Cost analysis of unscheduled shutdowns and slowdowns in the process industries has revealed that more than 35 percent of lost production is related to lack of availability and reliability in fixed equipment.

However, many plants still place greater emphasis towards condition-based maintenance of equipment assets, which often leads to a reactive response framework. This needs to change, especially in the context of availability of real-time Asset Integrity Management (AIM) tools, which integrate predictive data analytics with key process parameters and advanced degradation quantification models, and represents a new framework to achieve safer operations, enhanced productivity and optimised cost control in the process industry.

For plant operators who aim to achieve real-time asset integrity, Risk Based Inspection (RBI) principles offer an established methodology for efficient plant maintenance. This is the process of developing an inspection plan based on knowledge of the risk of failure of the equipment. RBI is the combination of an assessment of the likelihood (probability) of failure due to damage, deterioration or degradation with an assessment of the consequences of such failure.

The real-time information gained from process parameters may be used to identify the type and rate of damage that may potentially be present and the equipment or locations where failure would engender risks to plant safety to varying degrees. As RBI involves a large amount of data, using the right tools and software to process and correlate plant operational information is crucial.

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Such real-time data will in turn be the foundation for an operational framework for asset management supported by appropriate Integrity Operating Windows (IOW) for key process parameters and establishment of an effective boundary-management philosophy driven by accurate, real-time risk analyses.

In an operating plant, a relatively large percentage of risk is associated with a small percentage of operating equipment. Risk-based inspection focuses resources on high-risk items first. However, although RBI has gained ground in improving the availability of plant equipment and reducing unscheduled shutdowns, when utilised as an offline and periodic asset management practice, is encumbered with substantive challenges.

**Common RBI Challenges**
- Accurate quantification of material damage or loss for calculation of remaining useful life.
• Real-time measurements for immediate mitigation actions to minimise the damage when it is occurring vs after it has occurred.
• Equipping operations with an understanding of the impact its actions has on overall equipment reliability, since conventionally, alarm or alert indications are not set with integrity limits in mind.
• Visibility to the reliability team for deviations from acceptable corrosion and mechanical integrity limits impedes its ability to understand the potential impact on remaining useful equipment life. Making problems visible is a fundamental element in any defect elimination process.
• Integration of accurate prediction models with real-time process data to predict or infer corrosion rates. Such an implementation could allow operations to understand when the current operating conditions are leading to unacceptable corrosion rates and may consequently impact plant safety and operational integrity.

**Risk-Based Inspection**
Practitioners and process industry personnel utilise RBI to provide a framework for ranking the priority of inspection needs. This is achieved by comparing the likelihood that a failure will occur, with the quantification of risk such a failure would impose on Health, Safety, Environment (HSE), plant operations and productivity.

Numerous inspection techniques are available for in-plant measurement, and most are used intermittently during scheduled plant turnaround periods.

Advances in inspection techniques include the availability of newer sensing devices and approaches, as well as the use of simulation and modelling applications. Automated scanning, for example in the case of eddy current testing, can enable improved resolution, repeatability and integrity of testing. Speed and quality of measurement also have been improved, through the use of techniques that are applied at either multiple or a continuum of frequencies, such as the pulsed eddy current technique.

Historically, these plant equipment inspection techniques were performed on a routine or scheduled basis. Often, they did not take into account the criticality of the equipment availability to the plant’s productivity goals and, in some cases, ignored any change of service that may have impacted reliability adversely.

With the advent not only of improved inspection techniques, but also of data handling and statistical analysis methods, these techniques can be more readily implemented permanently and online, as such enabling the RBI analysis to be updated more frequently.

**Real-time Modelling And Monitoring**
In recent years, Honeywell, through a consortium of industry partners, has been involved in developing corrosion-prediction and quantification models for key process applications in the oil-and-gas industry, including models for oil/gas production, pipelines and refining. Refining is the application context used in this discussion.

These models incorporate extensive phase behaviour analyses and engineering data alongside numerical modelling to support rigorous refinery corrosion quantification. These predication models automate/quantify/integrate stemming from multiphase flow modelling, ionic/thermodynamic/phase behaviour modelling and comprehensive laboratory data.

Traditional corrosion measurement and monitoring methods, including inspection and weight-loss coupons, lack the ability to capture the ‘present’ criticality state of a corroding system. Real-time corrosion models, when combined with real-time monitoring technology, such as Honeywell’s SmartCET, are a compelling way to access corrosion rates as a ‘process variable.’

A complementary aspect of real-time monitoring allows corrosion prediction models working in tandem with the Distributed Control System (DCS) and process historian to provide quantified corrosion rates at multiple process locations. These online, real-time predictions represent ‘virtual’ monitoring points. They enhance the operator’s ability to closely
correlate process-upset conditions to detrimental changes in system corrosion behaviour.

This new real time corrosion quantification framework enables virtual monitoring of multiple unit locations, where corrosion rates sent to the historian are correlated and displayed alongside real-time process variations (in a cause-effect framework).

**Corrosion Monitoring — Online, Real-Time**

Inspection and weight loss coupons are traditional, off-line methods used to determine material performance. The latest technological offerings have greater speed of response and resolution, as such providing the most accurate data in an online, realtime framework, that more easily correlates with process and operational data. These offerings typically use a combination of multiple electrochemical techniques in one instrument.

The SmartCET technology combines techniques for output of general corrosion rate, pitting detection and surface film formation. The combination of techniques can assist greatly where protective or conductive films may render other measurement techniques unusable. This approach has been employed in a variety of process systems and plant utilities, enabling the system operator to ‘see’ potential for damage in real-time and establish the root cause before failure can occur. This technology has been used successfully to retrofit and replace other technologies.

The cost of installing probes in new equipment or across a greenfield site is often viewed at the design stage as an excess over and above the immediate expenditure needs. As such, probes are most often implemented as a retrofit (usually lagging considerably) after the asset has been commissioned, and perhaps even after the plant has experienced a loss. Although the omission of probes from the design may appear initially to make fiscal sense, the opportunity to track the performance of the asset throughout its operating lifetime has been lost and plant safety compromised when real time predictive, monitoring tools are not deployed.

The key aspect of real-time data is that it provides the ability to ‘see’ corrosion events as they happen, usually in response to process or operational changes. Correlation of corrosion events to changes allows users to analyse and investigate the cause of corrosion, develop a remediation response to potential process deviations/upsets causing corrosion and/or provide a method to update the RBI program or planned maintenance schedule dynamically. Such quantification of RBI data ultimately provides users a more accurate risk assessment and a better view of plant risk/safety.

**Predictive Modelling**

Moving away from physical methods to determine materials performance, predictive modelling applications are available. They are able to simulate the effects of typical process conditions on the behaviour of metallic materials. Such applications may be used during facility design or maintenance and repair planning to facilitate effective decision making by solving critical problems in materials selection.

The basis of the latest specific modelling applications now often includes the combination of real field data with accurate flow modelling and online pH computation. Such advances have exposed the weaknesses of off-line, reactive-response-based traditional methods.

**Ensuring Operational Integrity**

One of the key outputs of an RBI program or corrosion study is an understanding of the critical process variables that impact materials performance. The limits placed on the critical process variables are sometimes called IOWs or Operating Envelopes. In many cases, these limits are defined as part of the RBI work process and are then stored in an RBI software package, document or spreadsheet as an offline resource. All too often, these limits are not effectively enforced or even communicated to operations.

‘Operationalising’ Best Practices

An evolving best practice adopted by several companies across industries globally is to take the limits from these work processes and operationalise them. This means the complete set of limits is made available to the operator so he or she is always able to determine the plant status with respect to process capacity, damage to assets or other potential HSE impacts.

This approach provides an added level of safety and assurance where unintentional violations of corrosion limits cannot be ignored or missed. Operators also have access to information relating to the possible cause and consequence of deviation, as well as the all-important recommended corrective action to bring the process back into the normal operating range. This approach provides 24/7
monitoring of the critical process variables to reduce the likelihood of equipment failure and increase confidence in the integrity of the system.

**Conclusion**

Corrosion and degradation of material performance can adversely impact reliability and availability of plant equipment. Its associated costs — in terms of lost production and HSE incidents — far outweigh any expenditure in monitoring/mitigating corrosion. Risk analyses and management is an essential aspect of safe unit operations for process plants. A key challenge for accurate RBI is incorporation of real-time process and corrosion data. A framework has been proposed for defining meaningful integrity operating windows and deviation-management methodologies, as well as performing RBI and probability-of-failure computation through real-time corrosion modelling and monitoring technology.

Such implementation of real time models and monitoring systems could ensure process safety through imposition of process-unit appropriate limits and operation for enhanced asset integrity and effectiveness.

To ensure optimal performance from an improved asset integrity approach, the following needs must be satisfied:

- Implementation of predictive analytical tools and real time monitoring systems for accurate ‘damage’ quantification.
- Commitment from all operations and management personnel involved.
- Sufficient visibility within the enterprise to ensure all systems and communications are implemented and supported.
- Use of appropriate methods and technologies to give the plant its best advantage.
- Coordination of site and contractor personnel to make implementation as efficient as possible.

Every plant and refinery, potentially, has the ability to improve the quality and coordination of its asset integrity management, which represents a major untapped resource for plants to better manage cost control while maintaining their desired productivity and plant safety.

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