INNOVATIONS IN IN-SERVICE ROBOTIC INSPECTION OF UNPIGGABLE NATURAL GAS PIPELINES AT RIVER CROSSINGS FOR WHICH THERE ARE NO EXISTING LAUNCHING AND RECEIVING CAPABILITIES

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Abstract

With the critical role natural gas plays in our energy infrastructure, ensuring the integrity of these pipelines is paramount. This is especially true of river crossings for which External Corrosion Direct Assessment is not possible, In-Line Inspection (ILI) has not been previously possible, and line conditions are not known.

This paper explores the limitations of conventional methods such as manual diving, sonar survey, and traditional free-swimming ILI tools, highlighting their shortcomings in effectively assessing the condition of pipelines at river crossings. Moreover, this paper will emphasise the risks associated with not knowing the integrity condition of the pipeline which include potential leaks, ruptures, and environmental hazards. These risks are heightened at river crossings, where the consequences can be severe and far-reaching.

In response to these challenges and risks, the paper will explore advancements in inline robotic inspection technology which are able to be deployed into and recovered from in-service natural gas pipelines through hot taps installed on the line. This method of deployment avoids shutdowns and service interruptions, while allowing the pipeline operator the ability to gather multiple data sets (visual, deformation, and internal/external metal loss) as the line crosses the river.

The paper will then explore a case study and success story where robotic inspection technologies have been implemented, showcasing their ability to enhance safety, reduce costs, and minimize environmental impact. By embracing these innovations, operators of natural gas pipelines can proactively monitor and maintain the integrity of their infrastructure at river crossings, ensuring efficient operations and safeguarding the environment for future generations.

Introduction

With the critical role natural gas plays in our energy infrastructure, ensuring the integrity of transmission and distribution pipelines is paramount as these river crossing pipelines ensure infrastructure connectivity and energy availability to a vast array of communities and businesses worldwide. The critical nature of pipeline integrity is further heighted on river crossing pipelines for which External Corrosion Direct Assessment is not possible, In-Line Inspection (ILI) has not been previously possible, and line conditions are not known.

In the event of a pipeline failure on a river crossing pipeline, there are many series consequences which may arise such as: contamination of the local ecosystem, supply disruptions to businesses or households, a build-up of combustible gas or – even worse – an explosion. In the case of the pipeline operator, these consequences can be even more far reaching in the form of regulatory/legal repercussions, a damaged public image which can affect future project and energy policies, and the closure of the business.

Current Inspection Measures and Their Limitations

A number of techniques have been developed and honed over the years which can be used to assess the integrity of a pipeline, such as External Corrosion Direct Assessment (ECDA), sonar survey from a boat or Remotely Operated Vehicle (ROV), and traditional Free-Swimming Inline Inspection (ILI), each of which have varying levels of success and associated risk.

For an underwater river crossing pipeline, divers can be employed to swim along the length of the pipeline and visually inspecting the line for external signs of damage or leaks. This external assessment can be further enhanced with specialized equipment such as an ultrasonic (UT) probe to measure the wall thickness and detect corrosion at key locations along the pipe. There are, however, limitations to performing an external inspection with a diver such as visibility challenges, limited access to the line or the line might be buried, and time constraints of the diving equipment. Coupled with potential dangerous current/flow conditions of the line, can lead to a rushed inspection.

Another method of inspecting river crossing pipelines is sonar surveying which allows for a safer and remote inspection of the pipeline without the need to physically access the line. With a sonar survey of the pipeline, data can be seen in real-time allowing for immediate analysis and the speed of inspection is much higher than a diver which allows for longer sections of pipe to be covered in the same timeframe. Though sonar survey of the pipeline can provide some advantage over a diver inspection of the line, the data captured by the sonar can be low-resolution and insufficient for detecting small defects. This limited ability to penetrate the pipeline wall means that sonar can identify general features of the line, but it cannot provide the deeper level of analysis of the pipeline wall that other technologies can. Finally, sonar survey can experience a similar limitation to divers in that the pipelines are not always uncovered and easily accessible. While sonar does have a great detection capability than a diver's visual inspection, debris or rocks on top of the pipeline can potentially obscure the underlying defects within the pipeline.

Finally, a free-swimming inline inspection (ILI) tool can be used to determine the integrity condition of the pipeline. These tools will typically flow through the pipeline, either in the product being transported or some other medium, collecting data from within the pipeline. Most pipeline operators are familiar with these ILI options and utilize them throughout their network to assist better understand their pipe integrity and better plan their maintenance and operations activities going forward. While a suitable option for most piggable pipelines, this paper is focusing on the smaller subset of unpiggable natural gas pipelines which might not have existing launch/receive capabilities, which are the only form of energy delivery and – thus – cannot be taken offline, and for which the pipeline conditions are completely unknown. Without the launcher and receiver, the launching of a free-swimming ILI tool is simply not possible; however, even in cases where a free-swimming ILI tool can be launched from some distant location, the underwater location of the pipeline makes tracking the free-swimming tool difficult and the unknown conditions of the line could mean that the tool encounters a feature which causes it to get stuck in the line at an unknown location. In such cases, especially on pipelines which are the only source of gas for certain areas, the cost of recovery of the stuck tool, the loss of revenue from having to isolate the line, and the reputational damage to the operator will be significant.

While the preceding methods of inspection all offer some form of data collection and the ability to assess the integrity of the pipeline, these are not the most effective solutions for integrity assessment of underwater pipelines.

The Pipe Explorer MFL Robotic Solution

The Pipe Explorer MFL Robots (Figure 1) from Intero Integrity Services BV, were developed in Toronto, Canada, in 2010 to address a very specific need in the market: the inspection of critical natural gas pipelines which cannot be taken offline, for which no existing launch/receive facilities exist, where the need for integrity data is paramount, and where other methods of inspection might be considered too risky and the impact of a failed inspection too high to bear.

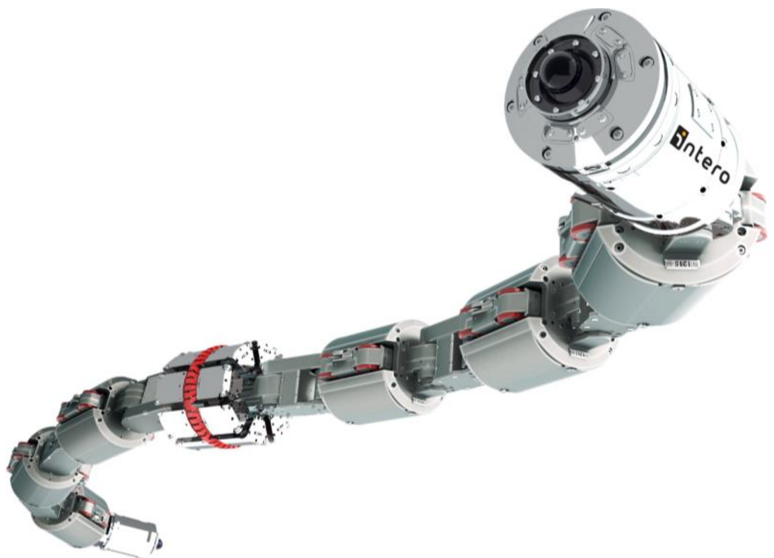

Figure 1: Pipe Explorer MFL Robot

Unlike a traditional free-swimming inspection tool which flows through the pipeline, Pipe Explorer MFL Robots are driven through the pipeline and remotely-controlled by an Intero operator who maintains communication with the robot throughout the entirety of the inspection via a proprietary wireless signal. Through this signal, the Intero operator can control where the robot travels, how quickly it moves, and a number of other operational features with real-time feedback on how individual components of the robot are functioning at any point of the inspection. Should the robot operator come across any previously unknown feature in the pipeline, the feature can be documented in real time and – depending on the severity of the feature – the decision whether to continue or turn back can be made. Due to the flexible nature of the Pipe Explorer MFL Robot and the real-time communication from the Intero operator, it is possible to compress, articulate, and rotate the various modules of the Pipe Explorer MFL Robot to go around the obstruction (up to 20% of OD) and continue the inspection of the pipeline. In the event that the Pipe Explorer cannot articulate past the obstruction, then the Intero operator will simply reverse direction and return to the launch location.

In cases of underwater pipelines which make tool tracking difficult, the location of the Pipe Explorer MFL Robot is always known thanks to the redundant odometers providing real-time reporting of the distance traveled and Intero operator creating a live pipe tally from the camera feed during the inspection in which all welds and features are noted and counted. The location of the Pipe Explorer MFL Robot is always known as the distance from launch and the distance from the most recent identifiable feature.

In order to overcome the lack of traditional launchers and receivers on the line, the Pipe Explorer MFL Robot has been designed to enter and exit the line through size-on-size hot tap fittings (Figure 2). Through these fittings, the Intero operator is able to launch and receive from a single hot tap (Out-and-Back), or to launch from one hot tap and receive at another hot tap further along the pipeline (Point-to-Point). The flexibility in launching/receiving and the bi-directional nature of the Pipe Explorer MFL Robot means that an operator can inspect a river crossing segment from 10m up to approximately 1.2km

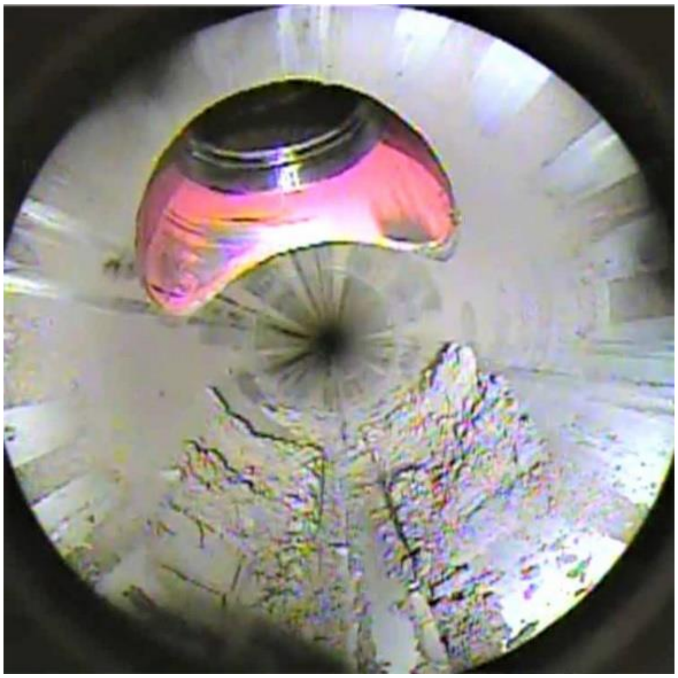

Figure 2: A Hot Tap Opening Viewed from Within the Pipeline

The Pipe Explorer MFL Robots range in size from 6” to 36” diameter (Figure 3) and collect three data sets with each inspection: Magnetic Flux Leakage (MFL) data for assessing internal/external metal loss, Laser Deformation data for determining the size and depth of pipeline deformities, and Video data from the onboard camera which allows the operator to visually see the internal condition of their pipeline. In addition to providing Preliminary and Final Reports summarizing the findings, Intero also supplies a free-use version of the Datatel software package which allows an operator to access the 3 data sets from the inspection in a user-friendly way

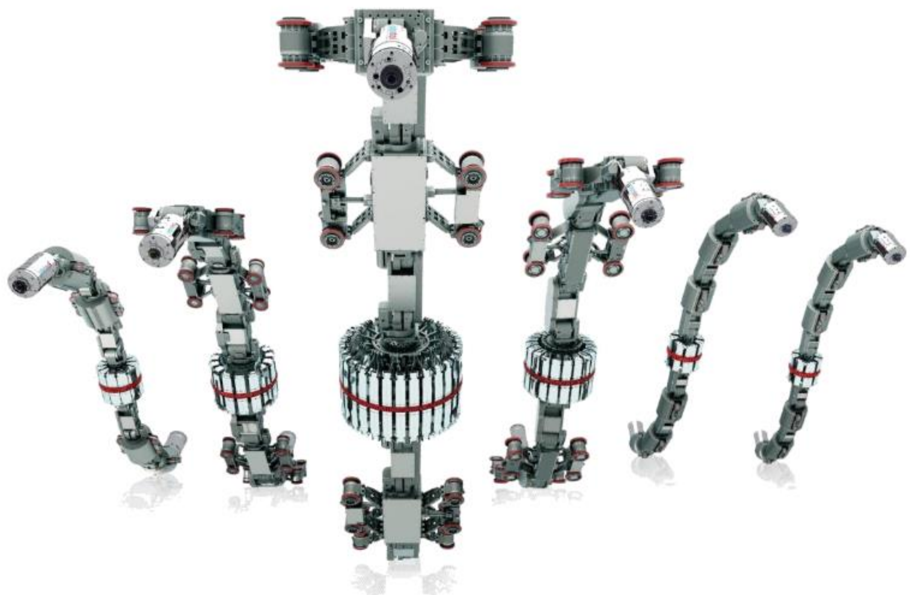

Figure 3: Pipe Explorer MFL Robot Fleet

A Case Study

A pipeline operator manages two parallel 24-inch pipelines that operate under high pressure, exceeding 40 bars. These pipelines, which were installed in the 1950s, cross a river that spans approximately 520 meters. The underwater location of both pipes poses significant challenges, as there is limited access to vital information regarding their current condition. Compounding this issue, neither pipeline is equipped with the necessary infrastructure, such as launchers or receivers, to facilitate traditional free-swimming inline inspection. Furthermore, any form of direct assessment is prohibited due to the pipes' submerged status, creating a pressing need for innovative inspection solutions.

In response to these challenges, Intero proposed a comprehensive solution that involves the installation of industry-standard hot tap fittings onto both of the pipelines and on opposite sides of the river (Figure 4).

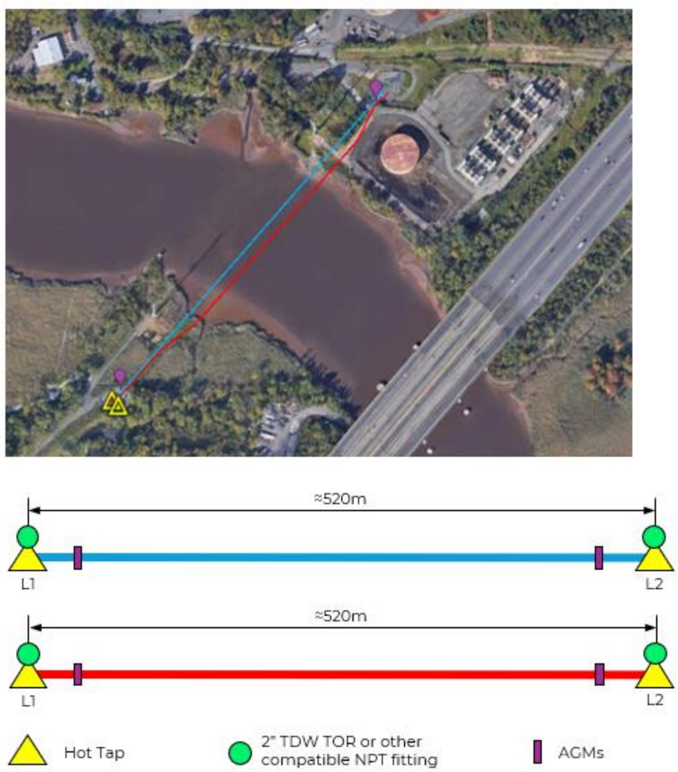

Figure 4: 24" River Crossing Inspection Schematic

These fittings are designed to allow the pipelines to remain fully operational during and after the installation process, which is crucial for minimizing downtime. A sandwich valve was installed atop each fitting, serving as a secure point for the attachment of pipe spool pieces provided by Intero. This arrangement (Figure 5) created a pathway for deploying the Pipe Explorer 20/26 into and out of the pipelines. This innovative deployment method alleviates the need for permanent infrastructure dedicated to inline inspection, ensuring flexibility and efficiency. The installation of the hot tap fittings was executed as a relatively routine operation, demonstrating the effectiveness of Intero's approach.

Figure 5: 24" Launcher Set-Up

The inspection of each pipeline took approximately six hours, a timeframe that was optimized by the use of the Pipe Explorer 20/26, which was deployed while the pipelines continued to operate normally. This efficient inspection process not only preserved the integrity of the pipelines but also demonstrated the advanced capabilities of the robotic system in real-world applications. The successful execution of this inspection highlighted the effectiveness of innovative technologies in overcoming traditional challenges in pipeline maintenance and assessment, ensuring continued operational reliability.

The successful acquisition of integrity data from the pipelines located beneath the river is crucial for ensuring their safe operation. This process allows operators to gain valuable insights into the condition and performance of the pipelines, enabling them to identify potential issues before they escalate into serious problems. By thoroughly analyzing this data, operators can make informed decisions regarding maintenance, repairs, and overall management of the pipelines. Consequently, this proactive approach not only enhances the safety and reliability of the pipelines but also helps to protect the surrounding environment and communities from potential hazards. Ultimately, the integrity data serves as a vital tool in fostering responsible operational practices and ensuring the long-term sustainability of the pipeline system.

Summary

In summary, the Pipe Explorer MFL Robotic inspection method offers a cost-effective and high-quality solution for accessing pipelines that are otherwise challenging to inspect. This innovative approach significantly enhances the ability to evaluate the condition of these pipelines, which may be difficult to reach using traditional inspection techniques. By utilizing advanced robotics, operators can gather comprehensive data and insights, ultimately leading to improved maintenance and safety outcomes. This method not only increases efficiency but also reduces the risks associated with manual inspections, making it a valuable tool in pipeline management.