Internal Ultrasonic Pipeline Inspection for Outer Continental Shelf (OCS) Hazardous Liquid Gathering Lines

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Abstract

Traditionally, Gulf of Mexico (GoM) Outer Continental Shelf (OCS) owners and operators have sought alternate methods to assess the integrity of their gathering lines than inline inspection. In April 2010, the Deepwater Horizon explosion and subsequent blowout brought significant scrutiny from state and federal regulatory agencies.

A customer approached Intero Integrity Services in 2019 to evaluate the feasibility of inline inspections of its liquid gathering system in the GoM. The feasibility included three areas: 1) Technical ability to inspect, 2) inspection cost, and 3) Value of reported results.

From a technical standpoint, the customer conditions challenged just about every aspect of standard inline inspections: Never pigged for maintenance nor integrity assessment; 1500 psi static pressure; limited operating space on the platform; remote location (90+ miles offshore); inability to track during the inspection (2,000' water depth); limited pipeline availability based on a production schedule; 8" nominal x 0.812 wall thickness x 25-mile pipeline; back to back "jumpers" to loop pipeline; and pumped in seawater. This paper will explain how flow conditions were tightly controlled when working closely with the operator.

From a cost perspective, the customer had limited assessment options. The field was initially developed in 1998 and has operated in multi-phase production for 20+ years. If pipeline replacement is required, the field will just shut-in based on ROI compared to the current production curve. External assessment methods are limited (ROVs and divers) and need to be more comprehensive. Other than inline inspection, a hydrotest was the only option. Again, not valuable information for the cost.

Corrosion was detected in an area that had limited access; therefore, the operator decided that an annual inspection would be conducted, detailed corrosion growth assessments would be completed, and the effectiveness of corrosion mitigation methods would be quantified. Data sets will be presented that show the challenges of detecting defects under external clamps, and the variability between said datasets.

With the 0.812" wall thickness, the only inline inspection solution was ultrasonic (UT) technology. Magnetic (MFL) tools could not saturate the pipe wall to provide accurate measurements.

Introduction

Maintaining the integrity and reliability of pipeline and energy storage infrastructure is crucial for stable energy delivery. As these assets age, it becomes even more critical to implement effective assessment strategies to identify potential issues and ensure their continued functionality.

By combining these advanced technologies and strategies, industries can enhance the assessment of critical assets, prolong the lifespan of infrastructure, and ensure the reliable delivery of energy. Regular and proactive inspections and integration of new technologies play a crucial role in addressing the challenges associated with aging pipelines and energy storage infrastructure.

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Using free-swimming inspection technologies for pipelines represents a significant advancement in the field, especially for pipelines that are challenging to inspect using traditional methods. These technologies offer innovative solutions to address the limitations of conventional inspection approaches.

We will provide an overview of the following:

Project Specifics

Scope : Traverse and inspection of an offshore riser.
Location : Gulf of Mexico
Customer : Subsea Offshore Operator

These projects and their unique challenges will be discussed to illustrate the importance of deploying the right technology for specific applications. We will also demonstrate that utilizing these systems reduced the overall engineering costs associated with traditional inspection technologies. Additionally, the benefits and values from understanding the integrity conditions of these critical elements of energy infrastructure will be shared to provide guidance on selecting appropriate inspection methods to acquire the breadth and quality of data that can assist operators in making informed decisions for their asset integrity programs.

This ensures reliable energy distribution, reduces environmental impact, and improves safety.

Operators should consider the type of inspection technology that will meet regulatory standards and provide all information required to get complete details to have a well-rounded asset integrity maintenance program. Inspection of those assets is vital to ensuring that pre-emptive maintenance is possible and the costs associated with adverse events are avoided.

Certainly, offshore pipeline inspections present a unique set of challenges due to their specific layout, features, and the demanding working environment. Addressing these challenges requires innovative approaches and technologies tailored to the complexities of offshore infrastructure.

As a 35-year-experienced inspection company, Intero Integrity Services gained much experience using their creative solutions to tackle these 'unpiggable' pipelines. These solutions are developed based on the in-house developed versatile inspection systems that allow a wide variety of deployment strategies without reducing the quality or reliability of the inspection data.

The system applies ultrasound technology to accurately scan the pipe wall, allowing inspection of heavy wall risers, cladded risers and even alloys like stainless steel or duplex as well as exotic materials.

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The anonymous case study will show accomplished developments that enable the inspection of these 'unpiggable' pipelines using creative solutions. Other solutions can include;

- Bidirectional inspection pigging using system backpressure.
- Subsea launching in case of open wye piece connections.
- Bidirectional inspection using on-line positioning systems.
- Gravity-fed, winch-controlled riser inspection.
- Tool customization for specific challenges like thick-walled bends, ovalities, or protrusions.

Introduction to Unpiggable

The challenges posed by upstream pipelines, especially those in remote areas and offshore networks, are significant, requiring careful consideration of logistics, safety measures, and specific operational difficulties. The unpiggable nature of many in-field pipelines adds an extra layer of complexity to routine maintenance and inspection procedures.

Offshore in-field pipelines are generally even more difficult to pig. While most main export lines are engineered to allow frequent pigging operations, both to prevent debris build-up as well as to perform inspections, most in-field lines are more challenging and often considered unpiggable.

The hostile environment has quite some consequences for the basic design of the pipelines. Riser pipes are vulnerable, especially in the splash-zone. Some designs use cladded, duplex, or stainless steel constructions or barriers, yielding their own inspection challenges. But usually, a riser is constructed with a thick wall thickness for corrosion allowance. Although most newly constructed risers might have been engineered with a single inner diameter to allow smooth flow and support pigging, most such structures worldwide have yet to be developed without such considerations in mind. As a result, diameter changes on both topsides and subsea are commonality rather than an exception.

As offshore fields have expanded over time, new platforms have been constructed, new wells drilled, and new pipelines laid. Nevertheless, as pipelines require significant investments, a consequence has been that such new additions often were 'tied-in' to existing assets. As such, a considerable number of lines contain features like Wye-pieces, Tees, or other constructional solutions. Of course, regardless of whether it is a platform or an FPSO, the topside of the lines can pose their own challenges, like short back-to-backs, hose connections, tee-pieces, and valves.

The challenges associated with offshore pipelines are indeed multifaceted, encompassing layout complexities, unique features, demanding working environments, and safety considerations. Internal inspections become necessary in specific scenarios, given the limitations posed by the pipelines' length, location, and particular features. However, external methods face constraints in covering critical areas such as clamps and supports.

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Materials and Methods

This paper discusses using free-swimming inspection technologies for pipelines that are challenging to inspect with traditional methods.

The Technology

Through a complete and comprehensive assessment of the Subsea Operator's specifications and unique platform layout, Intero found it imperative to develop a specially designed and tailored tool to ensure the least risk possible. A complete working procedure was developed, including pump speed and choke settings to meet the required flow rate and the calculated number of barrels needed to complete the inspection. This proposed a significantly beneficial timeline for the operator, outlining procedure details, tool design and build timeline, execution phase, and final reporting to meet customer ILI criteria.

The Project

This deep water, high pressure (100 bar), inline ultrasonic inspection successfully inspected the entire riser and seabed section, executed first in 2020, and then reinspected in 2021. A further reinspection of the riser section was completed again in 2022.

Three years before the 2022 riser inspection, the riser and seabed pipeline were successfully inspected by Intero. At depths of more than 2,000 feet, the subsea section contained insignificant low-level defects that posed no immediate integrity issues. However, corrosion was detected within the splash zone of the riser section. Situated under a support clamp, visual or external inspection methods posed engineering challenges. Therefore, it was decided to reinspect the riser section in 2021 to assess its corrosion characteristics further.

The 2020/2021 inspection of the entire riser and subsea connection utilized the Surveyor UT inspection system. The Client requested an ultra-high-resolution inspection, and as the pipeline product flowed at a low rate, the ultrasonic system was selected. As the riser section wall-thickness is 0.812 (in), traditional Magnetic Flux Leakage (MFL) could not be considered due to magnetic flux limited ability to saturate thick wall pipe.

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Other mitigating factors included the restrictions associated with launching and receiving the inspection equipment. Short launch barrels 118 inches, 3000 mm restricted the length of the technology. Longer inspection equipment would incur additional engineering effort to lengthen the barrels.

Retrieval of a lodged inspection tool is costly when this occurs onshore; offshore environments significantly increase the cost of retrieval. Therefore, one consideration to reduce the overall risk of a lodged inspection tool was to use a bi-directional system while collecting multiple UT data sets at high pressure. Thus, the inspection tool can return to its original launch point by design or as a precautionary measure.

Figure 1 -Short Barrel and tool retrieval

Once configured, the tool inspected the crude oil pipeline flowing from a platform along the seabed and terminating at a second platform. At a velocity averaging 2,525 ft/h, the inspection covered approximately 110,000 feet in under 45 hrs. This pipeline was initially constructed with seamless pipe with a nominal wall thickness of 0.812 inches, corresponding to an inner diameter of ~7 inches (17.8 cm).

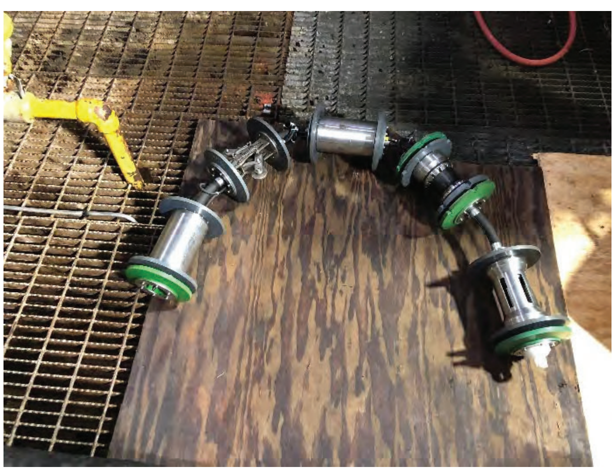

Figure 2 - Surveyor UT tool prior to launch

Seamless pipe in itself can pose a challenge for many inspection systems, as the aggressive mill process is where a steel billet is heated, pushed, or pulled until it is shaped into a hollow pipe. Then, it is extruded through a mandrel and die to reduce the outside diameter and expand the internal diameter. This manufacturing process creates a pattern within the lattes, which can sometimes mask low-level corrosion indications, especially with magnetic flux systems. Ultrasonic technology using a combination of A, B & C scans can filter out the manufacturing variances and more easily detect metal loss anomalies.

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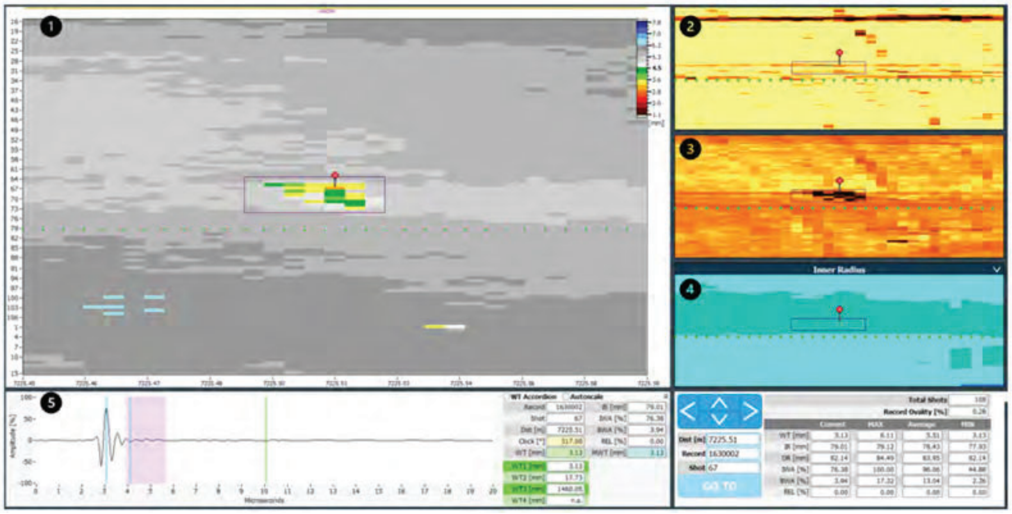

Figure 3 - Example UT Data Explained Below

Area 1:Wall Thickness C-Scan - the pipe has been represented as being unrolled and laid flat. On the x-axis distance is plotted in meters, on the y-axis clock position is plotted in degrees. The color bar in the upper-right corner shows the relation between the colors and the wall thickness values.

Area 2: Inner Wall Reflection Amplitude C-Scan - the pipe has been represented as being unrolled and laid flat. On the x-axis distance is plotted in meters, on the y-axis clock position is plotted in degrees. The color bar in the upper-right corner shows the relation between the colors and the inner wall amplitude values in percentages.

Area 3: Outer Wall Reflection Amplitude C-Scan - the pipe has been represented as being unrolled and laid flat. On the x-axis distance is plotted in meters, on the y-axis clock position is plotted in degrees. The color bar in the upper-right corner shows the relation between the colors and the outer wall amplitude values in percentages.

Area 4: Inner Radius C-Scan - the pipe has been represented as being unrolled and laid flat. On the x-axis distance is plotted in meters, on the y-axis clock position is plotted in degrees. The color bar in the upper-right corner shows the relation between the colors and the inner radius values.

Area 5: A-Scan plot - the ultrasonic signal from which all other graphical presentations are produced. On the x-axis time is plotted in microseconds, on the y-axis amplitude in percentages. The blue cursor lines correspond to the inner and outer wall echoes that were used to determine the minimum wall thickness of the anomaly.

The Amplitude C-Scans are mainly used to determine whether a particular feature is located at the inner or outer walls of the pipe. The Radius C-Scan identifies bends, ovalities, dents, and other

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features that might change the radial characteristics of the pipe. The Wall Thickness C-Scan detects and displays changes in wall thickness.

Considering that the subsea section was free of significant defects, it was decided that the 2022 inspection would utilize the bi-directional capabilities of the Surveyor tool and only inspect the riser section. Therefore, determine if the corrosion defects were active and growing. The plan was to safely pump the Surveyor UT tool to the seabed and utilize the receive platform pumps to return the Surveyor UT tool to the original launch point.

The clients' integrity group wanted to utilize the bi-directional capabilities (and therefore risk reduction) of the Surveyor tool and the tool's unique ability to record data in both directions. Thus, two passes of the same interest section enhance the complex area's resolution.

Another factor that all internal pipeline inspections must consider is the cleanliness of the pipeline. Crude oil pipelines cause a particular challenge, as when the product temperature falls, paraffin wax drops out to the product, obstructing both magnetic and ultrasonic sensors. Thus reducing or even wholly shielding and curtailing sensor detection capabilities. Figure 4 is a photograph of the actual Surveyor inspection tool after it was recovered during the 2021 inspection. Even though the tool contains levels of crude oil, the run was successful. It was later discovered that most of the oil covering the tool was from while waiting within the receiving barrel.

Preceding the 2021 inspection campaign, Intero preselected a mix of cleaning tools designed to clean the pipeline safely before inspection. Over-aggressive cleaning or incorrect tool selection can remove amounts of wax/debris that would overwhelm the receiving capabilities of an offshore platform and, in extreme cases, completely block the pipeline. Common practice is for pipelines with known large amounts of paraffin drop-out to utilize chemical cleaning, and Intero has successfully deployed this method both onshore and offshore.

Figure 4 - Condition of the tool when received in 2021

Preceding the 2021 inspection, Intero mobilized a number of cleaning tools, each designed to slowly remove debris at a manageable rate for the operator to receive. Overall conditions and debris levels were lower than expected, and the Surveyor UT tool was launched behind two cleaning tools to ensure a clear path forward.

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The proven approach was conducted for the cleaning of the riser section in 2022. Cleaning pigs pushed any debris in the riser ahead of the Surveyor tool, and then separately, both the Surveyor tool and cleaning tool were received topside. To ensure safe retrieval, Intero utilized a tracker unit. Small modifications to the Surveyor tool ensure the tracker signal could be detected through the thickwall riser section.

Reporting

Regardless of the technology deployed to inspect an asset, the final deliverable, the report, is the most significant aspect. The operational planning and cooperation between vendor and operator aim for successful data collection. Data sets from 2020, 2021 were compared to both data sets collected in 2022. Indeed, levels of external corrosion had spread from a volumetric perspective; however, interestingly, it was not significant from a depth perspective.

The operator deployed various external mitigation methods, one of which is using a bio-degradable spray to shield the slash zone area from the elements. This method has undoubtedly reduced the historical corrosion growth mechanism. Still, it could not wholly stop new low-level corrosion from being initiated, be it at a shallow sub-five percent wall thickness level. Also, this further superficial corrosion could have been there during the previous 2021 inspection, but it was too shallow to be detected in the complex mechanically supported section of the riser.

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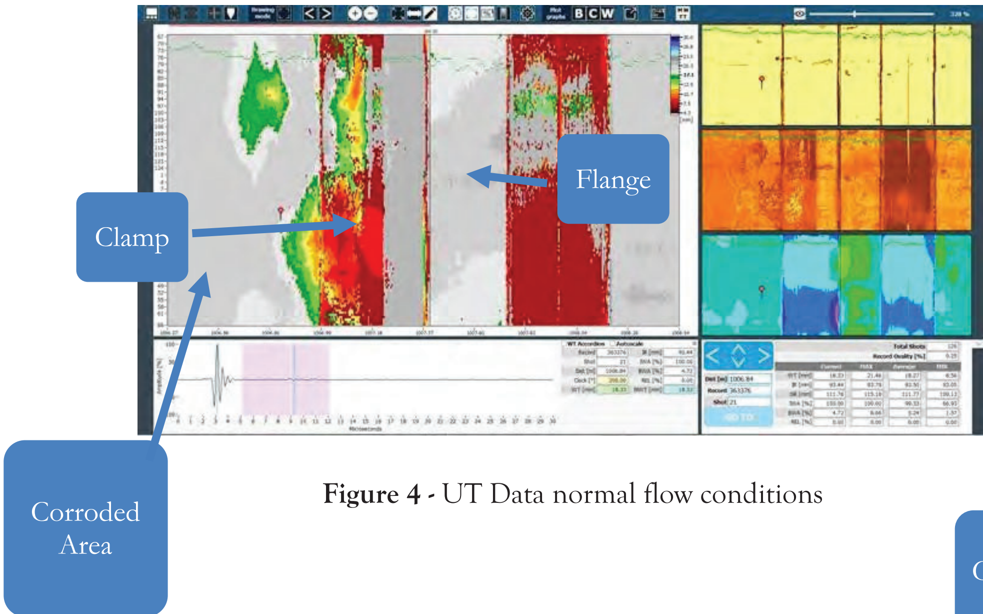

Figure 4 - UT Data normal flow conditions

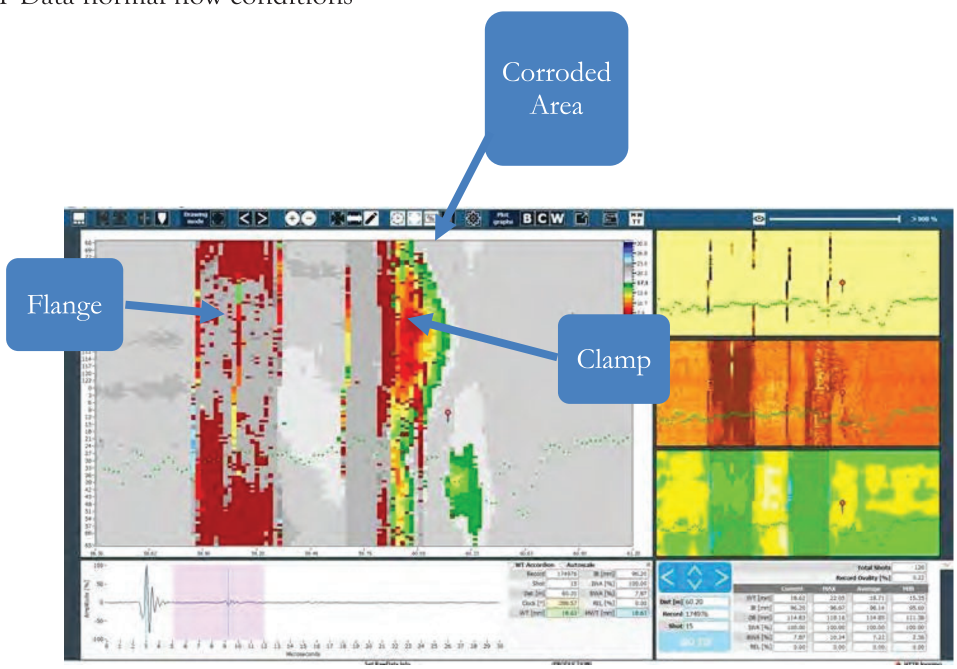

Figure 5 - UT Data recorded during reverse flow conditions

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Year	Distance at last inspection reported (ft)	2020-2021		2021-2022	
		Local corrosion growth (in)	Local corrosion growth rate (in/year)	Local corrosion growth (in)	Local corrosion growth rate (in/year)
2021 / 2022	37.11	0.1397	0.1397	0.0276	0.0276
2020 / 2021 / 2022	58.89	0.0097	0.0097	0.0706	0.0706
2022	59.22	-	-	0.0568	0.0568
2022	59.58	-	-	0.1413	0.1413
2022	59.84	-	-	0.1299	0.1299
2021 / 2022	61.29	0.1145	0.1145	0.0463	0.0463
2021 / 2022	61.52	0.1145	0.1145	0.0406	0.0406
2022	62.20	-	-	0.1421	0.1421
2022	63.02			0.0974	0.0974
2022	66.80	-	-	0.1551	0.1551
2020 / 2021 / 2022	77.07	0.0398	0.0398	-0.0114	-0.0114
2022	78.02	-	-	0.2980	0.2980
2021 / 2022	477.46	0.1470	0.1470	-0.0049	-0.0049
2020 / 2021 / 2022	477.56	-0.0065	-0.0065	-0.0081	-0.0081
2021 / 2022	477.59	0.1429	0.1429	-0.0097	-0.0097
2020	872.07	-	-	-	-
2020 / 2021 / 2022	1116.70	0.0057	0.0057	-0.0406	-0.0406
2021 / 2022	1276.31	0.1242	0.1242	0.0300	0.0300
2021 / 2022	1395.08	0.1413	0.1413	-0.0260	-0.0260
2021 / 2022	1395.24	0.1575	0.1575	-0.0390	-0.0390
2021 / 2022	1474.64	0.1324	0.1324	-0.0008	-0.0008

Figure 6 - Corrosion Growth Rates

2020 Inspection					2021 Inspection					2022 Inspection				
Distance (ft)	Clock Position (o'clock)	d peak (%)	Length (in.)	Width (in.)	Distance (ft)	Clock Position (o'clock)	d peak (%)	Length (in.)	Width (in.)	Distance (ft)	Clock Position (o'clock)	d peak (%)	Length (in.)	Width (in.)
-	-	-	-	-	36.42	11:38	17.2	2.56	3.86	37.11	11:54	20.6	17.28	14.61
58.21	n.a.	28.6	3.31	22.09	58.00	n.a.	29.8	3.54	27.09	58.89	n.a.	38.5	8.43	27.09
										59.22	n.a.	36.8	16.42	27.09
-	-	-	-	-	-	-	-	-	-	59.58	9:08	17.4	7.99	4.29
-	-	-	-	-	-	-	-	-	-	59.84	5:54	16.0	1.85	2.60
-	-	-	-	-	60.02	11:42	14.1	0.63	0.63	61.29	0:18	19.8	19.09	14.84
-	-	-	-	-	60.87	10:34	14.1	0.59	0.63	61.52	0:00	19.1	23.90	16.14
-	-	-	-	-	-	-	-	-	-	62.20	9:08	17.5	6.38	3.23
-	-	-	-	-	-	-	-	-	-	63.02	11:14	12.0	0.71	0.20
-	-	-	-	-	-	-	-	-	-	66.80	n.a.	19.1	1.06	0.63
76.91	n.a.	75.1	20.51	21.93	76.81	n.a.	80.0	20.31	27.09	77.07	n.a.	78.6	18.03	27.09
-	-	-	-	-	-	-	-	-	-	78.02	n.a.	36.7	9.88	15.47
-	-	-	-	-	475.97	n.a.	18.1	0.39	0.87	477.46	n.a.	17.5	0.63	0.87
475.31	4:58	18.9	2.28	1.42	476.05	n.a.	18.1	2.28	1.50	477.56	n.a.	17.1	2.52	2.17
-	-	-	-	-	476.10	n.a.	17.6	0.91	1.50	477.59	n.a.	16.4	1.06	1.93
872.07	0:40	22.8	6.26	1.22	-	-	-	-	-	-	-	-	-	-
1111.06	1:02	20.9	1.50	1.02	1113.15	n.a.	21.6	1.26	1.30	1116.70	n.a.	16.6	1.22	1.50
-	-	-	-	-	1272.26	n.a.	15.3	0.43	1.50	1276.31	n.a.	19.0	0.55	0.63
-	-	-	-	-	1390.94	n.a.	17.4	1.46	1.93	1395.08	n.a.	14.2	0.87	1.30
-	-	-	-	-	1391.08	n.a.	19.4	0.43	0.87	1395.24	n.a.	14.6	0.59	1.73
-	-	-	-	-	1470.35	11:08	16.3	0.83	0.63	1474.64	n.a.	16.2	0.67	0.43

Figure 7 - Riser Corrosion Growth Comparison

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Conclusion

Post inspection, a summary of anomalies based on standard requirements and calculations was reported, including categorized metal loss anomalies and the most severe ones overall.

A detailed defect assessment of the corrosion anomalies was also performed and documented. With this data, Intero was able to identify the corrosion growth rate.

Key factors that were considered and led to a successful campaign were;

- Tool design to meet customer ILI program (pre-build).
- The short length of the Survyor tool nullifies any pre-engineering barrel modifications.
- Surveyors' detection and sizing performance in the seamless pipe.
- Ultrasonic thick wall capabilities.
- Successful progressive cleaning approach.
- Tool bi-directional capability enables two shots at the same area of interest.
- Experienced offshore Project Management (PM) throughout the entire pre/post-project.

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