on the Risk Based Inspection (RBI) study output**. As such, the claimed outcomes in improvements of plant reliability, safety and financial benefits are questionable and so is the management decision to buy into this output and implement it in the hope that they are going to achieve these claimed benefits.

It is critical therefore that senior management at plant sites fully understand these requirements and are committed to providing the required resources and time allocation for the Risk Based Inspection (RBI) team study. Figure 1 below outlines the basic considerations involved in setting up the implementation strategy.

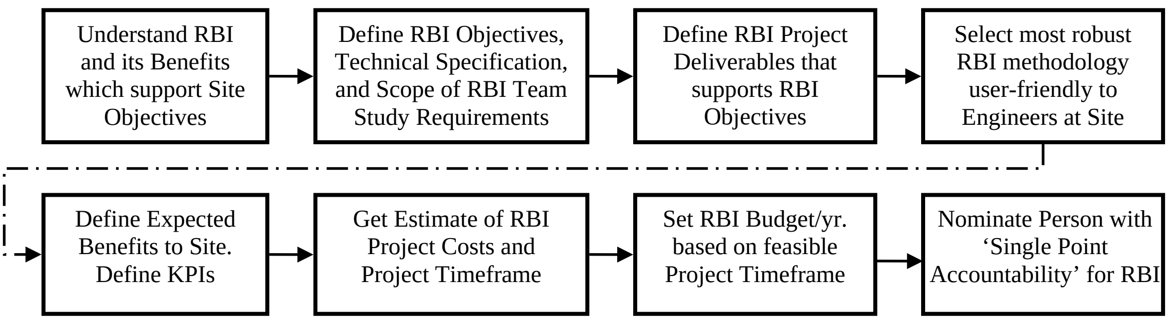


Fig.1. Plant Site Risk Based Inspection (RBI)Strategy – Management Commitment & Obligations

Having established the strategy for Risk Based Inspection (RBI) implementation, it is important for the plant site to ascertain the implementation process. Figure 2 below outlines the key tasks for the nominated person at plant site with 'Single Point Accountability' for the implementation project.

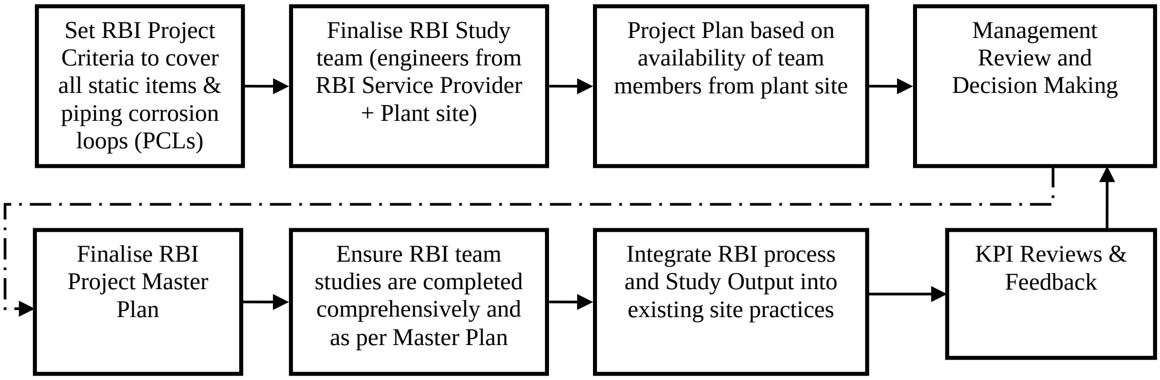


Figure. 2. Risk Based Inspection (RBI) Implementation Project – Role of Person with 'Single Point Accountability' for Risk Based Inspection (RBI) Implementation

3. Risk Based Inspection (RBI) Technology Incorporating Best Practice

Implementation of Risk Based Inspection (RBI) technology requires information on design, construction, fluid streams details (particularly, composition of damage causing chemicals) and inspection history of equipment & Piping of plant including past operational changes. Based on this information the integrity risk assessment is carried out using a competent multi-discipline team study process. It particularly focuses attention on the identification of all 'active' and 'potential' Damage Mechanisms (DMs), which could affect an item. This is followed by an evaluation of integrity risk profiles for each of the identified DMs applicable to item, which is based on DM Failure Mode, Consequences of Failure (CoF) & Probability of Failure (PoF).

It is imperative to ensure that the technology process used in assessing PoF for each of the identified DMs and the associated HSE and Business risk profiles for each DM need to be defendable, as the optimised inspection interval for an item is derived from this information. See Section 1 for guidance.

The inspection interval for item is optimised whilst ensuring that DMs risks are within acceptable levels & inspection plan is defined comprehensively. Where relevant, Integrity Operating Limits (e.g. temperature, composition, pH, moisture levels, etc) and/or monitoring requirements of relevant process streams & Critical Maintenance Activities are better defined to prevent increase in damage rates or initiation of a new DM. Other measures are also specified by Risk Based Inspection (RBI) study team to mitigate identified risks.

Best practices in Risk Based Inspection (RBI) technology implementation also demand responsibilities assigned for plant operations engineers to manage RBI study defined integrity operating parameters within agreed limits. Additionally, the initial Risk Based Inspection (RBI) study and the inspection plans for equipment also require reviews and updates after inspection or when operational changes are made or when integrity operating limits are violated.

3.1. Minimum Criteria for Successful Implementation of Risk Based Inspection (RBI)

For successful implementation, the following criteria must be met as a minimum:-

1. The chosen Risk Based Inspection (RBI) technology process must be robust & reliable (see Section 1.3 above) in assessing the Probability of Failure and the risk profile of active and potential damage mechanisms and optimum inspection interval for each item. Importantly the <u>chosen</u> Risk Based Inspection (RBI) <u>technology must be technically practical and user-friendly for Inspection Engineers</u> at plant site.

2. The team study applied to each Equipment and each Piping Corrosion Loop (PCL) must be comprehensive for self assurance in study output. In particular, this refers to the study process for identifying potential DMs & evaluation of PoF and risk profile for each DM, optimising inspection interval, defining inspection scope/method for each DM and defining integrity operating limits. (see Sections 3.3 & 3.4).

   Regarding Risk Based Inspection (RBI) study data, the plant Operations Engineer must ensure all damage causing chemicals including their actual compositions/temperatures at various locations in the plant are correctly established, including relevant past operational changes. Where their composition is unknown or uncertain, samples must be taken at relevant fluid stream locations for chemical analysis to ensure accuracy of item data.

3. The Risk Based Inspection (RBI) study team composition must include inspection, process and operation engineers from the plant site, in addition to Risk Based Inspection (RBI) specialist engineer and metallurgist/corrosion engineer. (see Section 3.2).

4. The Risk Based Inspection (RBI) software must fully support the Risk Based Inspection (RBI) method and team study as well as be transparent, auditable and be able to export the study output of each equipment and each PCL (e.g. inspection interval & inspection plan, next inspection due date, operating limits, critical maintenance activities, etc) to the overall site management software systems as required (see Section 6.2).

   It is emphasised that the main focus and priority with respect to Risk Based Inspection (RBI) software must be on these aspects only. Do not digress from this and dilute the key Risk Based Inspection (RBI) technology requirements by incorporating other 'nice to have needs' into the software specification.

5. The Risk Based Inspection (RBI) implementation must be managed as a project in order to progress the team studies on a regular basis and to successfully embed the output into plant site practices.

Procedures and responsibilities therefore must be set up and embedded into existing site practices to successfully implement and manage the process effectively at plant site. The dynamics of this Risk Based Inspection (RBI) technology implementation process is shown in Figure 3 below. It also highlights important interaction and proactive participation required from Operations/Process Engineers at plant site for effective integrity management.

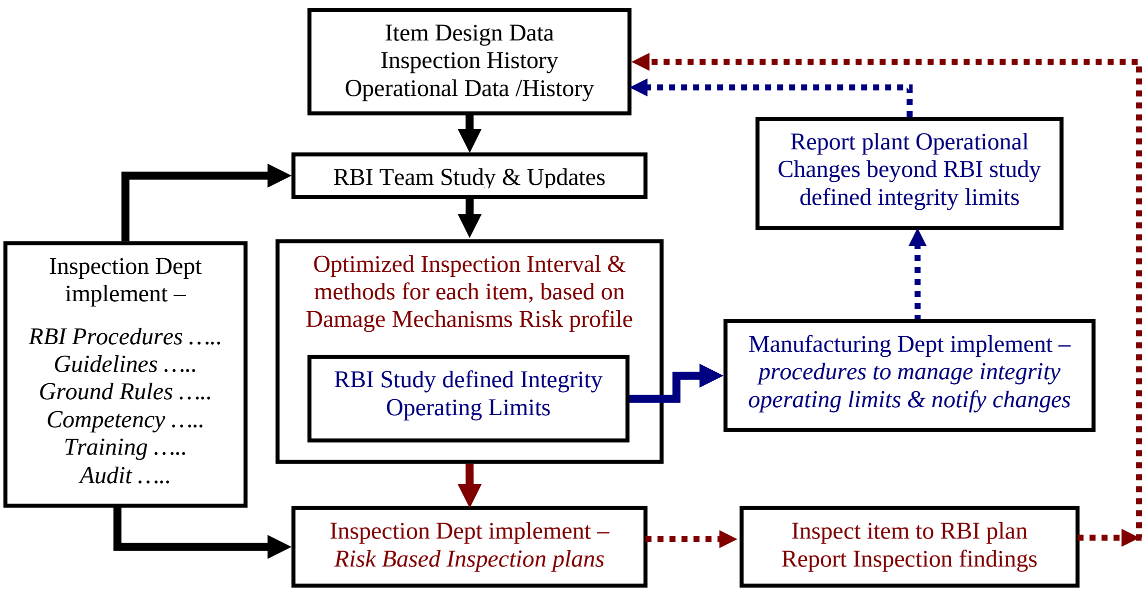
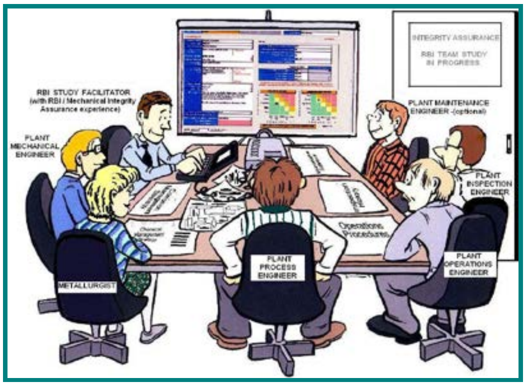


Figure 3. Risk Based Inspection (RBI) Technology Implementation – 'best practice' Model

3.2. The multi-discipline Risk Based Inspection (RBI) Study Team

The Risk Based Inspection (RBI) study must be carried out by a competent multi-discipline team, the members of which each having suitable qualifications and experience. It includes five core disciplines:-

- Risk Based Inspection (RBI) team study Facilitator (RBI & Fitness-for-Service assessment expertise)
- Plant Inspection Engineer
- Plant Operations Engineer
- Plant Process Engineer
- Corrosion Engineer (or Metallurgist)
- NDT Specialist – *part time (as needed)*



It is imperative that experienced engineers assigned to the Risk Based Inspection (RBI) study team and representing **core disciplines such as inspection, operations and process must be none other than from the plant site**. Industry experience clearly shows that without their commitment and input to the team study, Risk Based Inspection (RBI) cannot be successfully implemented and managed subsequently. The study Facilitator and Metallurgist/Corrosion specialist can be from the Risk Based Inspection (RBI) service provider. For audit reasons, team member names should be recorded in the study of each item.

3.3. Risk Based Inspection (RBI) Team Study – no shortcut to this task

It is emphasised that Risk Based Inspection (RBI) is a methodology to improve equipment reliability and safety and optimise inspection activities based on integrity risk assessment. As such, the team study using the Risk Based Inspection (RBI) methodology is a critical process itself, which must be performed comprehensively and competently. The key elements of the team study are shown in Figure 4 below for an Item (Equipment or a Piping Corrosion Loop – PCL).

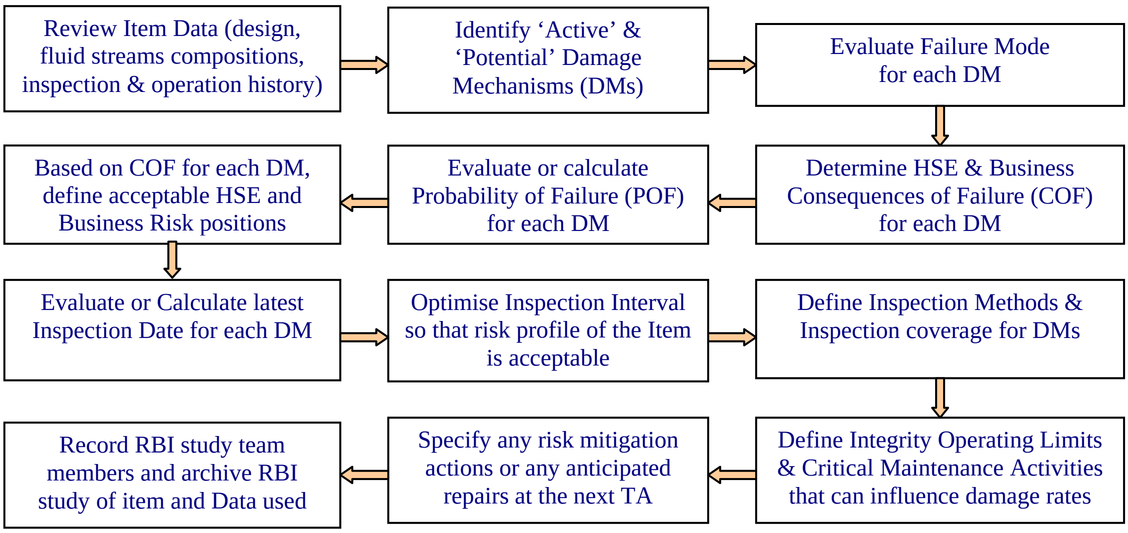


Figure 4. Key aspects of Risk Based Inspection (RBI) Team Study™ process for each

Clearly, there is no shortcut to this important task, as compromising the study time or study quality can adversely affect the confidence in the critical study output described under Project Deliverables in Section 3.5. The senior management at plant site must therefore be committed to providing the required resources & time allocation. Some of the important aspects of study are outlined in Section 5.1 (points 3-14).

The supporting software system must fully reflect each of the critical processes described in Fig.4 and be transparent, fully auditable with provision for archiving the studies carried out on each Equipment or PCL. It must also have facility for future updates of the study due to new inspection results or operational changes.

3.4. Risk Based Inspection (RBI) Team Study Time

Each Equipment and each PCL in a plant must be studied separately on its own entity. The comprehensiveness of the Risk Based Inspection (RBI) team study of each Equipment and each Piping Corrosion Loop (PCL) is critical to have confidence in the study output. Clearly this will reflect on the required study time for the Risk Based Inspection (RBI) project and hence the costs.

Initially, all required critical data for the study must be made available for each Equipment and each PCL, prior to commencement of study. The plant Operations Engineer must ensure all damage causing chemicals including their actual compositions/temperatures at various locations in the plant are correctly established, including relevant past operational changes. Where their composition is unknown or uncertain, samples must be taken at relevant fluid stream locations for chemical analysis to ensure accuracy of item data.

Assuming the above tasks are completed effectively, the Risk Based Inspection (RBI) Team study time for an Item (Equipment or PCL) can range from typically 2 hours for a simple Item and up to 1½ days for a complex Item with many Damage Mechanisms. Our experience of carrying out the study of several tens of thousands of Equipments & PCLs (with the help of competent study team and a user-friendly software system to record the study) shows that the average study time for a typical plant is approximately 2 items/day. Anything significantly shorter than this timescale is likely to affect the confidence on the study output.

Time & cost must also be allocated for Risk Based Inspection (RBI) study Data collection as well as Data entry in RBI software for each Equipment and each PCL. Allowing approximately 2 Items/day (on average) is considered reasonable to complete this task <u>accurately</u>. A trainee Inspection Engineer or equivalent can be assigned for this task under the supervision of an experienced Inspection Engineer. The entered operation data for each Item must be endorsed by the plant Process Engineer.

This gives a firm understanding of the Risk Based Inspection (RBI) project timescale and project costs, based on total number of Equipments and PCLs.

3.5. Risk Based Inspection (RBI) Project deliverables (Team Study Output) must include

A. For each Item (Equipment or PCL), the HSE and Business risk profile for each of the identified DMs as well as the overall HSE & Business risks for the Item.

B. Risk Based Inspection (RBI) plan for <u>each</u> Item (Equipment or PCL) of plant, based on ‘A’ above and as finalised by the Risk Based Inspection (RBI) study team. For <u>each</u> Item the inspection plan details …..

1) Optimised Major Inspection interval (definition of Major Inspection is where all the identified Damage Mechanisms (DMs) applicable to an item are inspected for).

2) Inspection type (where appropriate, advantage is taken of suitable Non-Intrusive inspection techniques to optimise Major Inspection interval. Non-intrusive NDT inspection is usually implemented as an Intermediate Inspection at a suitable date between Major Inspections, for example, to inspect for any critical DM. This is usually carried out without entering the item, when the plant is on-line or off-line).

3) Inspection methods to match the identified Damage Mechanisms (DMs). <u>Note</u>:- where relevant, NDT parameters (effectiveness and capability) are defined for the selected NDT methods, in order to improve confidence in inspection results.

4) Inspection coverage and locations which highlight the likely areas for damage occurring for each of the identified DMs.

C. Integrity Operational Limits (e.g. temperature, composition, flow rates, pH, etc) and monitoring requirements of relevant process streams including Critical Maintenance Activities are better defined to prevent increase in damage rates or initiation of a new DM, thus ensuring validity of (B) above.

D. Anticipated repairs, material upgrade or replacements at the next shutdown Turnaround.

E. Other measures to be actioned to mitigate identified unacceptable risks, which may lead to leakage or failure prior to the inspection date of the Equipment or PCL.

F. Recommendations on any need for special Fitness-For-Service assessment calculations to make decisions on "*run as is / monitor*", or "*repair*" or "*replace*" or "*upgrade material*". The results are then fed back to the Risk Based Inspection (RBI) study and inspection intervals adjusted.

This output consisting of A to F above ensures that identified risks are managed within defined acceptance levels, thus providing best-in-class mechanical integrity and reliability at optimum costs to the plant site.

4. Summary of an Risk Based Inspection (RBI) Implementation Study Output

In order to appreciate what is required from an Risk Based Inspection (RBI) study output, outlined below (Section 4.1) is a summary of the DMs and the important findings (see Section 4.3) from an Risk Based Inspection (RBI) project. These are in addition to the mandatory output of an RBI team study as per Section 3.5 for each Equipment and each PCL, based on DMs risk profile. The contents of the inspection plan output for each Equipment and each PCL were as detailed in Section 3.5.B. Information on common root cause chemicals which can initiate damage in equipment/piping is also provided in Section 4.2 below.

4.1. Damage Mechanisms identified by the Risk Based Inspection (RBI) study team

Damage Mechanisms (DMs) at Plant Units – A & B	
Fuel Ash Corrosion	Overheating – plastic collapse
Sulphidic Corrosion	Refractory Damage – pyro-sulphates
Naphthenic Acid Corrosion	Refractory Damage – acidic
Localised Corrosion	Chlorides – SCC
Crevice Corrosion	Caustic – SCC
Pitting Corrosion	CO-CO_2 – SCC
General corrosion	Amine – SCC
Shielding Corrosion	NH_3 – SCC
Galvanic Corrosion	Wet H2S – SSC
Wet H_2S Corrosion	Wet H_2S – HIC & Blistering
NH_4HS Corrosion	Wet H_2S – SOHIC
HCl Corrosion	HTHA
Dew Point Acid Corrosion	475°C Embrittlement
Erosion	Creep
Erosion Corrosion	Stress Relaxation Cracking
Corrosion under Insulation (CUI)	Fatigue – vibration / pressure cycling induced

4.2. Knowledge of Damage Causing Chemicals

There are over 70 DMs applicable to static equipment items of plant related to the oil, gas, petro-chemical, chemical and fertilizer industry. The correct identification of active and potential DMs applicable to each Equipment and each PCL in a plant is a critical part of the Risk Based Inspection (RBI) team study. The process used for the identification of DMs applicable to equipment as well as for PCLs must be consistent and the procedure must be documented.

Depending on the equipment materials, most of these DMs are caused by "damage causing" chemicals present in the process streams. Some of these chemicals only need to be present in ppm levels to cause deterioration.

It is imperative therefore the presence of damage causing chemicals is reliably identified. The quantity can only be confidently estimated by chemical analysis of samples taken from relevant process streams where composition is unknown or uncertain.

Listed below are most common damage causing chemicals which need to be considered in the Risk Based Inspection (RBI) study, in order ensure high confidence in identifying DMs applicable to each item of plant.

Hydrochloric acid HCl	Formates	CO_2
Hydrogen Iodide HI	Acetates	Chlorides
Hydrofluoric acid HF	Oxalates	Any other Halides
Sulphuric acid H_2SO_4	Carbamates	Nitrates
Sulphurous acid	Formaldehydes	Hydrogen
Carbonic Acid	Acetaldehydes	H_2S
Nitric Acid HNO_3	other corrosive Aldehydes	FeS
Phosphoric Acid	Other corrosive organics	Other Sulphides
other Inorganic Acids	NH_3	Sulphur
Acetic Acid	NH_4HS	Other Sulphur compounds
Formic Acid	NH_4Cl	HCN Cyanides
Propionic Acid	NaOH	Other corrosive inorganics
Naphthenic Acid	KOH	Mercury
Polythionic acid - PTA	Carbonates	Moisture
Phenol (Carbolic Acid)	Amines / Amine Salts	Flue gas
other Organic Acids	CO	Fuel ash

The Chemist / Process / Operations Engineers at plant site need to confirm – presence or absence of any of these chemicals; wet or dry; vapour or liquid or solid or two phase, etc.

4.3. Risk Based Inspection (RBI) Team Study – Critical Findings

Risk Based Inspection (RBI) Team Study Critical Findings in Plant Units – A & B	
Active Damage Mechanisms (all items total)	1157
Potential Damage Mechanisms (all items total)	941
No. of items LOW HSE Risk	288
No. of items LOW Business Risk	239
No. of items MEDIUM HSE Risk	180
No. of items MEDIUM Business Risk	225
No. of items HIGH HSE Risk	14
No. of items HIGH Business Risk	18
No. of items with RBI defined Integrity Operating Limits	68
No. of items with Recommendations / Risk Mitigation Actions	41
No. of items where Major Inspection Interval increased	396
No. of items where Major Inspection Interval decreased	27
No. of items where Major Inspection Interval unaltered	59

5. Writing a Technical Specification for Risk Based Inspection (RBI) Project Enquiry

For the reasons explained earlier, it is crucial that the selected Risk Based Inspection (RBI) Service Provider must be able to deliver a reliable Risk Based Inspection (RBI) technology process, which must also incorporate the industry best practices. The selected technology process and the team study method must be able to reliably assess equipment item risk profile based on correctly identified Damage Mechanisms (DMs). This together with comprehensiveness of the team study is critical to the whole process because evaluation of optimised inspection interval for an equipment or a PCL clearly depends on risk profile of the identified DMs.

Importantly, this whole technology process must be 'user-friendly' to the inspection engineers at plant site.

It is imperative that the plant site when writing a technical specification for an Risk Based Inspection (RBI) implementation project should therefore consider all these essential elements.

This is fundamental to ensuring that the end benefits as a result of Risk Based Inspection (RBI) implementation are achieved with improved confidence in equipment integrity and reliability. Also, satisfying these requirements would provide the required self-assurance to the plant site Senior Managers as well as to the inspection, operations and process engineers at site for effective implementation of the study output as well as subsequent management of the same due to new inspection results or process operational changes.

5.1. Technical Specification for an Risk Based Inspection (RBI) Project Enquiry

With the mindset outlined above, the key aspects of Technical Specification for a Risk Based Inspection (RBI) Project Enquiry must include all the mandatory points outlined below as a minimum. These have been proven by experience as the best-practice aspects of successful implementation. It must be written in such a way so that evaluation & final selection of the Service Provider is correctly carried out (see Section 6 below).

1. The Risk Based Inspection (RBI) technology must be robust and 'user-friendly' (see Section 1 and Section 3.1), must be supported by a comprehensive team study process and must provide the required self-assurance to plant inspection, process and operations engineers at site.

2. The methodology within the selected RBI technology should include at least the important guidance provided in API 580 and Health & Safety Executive (UK).

3. The Risk Based Inspection (RBI) methodology and team study process must be clearly defined and transparent. The application of the methodology and resulting output must be recorded in such a way that the study process for each Equipment or each Piping Corrosion Loop (PCL) is fully auditable so that future reviews / updates are carried out easily. The software must support this aspect (see Section 3.6).

4. The Risk Based Inspection (RBI) Team Study must be carried out by a competent team (see Section 3.2).

5. The Team Study of each Equipment & each PCL in a plant must be carried out separately on its own entity, so that output from the study is consistent as per Section 3.5, whether it is an Equipment or a PCL.

   The study process must be comprehensive (see Section 3.3) and there is no shortcut to this task (see Section 3.4).

   <u>*PCL definition*</u>:- *For a cost effective & more focused inspection of piping in a plant, lines of piping made of same material and carrying same process fluid within a particular temperature range and composition range is grouped together as a PCL. The PCL is treated similar to an Equipment in the study.*

6. The Study data (design, operating loads / fluid streams data and historical changes, inspection history) for each Equipment or PCL must be accurate, particularly the composition of damage causing chemicals. Take samples and do chemical analysis if such composition is unknown or uncertain.

7. The Damage Mechanisms (DMs) identification process within the Risk Based Inspection (RBI) study method must be clearly defined. It shall consider normal operation, start-up/shutdown conditions, process excursions and past operational changes. The DM identification process must be comprehensive & must provide a consistent method (and prompts in the Risk Based Inspection (RBI) Software) in order to ensure high confidence in determining all 'active' & 'potential' DMs for each Equipment and each PCL.

8. The Failure Mode for each of the identified DMs should be determined in order to evaluate realistic 'consequence of failure'.

9. The methodology must ensure reliable assessment of 'Probability of Failure' (PoF) and the risk profile for each of the 'active' and 'potential' DMs identified for an Equipment or PCL. From the assessment of the risk profile for each of the DMs, the optimised inspection interval for the Item (Equipment or PCL) must also be reliably evaluated against an acceptable risk profile.

10. The assessment of PoF must incorporate confidence levels the team has in the assessment, which may be reduced, for e.g. owing to limited data availability. The inspection interval must be adjusted accordingly.

11. Specific 'ground rules' must be set within the team study process to ensure consistency in application of the Risk Based Inspection (RBI) technology and the output.

12. The Integrity Operational Limits of key process parameters and Critical Maintenance Activities (coatings, fire-cladding, insulation seal, etc) must be defined (see Section 3.5), as part of the Risk Based Inspection (RBI) team study output. The implementation shall be audited by the plant site Inspection Department.

13. The RBI study output must also include a detailed inspection plan (see Section 3.5.B) with consideration and specification of reliable NDT methods linked to the DMs, with scope of coverage and inspection locations clearly defined. This inspection plan must consider NDT capabilities & effectiveness.

14. For high consequence items, speculative inspections and inspection sampling should be considered within the overall inspection programme in order to allow for the unexpected.

15. Procedures must be put in place at plant site to ensure that the RBI study output / deliverables (see Section 3.5) and the management of future reviews and updates are embedded into the site practices.

16. The supporting software for the selected Risk Based Inspection (RBI) technology must be in compliant with the key aspects outlined in Section 3.6. It is emphasised that the main focus, priority and selection of a Risk Based Inspection (RBI) software must only be based on the mandatory aspects described above.

    Do not digress from this and dilute the key Risk Based Inspection (RBI) requirements by incorporating other 'nice to have needs' into the Risk Based Inspection (RBI) software specification.

6. Selecting the correct Risk Based Inspection (RBI) Service Provider

The technical specification for the Risk Based Inspection (RBI) project enquiry as outlined in Section 5.1 above form the basis for selecting the correct Service Provider. Prior to finalising the Service Provider for the project, request a presentation on the RBI technology /Team Study method to be used and the deliverables from each of the invited Service Providers. Although the Engineers from Inspection/Integrity Department are responsible for the implementation, this presentation must also be attended by the Engineers from relevant Process and Plant Operations departments from site. Afterall they will be involved in the RBI study and study data, as well as they will be collectively responsible for managing integrity of equipment and piping after implementation. i.e. Inspection Engineers will have responsibility for implementing inspection program according to Risk Based Inspection (RBI) plan, future update of the study and inspection intervals due to new inspection results or operational changes. Whereas, the Process and Plant Operations Engineers will have responsibilities for managing the defined Integrity Operating Limits and Critical Maintenance Activities.

For these reasons, request each of the invited RBI Service Providers and ensure they address the following points in their presentation. Clearly specify to them the required Risk Based Inspection (RBI) project deliverables as outlined in Section 3.5. Also, allocate enough time for the presentation to comprehensively address the key technical aspects outlined in Sections 5.1, 6.1 & 6.2. This is necessary in order to understand all the aspects and the implications, as there is no room for error or misjudgement in this evaluation process.

6.1. The evaluation from the Risk Based Inspection (RBI) Technology presentation

The presentation from each Risk Based Inspection (RBI) Service Provider must be evaluated using a consistent method for robustness of the technology (regarding assessment method for PoF & risk profile of each DM, derivation of optimum inspection interval and comprehensiveness of the Risk Based Inspection (RBI) team study process) and user friendliness to Inspection Engineers (i.e. easily understandable technology process). It must be recognised that, confidence in the Risk Based Inspection (RBI) output entirely depends on the *robustness of the Risk Based Inspection (RBI) technology, quality of data, DM identification process and comprehensiveness of the team study.*

With this mindset on the evaluation process, anything less than 100% technical confidence should be treated with 'caution' or as 'non-acceptable' for the following critical technical aspects. This is simply because, the correct optimum inspection interval & inspection requirements for each Equipment or PCL & Integrity Operating Limits entirely dependent on these aspects.

- *Robustness (assessment method for PoF and the risk profile of each DM, derivation of inspection interval); user-friendliness to inspection engineers; comprehensiveness of the RBI team study.*
- *Confidence in the output (depends on the above, quality of data and DM identification process).*

1. The type of data considered in the Risk Based Inspection (RBI) study by the Risk Based Inspection (RBI) service provider and its reliability
2. The process used for addressing missing or uncertain data
3. The multi-discipline Risk Based Inspection (RBI) study team and competency of the team members
4. The process used for correctly identifying active and potential DMs for each Equipment
5. The process used for correctly identifying active and potential DMs for each PCL
6. The technology used for assessing PoF and the HSE & Business risk profiles for each of the identified DMs for an Equipment or PCL.
7. The method used for addressing confidence in the study (due to limited availability of data, uncertain data, etc) and how this is incorporated in the PoF assessment and the derivation of the risk profile (6 above) and the latest inspection date for a DM.
8. The method used for evaluating latest inspection date for each of the identified DMs for an Equipment or PCL, based on 6 above.
9. The method used for deriving optimum inspection interval for the Equipment or PCL, based on 6, 7 & 8.
10. Additional 'ground rules' used in the study in order to ensure equipment integrity is not compromised for the set inspection interval, particularly when inspection intervals are extended.
11. Finally, how will the RBI Service Provider deliver each of the Risk Based Inspection (RBI) project deliverables (see Section 3.5) set out by the plant site?

Key technical pointers are given below for anyone wishes to develop a check list for Risk Based Inspection (RBI) service provider evaluation & selection:-

1. Do the Inspection Engineers at plant site fully understand the technology process behind the offered Risk Based Inspection (RBI) methodology? This is mandatory in order to ensure future updates of the study, inspection plan, etc due to new inspection results or process operational changes are successfully managed, after implementation of the initial Risk Based Inspection (RBI) study output. It is imperative therefore **not to select an Risk Based Inspection (RBI) methodology where the responsible plant inspection engineers cannot fully understand the technology process behind it,** as buying into such a technology can lead to an increase in equipment risk rather than a reduction in risk.

2. Does the offered Risk Based Inspection (RBI) technology, study team composition and study method as well as the rest of the package necessary for effective RBI implementation provide the required self-assurance to plant site senior managers, operations, process and inspection engineers?

3. Does the offered Risk Based Inspection (RBI) technology process incorporate additional 'ground rules' so that the team study includes important practical aspects traditionally considered by the inspection engineers in managing equipment integrity? Does the offered RBI technology and team study method provide a process for incorporating inspection sampling to allow for the unexpected?

4. How comprehensive is the Risk Based Inspection (RBI) team study & method for addressing missing critical data, in order to ensure that both 'active' & 'potential' DMs applicable to <u>each</u> Equipment & <u>each</u> Piping Corrosion Loop (PCL) are competently identified?

5. What is the membership of the multi-discipline Risk Based Inspection (RBI) study team?

6. Typically, <u>on average</u>, how much study time (hours) is spent on RBI study of an <u>Equipment</u>?

   <u>Note</u>:- This varies substantially between Risk Based Inspection (RBI) service providers; hence it will reflect on project costs as well as study quality. See Sections 3.3 and 3.4 for guidance.

7. Typically, <u>on average</u>, how much study time (hours) is spent on RBI study of a <u>PCL</u>? See Note in 6.

8. What is the process used in the Risk Based Inspection (RBI) study for correctly identifying the potential DMs applicable to an Equipment and how effective is this process?

9. What is the process used in the Risk Based Inspection (RBI) study for correctly identifying the potential DMs applicable to a PCL and how effective is this process?

10. How reliable is the assessment of 'Probability of Failure' and the 'risk profile' for each of the identified DMs applicable to an item or PCL and how is this information translated into a reliably optimised inspection interval for the item or PCL?

11. How comprehensive is the inspection plan and other critical output of the study for each item (see RBI Team Study deliverables in Section 3.5) which would support effective implementation of RBI?

12. How transparent is the team study process and supporting software system in order to ensure audit trail of data used by Risk Based Inspection (RBI) study team, team study process, DMs status and risk profiles, key decisions and supporting reasons, study output, team members, etc?

13. Does the software provide comprehensive facilities to record the complete Risk Based Inspection (RBI) studies? Does it allow facilities for study and inspection plan updates as a result of future inspection findings or operational changes? Does it provide archiving facilities for studies and updates carried out?

14. Fitness-For-Service (FFS) assessment is a technology that is used to calculate or evaluate optimum remaining life of deteriorating equipment and as such it has become integral to the Risk Based Inspection (RBI) technology process. Does the Risk Based Inspection (RBI) Service Provider have the expertise to correctly identify and apply FFS technology where relevant and assist the plant site accordingly?

6.2. The evaluation of supporting Risk Based Inspection (RBI) Software

The main technical pointers are given below for anyone wishes to develop a check list for Risk Based Inspection (RBI) Software selection. However it is emphasized that this is a much lesser priority in comparison to the importance that must be placed to ensure correct Risk Based Inspection (RBI) technology is selected. The key reasons are clearly obvious from Section 1, Section 3.1 and Section 5.1.

Any missing gaps in Risk Based Inspection (RBI) software with respect to for e.g. export/import facility of data between the Risk Based Inspection (RBI) software and the main software system at plant site (e.g. SAP, Maximo, etc) can be quite easily addressed at a later date to meet the required functionality, on a 'need to requirement' basis for the plant site. See also the cautionary note below.

The Risk Based Inspection (RBI) software must have adequate functionality and details to facilitate the team study in a consistent manner and support Risk Based Inspection (RBI) best-practice technical aspects described in Section 5.1. Many of the functionalities specified are deemed mandatory to help updates of the study. The following are considered to be a minimum:-

1. Needs to fully support the Risk Based Inspection (RBI) technology process & the multi-discipline team study method described in Figure 4 and the resulting study output as outlined for each item (see Section 3.5). It also needs facility for recording Risk Based Inspection (RBI) team discussions, logic and decisions for each Equipment or PCL.

2. Needs to be transparent on how the 'active' and 'potential' Damage Mechanisms (DMs) applicable to an item are correctly identified. Need to have a process to prompt discussions in a consistent manner so that all 'potential' DMs applicable to an Equipment or PCL are correctly identified.

3. Needs to be transparent on how the DM induced integrity risk profiles (HSE and Business) for each of the identified DMs for an item are reliably assessed.

4. Needs to be transparent on how the optimised inspection interval for an item is reliably derived, based on identified DMs and the risk profile of each DM.

5. Facility for reporting inspections carried out on each item and the findings to match the applicable DMs, so that updating of the Risk Based Inspection (RBI) studies and resetting of the inspection intervals can be carried out effectively with minimum resource commitment.

6. All of the above records needs to be fully transparent & auditable, including Risk Based Inspection (RBI) study data used, the RBI study and study output (see Section 3.5), team members as well as the subsequent Reviews and Updates of the study due to inspection or operational changes.

7. Must have facility for future updates of the study due to new inspection results or operational changes.

8. Facility for reporting inspections carried out on each Item and the findings to match the applicable DMs, so that updating of the Risk Based Inspection (RBI) studies and resetting of the inspection intervals can be carried out effectively with minimum resource commitment.

9. Provision for archiving the Risk Based Inspection (RBI) Study (i.e. Study Data, Study, Study Output, Team Members involved in the study) as well as the Study updates carried out on each item.

10. Facility for exporting Risk Based Inspection (RBI) study output of each Equipment and each PCL (e.g. inspection interval & inspection plan, next inspection due date, operating limits, critical maintenance activities, etc) to the overall site management software systems as required.

The foregoing facilities in the Risk Based Inspection (RBI) software system has been proven to provide consistency in the study quality and documented evidence on improved reliability, safety and a reliably optimised inspection interval and inspection requirements for each item of plant. Additionally, on an 'evergreen' basis, it also provides an effective process to carry out reviews and updates of the Risk Based Inspection (RBI) study and output, as a result of inspection findings or process operational changes.

A caution on Risk Based Inspection (RBI) software specification: It is emphasised that the main focus, priority and selection of a Risk Based Inspection (RBI) software system must only be based on the mandatory aspects described above. Do not digress from this and dilute the key RBI technical requirements by incorporating other 'nice to have needs' into the Risk Based Inspection (RBI) software system. With the software coding capability available nowadays, the latter can be easily addressed later to suit plant site specific requirements.

7. Conclusion

This paper is written to help plant sites wishing to implement Risk Based Inspection (RBI) for the first time as well as for those plant sites not satisfied with their existing Risk Based Inspection (RBI) process at site and considering a change.

It is also considered of immense value for plant sites wishing to set up an Risk Based Inspection (RBI) audit programme to review their existing Risk Based Inspection (RBI) technology process and site practices and make the necessary improvements.

The technical specification and guidance provided in this paper for ensuring successful implementation of Risk Based Inspection (RBI) is based on current knowledge of Risk Based Inspection (RBI) technology, best practices, industry experience as well as useful feedback particularly from inspection engineers at a variety of plant sites.

Section 5 provides helpful guidance to plant sites for writing a clear Technical Specification for a Risk Based Inspection (RBI) Implementation Project. Similarly, Section 6 provides helpful guidance to plant sites for the evaluation and selection of the Risk Based Inspection (RBI) Service Provider. This should be adhered to for ensuring 'like for like' comparison, evaluation and final selection of the Risk Based Inspection (RBI) Service Provider in terms of Risk Based Inspection (RBI) implementation technical ability and the cost of Risk Based Inspection (RBI) Project.

Any plant site following these guidelines will ensure achievement of its site strategic Risk Based Inspection (RBI) goals, whilst help minimise the serious inconsistencies exist between Risk Based Inspection (RBI) service providers with respect to the 5 critical aspects described in Section 3.1

The paper describes a robust and proven Risk Based Inspection (RBI) implementation process, which is practical and incorporates leading edge of Risk Based Inspection (RBI) best-practice. There is clear evidence that there is no short cut to implementing Risk Based Inspection (RBI) successfully. As such, plant sites cannot claim that improvement in plant reliability & safety has been achieved if the necessary study time is compromised or if an Risk Based Inspection (RBI) methodology with technical uncertainties is used. It is critical therefore for plant sites wishing to successfully implement Risk Based Inspection (RBI), the senior management at plant site must be committed to providing the required resources and time allocation for Risk Based Inspection (RBI) team study as well as ensuring that the chosen technology process is robust, reliable and user-friendly to inspection engineers.

The inspection engineer needs to be fully conversant with the Risk Based Inspection (RBI) technology process used for derivation of DMs risks and the optimum inspection interval. Afterall, they are responsible for the inspection and certification of the optimum inspection interval for an equipment or piping for the intended operating conditions. So selecting a user-friendly Risk Based Inspection (RBI) technology is critical to successful implementation of RBI.

It is imperative therefore not to select a Risk Based Inspection (RBI) methodology where the responsible plant inspection engineers cannot fully understand the technology process behind it, as buying into such a technology can lead to an increase in equipment risk rather than a reduction in risk. For example, uncertainties in technology, complex mathematical and statistical procedures as in API 581 do not help the typical inspection engineers at plant sites given their background work experience and qualifications (e.g. API 510/570 certification), which is not conducive to competently manage any complex Risk Based Inspection (RBI) process.

The Risk Based Inspection (RBI) technical requirements which must be met are provided in Section 1, Section 3.1 and Section 5.1. The team study method for each Equipment and each Piping Corrosion Loop must be comprehensive in order to have confidence in the study output.

Equally, the Risk Based Inspection (RBI) study team composition must include inspection, process & operation engineers from the plant site, in addition to any external consulting engineers such as Risk Based Inspection (RBI) engineer and Corrosion Engineer.

The Risk Based Inspection (RBI) implementation must be managed as a project. A suitable person with Single Point Accountability must be nominated by plant site in order to progress the team studies regularly and to successfully embed the process and study output into the site technical practices and site culture.

On a final note, when it comes to implementing Risk Based Inspection (RBI) successfully, it is the reliability of the Risk Based Inspection (RBI) technology process, its technology user-friendliness to inspection engineers plus the comprehensiveness of the team study and the people involved in this from the plant site which deliver the set objectives & goals and not the Risk Based Inspection (RBI) software (see Section 6.2). *The Risk Based Inspection (RBI) software therefore must not be used to drive best practices in Risk Based Inspection (RBI) technology or quality of team study or replace experienced team input; instead it is a supporting tool.*

References

[1] UK Health & Safety Executive [HSEx] CHID [Control of Hazardous Installation Directorate] Technical Circular to HSEx Inspectors: ‘Risk Based Inspection (RBI) – A Risk Based Approach to Planned Plant Inspection’, 1999.

[2] UK HSEx Research Report - ‘Best practice for risk based inspection as a part of plant integrity management’, 2001.

[3] UK HSEx Gas and Process Safety Technology Division - ‘Best practice for the procurement and conduct of Non-Destructive Testing’ November 2000’.

[4] API 580 / API 581.

[5] Helle Henk PE (CorrosionControl Nu BV). Five fatal flaws in API RP 581. 14th NACE Middle East Corrosion Conference 2012, Bahrain, 12-15 Feb 2012.

[6] Selva RA (PP SIMTECH). Keynote Paper: What is Risk Based Inspection (RBI) best practice & how to implement it successfully?. API Conference, Doha, QATAR, 23-25 May 2011; and NACE Corrosion Conference, Mumbai, India, 28th Sept-1st Oct 2011.

[7] Selva RA (PP SIMTECH). Keynote Paper: Living with Defects – Replace/Repair or prove Fit-For-Service?. ICPVT-13 (13th International Conference on Pressure Vessels and Piping Technology), London, UK, 20-23 May 2012.

[8] API 571 / API 579 / BS 7910.

[9] Selva RA (PP SIMTECH). Confidently De-bottleneck Inspections by Implementing a Proven Risk Based Inspection (RBI) Technology. Syngas Conference 2008, Moscow, Russia, 20-23 April 2008.

[10] Rahim N (GPIC), Selva (PP SIMTECH). 'Best-practice on RBI driven Integrity Assurance of Process Plant Items – GPIC Experience. 4th Middle East NDT Inspection (MENDT) Conference, Bahrain, 2 – 5 Dec 2007.

[11] Selva RA (PP SIMTECH), Gordon I (PP SIMTECH). Managing Static Equipment Integrity based on Risk Based Inspection (RBI) Technology. 3rd FFC International Conference NH_3 & Urea Technology, Islamabad, Pakistan, Nov 2006.

[12] Selva RA (PP SIMTECH), Verdon-Smith J (British Petroleum). Inspection Strategies based on Mechanical Integrity Risk Assessments. ICPVT-9 (9th International Conference on Pressure Vessel Technology), Sydney, Australia, 9 - 14 April 2000.

[13] Selva RA (PP SIMTECH), Verdon-Smith J (British Petroleum), Riseborough WJ (Dow Chemicals). Risk regulating process to maximise return from plant assets. IMechE International Conference - Assuring Its Safe, Edinburgh, UK, May 1998.

[14] Selva RA (RSAL), Amphlett G (RSAL). High Integrity Plants In Service. IMechE International Conference - Operation and Risk management, London, UK, Oct 1995.

[15] Selva RA (RSAL), Heuser AH (BASF). Fitness-For-Service & Fracture Mechanics Assessment of a 12,000-Tonne Refrigerated Ammonia Storage Tank in the Presence of Stress Corrosion Cracks. AIChE Safety in Ammonia Plants and Related Facilities Symposium, San Francisco, USA, Sept 1989.

Hosted by

Institution of
MECHANICAL
ENGINEERS

ICPVT-13 KEY NOTE SPEAKERS

STUART CAMERON

CONSULTANT, DOOSAN BABCOCK ENERGY

Stuart Cameron is a Consultant for Doosan Babcock Energy. He has worked with the company, formerly Babcock & Wilcox, for over 40 years and held the position of Chief Engineer until 2011 with specific responsibility for technical risk management and investigations throughout all parts of the Company including compliance with existing and new legislation regarding pressure equipment. He is also a Visiting Professor at the University of Strathclyde, Vice President of the Institution of Mechanical Engineers and Chairman of the BSI Boiler Committee and the ISO Working group for procedures on international compliance of boiler and pressure vessel standards.

RON SELVA

ENGINEERING DIRECTOR, PP SIMTECH

Ron Selva has more than 35 years of experience in static equipment integrity managing technologies relating to the oil, gas, petrochemical and fertilizer manufacturing plants operating worldwide. As Engineering Director at PP SIMTECH, he has spent the last 20 years championing the development and implementation of best practice Risk Based Inspection (RBI), Fitness-For-Service (FFS) assessment and Total Integrity Management of Assets (TIMA) technologies.

PROFESSOR JIM BOYLE

TRADES HOUSE CHAIR IN MECHANICS OF MATERIALS, UNIVERSITY OF STRATHCLYDE

Jim Boyle is Trades House Professor of Mechanics of Materials in the Department of Mechanical & Aerospace Engineering at the University of Strathclyde. His main areas of research lie in nonlinear continuum mechanics and computational mechanics with special reference to high temperature design problems. Major practical applications continue to lie in the field of pressure vessel and piping design and design by analysis. Jim has been involved in Design by Analysis for over thirty years and was a co-writer of the Design by Analysis Manual for the DBA direct route in CEN's unfired pressure vessel standard prEN 13445-3.

NIGEL KNEE

HEAD OF NUCLEAR POLICY, NUCLEAR NEW BUILD, EDF ENERGY

Nigel Knee has over 25 years' experience in the electricity industry, starting out in engineering where he carried out failure investigations and research into the defect tolerance of reactor pressure vessel steels. He has also worked on safety assessment, research programme management and diverse commercial issues including electricity trading strategy, business planning and market regulation. He is currently responsible for nuclear policy issues within EDF Energy's nuclear new build team. Previously he was part of British Energy's strategy and business development team, focusing on the opportunity for new nuclear build.

CLAUDE FAIDY

SENIOR CONSULTANT ENGINEER, EDF-SEPTEN

Claude Faidy joined EDF in 1976 and SEPTEN Engineering Division in 1978. After working on Fracture Mechanic analysis, he moved to the major failure modes and degradation mechanisms analysis for PWR and FBR. Claude currently employs this experience to support the design and operation of French and International Codes and Standards. He is closely involved to the French Ageing Management program for the 58 PWRS and is a member of code organisations in Europe and the USA.