INTRODUCTION

Monitoring corrosion growth is a critical part of safe pipeline operation, and can help to extend the lifespan of a pipeline, while preventing leaks and ruptures. However, accurately measuring the minute changes in corrosion anomalies, which can impact pipeline lifespan and operating procedures, requires diligence, the proper technology and the expertise to interpret the data collected.

This White Paper will discuss the importance of monitoring corrosion in pipelines, and how regular ultrasonic inline inspections (ILI) can assist operators in safely managing the integrity of their pipeline.
**THE DANGER OF UNCHECKED PIPELINE CORROSION**

Corrosion can impact both internal and external pipe surfaces. When the transported medium, such as crude oil, carries amounts of water or bacteria, this can initiate internal corrosion and result in rapid growth, while third party damage and environmental factors can affect external coatings and result in external corrosion.

Between 2010 and 2014, the Canadian Energy Pipeline Association (CEPA) found that the leading cause of pipeline failure among its members was metal loss, at 34 per cent. This is usually caused by either internal or external corrosion, which can be detected and forecasted through ultrasonic ILI. Similarly, in the 30 years leading up to the turn of the century, the US Department of Interior Mineral Management Service found that internal corrosion was the leading cause of leaks in 35 per cent of reported incidents in offshore pipelines, with natural hazards trailing well behind.

Since there are a variety of factors that can affect the speed of corrosion growth, accurate forecasting can best be carried out when multiple ILIs have been performed to provide a rate of change. This information can be used to forecast the remaining lifespan of the pipeline, but is even more critical for offshore pipelines, where it is used to extrapolate the expected reduction of the maximum allowable safe operating pressure.

**Factors impacting corrosion growth rates**
- Pipeline material
- Manufacturing faults
- Medium being transported
- Temperature of the medium
- Particulate and bacteria in the pipeline
- Environmental factors (humidity, pollutants, etc.)

**TACKLING CORROSION GROWTH WITH CUTTING EDGE TECHNOLOGY**

In 2015, NDT Global launched a high-resolution metal loss inspection service using the new Evo Series 1.0 UMP tool. This service reliably detects defects as small as 5 mm (0.2 in), which represents a two-fold improvement in the minimum sizing threshold from the previous entry-level ultrasonic service, which could detect 10 mm (0.4 in) defects. This can be attributed to the improvement in wall thickness resolution from 0.24 mm (0.009 in) to 0.12 mm (0.0047 in). In addition to the latest technology, NDT Global has conducted ultrasonic testing on more than 183,000 km (114,000 miles) of pipeline and has 580 man years of data analysis experience.

Before inspection, pipelines are cleaned of dirt and debris, as this can cause echo loss that impacts the quality of the data collected. Once the line is cleared, the ILI tool is deployed. As it travels through the line, the tool’s ultrasonic sensors covering the full 360-degree range of the pipeline emit a short pulse of ultrasonic energy, which is reflected by the internal pipe wall. A portion of the signal enters the pipe wall and is reflected by the rear wall. Using the speed of sound for the medium and steel, the distance from sensor to the inner wall (standoff – SO) and the wall thickness (WT) can be calculated. Based on the change in SO distance, NDT Global determines whether an anomaly is internal or external. If the SO distance remains the same, it means the corrosion is on the outside of the pipe, while an increase in the distance indicates internal corrosion.

Ultrasonic metal loss inspection provides more accurate data than other technologies, such as magnetic flux leakage (MFL), which cannot provide direct wall thickness measurement or reliably detect the size of axially aligned corrosion defects (channeling corrosion), complex corrosion defects and mid-wall anomalies, such as laminations.

The Evo Series 1.0 records inspection data with higher axial and circumferential resolution while it is able to travel up to four times faster than older generation tools. The higher inspection speed leads to cost savings for operators, because the throughput doesn’t have to be reduced as much as with standard tools. Higher-resolution means more measured values per metal loss anomaly. This allows NDT Global to identify the contours of a defect more reliably, which is important for meaningful corrosion growth analysis and integrity assessments.
While higher accuracy is clearly a boon to accurately measuring and forecasting corrosion growth, it can also pose a challenge. Growth rates are determined by comparing datasets from two or more inspections, and because the latest generation tool was introduced only in 2015, engineers are sometimes comparing with data from older, less accurate tools. This can raise the question of whether an anomaly has grown rapidly, or simply wasn’t detected on the previous scan. To determine the difference, engineers turn to the number of sensors measuring possible corrosion growth. If only one or two sensors detect the deepest part of the anomaly, engineers conclude that it’s likely that it was missed by older technology. The more sensors that pick up this deepest section, the higher the likelihood that growth has occurred, rather than a technical miss.

**THE TECHNOLOGY IN ACTION**

**CASE STUDY 1**

NDT Global completed the first ultrasonic ILI of this offshore crude oil pipeline in early 2015. After this inspection, data analysis teams discovered that this five-year-old line had significant internal corrosion, which was unexpected given its age. Pitting and extensive channeling corrosion with depths up to 10 mm (0.4 in, 60 per cent of the nominal wall thickness) were found mainly on the bottom of the pipe, but also along the sides to the mid-point.

Based on the surprisingly advanced corrosion discovered in 2015, the customer expected to see corrosion growth between 2 mm and 2.5 mm (0.08 in and 0.10 in) per year. The customer believes the temperature of the crude oil, which was between 60 and 70 degrees Celsius, and insufficient cleaning of the pipeline during the first few years of operation, contributed to the significant corrosion growth. In an attempt to slow further damage, the procedures for cleaning and injecting of corrosion inhibitors were changed.

In order to prove the effectiveness of these measures, the customer decided to re-inspect the pipeline in 2016 (one year after the first ILI). Having two high-resolution ILI data sets enabled a detailed data-based corrosion growth assessment. That means the river-bottom profiles of the corrosion anomalies were compared instead of the peak depths only. This assessment revealed corrosion growth between 2015 and 2016 for the majority of the corrosion anomalies.

However, despite the ongoing corrosion, there was some positive news. Based on the 2015/2016 comparison, NDT Global found the maximum growth rate is approximately 1.2 mm (0.05 in) per year, which is not as fast as the customers expected based on the first inspection. As this is an offshore pipeline, one of the most critical pieces of information to determine is the safe operating pressure. As repairing offshore pipelines is very expensive, it is necessary to extrapolate the condition to know how long you will be able to operate the pipeline at certain pressure levels, or when you have to reduce pressure. Operation of offshore pipelines strongly relies on the output of these corrosion growth predictions and assessments.

The safe operating pressure was calculated according to Complex Shape Method of Recommended Practice DNV-RP-F101, which makes use of the detailed river-bottom profiles of the corrosion features. The calculated safe operating pressure of the pipeline dropped by 11 bar (160 psi) between 2015 and 2016, but is well above the maximum allowable operating pressure (MAOP) of 140 bar (2030 psi). Forecasts of the pipeline’s future safe operating pressure were calculated based on different corrosion growth scenarios. For the most conservative scenario, where corrosion growth of all anomalies continues at the maximum rate of 1.2 mm (0.05 in) per year determined from the 2015/2016 comparison, the remaining life of the pipeline at the established MAOP is eight years (Figure 1).

The comparison and assessment of the 2015 and 2016 ILI results showed that the initial prevention measures slowed the corrosion growth after the 2015 ILI. In order to reduce the still
high growth rate, the customer plans to optimize the cleaning and corrosion inhibition procedures. Therefore, a re-inspection and an updated corrosion growth analysis and integrity assessment are planned in order to prove the success of these strategies.

CASE STUDY 2

While the previous case study focused on internal corrosion, NDT Global worked with a pipeline operator in mid 2016 that had an issue with external corrosion on a riser section that was approximately 185 m (607 ft) in length and had previously been inspected by another company in 2014.

According to the 2016 ILI results, the most significant external anomaly was found in the splash zone, and had a peak depth of 8.0 mm (0.31 in), leaving a remaining wall thickness of 7.0 mm (0.28 in). It spans a length of 1.0 m (39 in) and covers the full circumference of the pipe. This heavy corrosion shows that the coating was damaged, allowing sea water to penetrate to the metal.

This customer needed a detailed growth assessment considering the high-resolution depth profile of this external corrosion. In order to take a detailed look at this particular anomaly, it was divided into eight 45-degree segments. Figure 2 illustrates the comparison of river-bottom and resulting characteristic wall thickness profiles from one of these segments. The growth rates calculated from the change in characteristic wall thickness are given in Figure 3.

Interestingly, the corrosion rate varied significantly along the length of the anomaly. The first 600 mm (24 in) of the 1000 mm (39 in) area featured corrosion that was growing about twice as fast as the spots in the latter half. In this first section, the rate ranged from 0.5 mm (0.02 in)/year to 0.6 mm (0.024 in)/year, depending on the circumferential position. However, after 600 mm (24 in) the anomaly was growing at a maximum rate of 0.2 mm (0.01 in)/year, and several of the regions showed no growth at all.

This type of high-level corrosion growth results serves as input for advanced 3D finite element pressure and remaining pipeline life predictions.

A DETAILED CORROSION GROWTH ASSESSMENT CONSIDERING THE HIGH-RESOLUTION PROFILE OF THIS EXTERNAL CORROSION WAS REQUESTED.
**SUMMARY**

Unchecked corrosion can lead to disastrous consequences, which is why regular monitoring and accurate data is critical. NDT Global uses cutting edge technology to provide high-resolution information about the condition of pipelines, both inside and out.

Having accurate data about the presence of internal and external corrosion, as well as the growth rate of those defects, allows pipeline operators to intelligently plan their maintenance, ramp up preventative measures and ensure the pipeline is always operating at safe pressure levels. It also gives a good indication of the lifespan of the pipeline, which can aid in long-term planning and safety.

**LEARN MORE**

For more information about NDT Global and their inspection services, visit www.ndt-global.com

---

**AUTHORS**

Dr. Christoph Jäger  
Project Leader Integrity Services, NDT Global

Andreas Pfanger  
Project Leader Integrity Services, NDT Global

E-Mail: europe@ndt-global.com