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Inspection Methodologies and Tradeoffs for Inspection of Unpiggable Pipelines

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ABSTRACT

Recent high-profile pipeline failures have focused increased regulatory scrutiny on the integrity assessment and management of pipeline assets throughout the world. This increase in scrutiny is even more pronounced for pipelines deemed "unpiggable." While a lack of launcher and receiver facilities and limited line flow are obvious challenges, other pipeline design issues ranging from unbarred tees, to multiple diameter step changes and reduced bore valves, and even mitered or small diameter bends have historically provided inspection difficulties.

Modern advances in inspection technologies now allow for inspection and assessment of these previously unpiggable pipelines, providing today's owner-operators a varied range of inspection options. However, not only does each inspection methodology have its own related costs and benefits, but each option can have a significant and varied impact on the entire asset integrity program.

This paper utilizes multiple case studies to highlight solutions that have worked for individual operators. By examining the results of various inspection methods and detailing how inspection data is used for assessment and asset management, we can understand how inspection data ties into the larger decision making process.

Key words: Inspection, unpiggable, integrity, assessment, pipeline, corrosion, compliance

INTRODUCTION

Recent high-profile pipeline failures have focused increased regulatory^{2 3} scrutiny on the integrity assessment and management of pipeline assets throughout the world. While many piping systems have historically been deemed "unpiggable," advances in smart pigging and other inspection technology now allow for inspection of these lines. While regulatory compliance may be achieved by hydrotesting some lines, this testing does not provide a complete picture of the condition of a pipeline to assist in predictive maintenance as part of the operator's integrity management program.

In-line inspection now allows operators to gather a large amount of inspection data about systems on which they previously were able to obtain very little or incomplete information. In addition to collecting information about more systems, the quality and resolution of the available data is also a powerful tool in understanding asset condition. Many modern high resolution inspection technologies may accurately size the length and depth of a flaw, but it is now possible to go beyond the older assessment methodologies and run FFS¹ Level 2 (Effective Area) assessments on areas of metal loss or build finite element models of individual dents in order to demonstrate fitness-for-service.

Competing inspection technologies can be evaluated not only by comparing the cost of inspection, site preparation and mechanical set-up, but also by examining what can be done with the data after the inspection. Discussions of in-line inspections often focus on the details of the data quality, precision of measurement and statistics about flaws of a variety of depths. These are important and easily quantifiable data, but for a pipeline operator the most crucial decisions come down to the ability to safely operate the pipeline and to spend maintenance budgets efficiently. Gathering a high quality data set from an inspection allows for better planning and overall management of a pipeline system.

With unpiggable pipelines, not only do the standard concerns about data quality arise, but further concerns such as the mechanical work required to make a line piggable, the effort required to clean a line, and potential issues regarding accessibility of the line for repairs can play a large role as well. As unpiggable lines, by definition, have not historically been pigged, the mechanical and operational setup required for an in-line inspection demands specialized attention. The owners of some unpiggable pipeline systems may not have the extensive experience with pigging programs that some of the larger traditional operators have. Whether it is replacing small radius bends or reduced bore valves, or the addition of launcher and/or receiver facilities, mechanical work to make a pipeline piggable can quickly add complexity and cost to an inspection project. Even the inspection medium itself can pose a challenge. If an inspection is not able to be carried out with the pipeline in-service, handling and disposing of the potentially large volume of water, or other fluids, must be considered in planning the inspection. An inspection tool that can simplify the inspection process will quickly reduce the overall cost of the entire project.

The logistical challenges operators face can pose significant hurdles as well. Incomplete records and unknown information about a pipeline often require an operator to make conservative decisions about what type of tool can be run, or whether an inspection run is even possible. Mapping information about the configuration and location of the pipeline generated by modern high-resolution ultrasonic inspection tools can prove as beneficial as the detailed reports on defects and anomalies within the line. In addition, increased ease of mobilization and operation during the in-line inspection can provide additional benefits by reducing the burden to an operator's Health, Safety and Environment department. The ability to have a successful first inspection of a complex piping system that has never been inspected is of great operational benefit.

The importance of a high resolution data set has become increasingly clear. Not only does such data allow an operator to draw a more complete picture about the state of the pipeline and what damage mechanisms may be involved, but precise direct measurements allow an operator to make more accurate decisions about remediation, inspection frequencies, and corrosion growth rates. In addition, for pipelines with restricted or limited access, high resolution data allows for further assessment of defects and damage mechanisms using methods such as finite element assessment or advanced statistical modeling. These advanced assessments provide the operator with greater value from each individual inspection reducing the need for costly and complex prove-up digs.

Pipelines in highly populated urban areas have another significant impact on piggibility. For lines that cannot afford to be taken out of service for any amount of time due to customer demand, it is important that the proper inspection methodology is utilized to ensure not only efficient, but also effective and accurate detection and prioritization of failure mechanisms. Prove-up and repair digs in dense pipeline corridors and urban areas are complex logistical projects. The ability to avoid digs caused by an overly conservative assessment methodology can save an operator money that could be used on other inspection or remediation projects. Unnecessary repairs can lead to an integrity management program that is not conservative because finite resources are diverted away from areas or projects where they could be more useful. High-resolution data allows for an integrity program which can correctly identify and prioritize the highest priority defects, and the rapid delivery of such data can allow an operator to take action while a line is still out of service.

Case Study	Piggibility Challenge	Product	Inspection Method	Summary of Findings
Case Study 1	Metropolitan Area, Difficult Pipeline to Navigate, Previous Inspection Failures	Gasoline	Ultrasonic In-Line Inspection	Third-party Damage, Schedule & Weld Type Changes
Case Study 2	High Consequence Area, Strict Operating Condition, No Historical Pipeline Data	Natural Gas	Ultrasonic In-Line Inspection	Unexpected Anomalies, Areas of Deformation
Case Study 3	Limited Launcher/Receiver Area, Mechanical Modifications Required	Gasoline	Ultrasonic In-Line Inspection	Areas of Corrosion, Significant Dent Anomaly
Case Study 4	Environmentally Sensitive Area, Lack of Launcher/Receiver Facilities, No Previous Inspection or Cleaning Performed	Crude Oil	Ultrasonic In-Line Inspection	General Areas of Wall Loss, Indications of Deformation

Table 1: Summary of Case Studies

CASE STUDY 1 – INSPECTION OF CRITICAL PIPELINE LOCATED IN POPULATED HIGH CONSEQUENCE AREA

A pipeline operator needed to inspect a pipeline running through a major metropolitan area. The pipeline had been constructed in various phases over time and contained numerous transitions from 6" to 8" and back again (see Figure 1). Several previous attempts at inspection had failed and the operator was left with hydrotesting as their only option for regulatory compliance.

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Figure 1. Challenging pipeline containing numerous transitions from 6" to 8".

Hydrotests only provide a snapshot of the condition of a pipeline on a particular day and are not useful in finding dents or small corrosion areas that do not impact the pressure carrying capacity of the line. Even areas of nearly through-wall corrosion can pass a hydrotest only to fail in service a few months later. The accuracy of inspection data was important to the client because of the high cost and complexity of prove-up digs at many of the populated locations along the length of the line. Additionally, any failure along the pipelines high consequence route could lead to catastrophic consequences and substantial pipeline downtime.

Another inspection methodology currently available is MTM (magnetic tomography method), an indirect inspection methodology for assessing damage in buried pipelines. Although this inspection method can be effective in certain rural circumstances, its capabilities are limited for pipelines located in urban areas where access to the pipeline topside is not always possible. External factors such as pipeline crossings, utility lines, power lines, road crossings and other industrial construction all can impact the success and reliability of an indirect inspection method.

To ensure regulatory compliance,^{2 3} a dual diameter 6"/8" inspection tool was developed to navigate the small radius bends present in the line while collecting radius and thickness data on both the 6" and 8" sections of pipe in a single inspection. Working collaboratively with the operator throughout the design and inspection process ensured that the tool would navigate the line, and designed and tested the tool using the actual available pump information. To facilitate this effort, multiple mobilizations were made on the project running both a sizing and inspection tool. As a result, the inspection was successful on the first run of the inspection tool and over 51km of high resolution ultrasonic data was collected.

This high-resolution inspection data provided the operator with not only wall thickness data, but also 2D and 3D ultrasonic inner radius (geometry) graphics (see Figure 2), allowing the operator to have a more complete picture of its pipeline which included a number of previously unknown third party damages (see Figure 3). In addition, information about the original construction of the pipeline could also be seen in the data. Previously unknown schedule and weld type changes were observed, creating an as-is pipe book, and all features were then mapped to known above ground locations.

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Figure 2. High resolution inspection data indicating areas of damage on pipe wall.



Figure 3. Critical topside dent defect that was detected during the in-line inspection.

A full fitness-for-service engineering assessment was delivered for the entire 51km length of the pipeline and hundreds of individual anomalies were sized and identified. A prove-up program commenced to repair critical anomalies and to develop statistical confidence in the inspection data for this run. Quest Integrity and the operator worked together in locating and investigating critical anomalies in the most cost effective and time efficient manner.

With high level data from a successful inspection, the operator can now address issues with this pipeline before they become significant problems, thus being proactive instead of reactive. In addition, the cost savings from subsequent hydrotests can instead be more efficiently redirected to other integrity management projects.

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CASE STUDY 2 – IN-LINE INSPECTION OF SENSITIVE CITY GAS PIPELINE

An unpiggable natural gas pipeline in a high consequence⁴ highly populated urban area suffered two leak failures, causing integrity concerns for the future sustainability of the pipeline. Due to operational constraints, lack of historical data, and the pipeline's location in a high density metropolitan area, the operator was faced with a number of challenges that made an inspection both highly critical and very challenging. In order to understand the full condition of the pipeline, the operator explored the available inspection methodologies and determined that an in-line inspection and advanced assessment could be performed during a short turnaround period.

The pipeline faced a number of potential limitations that were assessed during the planning and selection of the appropriate inspection methodology. There was very little historical data on the pipeline. Because there was limited construction and maintenance documentation, the operator was faced with unknown pipeline condition, which complicated the selection of an integrity asset management program.

Another significant inspection challenge was the pipeline's operating requirements. Strict line requirements and product delivery schedules prevented service outages of more than one (1) day. Many inspection techniques require multiple days to perform a full inspection. In this case, the operator could not afford to dedicate many days off-line.

There were a number of inspection options evaluated by the operator, including direct assessment (DA), MTM, pressure testing and in-line inspection. It was determined that direct assessment required topside access to the pipeline, which was difficult to attain in extensively paved or cemented areas. MTM did not provide the level of detail and confidence required in a city gas pipeline and would also be effected by the surrounding urban area. Pressure testing was also discounted, as it posed too high a risk to perform in a densely populated area. It was ultimately determined that an ultrasonic in-line inspection was the most viable option for effectively inspecting the pipeline due to its operational, navigational and environmental capabilities. The ultrasonic inspection tool's ability to reliably detect damage in a pipeline with challenging configurations, while mitigating risk associated with the pipeline's sensitive environmental and highly populated location made it the most effective inspection methodology.

The in-line inspection was successfully completed in one day, and provided the most comprehensive direct measurement data. The results of the advanced data assessment indicated a number of unexpected anomalies that were subsequently excavated and remediated. The entire in-line inspection process was safely completed within one day, and had no impact on the high density population surrounding the pipeline.



Figure 4. Inspection data showing indications of damage on pipeline (top); damaged segment of pipe seen during excavation and remediation (bottom).

CASE STUDY 3 – IN-LINE INSPECTION OF INACCESSIBLE PIPELINES

A terminal operator had a set of parallel pipelines that ran under a short span of a navigable waterway. The lines had no launcher or receiver facilities and were in an area where space for setup of any pigging equipment was at a premium. Guided wave ultrasonics had been used previously on the lines, but no pigging for either cleaning or inspection had been done. The operator wanted more detailed information about the current condition of the line than their current inspection program was able to deliver.

A variety of options were considered for the inspection, all of which required some mechanical work. One option was to break the lines at a flange on either side of the waterway and pull a Magnetic Flux Leakage (MFL) tool through each of the lines. Another option was to add a launcher to one end and a receiver to the other and push an inspection pig through the line. In both cases, there were flanged joints of pipe on either end that could be isolated by existing valves.

When considering the available inspection options, the operator took into account the total amount of mechanical work required for each inspection methodology, as well as the ease of operation. The inspection provider simplified the project for the operator by supplying the required launcher barrel and performing the cleaning of the pipeline as part of the contract, in addition to providing a high quality ultrasonic dataset.

The chosen ultrasonic tool's bidirectional capability further simplified the project for the operator. Therefore, a single launcher/receiver barrel could be used, and the impact on the far side of the water crossing would be minimized. A single temporary launcher/receiver barrel was used for both the cleaning and inspection of all four lines. While this barrel was unbolted from each of four separate laterals and reattached to the next one, data was downloaded from one run and the tool was prepared to run the next line. The efficiency and full service offering made the ultrasonic inspection very price-competitive.

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Figure 5. Single launch/receive barrel used during the inspection to minimize risk.

In addition to the operational cost-effectiveness and benefits, high quality data was collected and a full fitness-for- service report was delivered to the operator as part of the standard deliverable. The inspection and assessment reported areas of corrosion and made recommendations about corrective actions in the report. Furthermore, a dent greater than 6% was discovered in the line. Although the dent was difficult to access, further engineering assessment was performed using the detailed inspection data to demonstrate the fitness-for-service of the line inclusive of the dent.



Figure 6. High resolution inspection data revealing a dent greater than 6%.

CASE STUDY 4 – INSPECTION OF HIGH RISK CRUDE PIPELINE

An operator had a 6" pipeline on a wharf that was used for transporting crude oil from a marine terminal to its refinery. In such a critical area, the potential cost of any loss of containment would be very high. Any extensive mechanical work to this line would increase the risk of loss and the potential damages

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and costs because of the environmental sensitivity of the area. The line had no existing launcher or receiver facilities and did not have a regular cleaning program. However, there were sections of the pipeline which were set-up with flanged connections near valves, which could be used to control the flow and isolate these particular sections. By taking advantage of these flanged connections, an ultrasonic in-line pipeline inspection was carried out on the pipeline with no mechanical alterations to the pipeline. The tool was launched and received in nominal sized pipe at a single location accessed directly by the flanged joint.

A flanged connection was unbolted, and the tool was inserted into the pipeline at this opening by hand. At the receiving end, an orifice plate was inserted and the flanged connections were then re-bolted and the previously opened portions of the line were refilled using the plant's fire water. Once the line was again completely filled, local valves were opened and the tool was launched and successfully inspected two miles of pipeline.



Figure 7. Inspection tool launch performed by hand, mitigating the need for costly modifications to the pipeline.

The tool was propelled at a low pressure in the plant's fire water. Since the Quest Integrity InVista tool is lightweight and easily transportable by one person, no heavy lifting equipment was required to get the tool into the middle of a congested piping area or to place it into the pipeline, easing health and safety concerns and the logistics of the project. At the far end of the inspected pipeline, once the transmitter signal from the tool confirmed its arrival, the pipeline was again opened and in less than fifteen minutes, the inspection tool was removed by hand from the pipeline.

At the completion of the inspection, the data was analyzed and revealed a number of defect indications along the surface of the pipeline, as seen in Figure 8. A full fitness-for-service assessment was then prepared for the entire inspected length of the line. In addition, rapid analysis of the data while the inspection team was onsite allowed the operator to perform additional hand held inspections to verify the signatures seen in the inspection data on key portions of the line while the pipeline was still out of service.

NIGIS * CORCON 2017 * 17-20 September * Mumbai, India



Figure 8. Inspection data revealing areas of damage along length of pipeline.

CONCLUSIONS

Unpiggable pipelines present a unique set of challenges, but benefit from high resolution direct measurement as much as, if not more than, lines that are conventionally piggable. Difficulty in access puts a premium on ease of inspection as well as on accurate, actionable data and assessment. Sometimes, it is the high-level assessment of the data that can be of greatest benefit to the operator of an unpiggable pipeline, especially in populated urban areas

While a hydrotest may achieve regulatory compliance for a pipeline, this compliance alone is not an assurance of safe or cost-effective operation. By gaining the detailed inspection data an Ultrasonic ILI tool can provide, an operator is able to be proactive rather than reactive in their integrity management plan. This knowledge allows for better planning of inspection frequencies, corrosion growth analysis as well as repair and mitigation plans. Thus a high resolution dataset allows for increased overall cost savings which can be used to enhance the overall operational integrity of the entire pipeline system.

It is important to evaluate an inspection as part of the larger overall integrity management plan. An inline inspection is but a small part of a larger overall project. Ease of setup for getting an in-line inspection tool successfully through the line, ease of operation for conducting the inspection and the power of a high resolution data set that enables a complete fitness-for-service assessment are all part of a larger, overall more efficient integrity management program.

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