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From Ship to Shore: In-Line Inspection of Loading Pipelines

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Introduction

A substantial amount of hydrocarbons are transported via the world's waterways every day. This includes the transport of crude oil, gasoline, diesel fuel, and other bulk chemicals used to power the things that keep our world moving. This transport is done via ships (oil tankers) and barges over our oceans, seas, rivers, and canals. In terms of tonnage, oil tankers account for nearly 30% of global seaborne trade and each time they need to load or unload, they do so by connecting to a loading pipeline at an in-port terminal facility or a near-shore pipeline end mooring (PLEM) system. While loading pipelines aren't typically lengthy, they are a critical component in the global energy supply chain. Given their location near, above, or in water, loading pipelines are almost always situated in high consequence areas (HCAs).

Loss of containment for loading pipelines can have serious consequences for the environment as well as economic consequences due to loss of use of the pipeline or shutting down the port during cleanup operations. Inspection and maintenance considerations have not traditionally been high on the priority list during the design of loading pipelines. Most are not fitted with launching or receiving facilities for pigs, and access for external inspection is often limited. Traditionally, a combination of limited (i.e., spot check) external inspections and hydrotesting has been used to ensure that loading lines are fit-for-service and therefore safe to operate. This article discusses the advantages of advanced in-line inspection (ILI) technology combined with progressive cleaning to improve data acquisition and increase inspection intervals in loading lines. ILI combined with supplemental external techniques can provide the information for a comprehensive integrity management plan and the details required for preventive and mitigative measures to ensure that loading pipeline can be operated safely and responsibly for years to come.

Inspection Challenges

Safety and Economic

Access challenges present safety and economic concerns when considering manual or nondestructive examination (NDE) inspection methods. Loading pipelines are often located above, in, or near water, thus situating them in high consequence areas. This means that a loss of containment would result in impactful environmental consequences as well as supply chain and economic disruptions. Areas of the pipeline that are at particular risk for corrosion include contact areas with pipe supports, welded features, locations of damaged coating, areas of concentrated salt exposure via spray/immersion in the splash zone, areas experiencing a bio-chemical reaction (e.g., bird droppings also known as guano), and locations of anchor impacts (in subsea sections).

While above-water sections of loading pipelines may lend themselves to the use of rope access and/or scaffolding, boat or floating platform use can be challenging as access can often vary (**Figure 1**) by 20 feet or more depending upon the tide and season, and this can severely limit the timeslots available to inspect and/or maintain the pipeline. Additionally, such often inhibit complete (360°) exterior inspection, and make coating applications (or re-applications) difficult at best, especially if the inspection technique being used requires coating removal.

Subsea sections are complicated by marine fouling (e.g., barnacles, coral, and other growths on the pipe) and other physical barriers—such as cement weights, external coating, and sediment obstruction—all of which render the external inspection techniques challenging to implement for substantial sections of loading pipelines. Although underground pipeline sections present fewer safety issues, the physical location necessitates more costly and laborious access concerns, including excavation, shoring, and coating removal/reapplication (**Figure 2**).

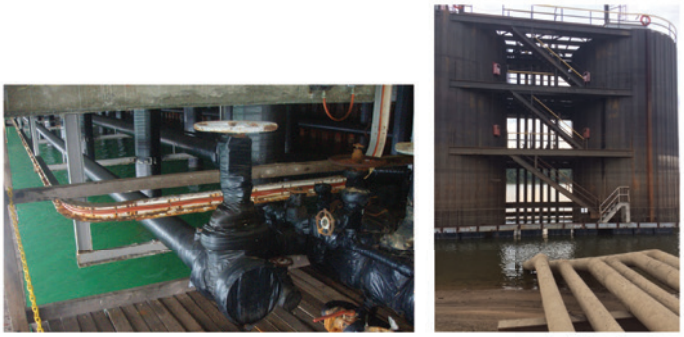

Figure 1. Examples of tide-limited loading line locations.

Figure 2. Example of access concerns when inspecting externally.

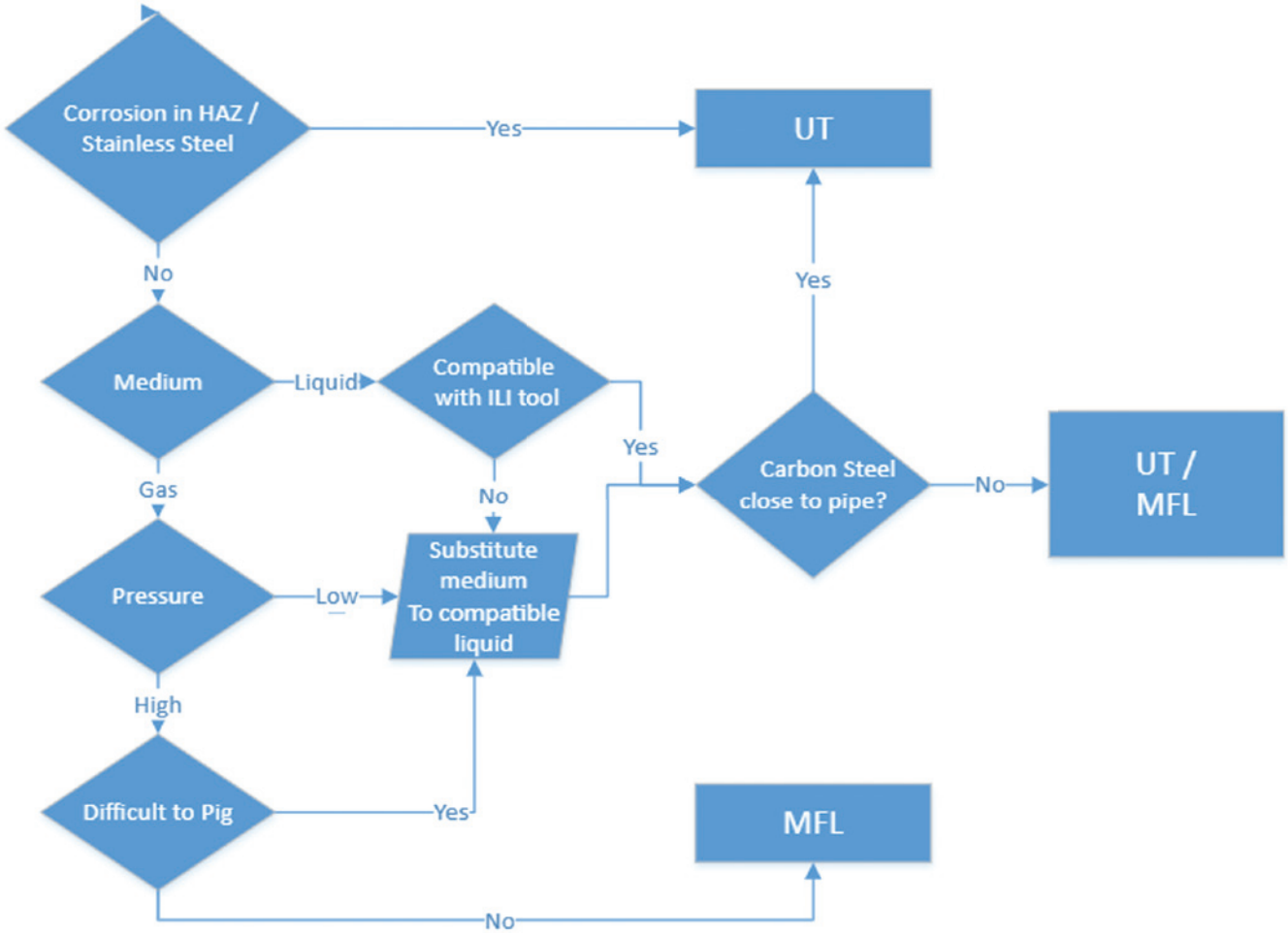

Figure 3. Inspection methodology decision tree.

These access issues above underlie significant economic challenges to performing external inspections on loading pipeline sections. Additional economic factors to note include ancillary variables like hydrostatic test wastewater disposal, scaffold installation, removal and reinstatement of insulation and coating, and lifting of pipes.

Technological Limitations

External and internal (ILI) NDE inspection methods have technical limitations. Both approaches play important roles in pipeline integrity management, and each carries distinct limitations. Hydrostatic testing can provide a one-time, maximum hold pressure snapshot that indicates if a leak is present at the time of the test, but it offers no actionable information about the overall pipeline material condition. Additionally, hydrostatic testing can exacerbate integrity issues. A hydrostatic test normally applies a pressure greater than the MAOP of the pipeline for a period of time. Small anomalies like cracks could be weakened by this without leading to a loss of containment during the hydrostatic test, but it could result in a leak later during normal operations with product in the pipeline. A hydrostatic test is capable of informing whether repair or replacement is needed; it cannot project or predict future metal loss.

External NDE is useful for detecting flaws and corrosion, but can be limited by access restrictions of the varying inspection technologies. The unique access issues that affect loading pipelines also present safety concerns discussed in the previous section. The data gathered by external NDE is often limited in its coverage given the challenges of achieving physical access to the entire pipeline. Selection of areas to inspect with external NDE is often based on accessibility and suspected integrity issues. However, it can be very difficult to predict these areas of concern based, for example, at visible insulation damage and/or low points given the potential for unknown integrity mechanisms. Moreover, external NDE data quality can vary widely among inspection technologies and providers, and combining data sets from different technologies, each with a different reporting format and accuracy, can present a challenge in and of itself.

Advance In-Line Inspection

A solution to these challenges and limitations is to inspect the loading pipelines from the inside using advanced in-line inspection (ILI) technology. Advanced ILI technology is capable of accurate, consistent, and predictive results. ILI is designed to assess pipeline integrity by detecting and evaluating potential defects

efficiently and cost-effectively from within the pipeline. Internal access allows the technology to detect both internal and external defects including corrosion, dents, bulges, and ovality along of the entire internal surface area. It also eliminates the need to remove and replace external coatings and insulation.

When combined with a progressive cleaning pig program, advanced ILI can capture high-resolution, full-coverage data. While many loading pipelines have often not been originally designed for pigging operations and frequently have features that have historically made them "unpiggable," modern ILI tools are specifically designed to navigate challenging features such as back-to-back bends, short radius bends, multiple diameters, and bi-directional requirements, and can overcome these pigging challenges. Loading pipelines that terminate subsea into a PLEM provide a unique challenge. These pipelines were sometimes designed with removable subsea launchers and receivers, or as a looped system. If such launchers/receivers are still functioning, then operation of them can be a significant undertaking. With the aid of subsea tracking systems, these pipelines can be cleaned and inspected with minimal work executed below the water line, thus improving efficiency and minimizing risk. Advanced ILI can also overcome complex geometries and only require one or two access points to inspect most of the pipeline, thus reducing safety concerns while solving access problems seen with other common inspection methods.

ILI inspections are commonly thought to be expensive compared to traditional external inspections. This is true if the focus is only on the cost of the inspection and not the total project cost, which includes access to the pipe and removal and reinstatement of the coating and/or insulation. Moreover, covering the entire section of pipeline with a high-quality singular data set versus a partial inspection for most external methods vastly increases the value case of an ILI inspection from an integrity management perspective.

A decision tree (**Figure 3**) has been developed to aid operators in deciding among the leading ILI technologies—magnetic flux leakage (MFL) and ultrasonic testing (UT). When selecting an ILI technology, operators must consider tool specifications and requirements. The technology must be compatible with the medium, meet accuracy and sizing requirements, and be suitable for the expected damage mechanisms. Operators must also consider the pipeline restrictions and navigation challenges, including whether a bi-directional run is required; the minimum bend radius; and the presence of miter bends, dual-diameter pipe, check valves, or un-barred tees.

Project Execution and Results

An ILI project begins with site and launcher/receiver preparation and pipeline cleaning using a progressive cleaning pig program to remove sediment and debris. It is important to note that areas of accumulated sediment can cause corrosion that may not be detectable via hydrostatic testing or external NDE methods. Where available, existing access points will be used to initiate cleaning and ILI, but modifications may be required to accommodate the tools. Possible access points (**Figure 4**) include:

- Blind flange
- Spool removal
- Removal of valve/inserting bend
- Pipe modification
- Existing launcher/receiver
- Temporary launcher/receiver

In subsea inspection projects, sensors should be installed near the end of the pipeline to facilitate pig tracking and ensure that the ILI tool is stopped close to the PLEM, and before the point of no return, if there is any. This practice maximizes inspection length while minimizing risk.

Figure 4. The location depicted in Figure 2 is now prepped for ILI via spool removal and the addition of temporary spools, valve, and launcher/receiver.

Cleaning is required prior to ILI because it confirms if the line is piggable and results in better quality inspection data. Loading pipelines can sometimes act like settlement tanks, and operators are sometimes unaware of the large amounts of sediment have accumulated over the years. Due to the relatively low-flow conditions in the loading pipelines, even "clean" products can leave a substantial amount of sediment and debris in the pipeline over time. This debris can sometimes be associated with localized internal corrosion and, when excessive, can also appear in the storage tanks. Removing debris and sediment from the pipeline can also improve the product quality. For instance, **Figure 5** shows the cleaning of a crude oil loading pipeline that resulted in 1,600 lbs of debris on its first run. Most "clean" product loading pipelines also see significant sediment removal after first-time cleaning.

The selection of the cleaning medium depends on the project goals. For instance, light crude oil can assist in removing paraffin wax and debris. Water as a medium is relatively easy to handle from the perspective of risk reduction and compatible with all ILI tools, but it can often only be used during out-of-service cleaning and ILI. Other potential cleaning media fluids include diesel fuels, gasoline, and jet fuels. Air, natural gas, or nitrogen can sometimes be used as well, but not as a cleaning media,

but rather when deploying an MFL tool. Pushing a pig with gas normally requires a higher pressure than pigging with a liquid, and this could expose a limitation if the pipeline was not designed for the higher pressure. For pipelines with challenging feature navigation, a liquid medium is advised because it allows for greater control of the pig movement compared to a compressible medium.

Figure 5. Sediment recovered from the smart pig cleaning technology.

ILI tools offer many benefits for loading pipeline operators, like facilitating inspection of large sections in a short period of time. ILI tools can also provide one data set that can be incorporated into an integrity management system, allowing for repair/replace decisions based on more complete data compared with external data, which is prone to limited coverage and can require various technologies with different reporting abilities and accuracy. When executing an ILI inspection during a shutdown or a shipping window, the downtime could be zero, thus minimizing the interruption to production. Safety risks can also be minimized by reducing the amount of time work is performed at height, subsea, in an excavation, or in an operational area. Less manpower and equipment not only lead to significant cost savings, but also reduced risk and improved safety, both on the project site and in surrounding HCAs. Further, improved data quality and consistent runs can better enable comparison and analysis of results and corrosion rates between multiple data sets when available. This is especially important to operators seeking inspection exemptions for regulated pipelines. **Figures 6** and **7** provide examples of advanced ultrasonic ILI data from loading lines.

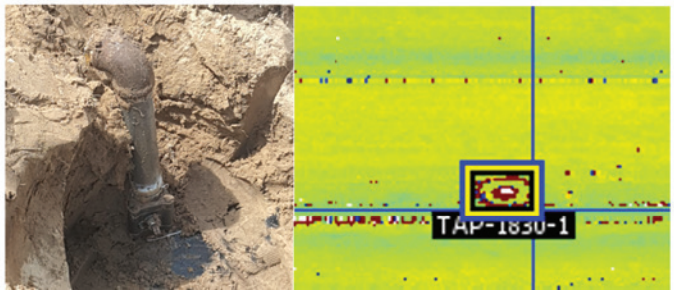

Figure 6. Illegal 2-inch tap detected in a 30-inch pipeline.

In **Figure 7**, you can see that most of the severe corrosion is concentrated on the inside of the support bracket. This location would be difficult to accurately inspect externally, as external surface preparation (to remove the protective coating) is very challenging due to the geometry of the support bracket. Moreover, the external welds of the support bracket have heat-affected zones that can increase the risk for corrosion. In **Figure 8**, you can see some examples of these welded supports.

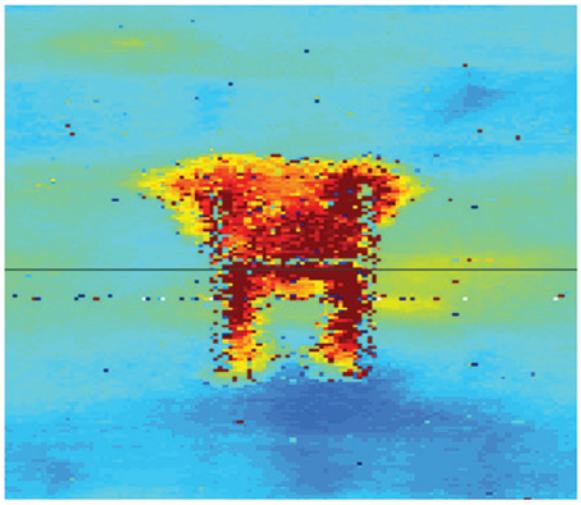

Figure 7. Detailed view of a welded "H" pipe support.

Figure 8. Examples of welded support brackets.

Conclusion

The loading pipelines from ship to shore are difficult to completely inspect with external technologies, presenting numerous accessibility and safety concerns. However, the environmental consequences and business/economic impacts of a leak in this portion of the loading pipeline can be significant to the port, to other pipelines, and to consumers/customers. Annual hydrostatic tests do not provide quantitative and actionable data, but rather only act as a "pass/fail" data point. External NDE methods can be limited in their ability to provide qualitative and quantitative data for the entire pipeline, causing operators who wish to improve their inspection and preventative maintenance plans, to strongly consider ILI inspection methods. ILI combined with a progressive cleaning program can mitigate these challenges, enabling operators to capture high-quality and complete external and internal inspection data, thus reducing equipment and manpower requirements, facilitating preventive maintenance, and minimizing safety risks. ■

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Geert Bontekoe has worked for over 20 years in the oil and gas industry. Before joining Quest Integrity in 2010, Geert worked in Seismology and fiber optic network installation in Europe and performed ILI inspections and development for A. Hak and Dacon. He also worked for TechCorr to develop new inspection applications and manage In-Service Robotic Tank inspections. Geert specializes in unpiggable pipeline inspections, development of procedures for the cleaning, batching, ILI inspections and leads projects worldwide. Since January 2019 he has been taking on the role of Service Line Manager InVista and PIMS for Quest Integrity. In March 2025 he took on the role as Sr. Technology Deployment Engineer within Quest Integrity.

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Melinda Larson is a Quality Specialist at Quest Integrity, where she develops and implements quality control processes, with an emphasis on providing clients with top-tier deliverables. Her background is in technical writing and editing, and she holds an MA in Bioethics. She has co-written, edited, and produced hundreds of technical documents for renowned journals and the USDA Forest Service on a variety of topics, from biomedical sciences to engineering and forestry.