MODERN ILI OF SUBSEA PIPELINES AND RISERS: CAPABILITIES FOR CHALLENGING PROJECTS

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ABSTRACT.
Managing risk and the performance of offshore oil and gas pipelines has become increasingly important in recent years. In-line inspection (ILI) technologies remain the preferred assessment method because ILI delivers extensive evaluation and comprehensive analysis fundamental to sustained pipeline safety, effective integrity management and optimized operations. Historically design and operational challenges prevented ILI tools from inspecting many non-traditional and difficult offshore pipelines.

This paper will demonstrate solutions that have worked in typical offshore environments. By examining the results of successful applications and understanding how inspection data is used for assessment and asset management, we can recognize how inspection methods tie-in to the bigger picture and the overall decision making process.

INTRODUCTION

Pipeline failures in the oil and gas industry continue to draw attention to the effectiveness of corrosion damage assessment methods, connected regulations and the prerequisite for accurate understanding of the physical condition of pipelines during sustained activity. Historically, pipeline assessment methods have been treated with equal prescriptive weighting. However, coupled with an aging infrastructure and increasing demands, operators are accepting that some previous systems of measurement and evaluation may no longer be sufficient for continued safe, reliable and efficient operations.

Accepting that improved safety and optimized performance is the goal, it remains difficult to achieve in such a dynamic environment. For example:

- Acquiring, training and retaining internal subject matter experts (SME) has become challenging with the competitive job market and retiring personnel.
- Some pipeline assets must perform in conditions beyond which they were originally intended or designed.
- Pipelines are acquired, not always with a complete transfer of records, pipeline familiarity or sufficient threat assessment.
• Operators “don’t know what they don’t know” (e.g. current inspection technology/capabilities, updated integrity strategy, unidentified threats).

Consequently, many pipeline operators are revisiting their established Integrity Management Programs (IMP) with a keen eye towards more modern, more effective solutions. As the public watches, perfunctory regulatory compliance is making way for active integrity management (see Figure 1).

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FIGURE 1. Ten separate headlines from February 1, 2012.

**SUBSEA CONSIDERATION**

Determining and prioritizing risk for offshore assets is generally no different than onshore assets although the consequences of failure are often elevated. ILI remains the preferred subsea inspection method because it delivers the most effective, best potential for extensive data evaluation and comprehensive analysis fundamental to sound engineering principles. Obtaining such comprehensive pipeline data is typically more difficult due to remote locations, limited access, challenging designs and extreme operational parameters. Inspection options are limited while expenses and timelines greatly increase.

Even as today’s ILI capabilities have improved as a whole, the continued development of deepwater fields requiring higher pressure ratings and the resultant thicker walled pipe, connectors, valves and fittings reinforces the barriers that many existing tools face (see Figure 2).
FIGURE 2. This slide depicts common difficulties for traditional ILI tools.

Opportunities for better capabilities in challenging projects not only exist in transmission lines, but also for the lesser regulated production and flow lines (U.S. Department of Interior-30 CFR Part 250: Code of Federal Regulations).

In response, we see providers pushing both the boundaries of ILI tools and what is considered conventional thinking. The traditional method of balancing known piggability limitations against budgets, comparing design or line modifications with less comprehensive integrity assessment methods is required less often. In other words, what used to be challenging is no longer the case.

MODERN INSPECTION APPROACH

To address the opportunity in the subsea environment, ILI tools have advanced via evolution and foresight. For instance, no longer is a constant bore or 3D minimum bend radius a pre-condition. Presently, there are cost-effective technologies providing modern in-line inspection solutions for challenging subsea pipelines. Quest Integrity Group’s InVista™ platform offers one such solution.
The proprietary InVistatechnology is an intelligent tool capable of rapid, automated, ultrasonic (UT) inspection of unpiggable pipelines up to over 100 miles in length. The tool platform derives from furnace tube inspection technology and has been used to inspect refinery heater coils during short notice emergencies and plant turnarounds since the 1990s (Figures 3a, b).

FIGURE 3a. Technology designed from inception for challenging projects.
As a global leader in challenging inspections, Quest Integrity Group is not a conventional provider. By focusing only on difficult and challenging environments, the company leaves ordinary surveys for commodity vendors.

The unique navigational abilities of the InVista platform are re-classifying piggability (Figures 4). This free-swimming, self-contained platform was designed from the outset to successfully inspect and perform in-challenging pipe systems. InVista’s superior design foregoes the risk associated with modifying conventional ILI tool configurations or attempting unproven design(s).
InVista overcomes many operational challenges in a single package:

- All tools are bi-directional (BIDI), dual-diameter capable, and navigate multi-diameter pipelines
- All tools negotiate 1.0D bends, including back-to-back and mitre bends
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- All tools can be hand carried, lifted, loaded and transported
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Moreover, modern data acquisition and integrity assessment methods allow the best possible understanding of actual current pipeline conditions. InVista makes use of direct measurement ultrasonics, producing higher resolution data sets with tighter tolerance and more accurate flaw sizing. Providing this data allows precise wall-thickness values and deformation data in objective, absolute figures.

Because of the unique sensor configuration, the tool remains unaffected by additional signal degradation (“noise”) that can diminish resolution and adversely affects defect characterization for tools that have sensors riding directly on the pipe surface. Confidence levels are inherently higher because the raw data is better.

**IMPROVED PIPELINE ASSESSMENT**

The magnitude of pipeline rehabilitation and repair work is greatly affected by tool tolerances. The best tolerances result in the fewest repairs, which can mean savings in time and money for the operator.
Accordingly, choosing to run tools with tighter tolerances increases operator efficiencies and decreases waste allowing more effective decision-making. It is especially important in offshore pipelines to determine whether a particular flaw exceeds established criteria for safe and reliable operation, or if it will exceed criteria before the next inspection interval.

At present, most ILI inspection in offshore pipeline systems employ tools based on magnetic flux leakage (MFL) technologies. Simply put, the MFL data sets record influences to a calibrated magnet circuit based on nominal wall-thickness throughout a pipeline. Defects are identified, subjectively interpreted, and then depicted or “boxed” using length and width with a rectangle containing the corresponding wall-loss data dimensions of flaws. Modern software enables analysts to estimate the geometry of the flaws (e.g., parabolic or river bottom shape) to create a richer qualitative characterization.

While software manipulation of MFL data to characterize the shape of individual flaws makes sense conceptually, it does not reduce the inherently broad tolerances in the data or increase an operator’s confidence that an indicated flaw merits excavation or further study. Such flaw-by-flaw basing in conjunction with verification is known to be resource intensive.

Compared with MFL tools, direct measurement UT inspection offers a higher return on investment due to accuracy driven efficiencies and providing superior results. UT inspection outputs a digital map of individual wall-thickness readings, ideally suited to effective area assessment methods such as RSTRENG and API 579 Level 2 Remaining Strength Factor (RSF) calculations.

By rapidly processing large quantities of ILI wall-loss data and evaluating the MAOP at distinct locations, ranking of these MAOP values serves as a rational and rapid means for prioritizing the severity of corrosion throughout a pipeline. With UT’s improved confidence and precision, operators are able to increase profitability, maximize resources and prepare more effective risk mitigation.

**VALUE IN UNDERSTANDING**

Offshore operators of all sizes seek ways to minimize expenditures relating to operations at the same time as maintaining safe, profitable and compliant inspection programs. Since inspections and repairs are usually budgeted years in advance, it makes sense to plan as well as possible.

Keeping up to date with the more advanced-in-line inspection and assessment technology is an initial step to reduce overall costs for their non-traditional pipelines because understanding current capabilities defines the operator’s return on investment. Similarly, increasing accuracy in locating and defining anomalies along with improving fitness-for-service (FFS) conditions can reduce maintenance costs while developing a better understanding of the current and future pipeline condition.

By fully employing the detailed inspection data that an advanced UT ILI tool can provide, operators are able to be proactive rather than reactive in their remediation and scheduling. This practice allows for better planning of inspection frequencies, corrosion growth
analysis as well as repair and mitigation plans. The ability to avoid unnecessary repairs caused by overly conservative assessment methodology saves operators money for other inspection or remediation projects.

Providing an overall cost savings and a sophisticated assessment of data, FFS is particularly well suited for offshore pipelines, as there is an increased likelihood of flaws or other damage being present. When utilized to this level however, a high resolution UT dataset combined with the FFS assessment is of enormous benefit to all pipeline assets because the real value lies in the fact that now operators have the power to predict and schedule before failures can occur.

The general result of the FFS assessment is a go/no-go outcome based on engineering principles for continued pipeline operations and current parameters. This multi-disciplinary approach calculates the failure condition of a defect and compares it with the operating and design limitations of the structure components. When running UT tools, this is a simple, precise computation because all valid pipeline wall-thickness readings are considered (Figure 5). In contrast, the measurements used in most MFL assessments ignores up to 99% of the wall-thickness data (Level 1 B31G modified acceptance criteria).

![InVista reports all data instead of just boxing flaws so you are able to look at the entire profile of an anomaly instead of mapping a single point. Better characterization of defects allows for greater accuracy when comparing datasets and is not overly conservative.](image)

The FFS Level 2 assessment of metal loss determines an effective-area method where a “riverbottom” profile is constructed from the wall-thickness measurements which are used to compute revised MAOP ratings (API 579-1/ASME FFS-1 2007). These calculations are typically performed over joint sections between girth welds of pipe though a single rating may be assigned for an entire pipe section.
Using this method results in a more technically sound MAOP and is less intensive and less subjective than flaw boxing. These advanced assessments provide the operator with greater value from each individual inspection, and now the operator can be proactive instead of reactive, addressing issues with this pipeline before problems arise.

CASE STUDY I
South Pacific

Quest Integrity was approached to inspect three South American subsea pipelines:

Line 1 was an 8” crude line running from a platform to shore. A geometry survey determined the scheduled MFL inspection would be blocked due to restrictions. InVista measured the minimum internal diameter (ID) at 6.77” (172mm). More surprisingly was the identification of a 5ft (1.5m) section where a sleeve had been used for repair. The ID in this section expanded from 8.03” (204mm) to 9.25” (235mm) which would have stalled out most ILI tools (Figure 6).

**FIGURE 6.** InVista passed with ease through this sleeve welded over a 5ft section subsea repair. The ID increased by 1.5”. Limited data collection is observed because the client was not able to clean the paraffin in the sleeved section nor was the 8” pipeline tool configured for dual-diameter measurement.

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Line 3 was a short 8” crude oil connector line running between two platforms. Here a gauge plate established pipeline ID from 7.28” (185mm) nominal to 6.5” (165mm)—a 15% reduction of the riser pipe—and also wall-loss
of 88%. Further, this line had limited pressure which was insufficient for conventional ILI tools (116 psi – 8bar).

The risers of all three pipelines had been inspected separately from the main pipelines by another company that specializes in riser inspections (0.500” – 12.7 mm). Several of the risers were connected to the main pipeline with a flex pipe (Figure 7). Although InVista does not measure the wall-thickness of the flex pipe, it does provide a complete geometry reading of the flexible pipe section.

![Image of InVista geometry reading](image1)

**FIGURE 7.** Change from the riser pipe to the flex pipe. Even without complete wall-thickness data in the flex hose, Quest Integrity can provide a good inner radius picture, and detection of damage to the flex hose.

The client was very pleased with the complete inspection of their pipelines. Some of the differences that the client noted were:

- The ease of operation: There was no heavy lifting for the operators or bulky transport. All tools were hand-carried and the crew arrived at the platforms via helicopter. Time for
tool set-up and launch was less than 15 minutes. InVista was accommodated in existing cleaning pig traps.

- Data presentation: Within hours of the inspection, the client was presented a site completion report indicating data quality, pipeline cleanliness and location(s) of debris.

- Complete inspection: The InVista inspection covered the complete pipeline, including the riser (Figures 8a, b). Because the risers are normally made out of pipes that have a considerable thicker wall-thickness than the main pipeline plus various metallic features like clamps are normally attached to it (Figures 9a, b), MFL tools have difficulty measuring corrosion in the riser.

- Reporting: The standard reporting time for InVista inspections is 30 days. The client was used to a reporting time ranging from 45 to 90 days. The report includes the full wall-thickness, deformation and remaining strength calculations represented in a user-friendly software package.

- Value: The client was appreciated that the quote was a complete package that included time to allow for some expected delays, coordinating a realistic inspection schedule, and the flexibility of deployment of the InVista tool (reruns could be performed within the hour if needed). Teams were responsive with short notice, coming in after another vendor’s effort.

FIGURE 8a& b. Riser corrosion.
FIGURE 9a. Corrosion often found on the riser under clamps is easily identified using ultrasonic technology, but usually remains undetected with standard MFL inspections.

FIGURE 9b. UT scan of corrosion under riser clamp.
CASE STUDY II
Arabian Gulf

Quest Integrity was asked to inspect a subsea pipeline that sat dormant for 2.5 years:

The 6” multiphase infield well-head to production platform pipeline had been mothballed and no traps were installed. The turn-key scope included supply of traps (Figures 10 a, b), connection hoses, cleaning, inspection, analysis and providing a full fitness-for-service pipeline assessment report (API Level 2). The engineering deliverable was valuable information for the client because they planned to reinstate the line for use following a $5 MM drilling investment.

The InVista tool identified wall-thickness changes that were not in the as-built drawings and defects in that thinner section. Minimum cleaning was required due to tolerance of the inspection tool, only two foam pigs runs were required (Figure 11). Good data was gathered—first run success—and the entire survey was completed in less than 1.5 hours.

As built drawings stated 0.562” wall (14.3mm) for some pipe sections, however the InVista tool provided information on actual wall-thickness data at 0.405” (10.3mm) along with identifying an area of external corrosion in this thinner wall with 41% metal loss (Figures 12 a, b, c).

FIGURES 10a. Installed temporary launcher.
FIGURES 10b. Installed temporary receiver.

FIGURE 11. Pipeline debris.
The client was very pleased with the complete inspection of their pipelines. Some of the noted advantages associated with InVista were:

- No infrastructure modifications were required; geometry and wall-thickness data provided in a single run resulting in a cost savings for the operator.
- Superior navigational capabilities including short radius back-to-back, unbarred off-takes, and pipe schedule changes including heavy wall.
- Bi-directional, low flow/low pressure and industry leading minimized tool passage requirements.

- Fully integrated, API 579 Compliant Level 2 Fitness-for-Service (FFS) assessment included as standard deliverable (Figures 13).
FIGURES 13. Examples of general corrosion, corrosion under support, and deformation.

CONCLUSIONS

Advances in modern approaches and comprehensive data assessment for in-line inspection of challenging subsea pipelines offer material improvements over past methods. Historically, the sequence of gathering overly conservative ILI data or reduced quality created a great deal of extra work, frittered away time, depleted scarce budgets and inhibited proper prioritization.

Corrosion causes and flaw calculations are critical in determining the remaining working life of the pipeline asset, its inspection interval, future repairs and operational efficiencies. Using modern approaches, offshore operators have a better understanding of the physical condition of the pipe and the unique degradation mechanisms affecting it.

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![Welded patch with corrosion](image)
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tool set-up and launch was less than 15 minutes. InVista was accommodated in existing cleaning pig traps.

- Data presentation: Within hours of the inspection, the client was presented a site completion report indicating data quality, pipeline cleanliness and location(s) of debris.

- Complete inspection: The InVista inspection covered the complete pipeline, including the riser (Figures 8a, b). Because the risers are normally made out of pipes that have a considerable thicker wall-thickness than the main pipeline plus various metallic features like clamps are normally attached to it (Figures 9a, b), MFL tools have difficulty measuring corrosion in the riser.

- Reporting: The standard reporting time for InVista inspections is 30 days. The client was used to a reporting time ranging from 45 to 90 days. The report includes the full wall-thickness, deformation and remaining strength calculations represented in a user-friendly software package.

- Value: The client was appreciated that the quote was a complete package that included time to allow for some expected delays, coordinating a realistic inspection schedule, and the flexibility of deployment of the InVista tool (reruns could be performed within the hour if needed). Teams were responsive with short notice, coming in after another vendor’s effort.

FIGURE 8a & b. Riser corrosion.
FIGURE 9a. Corrosion often found on the riser under clamps is easily identified using ultrasonic technology, but usually remains undetected with standard MFL inspections.

FIGURE 9b. UT scan of corrosion under riser clamp.
CASE STUDY II
Arabian Gulf

Quest Integrity was asked to inspect a subsea pipeline that sat dormant for 2.5 years:

The 6” multiphase infield well-head to production platform pipeline had been mothballed and no traps were installed. The turn-key scope included supply of traps (Figures 10 a, b), connection hoses, cleaning, inspection, analysis and providing a full fitness-for-service pipeline assessment report (API Level 2). The engineering deliverable was valuable information for the client because they planned to reinstate the line for use following a $5 MM drilling investment.

The InVista tool identified wall-thickness changes that were not in the as-built drawings and defects in that thinner section. Minimum cleaning was required due to tolerance of the inspection tool, only two foam pigs runs were required (Figure 11). Good data was gathered—first run success—and the entire survey was completed in less than1.5 hours.

As built drawings stated 0.562” wall (14.3mm) for some pipe sections, however the InVista tool provided information on actual wall-thickness data at 0.405” (10.3mm) along with identifying an area of external corrosion in this thinner wall with 41% metal loss (Figures 12 a, b, c).

FIGURES 10a. Installed temporary launcher.
FIGURES 10b. Installed temporary receiver.

FIGURE 11. Pipeline debris.
FIGURE 12a. External defects with 41% wall-loss where records indicated thicker than actual pipe.

FIGURE 12b. Three internal corrosion points max at 25.9% metal-loss.

FIGURE 12c: Three dents identified at 3.2% of pipe OD.

The client was very pleased with the complete inspection of their pipelines. Some of the noted advantages associated with InVista were:

- No infrastructure modifications were required; geometry and wall-thickness data provided in a single run resulting in a cost savings for the operator.
- Superior navigational capabilities including short radius back-to-back, unbarred off-takes, and pipe schedule changes including heavy wall.
- Bi-directional, low flow/low pressure and industry leading minimized tool passage requirements.

- Fully integrated, API 579 Compliant Level 2 Fitness-for-Service (FFS) assessment included as standard deliverable (Figures 13).
FIGURES 13. Examples of general corrosion, corrosion under support, and deformation.

CONCLUSIONS

Advances in modern approaches and comprehensive data assessment for in-line inspection of challenging subsea pipelines offer material improvements over past methods. Historically, the sequence of gathering overly conservative ILI data or reduced quality created a great deal of extra work, frittered away time, depleted scarce budgets and inhibited proper prioritization.

Corrosion causes and flaw calculations are critical in determining the remaining working life of the pipeline asset, its inspection interval, future repairs and operational efficiencies. Using modern approaches, offshore operators have a better understanding of the physical condition of the pipe and the unique degradation mechanisms affecting it.

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