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America's Evolving Oil and Natural Gas Transportation Infrastructure*
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CHALLENGES FOR IN-LINE INSPECTION

Prepared for the
Technology Advancement and Deployment Task Group

On December 12, 2019 the National Petroleum Council (NPC) in approving its report, *Dynamic Delivery – America's Evolving Oil and Natural Gas Transportation Infrastructure*, also approved the making available of certain materials used in the study process, including detailed, specific subject matter papers prepared or used by the study's Permitting, Siting, and Community Engagement for Infrastructure Development Task Group. These Topic Papers were working documents that were part of the analyses that led to development of the summary results presented in the report's Executive Summary and Chapters.

These Topic Papers represent the views and conclusions of the authors. The National Petroleum Council has not endorsed or approved the statements and conclusions contained in these documents, but approved the publication of these materials as part of the study process.

The NPC believes that these papers will be of interest to the readers of the report and will help them better understand the results. These materials are being made available in the interest of transparency.

The attached paper is one of 26 such working documents used in the study analyses. Appendix C of the final NPC report provides a complete list of the 26 Topic Papers. The full papers can be viewed and downloaded from the report section of the NPC website (www.npc.org).

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Topic Paper (Prepared for the National Petroleum Council Study on Oil and Natural Gas Transportation Infrastructure)	
4-2	**Challenges for In-Line Inspection**
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SUMMARY

Use of in-line inspection is expanding among pipeline operators. Research and development continues to expand the use cases of in-line inspection technology and to address limitations. In-line inspection can now address lines that were once deemed "unpiggable." New technologies allow these lines to be inspected with minimal modifications to the pipeline. Challenges to further expansion of in-line inspection include inspection tool access, pipe cleanliness, high fluid density, heavy wall thickness, transportation of natural gas liquids, and product flow rate. Development of new technologies and innovative techniques have helped to address these challenges and further expand the boundaries of what inspections are possible.

I. INTRODUCTION

To date, in-line inspection has been regarded as the preferred option for the collection of accurate data to support integrity assessment, but running in-line inspections on some pipelines can be challenging. Depending on line configuration, conditions, and operations, an in-line inspection can be considered “conventional” or “non-conventional,” and in some cases the line may be considered “unpiggable.”[1] A conventional inline inspection typically requires no modifications to the inspection tool or the pipeline to perform the inspection. A non-conventional inline inspection would require a specialized modification to a tool or existing pipeline asset to successfully complete passage and data collection. An unpiggable pipeline would be one that has constraints that hinder the passage of available inspection tools, such as pipe or tool geometry, product or flow constraints, line cleanliness, or operating conditions. Over the past decade there have been technological advancements have allowed pipelines once considered "unpiggable" to now be subject to in-line inspection.

[1] Inline inspection tools are often referred to as “pigs” and the process of conducting inspections with such tools as “pigging.”

Most pipeline inspections require some form of pipe modification, either temporary or permanent, and can become costly if not executed efficiently. The possibility of a stuck tool is a major concern as it can be a very time consuming and expensive risk that pipeline operators take when trying to inspect a pipeline for the first time. There are many other items that need to be considered to ensure efficient project execution is coupled with high quality data to guarantee that an in-line inspection provides the best information possible to support integrity decision making. This paper describes some of the challenges associated with in-line inspection of difficult pipelines and identifies technological advancements aimed at allowing successful inspections under challenging conditions.

II. INSPECTION CHALLENGES

There are several factors that need to be considered to efficiently and effectively complete non-conventional in-line inspections. These factors should be considered as early in the inspection planning process as possible to maximize the chance of success.

a. Inspection Tool Access

The installation of in-line inspection tools can be a major factor in non-conventional applications, as pipelines were often not designed for deployment of current in-line inspection tools. Some inspection tools require specific pipe modifications, which could include installation of tapped flanges, trap geometry changes, or the line being emptied and purged. From a cost perspective, it is generally ideal to select an inspection tool that requires minimal pipe modifications, but sometimes a specific measurement accuracy or technology type is required. When required, the operator should plan for permanent modifications that can support future re-inspections to avoid repeating modifications. While best practice is typically to have separate launch and receive points on the line to simplify tool passage, in some cases single point access is considered generally acceptable as it may help to reduce the resource and cost requirements of a second access point. In addition, inline inspection tool valves are currently on the market that can accommodate single bodied cleaning and inspection tools.

The location of the inline inspection tool traps and launchers can also create unique access issues, as urban, rural, and industrial environments all have different equipment requirements. Working in tightly confined spaces or those that require vertical or elevated launch cassettes require additional planning as they lead to additional safety and oversight requirements. Working in locations where other processes are occurring or where there are nearby population centers may require additional barriers or personnel to ensure that there are no risks to bystanders. Offshore locations have additional space limitations and may require installation of additional decking and support infrastructure to accommodate tools that can weigh in excess of 10,000 lbs.

With inspections that occur "out of general service" (where the line is shutdown for inspection), special planning must be considered to accommodate the amount and type of equipment needed to manage the tool inspection. This planning may require arranging for specialized equipment, such as holding tanks for water in a hydraulic push, space for a nitrogen generator and liquid nitrogen trucks for a pneumatic push, and space for tether-spool trucks if using a wireline-based tool.

As tool access can be a barrier to in-line inspection, advances in inspection tools should be considered when designing ILI access points, and improved technologies for tool handling and launching should be considered to help simplify future inspections.

b. Pipe Cleanliness

Cleaning programs are important for supporting both the internal corrosion mitigation programs and preparation for in-line inspection. For non-conventional in-line inspections, line cleanliness can be one of the primary uncertainties, as pipeline debris can hinder the inspection's success and drastically increase its cost and complexity. Effective inspection requires adequate planning of cleaning programs, which typically includes review of the pipeline, assessment of the level of cleanliness required for the tool technology, and inline cleaning tool and chemical cleaning technology required for the line conditions.

Preparation for a cleaning program should include a comprehensive review of prior cleaning runs, prior inspection runs, material product specifications considered when using cleaning products, and the potential effects of cleaning chemicals on the product stream. Depending upon the type of inline cleaning tool utilized, many other attributes such as bore passage and bend requirements should also be considered to ensure that the inline inspection tool do not become stuck in the pipeline. Operators should also assess how rigorous of a cleaning program is required, determining if it should include several aggressive levels of inline cleaning tools and chemical, or if simply a chemical injection and/or soak would be sufficient. In some cases, test cleaning runs are performed based on knowledge of the existing product flow and cleanliness requirements. These preparations are important to maximize the chance of success of a cleaning program.

Some in-line inspection tools have cleanliness requirements and debris in the line can severely degrade their performance depending upon the sensor technology used for inspection. Magnetic flux leakage sensors are fairly robust and can work through most types of debris in a pipeline as long as the debris moves along the pipe and with the tool. If the debris is hard and adhered to the pipe wall (such as scale, black powder, etc.), the sensors can ride over the debris and may mis-read or fail to capture data. Ultrasonic tools are most sensitive to soft materials (such as wax and paraffins) adhered to the pipe wall as these materials do not conduct the sound waves properly and distort the signal. It is generally critical to ensure a proper cleaning regime is in place prior to any ultrasonic inspection to remove any buildup and ensure proper conduction of the ultrasonic signal to the pipe wall to guarantee the best chance of success for good quality data. Electromagnetic acoustic transducer tools have the most significant cleaning requirements, especially when the tools are targeting specific crack features using combined sensor packages. Newer technologies such as acoustic resonance sensors have shown promising advances in being able to inspect the pipe wall while reading through various types of hard and soft adhered debris in both gas and liquid environments. Thus, planning of cleaning programs should include an assessment of the level of cleanliness required for the specific tool technologies used in the in-line inspection program.

For liquid lines, depending on the product being transported, there will often be some variety of paraffin attached on the pipe wall, which can be coupled with other debris, requiring complex cleaning programs consisting of multiple tools and/or cleaning products. In ideal cases where the line has an entry and exit point, multiple inline tools can usually be run to achieve acceptable cleaning results. In these cases, different types of inline cleaning tools should be considered (with or without cleaning product), typically leading to a train, which includes a lightweight foam tools, followed by a heavier density foam tool, followed by a fully urethane disc, followed by a steel mandrel brush or scraper tool with gauge plates, and finally a lightweight geometry tool. The geometry tool is used to provide a check for overall cleanliness on the cups and odometer armatures, pipeline centerline tracking with GPS, and minimum and maximum bore restriction through the entire inspection section of the pipeline (ensuring that other inspection tools can pass through). In the case where there is only a single entry point, paraffin cutters and biocides can be injected upstream of the product flow and can sometimes be isolated to perform a chemical soak. In harsh conditions, such as offshore pipelines, gel tools can be considered as they can be injected into the pipeline and transported over long distances. The cleaning agent in the gel can be modified to the specific debris threat and designed to capture and move the debris down the pipeline asset to a filter/separator package. The gel tool can then be introduced with a specific diluent, such as diesel, and broken down for capture within the same filter/separator package.

In general, line cleaning can be an important factor in the effectiveness of in-line inspection. As a simple rule, the cleaner the pipe wall, the better chance at success on the first attempt at the in-line inspection and the higher quality resultant data.

c. Heavy Crude

Fluid density can be an important factor in determining inspection tool performance, with heavy crudes being the most difficult for some measurement techniques. Magnetic flux leakage tools are typically not strongly affected by fluid properties and provide a reliable option for corrosion and wall thickness measurements in heavy crudes. Ultrasonic tools are highly sensitive to product density, and consistency of product density within an inspection is paramount. Operators may consider diluting the batch through injecting diesel, condensates, or other chemicals designed to lighten heavy crudes to ensure effective coupling between the ultrasonic sensor and the pipe wall. Most vendors can provide a range of acceptable specific gravities/densities required, but a single consistent liquid couplant is required across a single ultrasonic inspection tool run to ensure effectiveness.

d. Heavy Wall Thickness Pipe

Heavy wall pipelines can pose a challenge for some in-line inspection technologies, due to added energy requirements or increased complexity in the signal analysis. Most conventional onshore applications are able to use existing technologies, but deep water and offshore pipelines have additional inspection challenges and generally require thicker pipe to account for the pressures at subsea depths. For these heavy wall pipeline inspections, ultrasonic tool inspections are typically the preferred inspection method, as they have been shown to provide accurate readings in pipe wall thicknesses up to 2 inches. Magnetic flux leakage inspections are typically limited to full wall saturation at low speeds for wall thicknesses ranging from 0.500 to 0.750 inches. New technologies such as the acoustic resonance technology may be capable of successful measurement in pipes with wall thickness in excess of 2 inches. Continued technology development will help to ensure that these heavy wall thickness lines can be inspected to the same level of accuracy as more conventional lines.

e. Natural Gas Liquid Products

Most in-line inspection technologies such as caliper, magnetic flux leakage, electromagnetic acoustic, and acoustic resonance tools can typically be used to inspect liquified natural gas pipelines. For these technologies, the gas product in liquid form tends to have similar hydraulic properties as water/oil and therefore is very conducive to moving the inspection tools through the inspected segment. This assumes that the transported volumes and velocities meet the requirements needed due to the weight of the inspection tool as would be the case for standard liquid lines.

Special consideration, however, is needed for ultrasonic inspections as the resonant frequency of natural gas liquids may not be sufficient to allow it to be used as a couplant. In these cases, the tool may need to be moved along the pipeline segment with water, batched in a useable commodity such as diesel, or possibly transported within a large batch of corrosion inhibiting agent. The most appropriate transport medium is selected to ensure that sufficient coupling of the ultrasonic sensor and the pipe wall can be achieved. Future advances in ultrasonic sensor technologies may limit the fluid coupling restrictions and make inspection more efficient for this type of application.

f. Flow Rate Challenges

Pipelines with extreme (very low or very high) flow conditions are traditionally deemed as unpiggable as they can lead to stuck or damaged inspection tools. New technologies have been developed to help address these challenges and maximize the number of pipelines where in-line inspection can be performed.

In cases with high flow rates (such as larger diameter high pressure gas pipelines), inspection tools require some form of speed control as tools travelling too quickly may become damaged within the line. For these high flow conditions, some tools use onboard computers to read the pressure differentials across the tool's centralizing cups/discs and adjust valves built into the inspection tools' body to allow for more or less product flow past the tool as it traverses the inspection segment. This speed control system allows for the inspection tool to maintain a preset speed as needed for that sensor type to perform its data collection sequence. Other tools, without the automated valve capability to control tool speed, require modifications to the discs and cups of the inspection tool (based on test run performance) to allow for the appropriate inspection speed within the line.

For low pressure/low flow pipelines, there is a lack of motive force from the product in the pipe which can lead to slow movement or even stuck tools. Some inline inspection tool companies require a minimum pressure environment (generally around 150 psi, but pressure will depend on the tool) for their traditional free-swimming tools to "turn on" once loaded in the line. Some vendors use wheeled carriage assemblies to reduce friction and improve centralization while inspecting the pipe segment, allowing the tool to be moved with less flow. Some tools are built using brushes as centralizers within the pipe, with the body designed to stay neutrally buoyant within the liquid couplant and very lightweight. Being neutrally buoyant and having brushes as centralizers also allows for a significant increase in bore passage (in excess of 40% of the overall internal diameter) while still capturing data on the pipe wall.

Different technologies are required for pipeline assets with no flow or those that must be taken out of service to inspect. In these cases, conventional magnetic flux leakage tools can be pushed through the pipeline using water or nitrogen. However, the locations must be large enough to handle the equipment needed to perform this work and significant safety protocols must be in place in dealing with these mediums (as would oil, liquified natural gas, or natural gas products). Most of the inline inspection tool vendors have modules that can be used with a field services tether setup as long as access is available at both ends. Some vendors have inspection tools that can be wireline/tethered and pulled through an asset by a robotic tractor assembly. These tractors can be bi-directional in nature to allow for additional data retrieval if needed. For lines where single access is available, the robot can pull the tool into the pipeline and then reverse and back out; or it can be pulled out by a tether as a retrieval device. This is especially useful when inspecting offshore lines with moored buoy transfer facilities. Free swimming (non-tethered) robotic bi-directional tools that can be introduced through a single point of entry (if necessary), reversed, and retrieved are also available on the market. These free-swimming tools are currently most practical for short pipelines or facility pipe inspections as they can have limited battery capacity and must be recharged at periodic intervals through ports in the pipeline.

III. CONCLUSION

While there remain challenges with in-line inspection, technological advances are allowing the conversion from unpiggable lines to non-conventional inspections and then towards conventional inspection. Inspection tool vendors are developing and enhancing technologies to help alleviate or minimize difficult pipe modifications that were once very commonly required for in-line inspection. As more operators execute non-conventional inspections, new technologies will continue to be developed, tested, and then implemented into industry best practices. New cleaning procedures have been developed which have provided significant gains in line preparation to support more successful in-line inspections and reduce the risk of inspection failures. Technology research is continuing with the goal of allowing conventional and non-conventional inspections to be executed with the same level of confidence.