Robotic Inspection of Unpiggable Piping at Pump Station

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ALYESKA PIPELINE SERVICE COMPANY, a North American pipeline operator, has successfully used a robotic crawler to complete an inspection of an underground facility pipeline that was previously considered inaccessible. The inspection area was part of the Pump Station 03 (PS03) facility on the Trans-Alaska Pipeline System (TAPS). In addition to being underground, the inspection area was encased in a sand-cement slurry and had difficult geometry for traditional in-line inspection (ILI) tools to navigate, including vertical sections, a horizontal tee, and multiple back-to-back bends with elevation changes. These geometries were easily navigated by Diakont's robotic inspection crawler, made possible by the tank tread design which expands firmly into the ID of the pipe for traction. Figure 1 shows a Diakont crawler vertically entering a PS03 pipeline for inspection.

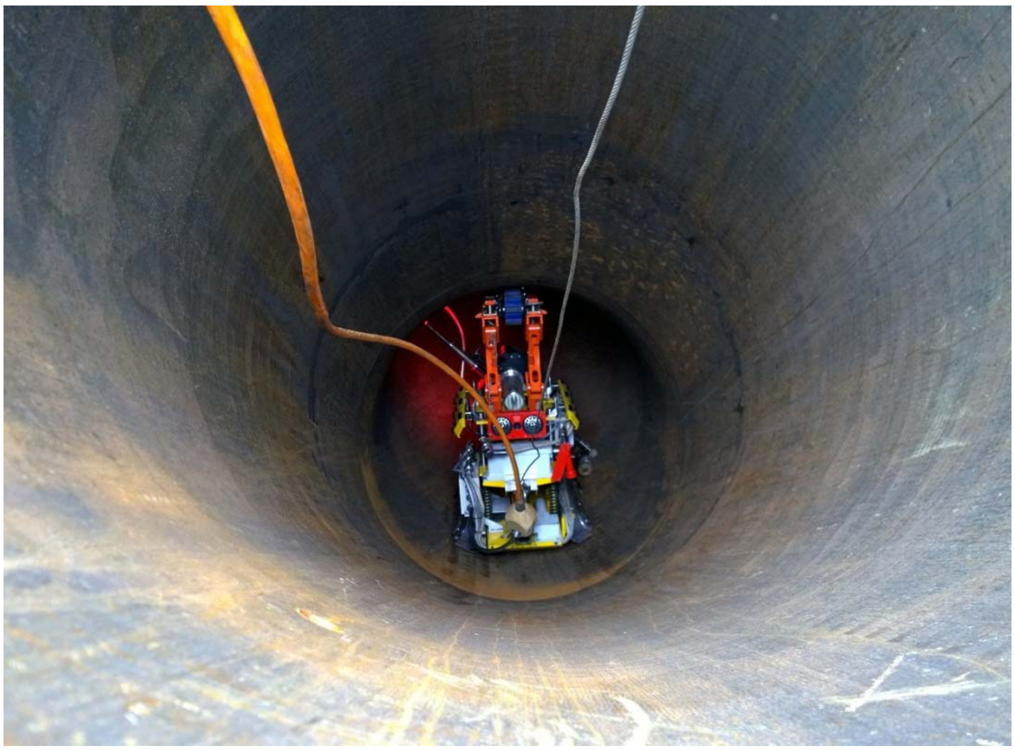

Figure 1: Robotic ILI Crawler Vertically Entering PS03 Inspection Area

The inspection of PS03 was performed in the aftermath of a crude oil leak to containment that occurred from a section of underground line at Pump Station 01 (PS01) in 2011.

After 2011, significant industry developments made remotely-operated ILI tools available that could inspect unpiggable facility piping. Alyeska reviewed these modern ILI technologies and selected Diakont to inspect the pipeline at PS03 using their robotic ILI crawler.

Buried Piping Function

Reconstructing the piping above-ground could cause a safety problem in the event of a pressure surge. The underground line connects the main oil line to a relief tank used to absorb excess oil pressure in the line. An event such as a pump problem could cause a pressure surge down the main pipeline, which would place huge forces on the pressure-relief pipeline. The ground around the buried line would absorb those forces, restraining the pipeline from moving and decreasing the risk of the pipeline breaking. Additionally, having the pipeline at a level below the relief tank maintains high enough oil pressure in the buried line to prevent dangerous gas vapor pockets effervescing from the oil. Given these potential problems with reconstructing the piping above ground, the best option was to conduct in-line inspection.

In-Line Inspection Robotic Crawler

Diakont developed the robotic crawler system to inspect unpiggable pipelines. Diakont's robotic crawler uses dual base tracks for navigation on horizontal surfaces and a single top track that stabilizes the crawler. The top track extends to the top of the pipe to provide necessary traction to hold the crawler rigidly in place while inspecting difficult pipe geometries such as vertical sections. Figure 2 shows the robotic crawler with its three tracks engaged into the pipe ID.

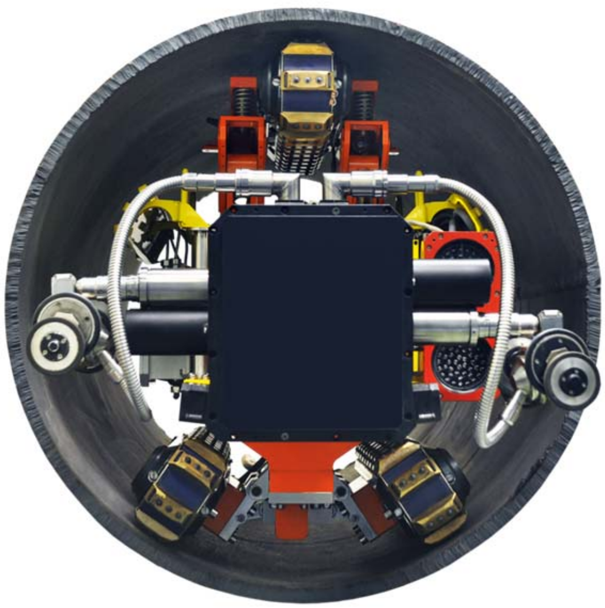

Figure 2: Robotic ILI Crawler with Three Tracks Engaged Into the Pipe ID

An umbilical cable connects the crawler to a central control station and provides for power, real-time data collection, and control of the crawler's tracks and sensor suite. A steel retrieval cable is also connected to the back of the tool for extraction in the event of a power failure.

The robotic crawler used at PS03 was equipped with three inspection technologies:

- Electromagnetic Acoustic Transducer (EMAT) ultrasonic testing (UT) sensors to measure pipeline wall thickness and locate corrosion damage on both the OD and ID.
- A laser profilometry gauge to make a detailed map of the pipeline's inner surface, including surface pitting and other irregularities, and take fine measurements of individual internal diameter (ID) anomalies.
- A video camera to create a video record of the pipeline's interior.

Unlike conventional UT instruments that require liquid couplant between the transducers and pipe body to measure wall thickness, the EMAT instrument does not require any couplant because the transducers are not in physical contact with the pipe body.

Tool Testing

During the planning phase for the PS03 inspection project, two key concerns were identified: the crawler's ability to negotiate the pipeline geometries, and the time investment required for a successful inspection. Before approving the tool to perform the inspection at PS03, Alyeska contracted with Diakont to test the robotic crawler on pipelines at Pump Station 10 (PS10), a pump station that had been removed from service several years earlier. PS10 was selected because it had similar piping to other operating stations, including PS03, and therefore could be used to validate the tool's inspection capabilities.

The crawler successfully negotiated the PS10 inspection area, including vertical sections, 90° bends, transitions from 36" to 48" pipe, and manifolds with multiple offtakes. The crew also demonstrated the ability to manually extract the tool by simulating a power failure, using the steel retrieval cable to pull the crawler out of the pipeline. This function was essential to Alyeska, as it proved there was no risk of the crawler becoming stuck in the pipeline.

The testing at PS10 also confirmed that cleanliness of the pipe was critical for the EMAT UT sensors to collect accurate data on pipe wall conditions. Pipes that were cleaned to abandonment specifications were successfully examined, but another section of pipe could not be inspected due to heavy scale from exposure to atmosphere. Although this type of scale was unlikely in the PS03 lines filled with crude, it was determined that excessive scale of any type could cause issues, including ultrasonic signal loss and obstruction of visual anomaly analysis.

Pre-Inspection Cleaning

Prior to the PS03 inspection, a work crew thoroughly cleaned the inspection area to remove accumulated wax and other debris. After flushing hot oil from the main pipeline through the relief piping, the cleaning crew packed the line with 16,000 gallons of diesel fuel to act as a solvent. The diesel flush was followed by a high-pressure wash with approximately 100,000 gallons of hot water. After the cleaning process, the inside of the pipe appeared like new, with some original stenciled lettering becoming visible.

PS03 Inspection

Alyeska and Diakont created an inspection plan comprised of five routes to access the complex piping systems of PS03. Figure 3 shows a diagram of pump station 03 along with the inspection routes. The pipelines that were inspected included:

- The suction relief line
- Tank farm line
- The discharge relief line 1st half
- The discharge relief line 2nd half
- Suction riser line

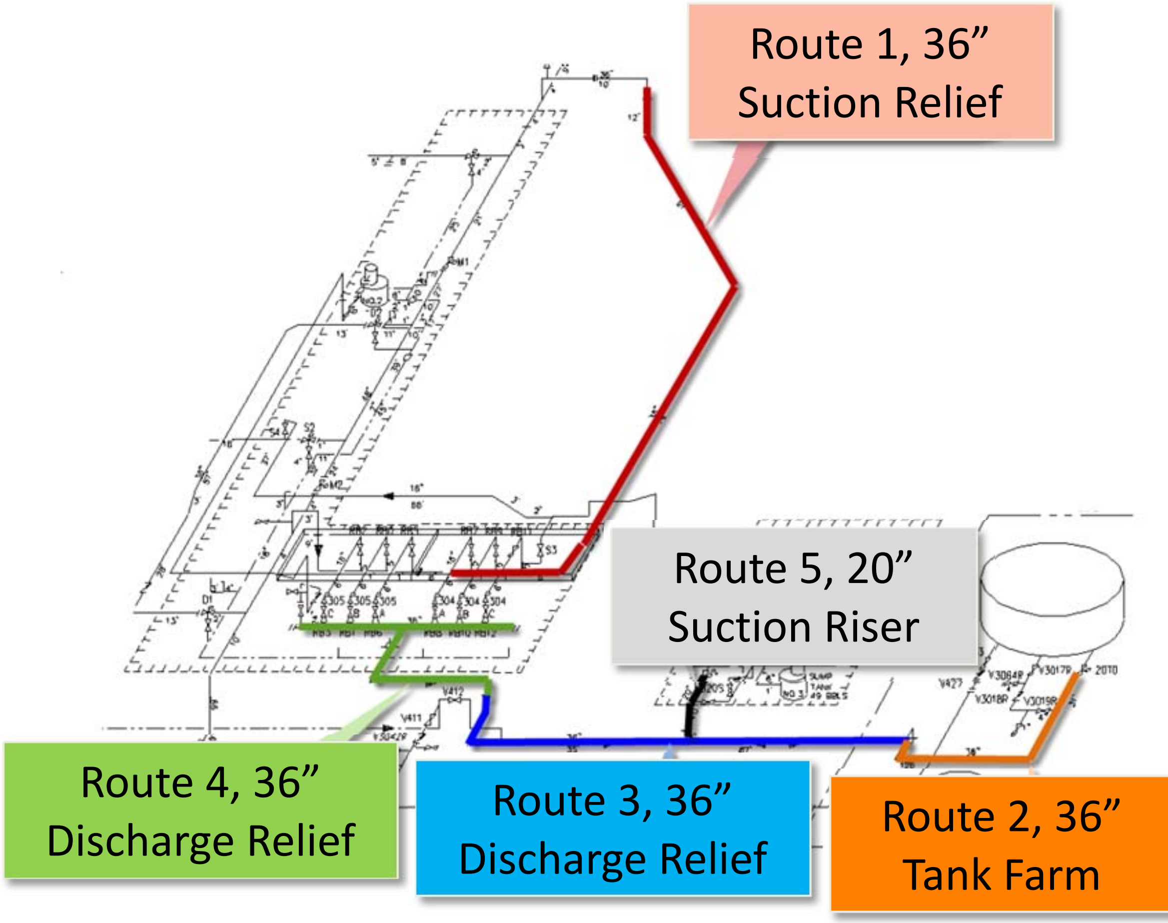

Figure 3: Diagram of Pump Station 03 Inspection Routes

The discharge relief line was split into two routes to accommodate its especially difficult geometry. All of the pipelines inspected had a 36” outside diameter (OD) except the 20” suction riser.

For each inspection route, the crawler performed a visual inspection to record pipeline geometry and document any gross anomalies found on the ID of the pipe. The crawler then conducted an automatic EMAT scan of the straight pipeline sections and manual scans in the elbows and fittings to detect anomalies such as general corrosion, pitting, and cracking. Throughout this initial scan, the Diakont NDE data analyst reviewed the resultant data in real time, monitored tool operation via telemetry, and recorded precise pipeline geometric data, which was incorporated into a pipe tally in the pipe feature list (PFL) report.

Following the EMAT scan, the robot operators navigated the tool back down the pipeline and stopped at each anomaly indication to perform a detailed manual inspection. These indications included all anomalies detected during the visual inspection and any section with wall loss of 0.04” or greater. During the detailed manual inspection, inspection technicians characterized and measured anomalies with the EMAT sensor.

After characterization, the crawler navigated back to the launch point where the EMAT module was replaced with the laser profilometry module, then returned to the indication sites to capture laser scans of the ID surface profiles and take close-up ID photographs. Following the laser profilometry scans, the robot navigated back to the launch point and was manually removed from the pipeline.

Inspection Results

The live inspection of PS03 progressed smoothly and was completed ahead of schedule. The inspection revealed that the pipeline was in good condition, with only two exterior dents and a gouge detected in the suction relief line. Alyeska confirmed that these three anomalies were documented in their database as sections that were damaged during the pipeline construction and did not represent safety or pipeline integrity concerns.

Laser profilometry scans were taken at each location where wall thinning measurements were 0.04” or greater. There were no signs of corrosion on the ID of the pipe at any of the locations where wall thinning was detected, indicating that the thinning was located on the OD of the pipe.

Laser profilometry scans were also taken at locations where anomalies were detected during the initial visual inspection of the pipe. Only a few anomalies were detected during visual inspection of the pipeline, but each of them had minimal wall loss of 0.09” or less. Figure shows an example picture and corresponding laser profilometry scan of an anomaly found in the discharge relief line.

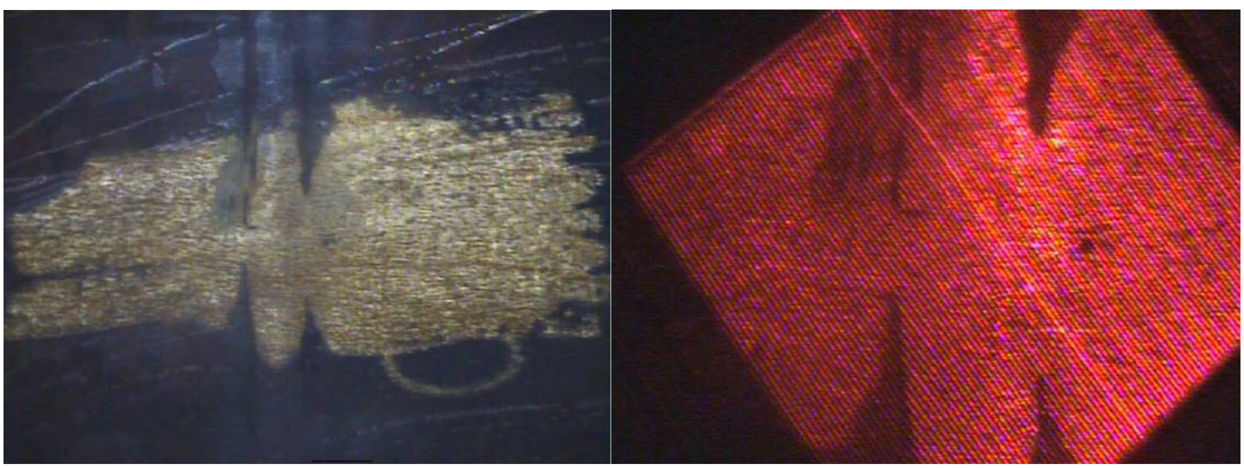

Figure 4: Photograph and Laser Profilometry Scan of Anomaly Found in Route 4b 70.2 Feet

The inspection results were analyzed by Diakont specialists, and the data was formally presented to the pipeline operator within hours of removing the tool from the pipeline. With the pipeline found to be in good shape, the PS03 system was returned to service.