Managing ageing plant through **Risk Based Inspection**

Recognising and addressing the risk of ageing at the beginning of the plant's life can increase its design life in many cases

All plants are susceptible to ageing, and so are automatically subject to the risks of mechanical integrity failure such as loss of containment. Given this, companies should be taking action to manage their ageing plant, but at the same time all companies need more output for less input; higher production and less investment, higher reliability but lower maintenance. Risk Based Inspection (RBI) may be a solution in effectively managing ageing plant and achieving that aspiration of higher productivity through less down time. RBI is about inspection of the plant in a manner which is bespoke to its needs, and finding the correct and most efficient inspection regime. This can remove the need for unnecessary and costly inspections, especially those which are legally enforced under PSSR (Pressure Systems Safety Regulations).

This article from Chilworth Global gives a real-life example of RBI being used to examine the inspection requirements on a mist eliminator in a sulphonation process, which is highly toxic and corrosive. This led to significant savings in parts replacement and in down time, as well as saving logistical costs in facilitating invasive-visual-internal inspection.

Background

Traditionally plant items have been inspected using prescriptive industry practices, for example statutory inspections of boilers and pressure vessels enforced under the PSSR. Here, the actual inspection method and interval is documented in the WSE (Written Scheme of Examination) but is based on prescriptive practices in most cases. Prescriptive practices by nature have fixed methods of inspection and inspection frequency which are based on general industrial experience. Although these prescriptive practices appear inflexible and potentially inappropriate for specialised situations, they "have on the whole provided adequate safety and reliability." [1]

However, the prescriptive inspection method has inherent shortcomings;

- It does not encourage the analysis of the specific threats to the integrity of the plant in question,
- It does not focus finite inspection resources on the areas of greatest concern. [1]

This inefficient usage of resources is shown in both the inspection time and the financial outlay to prepare the logistics for inspection by the Duty Holder, the owner and user of the equipment.

This problem is further exacerbated by the fact that statutory inspections have become an over-commoditised industry. Currently, inspections of pressurised equipment are conducted via insurance companies for most large organisations. Insurance brokers acting on behalf of their clients, the plants, seek a deal with insurance companies in providing the most cost effective policy. In practice, each relevant plant item is categorised in a rough group by equipment type (i.e. reactor, air receiver, heat exchanger etc.) and each item is quoted on the number of units, a unit being a quarter of an hour of an inspector's time. So X units for air receiver and Y units for reactor etc. and the PSSR WSE is sold as a standard commodity along with the inspection. All of this activity, which is meant to ensure plant integrity, is carried out without asking a single question about the complexity of the plant or how hazardous the materials handled are in terms of toxicity and flammability [2]. Instead of engineers both from the plant and the inspection company speaking to one another about what the requirements of the plant really are, too often it comes down to negotiations between insurance companies and brokers.

As one would expect, this issue itself leads to many other problems:

- The WSE may not be detailed enough to highlight the specific failure mechanisms of specialised vessels. Even if that is the case when the vessel is put in service, as companies change insurance providers over time seeking to make savings, WSEs may be just passed on without being reviewed. Hence, as plants age, the latest risks to the plant may not be reflected in the old WSE. This may then lead to unnecessary or inadequate inspection methods and intervals.
- Companies end up seeing PSSR inspections as just another legal requirement. They may feel like they do not own the risk anymore and thus become disengaged from taking benefit from this professional examination; inspectors are seen as trouble makers because they stop the plant.

The preparation work for statutory inspections can also be very costly and dangerous for those handling toxic and flammable materials. It is not unusual for large plants (over 100 vessels) to be spending over £100,000 in facilitating invasive-visual-internal inspections. It is here where applying the RBI method could address these problems.

RBI Method

The actual methodology used to carry out RBI studies can be taken from the best practice published by the Health and Safety Executive (HSE): *"CRR 363/2001; Best practice for risk based inspection as a part of plant integrity management"* [1]. The overview process for conducting an RBI is shown in Figure 1.1. The discussion of each stage can be found in reference [1].

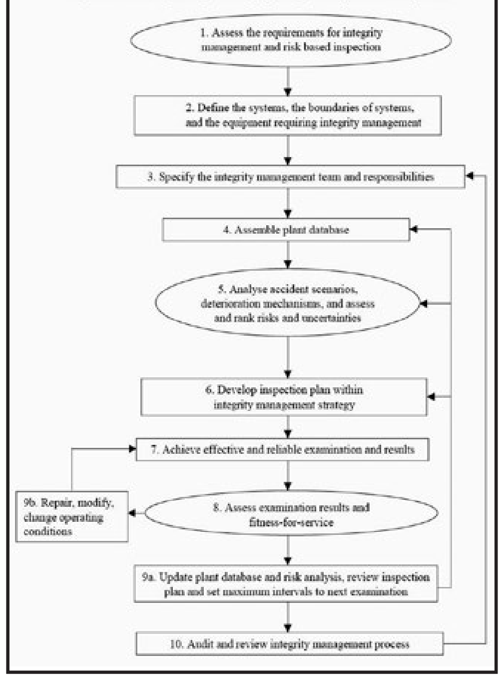

Fig. 1.1 Process diagram for plant integrity management by risk based inspection

RBI in Action

A real-life example of applying the RBI method is given but it is for demonstration purposes and so does not include the entire assessment details.

An RBI study was carried out on a large (>11 cu.m.) mist-eliminator pressure vessel in a Sulphonation process subject to statutory inspections. The study entailed a review of the process, the historical and current condition of the vessel, a mechanical integrity risk assessment and a proposal for inspection based on the RBI method.

The main reason for the RBI study was to explore the feasibility and scope in reducing internal visual inspections. This in turn would lead to other benefits:

- Decrease the risk of internal corrosion by minimising air exposure, because the reaction chemistry between the residual material inside of the vessel and atmospheric air introduced to the system when inspecting produces corrosive sulphuric acid. This serves to diminish plant ageing.
- Reduce exposure of personnel (inspectors and operators) to toxic atmospheres arising from inspections.
- Achieve financial savings; realised from reducing the need to facilitate an internal inspection every two years which requires logistical costs and irreversible damage to the filter causing approximately £10,000 in parts costs.

Facilitating the inspection of equipment handling toxic or flammable materials can be especially resource consuming. Such plant equipment can benefit greatly from an optimised inspection regime that the RBI method delivers

Team

The study was carried out in several meetings over a period of a month. The team included the site Maintenance Leader, Process Safety Leader, an Operator and an expert from the inspection company. The final document was then approved by the Principal Engineer of the inspection company.

Using site knowledge and expertise from the inspection company, all potential degradation mechanisms were then formally assessed. A sample of the assessment is shown in Table 1.

Vessel History

The historical inspection records for the vessel were reviewed; all inspection certificates and comments were studied in detail and taken into account as part of the assessment. Furthermore, other identical vessels in other production lines as well as those in other sister plants were taken into consideration. The main conclusions were:

- The only known degradation mechanism is internal corrosion.
- This corrosion is mainly concentrated at the bottom half of the vessel and at tangents to the filters on the shell of the vessel.
- The vessel appears to have a life of 10-12 years before requiring refurbishment work.

Degradation Mechanism Identification & Assessment

Description: Mist Eliminator for Sulphonation Plant on Train 1.
Material of Construction : Carbon Steel

No.	Degradation Mechanisms	Causes	Consequences	Safeguards & Mitigation	Recommendations
1	Corrosion	Internal - Moisture in process air reacting with SO_3 to produce sulphuric acid. Problem cited is exacerbated with over temp. - During shut downs when opening vessel to atmosphere and introducing the system to moist air which reacts to produce sulphuric acid External - Corrosion under insulation (CUI) - Exposed areas in-contact with atmospheric conditions	- Loss of wall thickness - Vessel failure and loss of containment - Personnel injury due to toxic exposure - Production loss	- Internal corrosion allowance by design - Vessel inside building (protection against CUI) - Routine external inspection by operators - Periodic statutory inspections - Restricted access to area - Emergency shutdown procedures	- Develop full thickness inspection program
2	Fatigue	- Cycling (pressure/temperature) loading during start-up. - Physical vibration arising from nearby equipment	- Similar to consequences of No.1 except no loss of wall thickness.	- Inherent safety; stable running temperatures. - Continuous running with minimal few shutdowns per year. - Vessel isolated from nearby plant.	
…	Embrittlement, Creep, Buckling… etc.	…			

Table 1: Identification and assessment of degradation mechanisms

		Probability of Failure				
Consequence of Failure		Highly Probable	Probable	Possible	Unlikely	Very Unlikely
	Very High					
	High					
	Moderate					
	Low					
	Very Low					

Table 2: Risk matrix used for the assessment

Risk Assessment

The risk assessment was carried out using a semi-quantitative approach: the 5x5 risk matrix shown in table 2:

Probability of Failure

For each of the identified degradation mechanisms, the probability of failure was assessed using the assessment tables given in CRR 363 [1], e.g. for internal corrosion:

Rating	Description
Highly probable	Allowable loss is already used up
Probable remaining life	3 - 5 years
Possible remaining life	5 – 7 years
Unlikely remaining life	7 – 10 years
Very unlikely remaining life	> 10 years

In this particular case, experience had shown that the vessel only requires refurbishment work once every 10-12 years. The last time the vessel was refurbished was in June 2009, so the estimated next date for refurbishment work is June 2019 - approximately 7 years from the date of assessment. Consequently, the rating is Unlikely.

The same style of assessment was carried out for the other identified degradation mechanisms. All of the results were then collated together and a qualitative assessment of the overall failure probability made. In this case the overall probability of failure was deemed to be Unlikely.

Consequence of Failure

The consequences of failures were similarly assessed using 'guide words' given in the practice and then rated numerically. The consequences considered different categories which included: location and personnel, impact on production, and others which took into account fluid pressures, temperatures and hazards.

These consequences were individually rated numerically and then collated to obtain an overall rating using Table 3. The numerical ratings given in Table 3 also correspond to a description which is identical to that given in the 5x5 risk matrix (Table 2), and thus the overall risk can be determined.

Description	Rating
Very high	16 – 19
High	13 – 15
Moderate	10 – 12
Low	8 – 10
Very low	6 – 8

Table 3: Consequence of failure rating

For example, the consequence of failure arising from location of the plant on personnel was assessed using the below criteria:

Rating	Description
3	Heavily populated
2	Routinely accessible
1	Inaccessible without clearance

Given the vessel is located inside a building which requires authorisation for access; it was rated as 1.

Similarly, the consequence rating for all other categories (i.e. impact on production, hazards of material etc.) was considered. These ratings were added up and the total was 15 (i.e. High using Table 3).

Taking the results from the probability of failure (Unlikely) and consequence of failure (High), and using Table 2 the overall risk assessed was Low.

Inspection Plan

The overall risk rating should influence the inspection method(s) and interval, but there is currently no guidance which translates risk rating to inspection plan. The inspection plan depends on the judgement of the team and competent person carrying out the RBI.

The most important part of the inspection plan is ensuring that each degradation mechanism identified has a suitable inspection methodology and interval.
The inspection plan proposed for the mist-eliminator is shown below:

Failure Mode	Scope of Examination and Periodicity
Internal Corrosion	Conduct comprehensive LFET (Low Frequency Electromagnetic Technique) around all parts of the vessel followed by Ultrasonic Thickness inspection. The location of these tests shall be as indicated in the drawing (not included here). Frequency: every 26 months. Conduct thorough internal inspection once every five years in alignment with the filter change. … Internal inspection shall be carried out in June 2014, or at the first opportunity where the vessel is available for internal inspection if before then.
General Condition, Fatigue, ... etc.	

External pitting (corrosion) on carbon steel vessels is inevitable and can eat away the wall thickness if untreated. Anti-corrosive paints can be especially helpful in inhibiting external corrosion

Recommendations & Conclusions

All plants are subject to ageing, and addressing this risk should be seen as an opportunity to interrogate the inspection regime of the plant. Currently, statutory inspections of pressurised equipment are prescriptive and under the influence of an over-commoditised industry. The Duty Holder's best course of action is to question the WSE they are following and ensure it calls for a level of inspection which highlights the degradation mechanisms that are really present and is proportional to the risk. WSEs should be reviewed periodically to ensure they are still meaningful; this point itself touches at the heart of RBI and can lead to many ancillary benefits.

In this example, the RBI method was used on a mist eliminator in a Sulphonation process which led to savings of approximately £10,000 in filter replacement charges weeks in down time, and logistical costs in facilitating invasive-visual-internal inspection.

RBI can lead to profitable operations through effective maintenance and should be part of an integrated strategy for managing the risk of ageing plants. Implementing the RBI methodology does require expertise and so care should be taken in ensuring a competent team is formed before making radical changes. Further reading can be found in CRR 363/2001.

References

1. CRR 363/2001, Best practice for risk based inspection as a part of plant integrity management, HSE.
2. SAFed's Approach to Ageing Plant, May 2012, Miles Gardiner.
3. RR823, Plant Ageing Study; Phase 1 Report, 2010 HSE.