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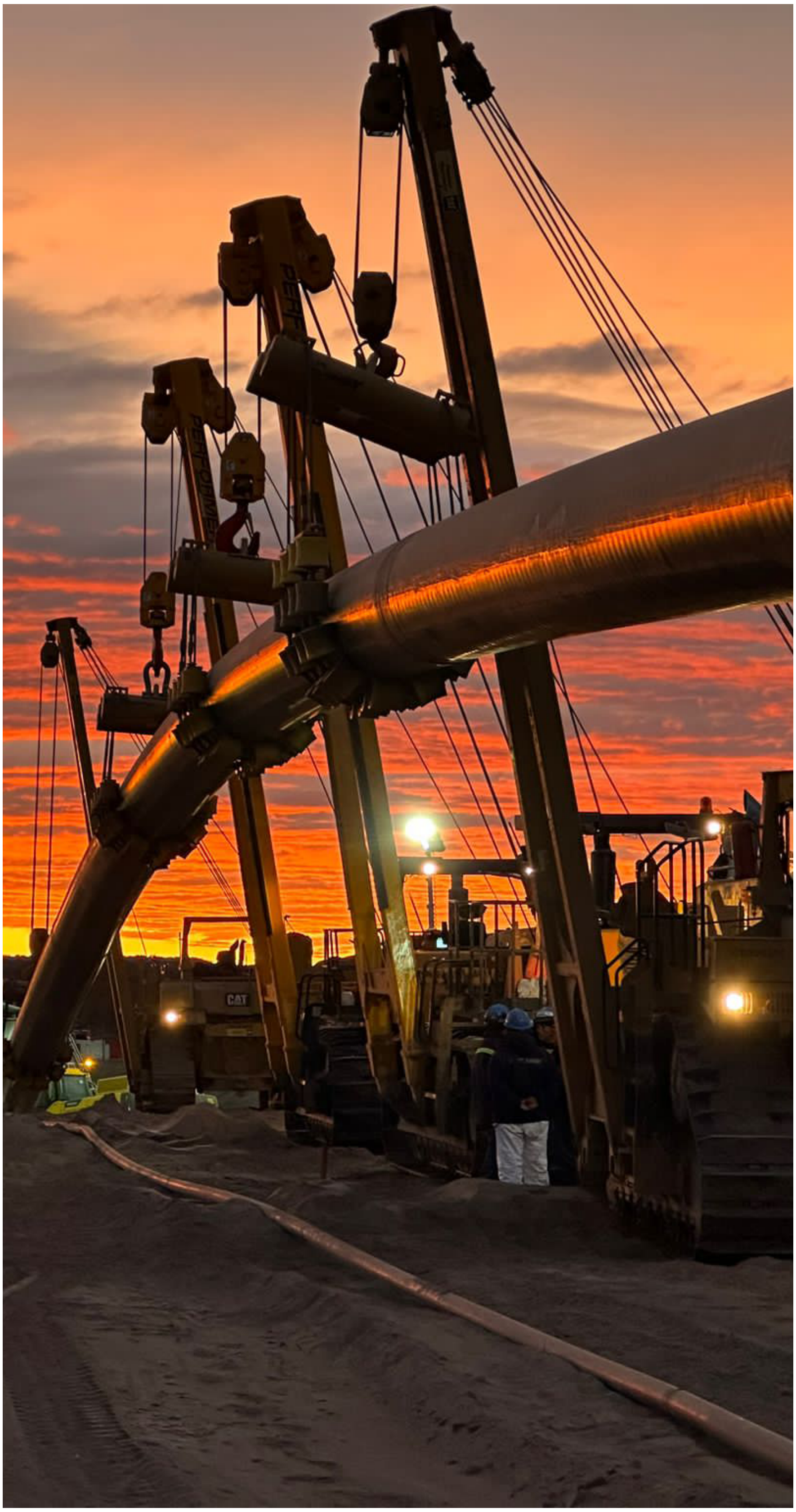

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AIoT-Driven Deadleg Corrosion Monitoring: Future-Ready Asset Integrity Management

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Abstract

Efficient hydrocarbon transportation depends on extensive pipeline networks requiring regular inspections for safety and efficiency. Deadlegs, parts of the system prone to corrosion, pose significant challenges. Traditional manual ultrasonic testing lacks the accuracy needed for effective corrosion assessment. Permanently installed ultrasonic sensors, enhanced with Artificial Intelligence of Things (AIoT) and NDE 4.0, provide a better solution. These technologies use non-destructive methods and digital tools, like AI and machine learning, to detect material flaws, offering higher quality and more frequent data. A case study demonstrates how advanced AIoT solutions effectively monitor deadlegs, ensuring pipeline integrity. Implementing these technologies enhances corrosion detection and mitigation, safeguarding critical infrastructure.

1. Introduction

The seamless transportation of hydrocarbon products is vital to the energy sector, relying heavily on an extensive network of pipelines and associated infrastructure, such as pump stations, compressor stations, tank farms, and terminals. These facilities house a vast amount of piping that demands regular inspection to ensure safety and efficiency. One of the most challenging aspects of pipeline maintenance is managing and inspecting deadlegs.

According to API 570 , deadlegs are components of a piping system that typically have no significant flow and may include piping no longer in use but still connected to the process. Deadlegs, whether above or below ground, are particularly susceptible to various internal corrosion mechanisms such as microbiologically influenced corrosion (MIC), CO_2 corrosion, and brine corrosion. API 570 suggests the removal of non-essential deadlegs that are potentially corrosive. When removal isn't feasible, a thorough risk assessment is imperative, as deadlegs can pose a greater threat of accelerated corrosion compared to active piping circuits. Since deadlegs are usually unpiggable, their inspection primarily relies on manual ultrasonic testing (UT) at predefined Condition Monitoring Locations (CMLs). However, manual UT has significant limitations in both accuracy and precision. These limitations affect the subsequent calculations of corrosion rates and remaining life, complicating risk assessments and often necessitating large safety margins to prevent component failure and unplanned maintenance. Permanently installed ultrasonic sensor solutions offer an alternative to manual UT. Industry standards such as API RP 571 provide guidance on which damage mechanisms can be effectively monitored with these sensors. However, their successful application comes with its own set of challenges, particularly in maintaining accuracy and precision.

2. Unlocking Opportunities Amidst Challanges

2.1 Effective Ultrasonic Sensor Installation on Small-Bore Piping

Permanently installed ultrasonic sensors are usually straight-beam direct contact sensors, mounted directly onto a component using an ultrasonic couplant. The ultrasonic waves transmit through the contact area between the sensor and the surface. However, this setup can be challenging for small-bore piping, as the contact area decreases with the pipe's outer diameter, particularly for pipes with diameters of three inches or smaller. The success of these applications depends on mounting fixtures that hold the sensor in a stable position while optimizing the ultrasonic signal. Figure 1 shows an example of a sensor installed on small-bore piping, demonstrating a balance between signal stability and ease of installation.

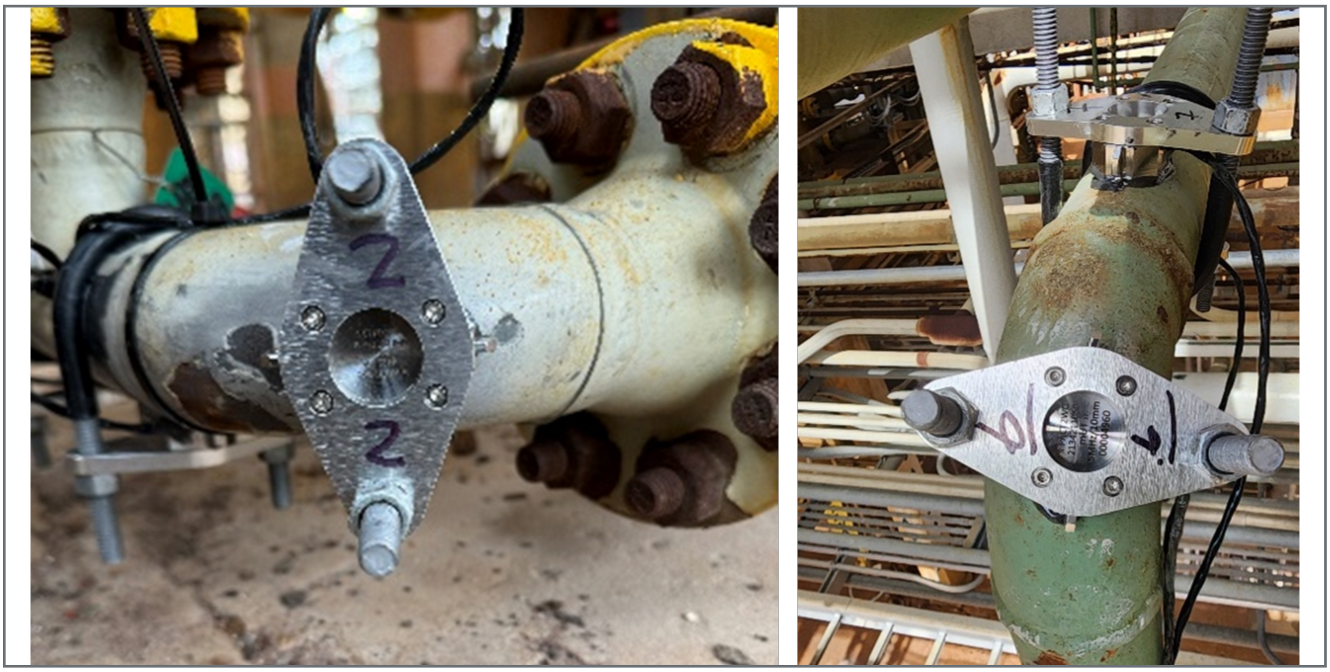

Figure 1: Ultrasonic Sensors with Mounting Fixtures on 2-inch Piping

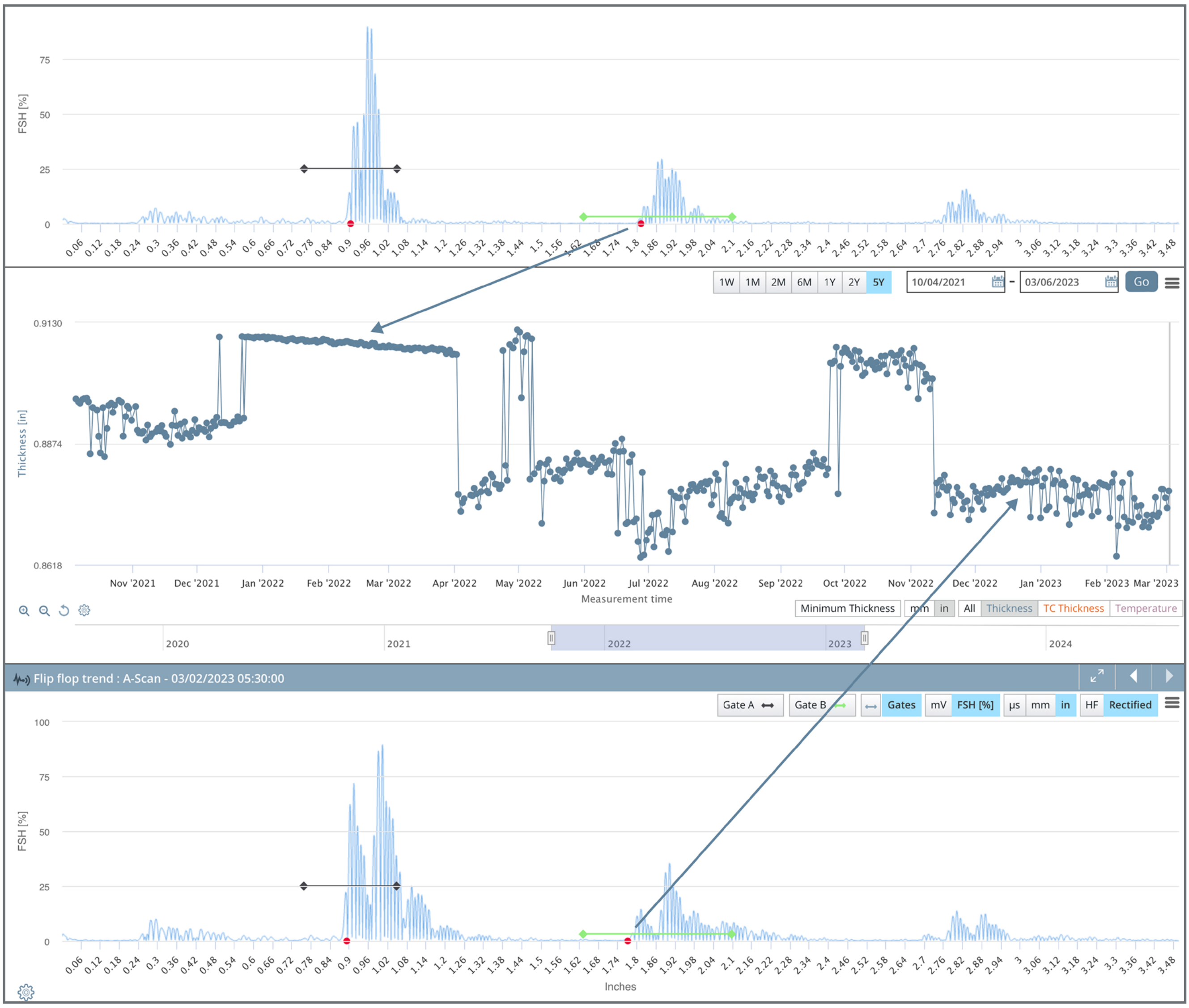

Figure 2: Impact of Corroding Surfaces on Ultrasonic Waveforms and Thickness Measurements

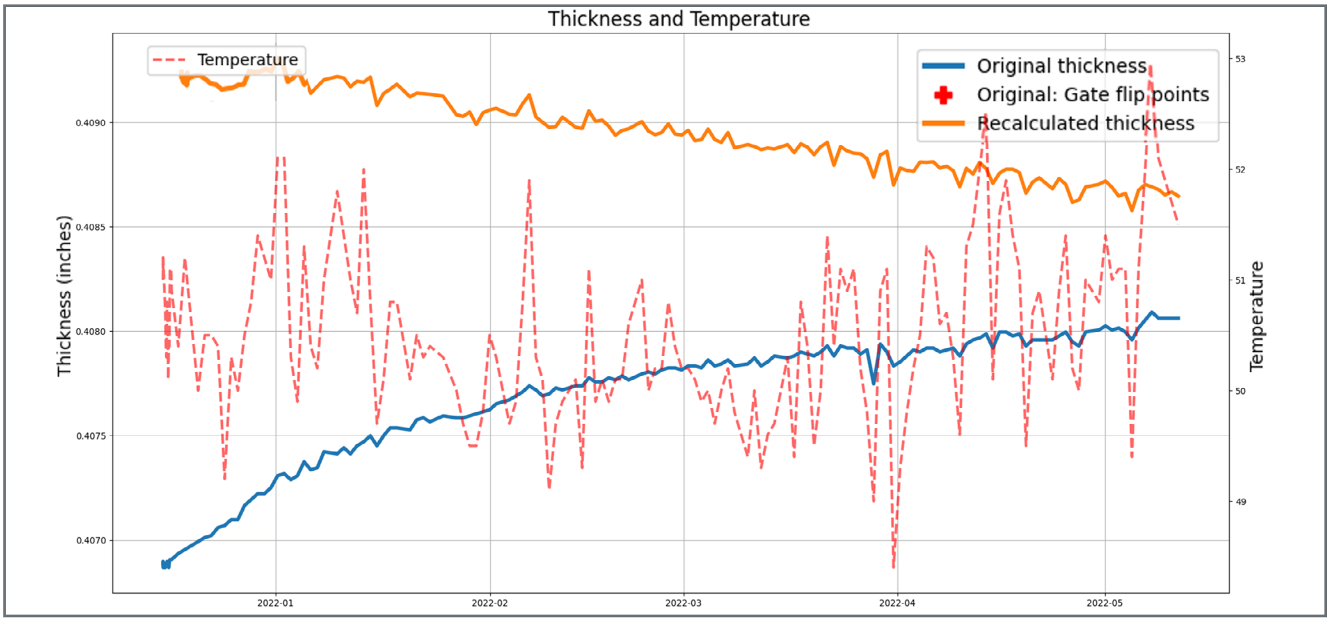

Figure 3: Misleading Thickness Increase Due to Active Corrosion

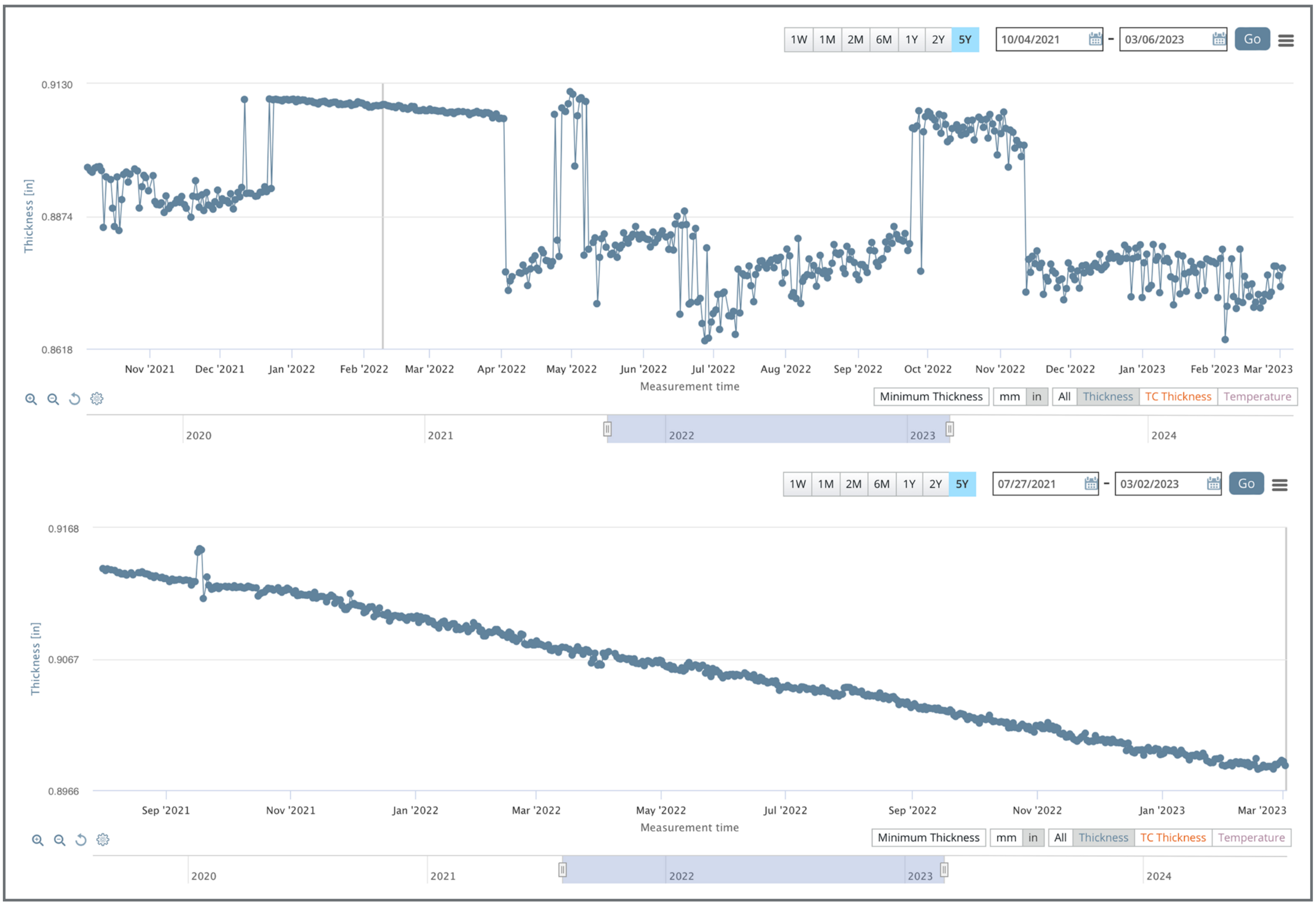

Figure 4: Static Gates vs. Dynamic Gates: A Comparative Study of Thickness Trends

2.2 Dynamic adjustments to address Data Quality

Accurate thickness measurements are challenging when ultrasonic waves interact with irregular surfaces. Corroding parts often experience metal loss or changes in surface roughness, resulting in broader, lower-amplitude echoes in ultrasonic testing. In an Amplitude-Scan (A-Scan), these echoes appear weaker and wider (Figure 2, bottom panel) compared to those from smooth surfaces (Figure 2, top panel). Each reflection worsens the effect, sometimes splitting the echo into multiple peaks. Variations in SNR and ToF can sometimes lead to dangerous misinterpretations. For instance, Figure 3 illustrates a scenario where these variations create a rising trendline, which could be mistakenly interpreted as the buildup of deposits inside the backwall (blue line in Figure 3). In reality, however, the part is undergoing active wall thinning (orange line in Figure 3).

These interactions reduce the signal-to-noise ratio (SNR), complicating the thickness determination process. Time-of-flight (ToF) algorithms, such as those using maximum peaks or zero-crossings, are common in ultrasonic testing. The zero-crossing method, while accurate, is highly sensitive to SNR variations, causing static ToF algorithms to fail. This results in step-function-like thickness trendlines, which are unsuitable for tracking thickness changes or determining corrosion rates and remaining life (Figure 2, middle panel).

The limitations of traditional, permanently installed ultrasonic sensors can be addressed by adopting Artificial Intelligence of Things (AIoT) technologies. Machine learning algorithms can dynamically adjust gates in real-time to account for changes in ultrasonic waveforms caused by active corrosion. As demonstrated in Figure 4, these dynamic gate algorithms can transform an unusable thickness trend (as seen in Figure 2) into a reliable trend, accurately determining corrosion rates and remaining life with high confidence.

2.3 Intuitive Circuit-Level Dashboards for Effective Monitoring

The number of deadlegs in a facility can change over time, making manual trendline reviews impractical. Automated solutions improve monitoring by tracking thickness and corrosion rates against set thresholds but often lack operational context.

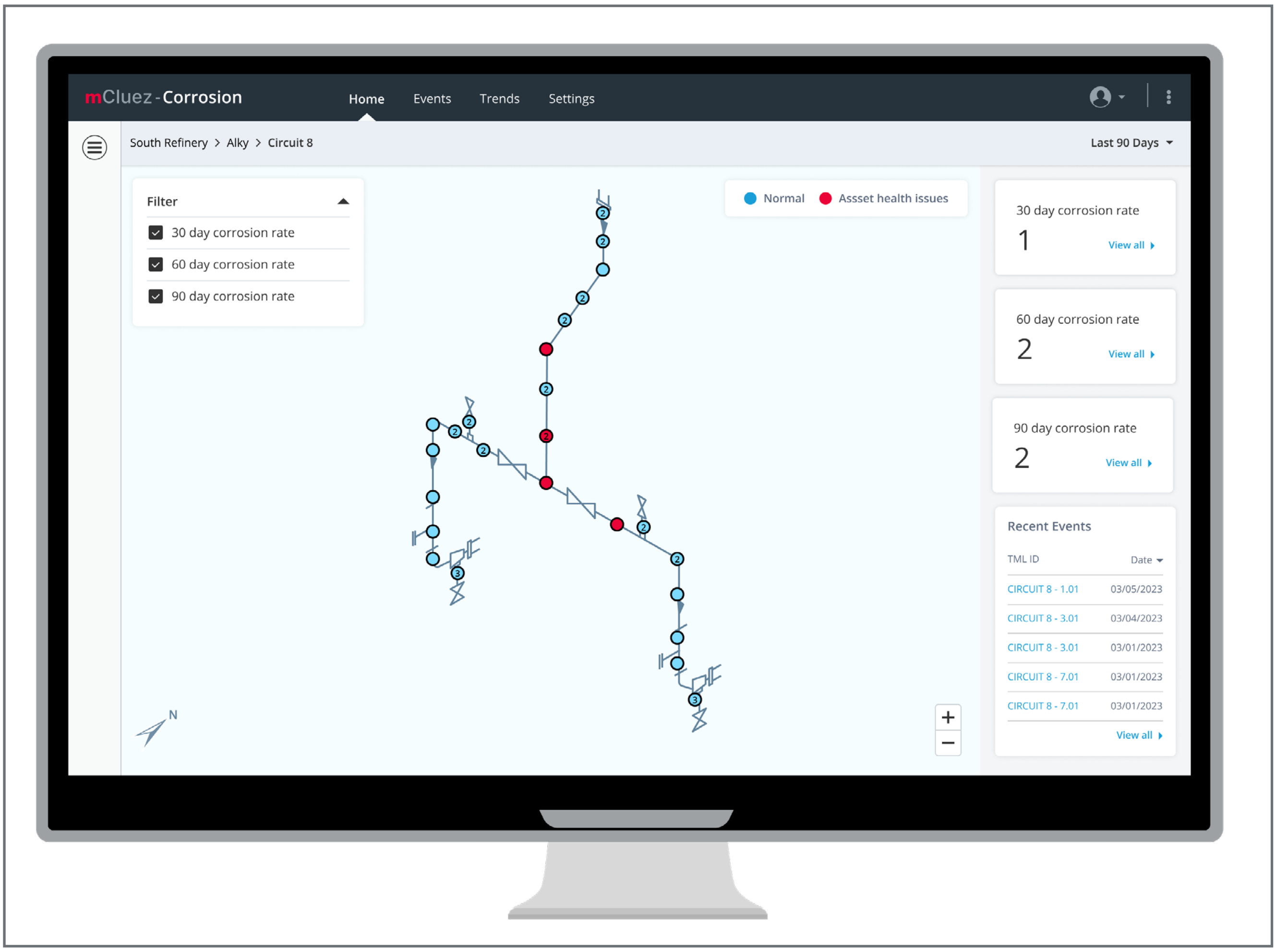

Figure 5: Circuit-Level Visualization of CML Status

Machine learning can contextualize data from numerous Condition Monitoring Locations (CMLs). Figure 5 illustrates a circuit-level dashboard displaying sensor locations on an ISO diagram, with colors indicating CML status relative to thresholds—red signals a breach. Event and list widgets provide circuit overviews, and linked dashboards enable seamless navigation between detailed analyses and circuit-level views.

3. Proven Customer Deployment

One of the largest oil and gas companies has transformed its corrosion monitoring by implementing mPACT2WO's mCluezTM Corrosion Monitoring solution. This advanced technology has significantly enhanced the monitoring of hundreds of CMLs on deadlegs, including those with piping diameters as small as two inches.

The AIoT solution, that uses sensors to deliver precise, real-time insights,has been instrumental in accurately identifying long-term corrosion rates, with some CMLs exhibiting rates as high as 15 mils per year. Figure 6 illustrates the thickness trend for a CML on a deadleg within the facility. The high data quality visible in the A-Scan ensures that the thickness trend and the corrosion rate of 15 mils per year were determined with high confidence. This precise determination starkly contrasts with surrounding CMLs, which show corrosion rates not exceeding 3 mils per year.

This case study underscores the effectiveness of this advanced technology in providing reliable, high-quality data, enabling the company to maintain pipeline integrity and prevent costly failures.

4. Summary

Internal corrosion of deadlegs in pipeline facilities is a leading cause of failures. Industry standards such as API 570 recommend closely monitoring deadlegs when their elimination isn't feasible. Permanently

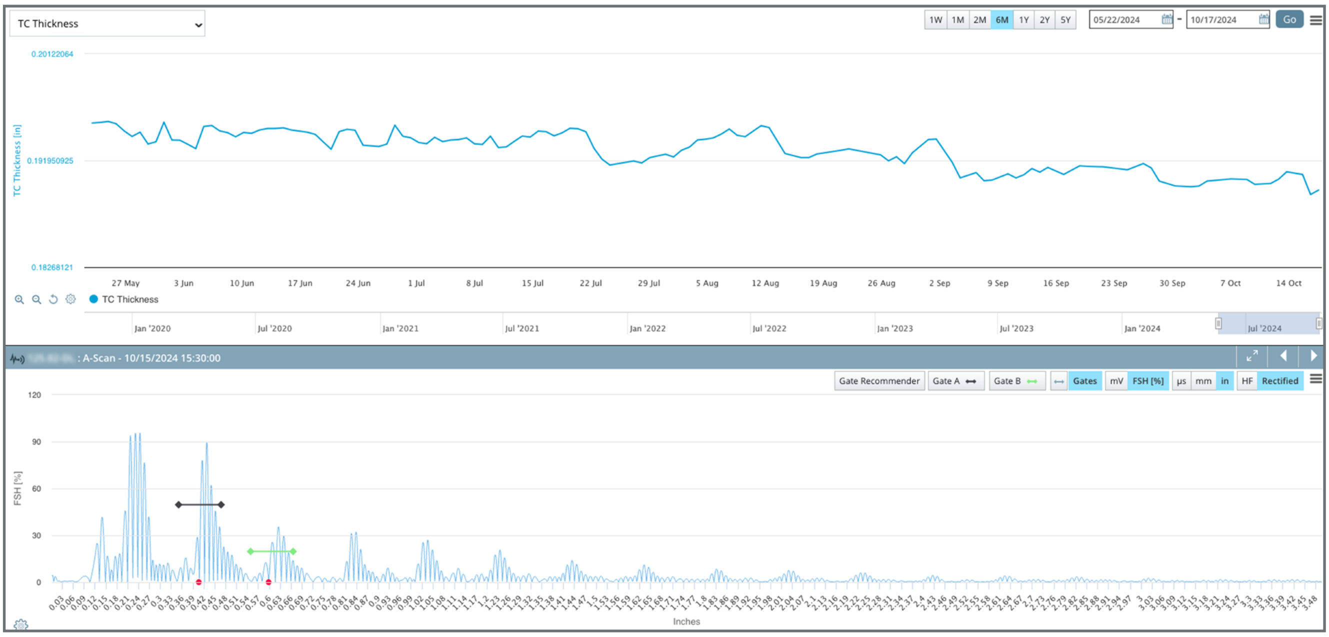

Figure 6: Thickness Trend Analysis of CML on 2-Inch Piping

installed ultrasonic sensors, combined with AIoT and NDE 4.0, provide an excellent solution for material evaluation. This approach uses non-destructive evaluation techniques, incorporating digitalization, networking, communication, and processing tools like AI and machine learning. These tools detect flaws and imperfections in materials and ensure structural integrity. This method delivers higher data quality and more frequent measurements than traditional manual techniques. The case study demonstrates that an advanced AIoTsolution effectively monitors hundreds of deadlegs, enabling inspectors and operators to focus on critical areas, thus ensuring the integrity and reliability of pipeline facilities.

By leveraging advanced technologies, the industry can significantly enhance its ability to detect and mitigate corrosion, thereby safeguarding the infrastructure that underpins our energy needs.

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