All the right ingredients

Marguerite Forde, Andrew Wilde, Erika Santana and Roland Palmer-Jones, ROSEN Group, UK, discuss the combination of key elements under a single framework to optimise corrosion management.

Recent studies indicate that corrosion is a major cause of pipeline failure, with up to 25% of failures attributed to corrosion in Europe and 18% of reported pipeline incidents due to corrosion in the US.[1,2,3] Figure 1 illustrates that some reduction in failure frequencies due to corrosion has been seen since the 1970s, which may be attributed to technological developments such as condition monitoring using inline inspection (ILI) and improved corrosion management practices.

The pipeline industry has been using ILI tools to detect and size corrosion and to support integrity assessments for decades, amassing an incredible amount of metal loss-related data. The industry has more corrosion-related data than ever. So why is corrosion still one of the main drivers compromising pipeline integrity and reducing operational life?

Proactive corrosion management is required, but how often are pipelines inspected as a routine activity? How often is the same inspection process repeated without considering in detail why, or investigating what is done with the data once the inspection is run? The industry has a number of standards that require these questions to be answered and set the basic requirements for pipeline inspections, i.e. API 1163, NACE SP0102 and ANSI/ASNT ILI-PQ-2010.[4] These are not new documents, and while some operators may have adhered to one or all of these standards in the past, Pipeline and Hazardous Materials Safety Administration (PHMSA) 49 CFR §195.591 now requires operators of all hazardous liquid pipelines to comply with them.

For example, API 1163 outlines that while the service provider is responsible for identifying ILI system capabilities, the operator is responsible for:

- Identifying the threats to be investigated.
- Choosing the proper inspection technology.
- Maintaining operating conditions within performance specification limits.
- Confirming inspection results.

These standards and companion documents are there to outline the minimum requirements to ensure safety and reliability, and are not intended to restrain operators from aiming for best practice. The aim is to foster continuous improvement, rather than conforming to the status quo.

Creating a common understanding

In order to address this acceptance of routine inspections and assessment, the industry must challenge the status quo – one of the most concerning approaches to corrosion management is thinking, 'This is how it has always been done.' To support the pipeline industry, ROSEN Group has not only invested in developing inspection tools and best practice corrosion management services, but is also investigating different approaches to combining traditional integrity management methodologies with analytics, AI and pattern recognition techniques. Drawing on experience working with pipeline operators worldwide, seeing first-hand the different ways that corrosion threats are managed and getting a clear view via inspections of how effective the different approaches are, the company has attempted to illustrate best practice in the form of a corrosion management framework. This type of approach is designed to create a robust structure to proactively identify corrosion threats, select appropriate detection methods, complete suitable assessments and develop corrosion management plans to ensure long-term safe pipeline operation.

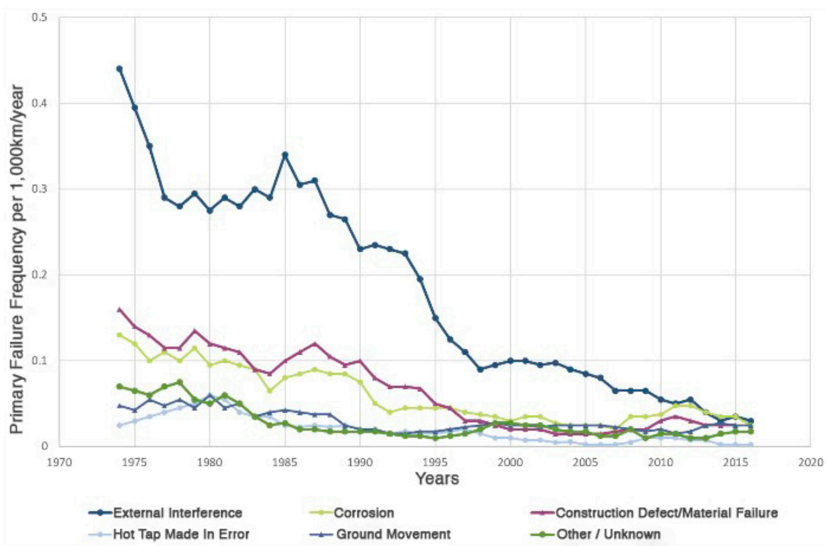

Figure 1. Primary failure frequencies per cause (five-year moving average).[2]

The corrosion management framework may be split into a number of key activities: (i) pre-inspection, (ii) inspection, (iii) post-inspection integrity assessments and (iv) post-inspection corrosion management planning. Data management and code/regulatory compliance are omnipresent, as they are essential in ensuring efficient and traceable corrosion management. Similarly, structured learning programmes that focus on the acquisition of different skill sets, subject knowledge and practical experience, while sitting outside the key framework activities, are essential to the ongoing safe management of pipelines.

Selecting the right tool

Selecting an inspection tool is not a simple decision; it is not just based on operational and infrastructural constraints, but also on the inspection tool capabilities and the type of corrosion and growth mechanism that is being inspected for. Pipeline inspection experts must consider what the pipeline system can accommodate, looking at the pipeline geometry, pig trap configuration and operational parameters. Meanwhile, corrosion and integrity engineers conduct a corrosion diagnosis to review the operational fluids and history, to determine the most likely degradation mechanisms the pipeline will experience. Each pipeline system is unique, with its own variety of threats, so the combination of these two activities generates a number of viable options (each with distinct advantages and disadvantages), as there is often no single correct option.

Magnetic flux leakage (MFL) and ultrasonic testing (UT) are currently the two most widely used non-destructive inspection methods for detecting and sizing metal loss defects.[5,6] It is imperative to understand how these tools detect metal loss and what limitations need to be considered. For example, since MFL is based on measurements of magnetic leakage fields, it is relatively insensitive to large, uniformly corroded areas that cause only a small disturbance to the magnetic field. Metal loss caused by channelling corrosion resulting from erosion-corrosion in oil and water injection pipelines is an example of this.[7,8]

On the other hand, UT provides a direct measurement of remaining wall thickness and so has no such issues with sizing uniform metal loss. It does, however, have its own limitations, for example relating to reliable performance within waxy pipelines and differentiation between flat-bottomed external metal loss and mid-wall, planar defects, such as laminations.[9] Utilising a UT ILI tool in a water injection pipeline may, on the face of it, appear to be obvious – water injection pipelines often suffer from bottom-of-the-line corrosion, which, combined with scaling and certain flow conditions, can become a channelling defect. UT is the right tool for this job. However, if the threat of channelling is not realised in the pipeline or is managed effectively (and this is demonstrated by multiple inspection campaigns), then other corrosion mechanisms and threats should be considered. For example, if the next-highest threat to the pipeline is microbiologically influenced corrosion (MIC) under debris, then perhaps an MFL tool would be better to identify the presence of this in the pipeline. Without an upfront corrosion diagnosis to guide the selection of an inspection tool, operators may be looking for a threat that does not exist.

Using inspection data

ILI tool performance and accuracy is well documented, and while inspection is central to the corrosion management framework, the purpose of this article is not to discuss the inspection itself but how the resulting data can be used to support the development of an improved corrosion management strategy. Once the most appropriate inspection tool has been selected for perceived threats to pipeline integrity and the inspection has been carried out successfully, an operator should complete the appropriate integrity assessments. This step is no less important than the selection of the tool – if an inspection is not followed up with appropriate assessments, then the full value of the inspection data is lost. For example, following repeat inspections, the opportunity exists to compare data in order to identify and quantify changes. A multitude of approaches can be taken for the comparison, but, if performed correctly, active areas of corrosion can be differentiated from stable corrosion, and follow-up in-field investigations and repair work can be targeted correctly.

A successful inspection followed by a comparison against previous data and a fitness-for-service assessment is where some operators stop; it represents the status quo in the use of ILI. However, there is a need for combining such inspection activities with updated corrosion diagnosis (risk) assessments in order to increase the chances of identifying active corrosion features, validating estimated corrosion growth rates and identifying correct variables, if updates to existing corrosion control strategies are required.[10,11] This updated diagnosis can look at questions such as: did the inspection identify the corrosion expected from the upfront pre-inspection activities, and, if so, was it in the locations predicted? In this way, the updated corrosion diagnosis adds confidence to the inspection results. If corrosion was not reported, is that because the corrosion mitigations in place are effective? Is the corrosion inhibitor functioning as required? Are the cleaning pigs removing water and debris from the line efficiently? Is the coating in good condition, forming a successful barrier between the pipe surface and the soil?

If corrosion was reported, while repairs may be required and this could be a priority, is action taken to investigate and confirm why the corrosion occurred and develop targeted mitigation measures? There can be numerous reasons for active corrosion in a pipeline, and addressing it requires a systematic approach. While mitigation options for external corrosion may be more limited than some forms of internal corrosion, the updated corrosion diagnosis and development of a corrosion management plan (CMP) can contribute to a structured, prioritised coating repair plan or recommendations for improving a cathodic protection (CP) system. In most cases, the mitigation of internal corrosion can involve a variety of options; however, in completing this updated corrosion diagnosis and causal analysis, the CMP and determined corrosion mitigation measures then represent the basis of an appropriate and cost-effective corrosion management system.

From an integrity perspective, it is important to challenge 'routine activities' to be in a proactive situation where the questions being answered include 'What might go wrong?' and 'How can we prevent it from happening?' Utilising corrosion diagnosis to answer the questions 'What went wrong?' and 'Could we have prevented it?' following an inspection is a far better position to be in than after a failure occurs.

The final element in this framework is ensuring that all the corrosion-related data is incorporated into the data management system for future assessments, projects and inspections. Feedback from inspections and monitoring surveys is essential, since integrity engineering teams need to understand what works well or needs to be reviewed and updated. A substantial volume of knowledge is held by technical personnel, which is an additional critical component of continuous operation of assets and their integrity. Often, due to fast-paced operational working environments, crucial data is not captured, so regularly running through a process as described by the corrosion management framework and documenting the results of each phase ensures the collection and organisation of this critical data.

The corrosion management framework provides a mechanism by which existing processes can be combined to achieve improved corrosion management. However, it is also important to constantly strive to improve inspection and assessment processes, and to maximise the value of pipeline-related data. Predictive analytic techniques, specifically the use of machine learning and Bayesian inference and networks to improve corrosion growth rate estimates, increase our ability to learn lessons from the vast array of pipeline inspection and integrity data that exists; these lessons can then be incorporated into the development of corrosion management plans.[12,13] As

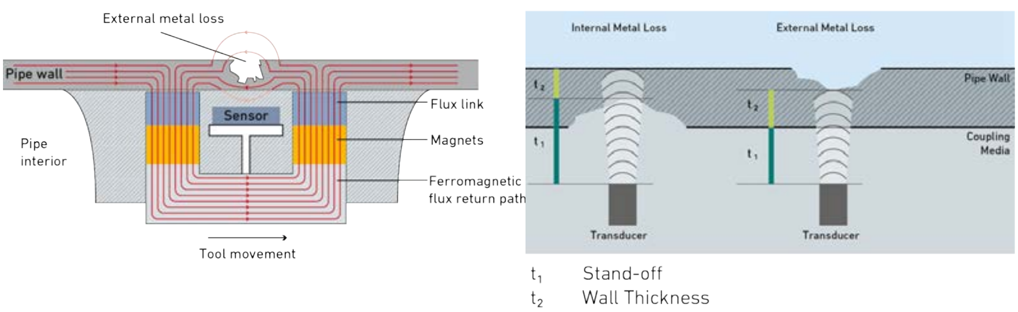

Figure 2. MFL and UT each have their advantages. Choosing the right technology is vital for identifying threats to a pipeline's integrity.

data analytics and pattern recognition abilities develop further, the upfront corrosion diagnosis can become even more predictive, and the potential for inappropriate inspection technology being selected for a particular pipeline can be vastly reduced.[14]

A framework for collaboration

Every pipeline is unique, so the corrosion management framework is flexible in application. Not every element will be required for every pipeline or operator, but it ensures a common understanding of the issues and allows for a tailored partnership approach that brings together expertise in the specific pipeline, inspection technology and corrosion management.

The components of the corrosion management framework are also not new concepts; it is not intended to introduce new inspection or assessment models, as each individual step may have been utilised by operators for many years. However, when there are operational and management pressures to close out inspection contracts as soon as possible, this systematic and thorough approach to combined working can easily be compromised. The corrosion management framework facilitates the flow of information between stakeholders – the operator themselves, ILI vendors, integrity specialists, corrosion engineers, etc. – to ensure that key elements of corrosion management are addressed adequately with the intention not just of ensuring compliance with industry standards and regulations, but of guaranteeing pipeline safety and availability.

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