Reprinted from May 2019 HYDROCARBON ENGINEERING

Leon de Ridder and Lewis Barton, ROSEN Group, describe how three technologies come together for corrosion detection and management of an aboveground fuel pipeline.

THE TEAM APPROACH

A product leak is every storage terminal operator's worst nightmare, correlated with environmental, safety and financial concerns.

In most cases, the culprit is corrosion. However, given that most asset owners have at least an appreciation for corrosion mechanisms and means of prevention, why do corrosion leaks, failures and accidents continue to occur? The answer is not simple, and there is a long list of reasons. The most common are:

- Short-term policy that puts asset maintenance at a lower priority.
- Lack of resources or competent personnel.
- Acquisitions or change in ownership.
- Lack of appreciation by budget holders.

Corrosion affects all metallic assets in one form or another, and effective remediation or mitigation of corrosion generally accounts for the largest share of maintenance and management budgeting. Consequently, corrosion management activities are often the first subjected to budget cuts or 'efficiency drives,' as there is no direct profit attributed to such activity. 'More product equals more profit,' and maintenance and mitigation activities eat into this margin, which creates and enables a culture of reactive maintenance approaches. Adopting this reactive 'firefighting' approach is the least cost-effective and highest-risk method of integrity management. Corrosion control is far more difficult once corrosion has been given a chance to take hold.

In early 2018, an operator who had acquired a tank terminal approached the ROSEN Group after identifying a spontaneous leak in one of the main petroleum lines, just a few months after acquisition. The customer now needed to know the condition of the remaining 8 in. pipeline section, a total of 300 m in length, with several road crossings. The objective of the inspection was to detect defects in the pipeline and understand whether immediate intervention was required, and/or to achieve a long-term maintenance and monitoring plan.

To reach this goal, ROSEN offered an inspection scope that would scan, detect and size anomalies on the inner and outer surfaces of the pipe. This also included detecting and sizing corrosion under pipe supports. The package consisted of three different advanced non-destructive testing (NDT) technologies with four applications, creating 100% coverage of the pipeline. In summary, the following was conducted:

- Full pipe-body scan using electromagnetic acoustic transducer (EMAT) in-field service equipment (IFSE), circumferentially and axially.
- Pipe support inspection also using the EMAT IFSE device, both circumferentially and axially.
- Inspection of the line at road crossings and bund walls using a long range ultrasonic testing (LRUT) technique.
- Inspection of heat-affected zones (HAZ) in relation to circumferential welds and bends using a linear array ultrasonic testing (LAUT) technology.

The technologies explained

It may seem that aboveground piping is simple to inspect because it can be seen. But collecting reliable data for the entire length of pipe, even in tight bends

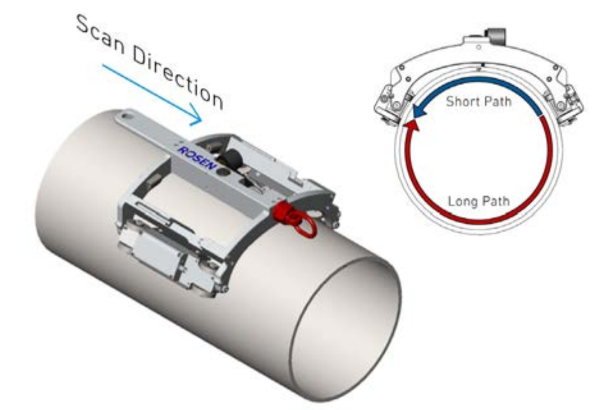

Figure 1. A guided wave UT signal travels around the pipe body circumferentially, and the CIRC tool moves axially along the pipe.

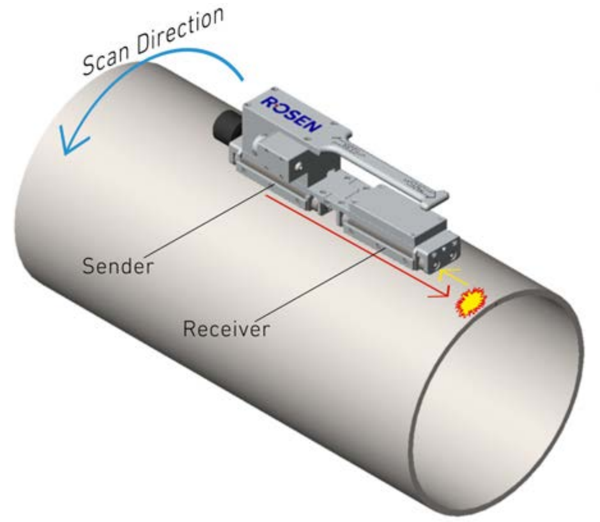

Figure 2. The AXUS tool sends a guided wave UT signal (red arrow), which is bounced back by the wall loss indication (yellow arrow) while the scanner moves circumferentially around the pipe.

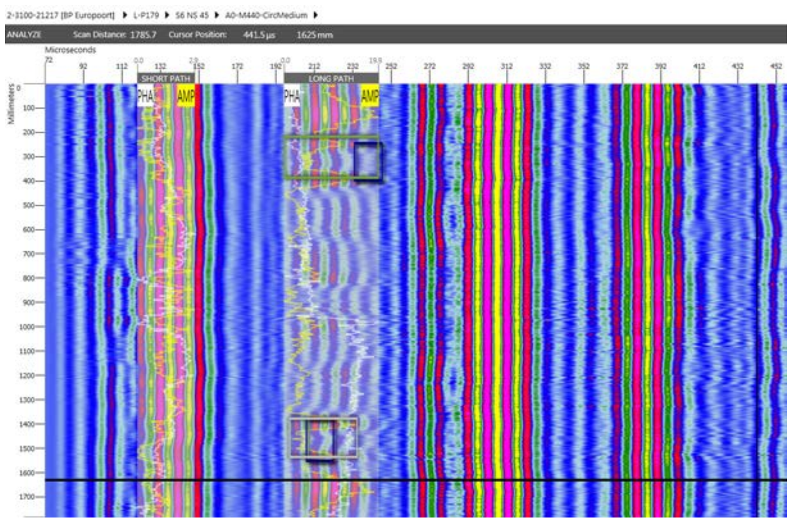

Figure 3. EMAT IFSE scan performed with the CIRC tool. The image shows the section with 40% wall thickness loss.

or when it does dip underground, requires a plethora of technologies. For this extensive setup and the varying assets in play, a range of technology applications were used, each with distinctive benefits.

EMAT IFSE for the pipe body and supports

EMAT technology is not new to the ROSEN Group and has a variety of applications for pipeline inspection. As an NDT application, EMAT induces a soundwave into the pipe wall, without the need for a coupling medium or extensive surface preparation. The technology provides many different wave modes to inspect a structure, each with unique characteristics with their own specific application for optimal feature detection. The in-field service equipment has two configurations, circumferentially with the CIRC tool, and axially with its partner, the AXUS tool.

The circumferential inspection of the pipe body can be performed rather quickly as the CIRC tool travels along the entire length of the pipe, sending the EMAT signal through the entire circumference of the line – providing a full-body inspection in one shot (Figure 1).

Once the tool has scanned the length of the pipe, the AXUS tool follows. This tool visualises any anomaly by sending a high-frequency wave in an axial direction in search of an echo from the feature itself. The AXUS tool is directed around the circumference of the pipe to provide a complete image (Figure 2).

Corrosion is a natural process and can have various shapes. Together, these tools can visualise these shapes for a better understanding of features. The CIRC tool provides an axial profile of the corrosion, and the AXUS tool provides the circumferential extent of corrosion, as well as some axial distance information. Combining both techniques can provide considerable information about the condition of corrosion under a pipe support and permit for more informed decisions on remediation. This also allows for a complete and comprehensive pipe body scan.

In total, 114 supports of the 8 in. pipeline were inspected. In those, 46 features with a metal loss of ≥20% were detected.

Nine supports had features with a metal loss between 40% and 59%, and for these the operator scheduled a short-term repair. In regard to the inspection of the pipe body, no features were detected (Figures 3 and 4).

LRUT for road crossings

Pipelines and piping with limited accessibility, for example at road crossings, can often only be inspected with an immense effort. However, applying LRUT technologies allows for a low-frequency guided ultrasonic bulk wave transmission to be propagated into the pipe from a transducer array fixed around the pipe; the technology operates just above audible frequencies. These low frequencies are necessary to enable an appropriate wave mode to travel the surface of the pipe. At these frequencies, a liquid couplant between the transducers and the surface is not necessary; a satisfactory ultrasonic coupling is achieved by pneumatic pressure applied to the back of the transducers to maintain close contact with the pipe surface (Figure 5).

The uniform spacing of the ultrasonic transducers around the pipe circumference allows guided waves to be generated that propagate symmetrically around the pipe axis. These are visualised as a circular wave that sweeps along the pipe. The whole of the pipe wall thickness is excited by the wave motion, with the pipe acting as a wave guide – hence the term guided waves.

The propagation of these guided waves is governed by the frequency of the sound wave and the pipe material thickness. When the sound wave encounters a change in pipe wall thickness, whether an increase or a decrease, a proportion of the sound energy is reflected back to the transducer array, thereby providing a mechanism for the detection of discontinuities. In the case of a constructional feature such as a girth weld, the increase in thickness is symmetrical around the pipe, so that the advancing circular wave front is reflected uniformly and is also symmetrical, consisting predominantly of the same wave mode as the wave created by the feature. In the case of an area of corrosion limited to a small area, the decrease in thickness will be localised, leading to scattering of the signal in addition to reflection, and mode conversion will occur. The reflected wave will therefore consist of the incident wave mode and the mode-converted components. The mode-converted waves tend to cause the pipe to flex as they arise from a non-uniform source. The presence of these signals is a strong indicator of discontinuities such as corrosion.

The guided waves can travel many meters and therefore be used to test large areas from a single point. Any changes in the thickness of the pipe – on either the interior or the exterior wall – cause reflections that are detected by the transducer array wrapped around the pipe. The system enables a trained operator to discriminate between metal loss and pipe features – welds, in particular.

Girth welds in the pipe produce dominant signals in the A-scan and act as important markers. Their peak amplitudes are used to set a distance amplitude correction (DAC) curve on the display, and signals from anomalies can be compared to DAC curves (Figure 6).

Figure 4. Image of the pipe support with 40% wall thickness loss from the exterior.

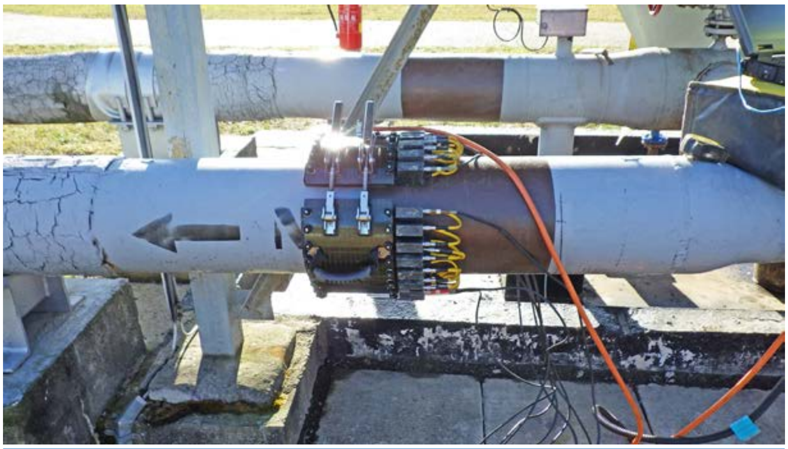

Figure 5. LRUT collar with multi-mode modules and transducers sending soundwaves for tens of meters in both directions.

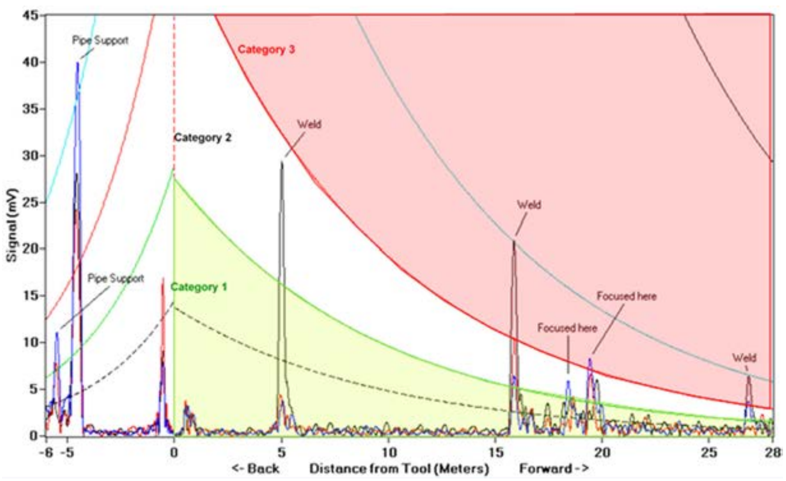

Figure 6. Distance amplitude correction (DAC) curve.

The survey engineer must evaluate all collected data while onsite to ensure the highest possible quality. This includes any necessary follow up/verification of signals when possible. Indications are subject to a two-step evaluation process that considers:

- Assessment of whether the indication is a direct response or a mode-converted signal.
- The position of the indication relative to known pipeline features (ghost echoes).
- The amplitude in relation to DAC reference levels (step 1).
- The directionality of the focused response when utilised (step 2).

Overall evaluation, in turn, is represented by way of a priority ranking in which the signals are described as being high (Category 3), medium (Category 2) or low (Category 1) priority for follow-up evaluation.

As the 8 in. pipeline described in this case study had a variety of road crossing sites, this technology application became extremely relevant. To get the best possible coverage of the full 300 m of pipeline, the LRUT technology was applied on four road crossings, one pipe bridge and six additional pipeline sections. The average coverage per scan was 30 m. Constraints were flange connections in a number of valves in the pipeline and the amount of bends in succession, meaning the inspection unit needed to be placed at the optimal location on the pipe to ensure full coverage. When the inspection was completed, six indications in the highest category – Category 3 – had been reported.

Figure 7 shows the results of one of the inspected road crossings. This inspection detected a Category 1 feature at 1.84 m, a Category 2 feature at 13.3 m, and Category 3 features at 3.93 m and 12.91 m.

LAUT for the inspection of heat-affected areas

To gather comprehensive data for the entire section of pipe, a dedicated inspection for HAZ is necessary. These areas consist of base material, either metal or thermoplastic, where the microstructure and properties have been altered by welding or heat-intensive cutting. The heat from the welding process and subsequent cooling causes this change to the base material and can increase sensitivity at these locations.

These unique and high-risk areas can be inspected using an advanced method of ultrasonic testing (UT) referred to as LAUT. This technology uses an array of UT probes consisting of many small ultrasonic transducers, each of which can be pulsed independently. By varying the timing, for instance by pulsing the elements one by one in sequence along a row, a pattern of constructive interference is set up that results in a beam at a set angle. In other words, the beam can be focused and steered electronically (Figure 8).

Pitting, a unique form of corrosion that refers to features smaller than 2 mm, cannot be reliably detected by conventional UT methods, simply because the size of the defect is too small compared to the area inspected. LAUT techniques can be used to approach the needed precision and get great coverage quickly.

A successful corrosion mapping inspection is the result of the combination of a high probability of detection on corrosion damages like pitting with the confidence that the full area of interest has been totally covered. In the 8 in. pipeline in question, the LAUT technology found no indications.

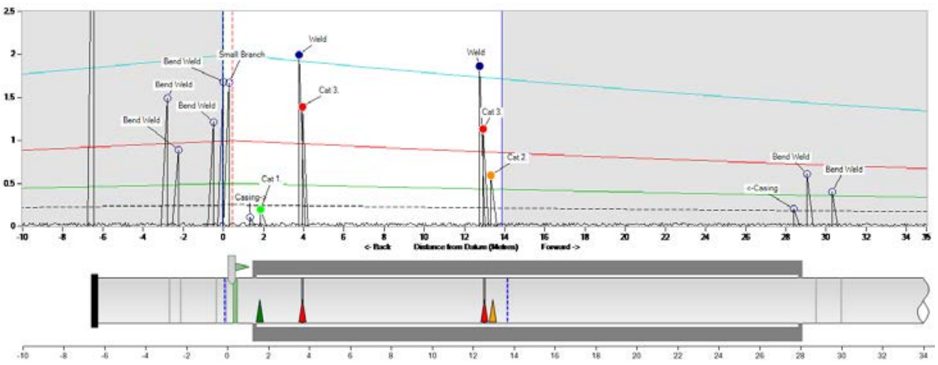

Figure 7. The result of one of the road crossings.

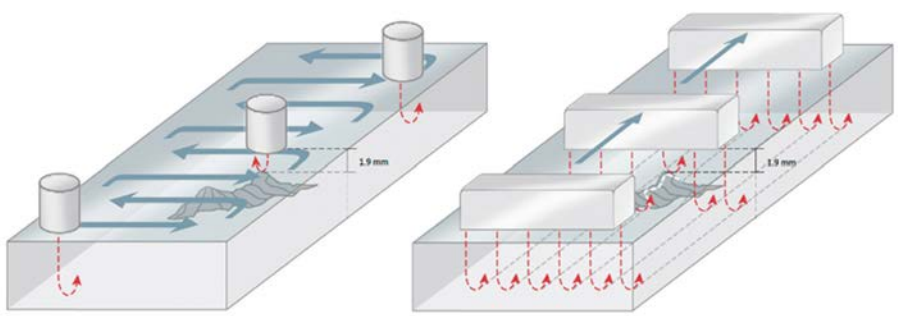

Figure 8. With traditional thickness gauges, finding a pinhole is just as difficult as finding a needle in a haystack. Linear array corrosion mapping makes finding the needle possible.

Collecting the data is great, but what about a predictive approach?

Inspection alone is not enough to manage corrosion, a fact that is sometimes forgotten or overlooked. As a result, integrity engineers can be faced with predicting and diagnosing corrosion, with inspection data as the only reference source. In this case, engineers become mere observers, as inspections only represent snapshots of the pipeline's operational history. Furthermore, this approach has the potential of providing a false indication of the situation.

Although every effort is made to achieve the best possible inspection, it may not be possible due to girth welds, physical access, small-bore pipework, etc. Therefore, to provide the best result to operators, ROSEN employs condition inference methodologies that use data analytics, utilising available environmental and inspection data to understand corrosion behaviour in areas with no inspection results. This approach uses similar methodical approaches as NACE standard practices for direct assessment with certain elements of risk-based inspection. This method limits the need for follow-up activities to where inspection data is missing or questionable. Further refinement is possible to reduce the number of inspections by identifying locations at a higher susceptibility to corrosion. Ultimately, inspections become more focused, allowing integrity management with specific remedial actions and strategies to be developed. This drives efficiency, rather than a generalised inefficient approach.

Only by combining repeat inspections with corrosion assessments can corrosion be diagnosed and managed. Although awareness of this is slowly growing, there is still a large disconnect between different operators, regions and countries. The current industry initiative is to move from a reactive culture towards smart predictive techniques. This means that a smarter, more holistic analysis of inspection, operational and environmental data must be embraced.

Conclusion

Each asset has unique features; in this case, the 8 in. fuel pipeline had a collection of bends, welds, road crossings and more, all in its short 300 m length. Corrosion will find its way into any pipeline; it is, so to speak, the all-intrusive threat. Although managing it may seem hopeless, with the proper technologies to gain a comprehensive understanding of an asset, plus proper maintenance and remediation plans and perhaps even the thought of using reliable data to precisely predict its future condition, managing corrosion is very much possible.