# Bi-Directional Tethered EMAT In-Line Inspections: A Case Study

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## Abstract

Small-diameter, difficult-to-inspect, or unpiggable pipelines have limited inspection options in their Integrity Management tool kit. When the threats of concern are cracking-related, such as Stress Corrosion Cracking (SCC), the available options are usually limited to Hydrotest or Direct Assessment (SCCDA). This paper presents a case study on the pivotal role that bi-directional tethered In-Line Inspection (ILI) tools can bring to pipeline integrity programs. It will provide an overview of a recent tethered inspection of an 11.9 km NPS10 lateral natural gas pipeline, employing multiple cut points and a bi-directional EMAT (Electromagnetic Acoustic Transducer) ILI tool.

Designed for pipeline operators, integrity engineers, ILI coordinators, planners, and construction managers with intermediate to advanced technical expertise, the session will first address the operational challenges that bi-directional tethered ILI solutions can effectively resolve. Following this, the EMAT technology and its application in performing a multi-cut point bi-directional tethered inspection will be reviewed, along with the challenges encountered during the process and the key lessons learned. This examination aims to provide actionable insights and advancements in pipeline inspection technology utilization and threat detection.

## The Case for Unconventional In-Line Inspections

TC Energy has many sections of pipeline deemed “unpiggable,” and the condition in these locations is often assessed through investigative direct assessment (DA) programs, hydrostatic tests, or unconventional ILIs. Selecting the appropriate inspection program relies heavily on known or perceived risk, as well as cost-benefit analysis. The cost of a hydrostatic test is relatively high, and while this tool typically ensures operational safety for a prolonged period, it does little to determine the actual level of risk in a line without failures. An investigative SSCDA program is a low-cost alternative, and with proper use, serves to either reinforce an asset’s low risk or identify assets for which more comprehensive inspection approaches are necessary. Thus, unconventional ILIs fill a gap between these two methods, where assets do not operate at low enough risk to consider DA programs effective but are not considered sufficiently high risk to warrant frequent, costly hydrostatic testing. ILIs also provide a more quantitative holistic assessment of an asset, as the quantity and severity of reported features vary greatly. ILIs can be a useful proxy for true risk level.

### Bi-directional EMAT Tethers

The situation that would warrant an unconventional ILI often involves an asset for which configuration, length, or anticipated service life do not warrant the capital investment required for “make piggable” projects that would install full ILI launchers/receivers and remove problematic fittings, bends, and instrumentation. Within the larger umbrella of unconventional ILIs, bi-

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directional tethers have long filled a niche in Magnetic Flux Leakage (MFL) inspections for external corrosion; they arose primarily through cost-benefit analysis, where fewer pipeline cut points avoid additional field activities. With their ability to also tether in and out of difficult access areas or longer permitting timelines, bi-directional inspection continues to be a valuable part of any ILI program. With the advent of bi-directional EMAT capability, Quest Integrity is expanding the reach of crack detection programs to these locations of, historically, corrosion-driven risk.

### NPS 10 Case Study

An 11.9-km NPS 10 pipeline segment in northern Alberta was originally scoped for assessment in 2014. The lack of crack detection technology combined with the pipeline's short length, prompted the selection of a hydrostatic test (conducted in 2017) to manage both corrosion and cracking risk. Nearing its reinspection interval in 2023, the line was instead scoped for MFL tether due to anticipated cost savings. The client approached Quest Integrity to determine the viability of bi-directional crack detection. The bi-directional solution to this inspection eliminated one pipeline excavation and cut point, saving the engineering, manufacturing and installation/removal of temporary launcher/receiver traps and associated piping, and avoided the gas handling and flaring/venting emissions associated with pig-to-flare operations. This approach produced 40% cost savings over free swimming with temporary traps and 25% savings over unidirectional tethering.

## Project Overview

In 2023, TC Energy approached Quest Integrity with an opportunity to perform an EMAT-tethered inspection of a previously uninspected NPS 10 11.89-km lateral line segment in Alberta, Canada. This project was required to be bi-directional, a novel requirement for an EMAT ILI tool. A bi-directional tethered inspection involves attaching the tether to the rear of the tool, loading the tool into the pipeline, sending the tool to the desired distance downstream of the cut point using compressed air, and then pulling the tool back to the cut point with a winch or wireline truck. For this project, two wireline units were used—one truck had a 5/16-inch wireline wire rope and the other a 7/8-inch wire rope. Both trucks had onboard compressors using a 1 ¼-inch airline. Consideration of the equipment and process is critical when designing the ILI tool for this specific application.

### Pipeline Route and Cut Points

Involving a total of three cut points, the longest distance between cut points was approximately 5.9 km. Due to the distances between the cut points and the limitations of the tethering equipment, a total of six inspection runs were performed between the three cut points. A meter station was excluded from the inspection plan due to the high number of bends and pipeline fittings in that station. Figure 1 illustrates the line route and cut points.

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**Figure 1.** Pipeline Route and Cut Points.

In addition to the requirement for bi-directionality, the inspections involved several road crossings, wall thickness transitions, and bends that the ILI tool needed to navigate. These standard pipeline features are typically not a concern in a free-swimming ILI. However, in a bi-directional tethered inspection, these types of features need to be carefully considered for both tool navigation and the effect on the forces on both the winch and tool side. The wall thickness in these inspections was between 4.78 mm and 6.38 mm. Table 1 outlines these bends as seen by the inspection tool, all of which were identified as field bends. The details of these bends were unknown until after the inspection.

**Table 1.** Pipeline Bends.

| Direction | Number of Field Bends | Total Degrees of Bends |
|---|---|---|
| Cut Point (CP) 1 – End 1 | 15 | 159 degrees |
| CP 1 CP 2 | 3 | 19 degrees |
| CP 2 - CP 1 | 10 | 104 degrees |
| CP 2 – CP 3 | 7 | 78 degrees |
| CP 3 - CP2 | 1 | 35 degrees |
| CP 3 – End 2 | 8 | 150 degrees |

## Designing an ILI Tool and Equipment for Tethered Operations

There are multiple considerations when designing an ILI tool for a bi-directional tethered inspection, including tool length, insertion method, drive elements, drag forces, and tool directionality. The EMAT ILI tool was originally designed for unpiggable markets, including tethered operations. Bondurant, et al (1,2,3) provides an overview of the original goals, motivation, and results of the original program. Based on market needs, the design of this tool quickly shifted, and the subsequent designs of the tool fleet focused on free-swimming tools. Although the 10-inch ILI EMAT tool design was focused on free-swimming, the engineers kept the bi-directionality and short tool length in the design requirements, allowing for a quick transition back to bi-directional tethered operations.

### Bi-directional drive

One aspect of the tool that required redesign was the drive or tow section. Free-swimming ILI tools typically utilize polyurethane cups to drive the ILI tool through the pipeline. The Quest Integrity

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project team elected not to utilize this drive method out of concern for the pull-back portion of the inspection. With the goal of reducing the tool length further, the team designed flanges for the battery sections of the tool to accommodate polyurethane drive discs. These discs would provide the drive necessary to pull the tool down the line to the desired location and the ability to flip in direction when transitioning between the blow-down and pull-back portion of the inspection. This would reduce the likelihood of catching on pipeline features such as protruding girth welds, tees, dents, or other obstructions that a cup has a higher potential to catch on and exceed the safe working limits of the tethering equipment. Although adequate for this project, it was later determined it was determined that a change to the drive could be improved for better results (further discussed in the Lessons Learned section).

### Load force testing

Due to the safe working load limits (WLL) of the equipment, it was necessary to understand the anticipated drag forces at all points throughout the operations of this project. A test plan was created to measure and record the forces seen at the connection point between the tether and EMAT ILI tool in its final design through various pipe wall thicknesses, wall thickness transitions, and during the drive disc flip. These tests were done in both forward and backward orientations. The graph in Figure 2 shows the results of these tests through two pipe wall thicknesses with various sections of the tool, the complete tool, and the calculated differential pressure required to drive the tool based on these forces. The tool had a slightly higher drag force when travelling in reverse and the maximum load was during the flip in the direction of the drive discs. However, these forces were well within the WLL of the equipment being utilized.

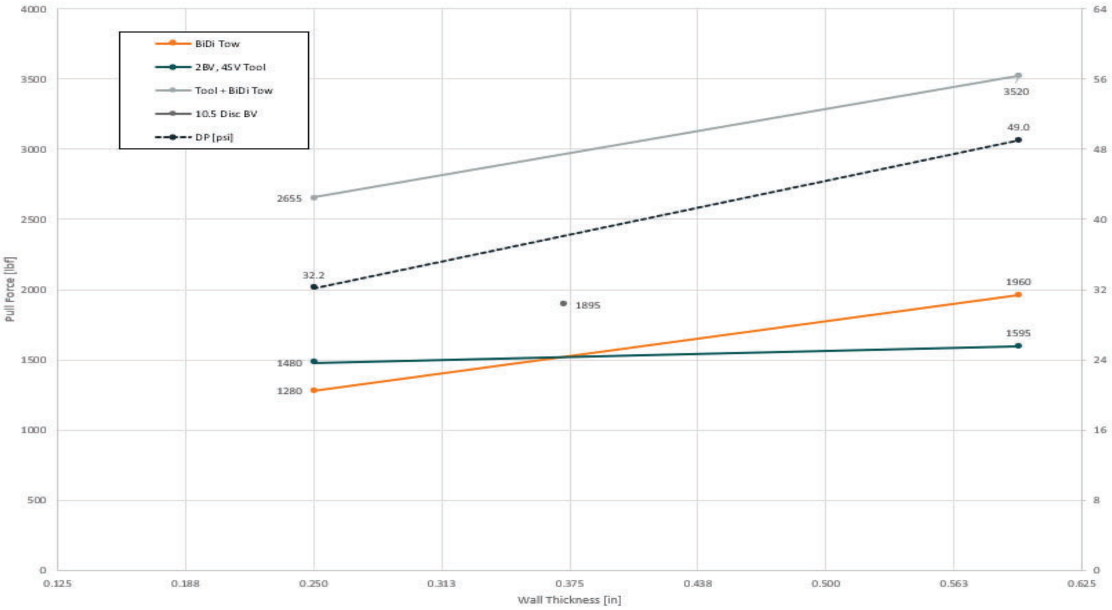

**Figure 2.** EMAT Pull Force Versus Pipe Wall Thickness.

### Consideration of tool directionality

Free-swimming ILI tools generally have a preferred direction to their design. While the EMAT ILI tool used in this inspection is no different, the tool is capable of travelling bi-directionally without damage. The pros and cons of loading the tool in either direction were weighed, but Quest Integrity elected to load the tool into the pipeline in reverse, with the drive discs mounted on the rear battery vessel, despite the measured drag forces being higher. This decision was made for two reasons. First the speeds were likely to be more controlled on the pull-back (toward) portion of the inspection. Second, all validation testing had been conducted in the forward direction, meaning that the impact on data quality was unknown while travelling in the reverse direction.

### Launching and receiving a tethered EMAT ILI tool

Typical EMAT ILI tools are exceedingly long, making the handling and loading of these ILI tools difficult even in ideal scenarios with permanent launchers/receivers and level ground. In a tethering ILI environment with below-grade exposed pipe, uneven ground, and limited workspace, handling a long EMAT ILI tool is nearly impossible. The short length of the Quest Integrity EMAT ILI tool allowed for a safe and relatively easy loading process. Considering the advantages of this shorter EMAT ILI tool, a custom insertion method was designed for this project. This method involved loading the tool into a custom-designed launch spool that could be bolted to the pipeline and the pack-off flange. This flange contains a pack-off assembly designed with an outlet for wire rope that also serves to seal off the pipeline. For this project, the EMAT ILI tool was tested, turned on, and loaded into the launch spool prior to being lifted down into the excavation point and bolted to the pipeline. At this point, the wireline rope was connected to the rear of the ILI tool, and the pack-off flange was bolted to the rear of the launch spool. The ILI tool was then ready to be launched using compressed air. Figure 3 illustrates this launch setup. Once the ILI tool was received back at the launch point and verified to be in the launch spool, the reverse order of operations was used to retrieve the tool.

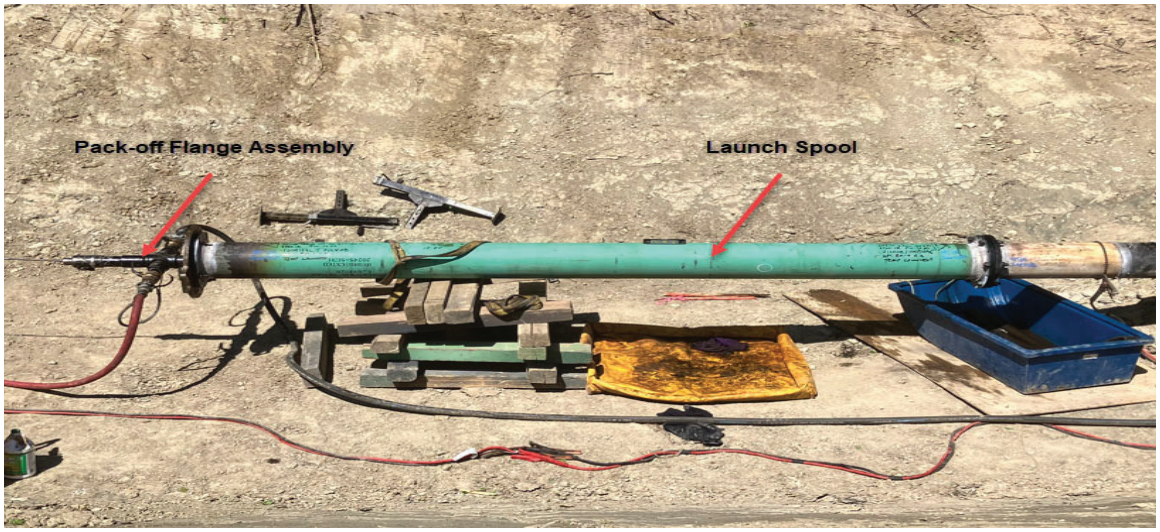

**Figure 3.** Launch Setup.

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## Inspection Results

The bi-directional tethered EMAT ILI of this pipeline yielded highly promising operational and field data quality results. The ILI tool was successfully loaded and unloaded into the pipeline, navigated the pipeline in both away and toward directions (as seen from the launch point), and suffered no mechanical damage throughout the project, demonstrating the ILI tool's robustness and adaptability. For each of the inspections, a comprehensive set of data was collected in both away and toward directions, allowing for redundancy and confirmation in data analysis. These results provide a solid foundation for future bi-directional tethered EMAT ILI inspections.

### Operational results

Operationally, the six tethered inspections were successful. The EMAT ILI tool was loaded and unloaded into the launch spool for each inspection without issue, enabling efficient on-site operations. The ILI tool navigated all pipeline features, including several bends and wall thickness transitions in both the away and toward directions, all while staying within the air pressure and pull force limitations of the equipment and without incurring mechanical damage.

However, not all aspects of the project went as planned. Relatively significant velocity excursions were recorded by the ILI tool in four of the six inspections in both the away and toward excursions. Velocity excursions in the away direction while being propelled down the pipeline with compressed air and in the reverse orientation were not unexpected, but velocity excursions on the pull-back (or toward direction) were surprising considering the wireline speed was consistent for that portion of the inspection. Velocity excursions occurred in three of the four inspections at distances greater than approximately 1500 m from the wireline unit, while distances within 1500 m generally produced consistent velocity, within the specification. The one inspection with different results had the thinner 5/16-inch wireline unit. This inspection had similar results, but the excursions occurred at a distance greater than 750 m (versus 1500 m). These velocity excursions were also relatively short and distant (<1 m) but contained significant acceleration, which affected the tool's attitude during these acceleration periods. Figure 4 was taken directly from the Data Quality Report for one of the cut points with velocity excursions. The red dotted line indicates the maximum velocity of 2 m/s. Note that the chainage is shown with 0 m being the start of the pull-back.

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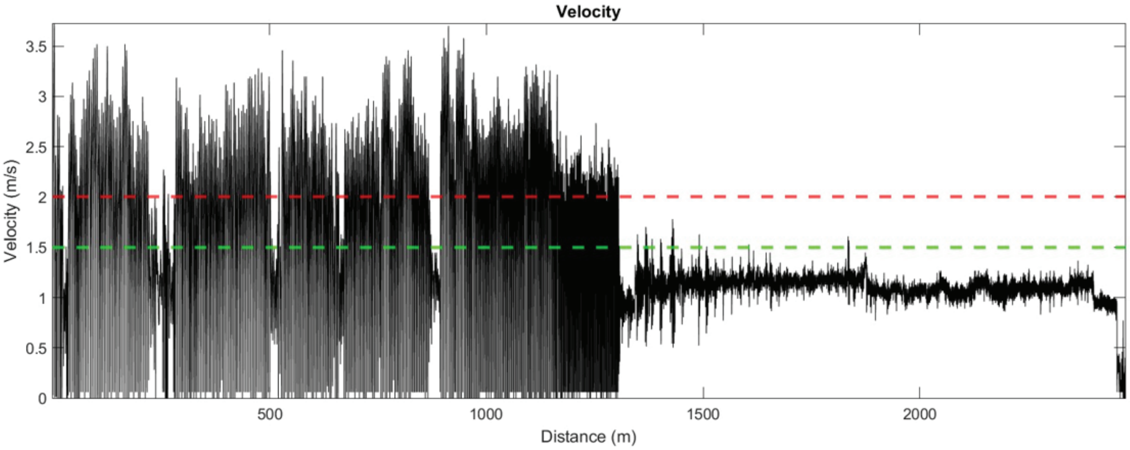

**Figure 4.** Velocity Excursion Example.

**Data quality results**

The EMAT ILI data quality results were promising. The expected Pipe Line Questionnaire (PLQ) distance was 11,889 m compared to a recorded distance of 23,518 m, meaning approximately 11,759 m was recorded twice. Accounting for the overlap and the metering station that was excluded from the inspection, Quest Integrity and TC Energy considered this a full set of data. The circumferential coverage was calculated to be 100% for most of the pipeline when utilizing two of the four sensor carriers, leaving the other two for redundancy and confirmation. Figure 5 illustrates the data coverage from one of the four sensor carriers on the tool during one of the tethered operations.

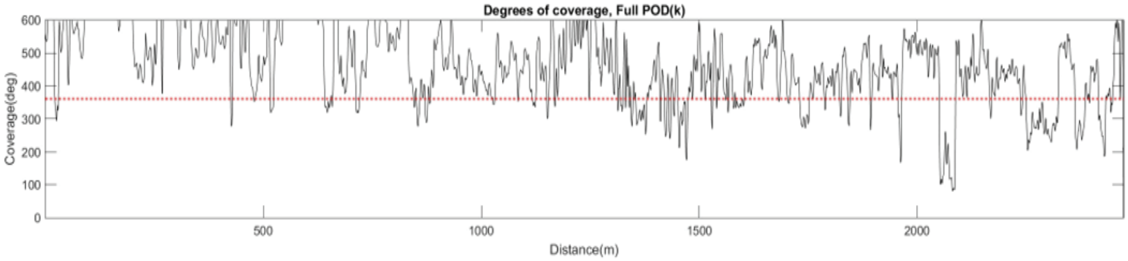

**Figure 5.** Degrees of Coverage.

There was also no discernible difference in the data quality while travelling in the reverse orientation. Except for the overspeed, the field-level data quality was acceptable for data analysis and within the team's expectations. Given the excellent data quality, the detection and identification of features reduced the analysis effort. Figure 6 is an example of the EMAT B-Scan and A-Scan data, as seen by the Quest Integrity analysts.

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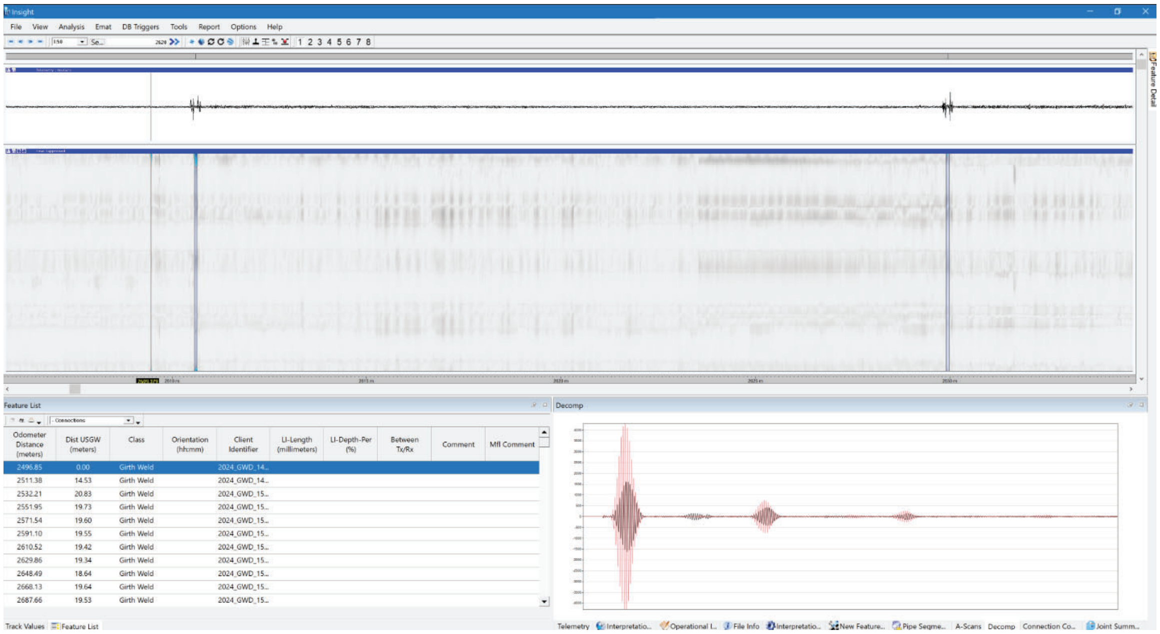

| Odometer Distance (meters) | Dist USGW (meters) | Class | Orientation (hh:mm) | Client Identifier | LI-Length (millimeters) | LI-Depth-Per (%) | Between Tx/Rx | Comment | Mfl Comment |
|---|---|---|---|---|---|---|---|---|---|
| 2496.85 | 0.00 | Girth Weld | | 2024_GWD_14... | | | | | |
| 2511.38 | 14.53 | Girth Weld | | 2024_GWD_14... | | | | | |
| 2532.21 | 20.83 | Girth Weld | | 2024_GWD_15... | | | | | |
| 2551.95 | 19.73 | Girth Weld | | 2024_GWD_15... | | | | | |
| 2571.54 | 19.60 | Girth Weld | | 2024_GWD_15... | | | | | |
| 2591.10 | 19.55 | Girth Weld | | 2024_GWD_15... | | | | | |
| 2610.52 | 19.42 | Girth Weld | | 2024_GWD_15... | | | | | |
| 2629.86 | 19.34 | Girth Weld | | 2024_GWD_15... | | | | | |
| 2648.49 | 18.64 | Girth Weld | | 2024_GWD_15... | | | | | |
| 2668.13 | 19.64 | Girth Weld | | 2024_GWD_15... | | | | | |
| 2687.66 | 19.53 | Girth Weld | | 2024_GWD_15... | | | | | |

**Figure 6.** EMAT data.

## Lessons Learned

The Quest Integrity EMAT team performed a post-inspection review to determine successes and opportunities for improvement in future bi-directional tethered EMAT inspections. All aspects of the project were reviewed, including tool design, wireline and launch equipment, operational and data quality results, and project planning. This review resulted in several lessons learned, which will be implemented for future projects.

### Velocity excursions

The most significant issue in this project, from both an operational and data quality perspective, was the velocity excursions. The Quest Integrity team reviewed the characteristics of these excursions as well as the differences in relative distances where these velocity excursions between the 7/16-inch and 5/16-inch wireline rope. Based on the results of that review, it is theorized that the interplay between friction coefficients required to move the EMAT ILI tool as it navigates various pipeline features caused the wire rope to elongate excessively, leading to delays in the tool movement. This caused a weight-loading or "Yo-Yo" effect that was exaggerated by the differences in static and dynamic drag coefficients of the ILI tool. Below are discussion points on ways to reduce this effect.

#### Tether Materials

As previously described, the distance travelled before the velocity excursions became significant and approximately doubled between the 5/16-inch and 7/16-inch wire ropes. During the investigation, the stretch coefficients of the 5/16-inch wire rope provided by the wireline operator were 1.2 ft/Kft/lbs or about double that of the 7/16-inch wire rope at 0.61 ft/Kft/lbs. The recommendation for future inspections is to utilize a high-modulus polyethylene (HMPE) or Dyneema rope, which in the same diameter averages about one-seventh the weight and half the friction coefficient. It has a higher breaking strength and similar elastic elongation properties to a wire rope of the same diameter.

Take, for example, the 7/16-inch wire rope used for most of this project. Its weight in air is measured at 603 kg/km, meaning that at 1500 m, there is approximately 905 kg or approximately 2000 lbs of wire rope weight alone. Due to the lower weight and ease of handling, a larger-diameter rope could be used for these operations. A 1-inch synthetic rope is still about half the weight of the wire rope at 330 kg/km. For this example, let's use 2700 kg (6000 lbs) as the load force and 1500 m as the distance. The 7/16-inch wire rope has a breaking strength of 13,607 kg (30,000 lbs), whereas the 1-inch synthetic rope can have a breaking strength of close to 39,600 kg (87,300 lbs). At 2700 kg, the wire rope is at approximately 20% of its break strength, and the synthetic rope would be at 6.8%. The synthetic rope is now working at a significantly lower percentage of its break strength when compared to the wire rope. Elongation coefficients are not typically provided for a synthetic rope; however, the elongation is relatively linear in the elastic region at percentages of breaking strength below 30%. Based on the values in Table 2 taken from the Samson Amsteel product sheet, the slope of the curve was calculated to be .025, meaning that at 8.07% (the total percent of breaking strength), when including the weight of the cable, the elastic elongation is 16% less with a synthetic rope. This reduction in elongation would be applicable across the elastic range of the rope. Table 3 outlines these calculations.

**Table 2.** Amsteel elastic elongation (4).

| **Elastic Elongation per % of Breaking Strength** | | |
|---|---|---|
| 10% | 20% | 30% |
| 0.46% Elongation | 0.70% Elongation | 0.96% Elongation |

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**Table 3.** Elongation Calculations.

| Material | Line Length (m) | Weight of Rope (kg) | Tension (kg) |
|---|---|---|---|
| Wire Rope | 1500 | 905 | 2700 |
| Synthetic Rope | 1500 | 495 | 2700 |
| **Total Tension (kg)** | **% Break Strength** | **Elongation (m)** | **% Difference** |
| 3605 | 26.49% | 7.321 | 16% |
| 3195 | 8.07% | 6.150 | |

**Tool Drag**

Another way to reduce the amount of elastic elongation of the tether materials would be to reduce the tension on the rope. This tension in this system mainly comes from the drag from the ILI tool as it is being pulled through the pipeline and navigating pipeline features. Reducing ILI tool drag can be a challenging endeavour; however, the Quest Integrity team proactively measured the drag forces of each section of the EMAT tool, as shown in Figure 2. These measurements showed that the drive section on the tool, which was a modified battery vessel, accounted for approximately 50% of the total drag. A typical battery vessel without any drive elements has very low drag, implying that a significant portion of the drag is coming from polyurethane drive discs specifically designed for this bi-directional tethering application. The solutions proposed for this observation included lowering the durometer of the discs or using low-interference cups with bevelled edges to reduce the risk of catching on pipeline features. These changes are still being investigated to reduce the overall drag of the EMAT ILI tool.

## Conclusions

This case study has reviewed the operational details of a bi-directional tethered inspection, its role in integrity programs, and the operational results of the project. Although the project was considered successful, there were issues maintaining the velocity of the ILI tool within specification while at distance. A theory was presented that may explain the cause for this effect, as well as potential solutions for this issue. Despite this challenge, the inspection was considered a success, and the technology could be deemed a viable solution to detect and assess SCC threats in otherwise unpiggable pipelines. This study does not cover the validation results of this project, as no validation digs have been performed to date.

Since this inspection, Quest Integrity has conducted two other tethered EMAT inspections—one in the NPS 10 and one in the NPS 20 diameter. A 1-inch diameter synthetic rope was used on both inspections, and although the inspections were uni-directional, both inspections had the requirement to navigate more than 400 degrees of bends. These inspections were both considered successful and had very minor velocity excursions.

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