RBI – A TRANSPARENT PROCESS?

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ABSTRACT

The use of Risk Based Inspection (RBI) is widespread in the oil and gas industry. Whilst the underlying methodologies of many of these schemes are similar there is considerable variation in how they are translated into actual working schemes. This paper focuses on the practical issues of creating, implementing and operating an RBI scheme which not only optimises inspection intervals across the assets of a major North Sea Operator but is sufficiently transparent to demonstrate that it can be readily audited both internally and by external bodies.

INTRODUCTION

Risk Based Inspection (RBI) schemes are in general use in a number of industrial sectors, such as nuclear, aviation and oil and gas. Whilst the underlying methodologies of most oil and gas industry schemes are quite similar there is noted to be considerable variation in how they are implemented. The emphasis in many schemes is naturally on optimising and prioritising inspection intervals to ensure safe operation of the production facility but there is also a requirement to ensure the process is sufficiently transparent to demonstrate the scheme satisfies regulatory standards. This paper deals with the practical issues of creating, implementing and operating such a transparent topsides RBI scheme for a major North Sea Oil and Gas Operator.

MACAW is a Newcastle based engineering consultancy, established in 1996, to provide materials, corrosion and welding expertise as well as asset integrity management services to the oil and gas industry. MACAW have supplied integrity support services to Talisman's Assurance Group since 2000. In 2007 Talisman invited MACAW to support them in developing RBI and corrosion control schemes across their topsides assets and pipeline networks.

WHAT IS RISK BASED INSPECTION?

In the past inspection intervals for equipment were defined in a prescriptive manner. In contrast to a prescriptive maintenance programme, RBI is a method of prioritising inspection based on an assessment of the risk to items of equipment. The perceived benefit of an RBI scheme is that it prioritises inspections and optimises safety whilst allowing budgetary control. The responsibility that comes with operating an RBI scheme is for the duty holder to be able to demonstrate that its scheme does not compromise safety of the assets. RBI schemes are commonly applied throughout the offshore industry to topsides process vessels and pipework, sub-sea pipeline networks and onshore terminals.

The key outcome of any RBI scheme is a measure of the level of risk to items of equipment and determination of next inspection dates resulting in a prioritised inspection schedule. This ensures high risk items are inspected more frequently than low risk items which results in a safety focused and cost effective inspection scheme. RBI is now recognised as a key tool in meeting legislative requirements, as detailed in the HSE's best practice guidelines for RBI[1].

Whilst there are many versions of RBI schemes in use they have a number of common elements; namely:

a. Assessment of the credible threats to an item of equipment
b. Potential failure modes and mitigation measures
c. Resulting consequences
d. Associating a measure of risk with each item
e. Combining risk with inspection history to determine future inspection intervals.

These elements are effectively covered by a Corrosion Risk assessment and Inspection History assessment.

Threats

Corrosion constitutes the major threat to offshore equipment. Typical corrosion threats, both internal and external, to be considered in an RBI scheme are listed in Table 1. The list is not exhaustive and consideration should always be given to unusual or unexpected mechanisms, such as acetic acid corrosion.

Internal Corrosion Threats	**External Corrosion Threats**
Sweet Corrosion	Atmospheric Corrosion
Sour Corrosion and Cracking Mechanisms	Corrosion Under Insulation (CUI)
Microbiologically Influenced Corrosion (MIC)	Chloride Pitting
Oxygen Corrosion	Stress Corrosion Cracking (SCC)
Erosion / Erosion-Corrosion	-

Table 1: Typical Internal and External Corrosion Mechanisms

Mitigation

Consideration must be given to any mitigating actions the operator has in place that would reduce likelihood of failure.

Consequences

Consequences of failure, such as danger to personnel, loss of production and impact on the environment are an essential component of any RBI scheme along with the possible failure modes arising from different threats.

Risk

Risk is generally expressed as the product of the likelihood and consequence of failure and is often determined using a risk matrix approach. The most common approach is the so called “traffic-light” system based on the type of 3x3 risk matrix shown in Figure 1.

Likelihood of Failure	High	Medium	High	High
	Medium	Low	Medium	High
	Low	Low	Low	Medium
RISK		Low	Medium	High
		Consequence of Failure		

Figure 1: Example 3x3 Risk Matrix

Inspection History

The assessment of inspection history in RBI schemes can either be a quantitative approach to determine remaining service life; or a qualitative assessment of the results of actual inspections. The American Petroleum Institute (API) provides guidelines for the remaining life approach in their inspection code recommended practice API 510[2] and API 570[3]. The Institute of Petroleum's (IP) Model Code of Safe Practice, IP 12[4] and IP 13[5], details a qualitative approach by assigning an inspection grade based upon the results and efficiency of any historical inspection information.

Outcome from an RBI

Using remaining service life or inspection grade along with associated risk to an item of equipment can be used to determine the next inspection date for that item. An effective RBI scheme should not only produce an inspection interval but should also detail the types of damage to be anticipated and where damage is likely to occur. It should also identify the inspection techniques required to detect various types of damage.

DIFFERENT TYPES OF RBI SCHEME

RBI schemes can range from a completely qualitative approach, relying exclusively on the judgement of experienced staff, through to a detailed quantitative model that uses a series of algorithms to determine such factors as corrosion rates and remaining service life.

Due to the variation in how RBI methodologies are implemented, an HSE funded study[6] was conducted which compared the results of 7 different RBI schemes. The HSE study identified the need for:

- A transparent process for users and auditors
- A balance between quantitative and qualitative methods
- A balance between theoretical, actual and engineering judgement

Applying a formal RBI scheme can be a lengthy process so a completely qualitative approach whereby an experienced corrosion engineer reviews available data then allocates an "appropriate" risk level to equipment may appear to be the most cost-effective solution. Although the involvement of experienced corrosion engineers is essential in an RBI scheme, the major drawbacks to this approach are a lack of documented justification for decisions taken and reliance on a single person's judgement (they may not be available in future). Ideally input is required from all involved parties in order to get a balanced and unbiased RBI.

At the other extreme is the so called "black box" approach in which a fully quantitative model is implemented as a software package. This approach is usually data intensive and cannot readily cope with missing or ill defined data – as is often the case with older assets. Furthermore, the decision making process associated with determining an inspection interval using this process is often not transparent to the user - or an auditor.

These two extreme cases also share a major drawback in that they do not satisfy one of the main criteria set out at the start of this paper, namely transparency to enable a third party to assess and audit the results.

HOW DOES RBI FIT INTO THE OPERATORS INTEGRITY MANAGEMENT PROCEDURE?

Inspection, monitoring and mitigation requirements are integral to an operator's integrity management procedure for both topsides and subsea systems (Figure 1). Typically RBI is used for topside process plant and piping inspection planning. Pipelines and Structures also require a number of other forms of risk assessment and future integrity assessment for planning inspection frequencies. However, these assessments are not entirely separate and do share many areas of commonality with the most obvious being the corrosion risk assessment. The internal corrosion threats topside will carry on into the pipeline therefore both risk assessments should highlight the same issues.

Monitoring and mitigation requirements are detailed in the Operators' Corrosion Control Scheme (CCS); this document should deal with both topsides and subsea systems. The results and efficiency of topside monitoring and mitigation will impact on the condition of a sub-sea pipeline. Conversely, results from a pipeline integrity analysis can inform about topside conditions, for example evidence of "wet gas" in a pipeline is indicative of failures in topsides drying plant.

Other examples include; inhibitor efficiency, residual inhibitor levels, microbial sampling at topside locations and pig trash analysis. A better understanding of a Microbial Induced Corrosion (MIC) threat can be gained by looking not only at the inlet and outlet of the pipeline but also at the variation through the processing plant and across the whole pipeline network. This allows for improved mitigation strategies and better control of the MIC issue.

The need for data and information sharing between topside and subsea integrity/assurance teams is essential to ensure all threats are identified and dealt with an appropriate and consistent manner.

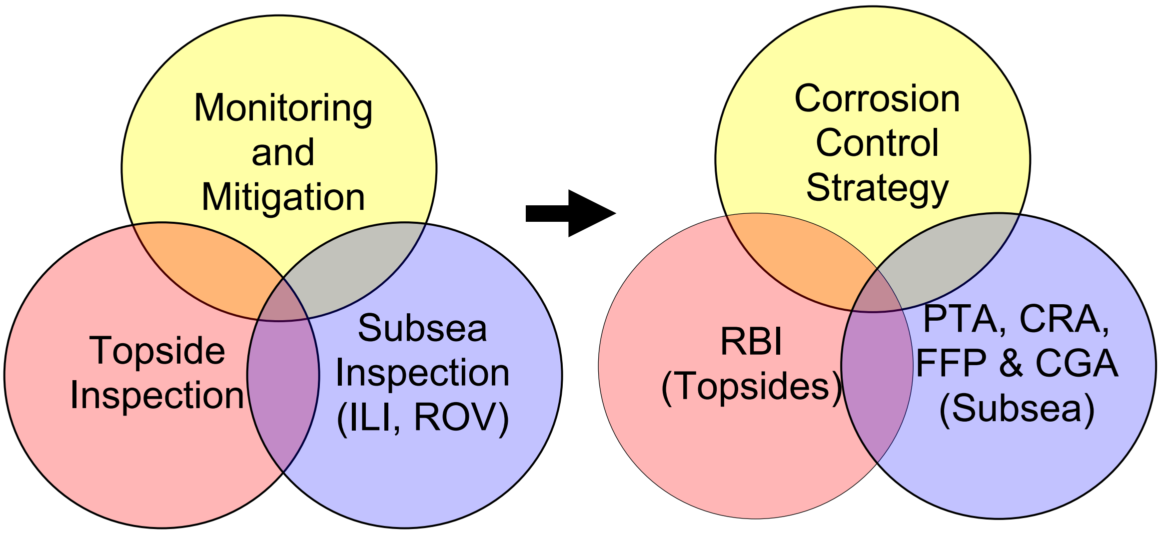

Figure 2: Three Key Areas of Operators Integrity Management Plan[i]

OPERATORS' ASSETS

Talisman Energy (UK) Ltd is a major operator in the North Sea offshore industry. Talisman in the UK operate 11 North Sea platforms, 1 FPSO and two onshore terminals as well as a network of over 3000 km of sub-sea pipelines. Talisman acquired its portfolio of assets from a variety of operators. A number of these assets have been in service for over 25 years and

[i] Key: PTA – Pipeline Threat Analysis, CRA – Corrosion Risk Assessment, FFP – Fitness for Purpose, CGA – Corrosion Growth Analysis, ILI – In Line Inspection, ROV – Remotely Operated Vehicle

some have had a number of previous owners and inspection companies. Due to the age of some of these assets a significant amount of Integrity information is primarily held in hard copy format and a number of gaps in historical inspection records and operating history existed. Where information was held electronically, it was more complete.

DEVELOPMENT OF RBI SCHEME

Initial Approach

A number of the Talisman assets had RBI schemes from previous operators or Talisman generated RBI, but these differed in type and complexity. Talisman was keen to develop a common approach to RBI across all of its topside assets, but any RBI scheme would also need to address the gaps and variability in historical information quality.

Talisman's initial approach at a unified RBI scheme in 2005 was based on a software package which was internally developed. MACAW's initial role was to collect data to populate this model and run the program to generate inspection intervals for use by the inspection contractor.

The underlying methodology and its implementation in a software package was more than adequate to deal with assets that had a complete operating and inspection history. However, the reality was that the necessary information to completely populate this model was either incomplete or lacked provenance so the system struggled to produce results – a common feature of quantitative models. The model was based on the API remaining service life approach but the gaps in inspection history and confidence in the inspection results soon demonstrated that this scheme was not appropriate.

Methodology modification

MACAW and Talisman then collaboratively set about developing a more robust scheme that could cope with information deficiencies. Development of the RBI software package was stopped and an approach based on spreadsheets was adopted. The use of a standard software package, such as Microsoft Excel™, was felt to aid transparency and reduce programming effort whilst still offering the necessary flexibility and control. One of the major changes was to move away from the API remaining service life approach to the IP qualitative grading approach. The remaining life approach relies on knowledge of corrosion rates, usually based on repeat wall thickness measurements. In many cases inspection reports only showed a qualitative assessment of the condition of the item rather than any quantitative (e.g. wall thickness) measurements. Therefore, changing to the IP code allowed best use to be made of the inspection history available.

Top-down approach

Initially, a 'top-down' approach was adopted to differentiate high risk systems from those at lower risk and then undertake a more detailed assessment of the high risk systems. The less critical items would be reviewed in subsequent phase of the work. As the methodology was developed it became clear that all items required much the same level of detailed assessment. However the lower criticality items could be grouped together and covered by one RBI assessment. For example air accumulators within a particular system could be grouped and covered by a single RBI assessment. This meant that the system overview stage developed into more of a high level assessment which identifies the more safety critical systems to be assessed in Phase 1 and the less critical systems for Phases 2 and 3.

Another reason for prioritising the process into three separate phases was the sheer volume of work required to complete RBI's across all the assets. Talisman's North Sea assets currently comprise 11 platforms, 1 FPSO and 2 onshore terminals. A typical offshore facility has ~350 vessels and ~3000 items of pipework (for the purposes of this RBI, pipework was grouped into streams that had similar properties). This equates to approximately 4900 vessel RBI's and 1680 stream RBI's for all of Talismans' assets. Therefore the project was phased so that in Phase 1 all of the assets would have an RBI scheme implemented for their primary safety critical hydrocarbon systems. Subsequent Phases 2 and 3 dealt with those systems considered to be of lower criticality.

THE PROCESS

An overview of the process that MACAW has developed in collaboration with Talisman Assurance Group and CAN their inspection company is detailed in this section.

The Team

MACAW set up an RBI team of four main roles to carry out the RBI analysis for all of Talisman's assets. These are listed below; the number in brackets indicates the number of people functioning in these roles at the present time.

MACAW Engineering

- Project Manager (1) – To ensure project runs on time and on budget. This is achieved by in-house meetings and regular client updates.
- Senior Corrosion Engineer (2) – Internal review of RBI's, on-hand technical advice and participation in client meetings.
- Project Supervisor (3) – To provide technical advice and guidance to Technical Assistants. Internal review of RBI's. Chairing client meetings and preparation of documents and reports for review and handover to client.
- Technical Assistant (6) – Data collection and implementation into RBI documents. Assist in preparation of RBI's for review and handover to client and participation in client meetings.

At the kick-off stage of the project individuals were identified both within Talisman and in the inspection company who are key contacts for supplying data and reviewing the RBI's. These key personnel typically include:

Talisman

- Assurance Engineer
- Focal Point Engineer
- Process Engineer
- Chemist
- Offshore Inspection Engineer

Inspection Company

- Inspection Engineer
- Corrosion Engineer

Data Collection

As previously mentioned gaps and provenance of data was an issue. The methodology was developed to be able to cope with these data issues, however in order to optimise inspection it was beneficial to have up to date accurate information. Where the RBI process highlighted gaps in data, efforts were made to try and fill those gaps, i.e. sampling was conducted to acquire up to date fluid composition, offshore personnel were involved in sourcing historical records held offshore. Offshore personnel proved vital sources of information because, although operators and inspection companies had changed over the years, many of the offshore personnel had remained in place.

The main data requirements are detailed in Table 2 below.

Fluid Details	Design and Operating Details	Inspection History
CO_2	Material	Inspection Date
H_2S	Wall thickness	Inspection Type
O_2	Design and Operating Temperature	Results and Conclusions
pH	Design and Operating Pressure	-
Water cut	Corrosion Allowance	-
Bug count and type	Internal Lining	-
Sand content	Coatings/Insulation	-

Table 2: RBI Data Requirements

Define Streams

Systems are typically defined by their functions, for example Gas Compression, Gas Dehydration, Gas Export, etc. Within a system there will be variations in fluid properties, fluid composition, etc. and so these factors are used to split up the pipework within a system into streams.

Assess Corrosion Threats and Consequences

Standard tools and guidelines, for example NORSOK model[7] for sweet corrosion, are used to assess corrosion threats. Guidelines to assess the consequences of failure have been developed in collaboration with Talisman's safety and environmental advisors. Once a corrosion risk assessment has been completed according to the methodology it is then reviewed by a Senior Corrosion Engineer for accuracy and for consideration of any unusual corrosion mechanisms. This maintains the balance of theoretical, actual and engineering judgement as recommended by the HSE study.

Assess Inspection History

The inspection history is assessed in accordance with the IP grade definitions, as shown in. These grades are assigned inspection frequencies based on the IP code which has then been modified slightly for use within MACAW's methodology to incorporate the levels of risk, as shown in Table 4. MACAW also used the same methodology for external inspections although the IP code does not specify external inspection intervals.

Grade	Definition
Grade 0	Equipment should be allocated to this Grade when the conditions of service are such that either: a) deterioration in whole or in part is possible at a relatively rapid rate, OR b) there is little evidence or knowledge of operational effects on which to predict behaviour in service
Grade 1 and Grade 2	Equipment should be allocated to one of these Grades when the conditions of service are such that either: a) deterioration in whole or in part has been shown to be at a reasonable and predictable rate consistent with the increased examination interval given for the item under the Grade selected, OR b) evidence or knowledge of actual behaviour in service is sufficiently reliable to justify the examination interval permitted by the Grade selected.
Grade 3	Equipment may be allocated to this Grade, when the item has successfully concluded a period of service in Grade 2 or service history is available on similar systems operating on similar duties and service conditions are such that either: a) deterioration in whole or in part has been shown to be at a low and predictable rate consistent with the increased examination interval given for the time in this Grade, OR b) evidence and knowledge or actual service conditions are sufficiently accurate and reliable that an increased interval is justified.

Table 3: IP13 Grade Definitions

Internal Risk		Grade 0	Grade 1	Grade 2	Grade 3
	High	24	36	72	84
	Medium	36	48	84	144
	Low	48	72	144	144

Table 4: Internal Inspection Intervals for Vessels and Heat Exchangers (Months)

Review Process

The review process begins with an internal review by a MACAW senior corrosion engineer. The RBI's are then issued in draft to Talisman and a peer review meeting is held with the key personnel identified at the beginning of the project. Changes are agreed at the peer review meeting and once the documents are updated an integrity review is held to present the results of the RBI.

Documentation and Handover

In order to provide an accurate result, the RBI must use the most recently available data to assess the overall risk and inspection interval. This is possible up until handover, with data provided during client reviews or upon request. However subsequent inspections or changes in operation should be recorded, as the information becomes available, to maintain an effective RBI. In order to achieve this, the RBI's are live documents with control handed over to the inspection company, allowing regular updates of the RBI from day to day information.

In order to improve the usability of the documents a process flow diagram (PFD) is used as a front sheet for each system. This allows the end user to choose an individual RBI assessment from a diagram and understand its relationship with others.

In order to maintain a transparent process to satisfy the regulatory requirement aspect, each step of the RBI process must be well documented. To fulfil this requirement a complete handover document is issued to the client upon completion of the project. This contains the release version of the RBI for uploading to the client system, as well as copies of meeting minutes, email correspondence and any other documented evidence of key decisions made throughout the RBI process.

Training and Technical Support

Training is provided to the end users (inspection contractor staff) of the RBI when the documents are handed over. To provide a more user friendly interface the RBI includes prompts so that if a change is made the user is prompted to consider the knock-on effect of that change.

Security of the RBI is included in the form of an inbuilt change log which records the user's logon ID when a change is made and tracks any modifications made by that user. This allows the user to freely update the RBI and supports the transparent nature of the RBI, while ensuring a level of auditability.

MACAW provides ongoing technical support to the inspection company in the form of an e-mail based help desk with problem tracking and FAQ register.

Implementing, Reviewing and Updating the RBI's

Once the RBI assessments have been handed over to Talisman and sufficient training has been provided, they become live documents to be updated by the appointed personnel within Talisman and the inspection company. Typical scenarios that could prompt an update of the RBI's would be:

- An inspection has been carried out
- Change in service/operation
- New sampling information (e.g. bacterial sampling)

Although the documents are live, it is advisable that a regular (e.g. annual) audit be carried out to ensure the documents are maintained in an up to date and accurate condition.

OBSERVATIONS

The main observations that MACAW would draw from being involved in the development of this RBI scheme are:

- Select a methodology that is compatible with the quality and quantity of available data.
- Don't underestimate the effort and time required to implement an RBI scheme.
- Essential to identify and involve all stakeholders throughout the process.
- A successful RBI scheme requires team effort. In this case there was a MACAW team to deliver assessments, technical input from Operator's onshore and offshore staff together with representatives from the inspection company.

- RBI is an ongoing process, in order to optimise inspection the RBI assessments should be used as live documents and audited on a regular basis.
- The need for data and information sharing between topside and subsea integrity/assurance teams is essential to ensure all threats are identified and dealt with in the appropriate manner and to maintain consistency.

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