Risk Based Inspection. The cost-effective tool to optimise salt plant integrity.

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In order to be able to realise integrity management of salt plant in a more (cost) effective and efficient way, the Akzo Nobel Material Technology Centre has developed and implemented a Risk Based Inspection (RBI) program in the production plants of business unit Salt. In this program Risk of Failure (by corrosion, erosion, wear, fatigue, fouling etc) is quantified.

To determine a ranking in the priority of maintenance activities (incl. inspections), the program starts with a quick scan risk analysis (i.e. starting from the present condition and no planned inspection activities). For the high-risk items a detailed inspection procedure has been drawn up and carried out during the next possible plant shutdown. By this procedure the present condition and degradation rate of these items are unequivocally known, so with the minimum condition defined an optimum inspection interval and "time to repair/replacement" has been determined. For most items the risk of failure before the next inspection is thereby reduced to an acceptable level. For the remaining high-risk items other preventive measures have been advised. By implementing these measures, this risk is also reduced to an acceptable level.

This RBI method can, in a sound and relatively simple way format a **preventive maintenance policy** and create **towards the authorities** a clear and verifiable instrument with which can be demonstrated how the **integrity** of the salt plant is controlled and optimised. Such an instrument is an essential condition in discussions on flexibility in demanded inspection intervals and control of inspector's cost and insurance fee.

The executed RBI projects showed a pay back time within 2 years if judged by the reduction of direct maintenance costs; Much larger benefits however are gained by the increased availability. RBI projects include installation and "filling" of the RBI (Access) software, implementation in the local maintenance practice and training of the local responsibles.

1. PRIORITIZING BY QUANTIFYING RISK

For determining an integrity program over the whole lifecycle of a plant in the most cost-effective way it is essential to be able to discriminate between the different equipment items regarding the priority of the most beneficial maintenance activities. An adequate and presently much applied discriminator is "the risk of failure". Risk is defined as the product of likelihood and consequence of failure.

Risk = Consequence of failure X Likelihood of failure

When **consequence and likelihood** of each process item have been quantified/categorised, the risk per item can be classified in a risk matrix (see figure 1)

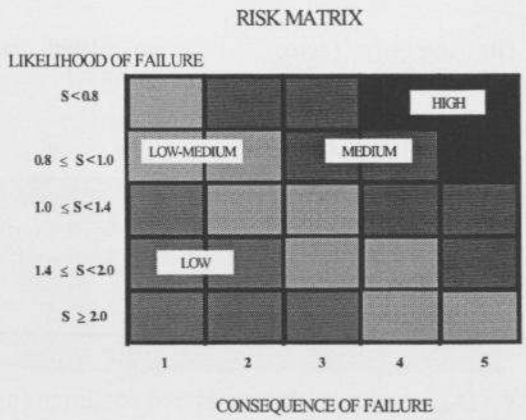

Figure 1: Risk Matrix, categorising the risk of failure of equipment from low to high.

2 THE CONSEQUENCE OF FAILURE

The consequence of failure is classified in 5 categories (see figure 5) with respect to:

- Cost (for repair and/or down time)
- Down time/ lost availability
- Danger group
- Environment
- Safety

To the classification of an item in a consequence category we apply the HIGHEST consequence aspect.

At the start of the RBI implementation project for salt plants, the consequence category of all process items is determined by means of the matrix figure 5.

3 THE LIKELIHOOD OF FAILURE

The likelihood of failure is expressed as the probability that the condition of an item falls below the defined minimum condition <u>before the next inspection.</u>

This likelihood of failure is ranked in 5 integrity categories; Integrity is the reverse of likelihood of failure

LIKELIHOOD OF FAILURE	INTEGRITY FACTOR
5 Very probably	$S < 0.8$
4 Probably	$0.8 < S < 1.0$
3 Neutral	$1.0 < S < 1.4$
2 Unlikely	$1.4 < S < 2.0$
1 Very unlikely	$S > 2.0$

Figure 2: Relation between the calculated integrity factor and the likelihood of failure.

The integrity factor (S) is calculated in the following way:

Integrity factor (S)

$$S = \frac{D_{latest} - (CR \cdot I) \cdot U}{D_{min}}$$

- D_{latest} = lowest last measured condition (mm, visual)
- CR = degradation rate (in general mm/yr)
- I = inspection interval (yr)
- U = uncertainty factor (of CR)
- D_{min} = minimum condition (mm, visual)

If $S = 1$ this means that the expected condition at the next inspection equals the preliminary defined minimum condition.

If $S < 1$ this means that it is expected that the minimum condition has been reached before the next inspection, consequently the likelihood of failure being correspondingly high.

4. IMPLEMENTING RBI: THE QUICK SCAN

In order to be able to focus on the "short term high risk items" as soon as possible in the project, a quick scan procedure was developed in which historical inspection data are used to predict whether an item is expected to fail (reach its minimal condition) within twice the actual maintenance shutdown interval; thereby preliminary dividing the items in the likelihood of failure categories (potential) high (categories 4 and 5) and acceptable low (categories 1,2 and 3).

When for each item both consequence and likelihood of failure are determined, the risk matrix is filled; now it can be evaluated and optimised.

The AMC system uses as starting point that **"a high risk (the red area)" is unacceptable;** in other words, with priority one the consequence and/or the likelihood of failure should be reduced when a process item has been classified in the "high risk" area.

When all process items from the high-risk area have disappeared, the **middle area** can be focussed. Dependent on time and budget available it can be decided whether risk reducing maintenance actions are "profitable". If the likelihood of failure is reduced (e.g. by a more optimal/intensive inspection program) this will result in a higher availability owing to unplanned stops, as a result of which these inspection/maintenance cost will be very quickly recovered, in case of continuously operating units where products have been sold out. When equipment (with or without a regular inspection program) ends up in the **low-middle** risk area, there is no further need (at first) to initiate optimisation actions.

Process items in the **low risk area** need not be **paid attention/cost** to from the inspection-technical point of view.

5 MANAGING RISK

Risk can be managed by changing the consequence and / or likelihood of failure.

The consequence of failure can be reduced by:

- Constructive adaptations, additional safety measures, second containment etc.
- Reducing the volume of the items (more valves)
- Logistic measures (e.g. bigger store formation / install redundant (spare)).

The likelihood of failure can be reduced by:

- a more frequent/optimal/intensive inspection program,
- reduction/control of the corrosion rate (adaptation material and/or process conditions),
- constructive adaptations (reinforcement rings/doubling plates),
- (Re) calculation of the really needed minimum values (nominal values can be chosen higher).

Optimising inspection is often the most cost effective way to reduce likelihood (and thereby risk) of failure. This is illustrated in the next case; a salt plant in a not-sold out situation, without an inspection program, turned out to have 23 high risk item after the quick scan. In figure 3 is shown how this risk is reduced after implementation of the inspection procedure for these items.
The 3 still high risk items could not be reduced by inspection alone, because of

- the actual condition was too bad (repair/replacement)
- the corrosion rate was too high to meet the interval between to maintenance stops (corrosion in monel clad welding)
- the critical place was not (yet) accessible for inspection

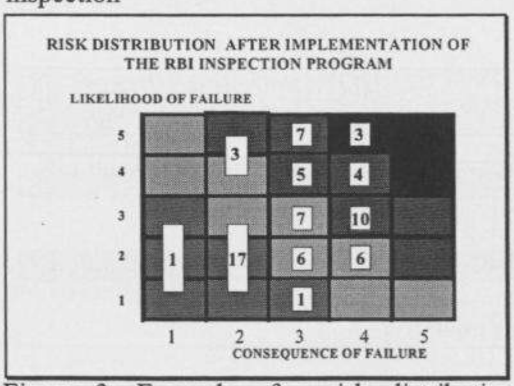

Figure 3: Example of a risk distribution after implementation of the risk based inspection program.

By means of this risk matrix it is also simple to quantify where the risks are found, when going, for instance, from a 'not sold out' to a 'sold out/full load' situation. The consequence category "Cost of failure" will be considerably higher then, "automatically" resulting in more items ending up in a higher consequence category (category 4 and 5).

6 INSPECTION PROGRAMS

For critical items an (optimal) inspection program is drawn up. In general for salt and chemical plants the RBI program starts with the static equipment including the integrity of the isolation regarding corrosion under isolation. But RBI is however applicable for all plant items, being

- static equipment
- storage tanks
- piping incl.
- electrical and instrumentation
- rotating equipment
- civil constructions

The result of the inspection is focussed on the minimum **value**. Although many data will be stored, always the worst condition (e.g. minimum wall thickness) is "taken into account" in the RBI calculation for the likelihood of failure.
With the inspection results, the RBI program generates

- The degradation rate or corrosion rate respectively
- Time till repair (residual lifetime)
- Next inspection date
- The "new" risk

The result of the RBI program comprises:

- a list of all process items
- a list of all process items with the following inspection date and time till repair
- a sheet to be filled out per item for the inspector with the inspection program (exact measuring position and measuring technique) and last inspection results
- a survey list with all last inspection results on position level.

7. COST AND BENEFITS

Because the prioritising by risk helps you to focus on high-risk items, by implementing RBI direct and indirect maintenance costs are reduced keeping the same level of risk. Figure 4 illustrates this.

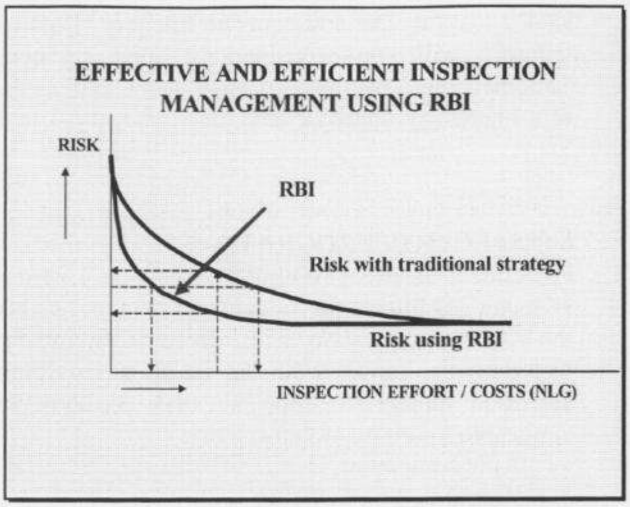

Figure 4: Relation between inspection effort and resulting risk, with and without RBI.

The RBI method can, in a sound and relatively simple way render shape and content to a cost effective preventive maintenance policy.
Towards the authorities a clear and verifiable instrument is available with which it can be demonstrated how the integrity of the salt plant is controlled and optimised. Such an instrument is an essential condition in discussions on flexibility in demanded inspection intervals and control of inspector's cost and insurance fee.

The executed RBI projects showed a pay back time within 2 years by reduced direct maintenance costs; Much larger benefits however are gained by the increased availability

REFERENCES

1. MP, Materials Selection & Design July 1998 p.70, R.J. Horvath (Shell, Houston) The role of the corrosion engineer in the development and application of risk-based inspection for plant equipment.
2. Professional Engineering 22 Sept. 1999. P.26 G. Amphlett (Royal Sun Alliance) RBI, Saving without fail.
3. Reliability and risk in pressure vessels & piping PVP vol251 ASME 1993 J.E. Aller et al. (DNV) The risk based management system: A new tool for assessing mechanical integrity
4. MTI publication No 44 (1995) J.E. Aller, M.N. Tayloe Materials engineering and risk management in chemical plant operations
5. NPRA Maintenance conference 1997 J.T. Reynolds API Risk based inspection (directive).
6. Corrosion 98 Nace paper 588 P. Barrien (Mobil) Optimising refinery dependability and turnaround costs by the application of a RBI program
7. Det Norske Veritas, Hovik Norway p. 659 J.D. Edwards Risk Based Inspections; State of the art

Cat.	*Cost (kNLG)*	*Environment*	*Safety*	*Down time / lost availability*	*Danger group*
1	<50	no emission	no consequences	0	not appl.
2	50-100	small emission	small consequences	0-1 day	1
3	100-200	some emission	unpleasant/small injury	1-2 days	2
4	200-400	inadmissible emission	injury without absence	2-7 days	3
5	>400	inadmissible emission/ shutdown	absence due to accident/serious injury	>7 days	3

Figure 5: Consequence criteria and categories (1 thru 5)