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NDE Techniques for Water and Wastewater Pipe Condition Assessment

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ABSTRACT: This paper will focus on two Direct Condition Assessment (DCA) projects that are using Remote Field Testing (RFT). Both projects will have been completed by the NASTT conference and were selected because they cover different applications, materials and pipe sizes. The first project used the PICA SeeSnake™ In-Line Inspection tool (ILI) to determine the condition of a 12" Steel pipeline. The pipeline had epoxy coating and a wall thickness of .375-inch. The second project was completed in late-fall of 2011. Again, a SeeSnake™ tool was used, this time to inspect a 24" ductile iron line.

Project One occurred in November and December of 2010. Two sub-aqueous water lines were inspected in Asia using the 12" ILI tool. The lines were water transmission lines used to transport water from a main island to one of its smaller, neighboring islands. A free-swimming SeeSnake™ tool was inserted into the line and propelled to the other island using water flow. The ILI tool collected data continuously along the length of the line.

The second project occurred in late-fall of 2011 in the Midwest U.S. A 24" wastewater force main was inspected using a 24" ILI tool. The line is Ductile Iron with a Cement Liner. Interesting features of this project include the launch of the tool, multiple bends throughout the line, and recent break history.

This paper will be particularly of use to those interested in free-swimming In-Line Inspections of water and/or wastewater lines; alternatives to leak detection and CCTV inspections; and how to stretch their replacement budgets with proactive approaches to asset management.

1. INTRODUCTION

The US EPA conducts a review of US water system needs every four years (United States EPA). The study includes a 20-year budgetary forecast of the nation's water transmission and distribution infrastructure requirements. The last available survey from 2007 reported an estimated need of US$200 billion over the period from 2007 to 2026. Prior surveys were performed in 1995, 1999 and 2003. With each survey the forecasted budget demands over the subsequent 20 years were revised upwards.

Part of the problem in attempting to compile accurate long-range budget forecasts is the "invisibility" of the condition of subsurface (buried) infrastructure. Many municipalities rely on indirect indicators like age, soil resistivity and leak records, to guide in the management of their infrastructure. However, these indicators lack the predictive value needed to accurately drive 10-15 year budget plans. Certain indicators, like break history, should be considered reactive instead of predictive.

There is therefore a need to improve the understanding of the condition of the existing infrastructure through Direct Condition Assessment (DCA). DCA is achieved through the use of high technology electronics and sensors embodied in State-of-the-art In-Line Inspection Tools. Effective use of DCA equipment leads to better infrastructure planning and more precise budget forecasts. In the long term, benefits include improved operating efficiencies and customer service, while liability and third party damage (societal costs) are reduced.

This paper highlights two recent DCA projects: one water and one wastewater. Project parameters are briefly discussed, followed by an analysis of the information provided.

2. PROJECT ONE: 18,900 Feet of Steel water pipe in Hong Kong. Winter 2010

In the fall of 2010, a large inspection project commenced involving two 12" steel water transmission lines. The first line was 11,800' and the second was 7,100', with both lines having .37" (9.5mm) wall thickness and fragile internal liners. The proposed inspection tool was the 12" SeeSnake tool by PICA. These lines were classified as "high consequence lines" because of their fragile location. Each line started on the shore of one island and ran underneath a major intercontinenal shipping channel. Failure in either of these lines would be of high economic consequence, yet budgeting appropriate maintenance and replacement fees was difficult because of the unknown condition of the line.

Table 1. Hong Kong Overview

Project One Pipeline Summary	
Diameter	12"
Material/Liner	Steel with exopy coating
Nominal Wall Thickness	.37"
Installation Date	1980s
Total Distance Inspected	18,900 feet

The primary goal of the inspection was to better understand the condition of these two critical lines that supply water to an isolated community. A clear understanding would allow the pipeline owner to determine the remaining life and define a maintenance (or replacement) strategy. An inspection would also provide the pipeline owner insight ino the effectiveness of internal liners for water pipes after 30 years of service.

With these goals in mind, there were specific challenges to the inspection. Primarily, the underwater nature of these lines required a hightened concern for the tool becoming logded or trapped. In addition to the fragile internal liners, tight mitred elbows would require a tool built with specific non-invasive qualities. Lastly, the tool must have a high level of sensitivity as the client was concerned about localized pitting.

To address these challenges, a thorough pre-planning phase was implemented. By having access to line drawings as part of the planning phase, PICA was able to utilize existing valve chamber infrastructure for line access (Figure 1). A Progresive Pigging Program was employed to prevent the tool becoming lodged (described below). PICA designed a custom high-resolution tool with a "soft touch" to prevent damage to the liner and flexiblity to negotiate the mitred bends.

For both pipelines, a local contractor built access and receive facilities for the lines. The project commenced with a Progressive Pigging Program. The goal of this program is to push foam pigs through the line to ensure the SeeSnake tool can safely travel through the line during the actual inspection. The pigging begins with a low density 10" pig and gradually builds to a higher density 12" pig. The process not only provides a light cleaning of the interior wall, but also likely improves flow characteristics.

After succificent pigging, the civil contractor ran a "gauge pig". The gauge pig consists of an array of metal fins that will deflect in the event that they hit an obstruction in the pipe. This is the final step in ensuring the SeeSnake tool a safe journey through the pipe.

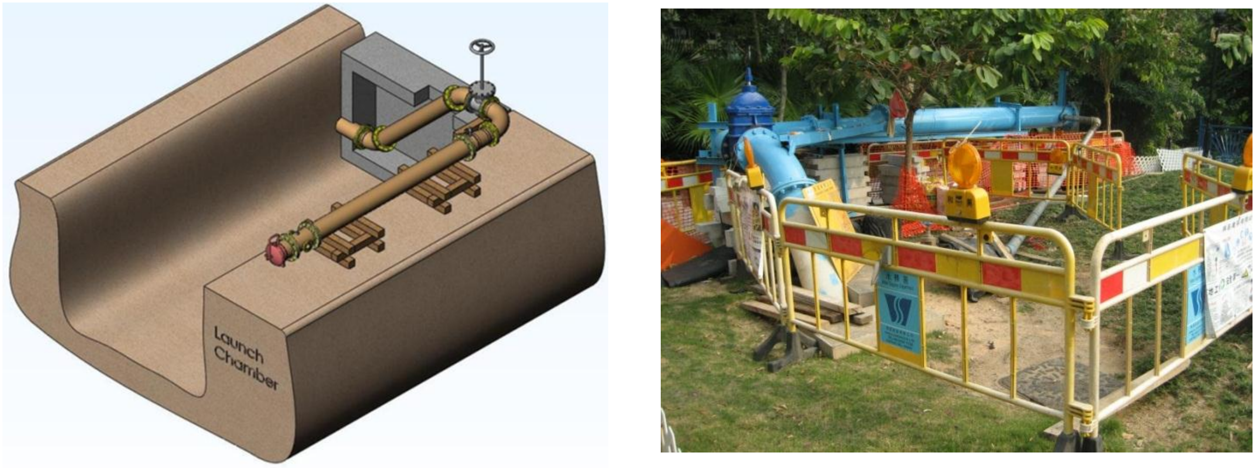

Figure 1. Pictures of 12” Launch Location for Hong Kong

For the first run, the SeeSnake tool was launched in the morning, with an estimated travel time of 10 hours. The tool was loaded into the line and pushed through to the other island by using the line’s natural water flow. A flow meter was installed onto the line and regularly monitored as flow was regulated by a valve. Typically the SeeSnake technicians will track the tool from above ground, but because these lines were subaqueous, that was not possible.

The tool arrived at 11:00pm and the tool was returned to the contractor’s office. After the run, the tool’s velocity was analyzed and it was determined that the tool traveled smoothly through the pipeline. This smooth travel produced good quality data.

The second run was similar to the first. The tool was launched at 10pm with an expected travel time of 14 hours. The actual time was 15 hours, again with a constant velocity.

After the inspection of both subaqueous lines, the data was returned to Edmonton for analysis. Preliminary and then Final Reports were issued explaining the extent of measured corrosion in each line. This section of the paper will share information discovered via the inspection and discuss the verification process.

For this client, a total of 18,900 feet was inspected. The SeeSnake tool registered recordings of 515 pipe joints, 22 features (bends, elbows, ARVs, etc.). The average joint length was 39.48 feet with an average wall thickness of almost exactly the nominal .37” thickness (one line was about 5% over the nominal). The tool was also able to detect the exact location of sacrificial Zinc anodes on the exterior of the pipes. This is important in case the pipe owner decides to refresh the anodes as part of the maintenenance program. In general the tool found few problems with the bodies of the pipe. Most of the indications are at or near the welded joints, where the internal liner is difficult to apply and as a result may not have adhered as well as in the bodies of the pipes.

The verification process for this inspection was limited by the fact that a majority of the line is subaqueous and according to the data, in relatively good condition. At the launch and receive locations of each line, there are sections of pipe that are not subaqueous. Interestingly enough, some larger wall loss anomalies were identified on the launch leg of one of the two lines. This may suggest that the CP system is locally compromised and changes in tidal levels have had an adverse effect on pipe lifespan. Verification is still on-going and recommendations to the pipeline owner are being determined by a third party (in concert with other available information).

Extensive pre-planning led to a very smooth field experience. Needless to say, PICA was eager to avoid traveling halfway around the world and experience any issues. Fortunately that was the case for this inspection.. Notable lessons included effective use of existing infrastructure and proper management of timeline expectations for similar major, long distance projects. For example, the pigging/cleaning program was conducted exclusively by local contractors. The plan was for the contractors to send the foam pigs through the line and then email pictures to PICA to analyze. This was a cost-effective approach (versus sending a PICA rep to supervise the process), and ultimately led to a successful inspection with no on site problems. The pre-planning was also rewarded with the tool successfully navigating the mitred elbows and minimal liner damage (before and after CCTV recordings showed no significant damage to the liner).

3. PROJECT TWO: 17,000 Feet of Ductile Iron wastewater pipe in western Missouri. Winter 2011

In the fall of 2010, a client in western Missouri issued an RFP for the partial inspection of 17,000 feet of 24" ductile iron wastewater pipeline. The target line had experienced multiple breaks over the previous two year period and soil tests had returned "hot" and "highly corrosive". The City was in the position of needing to determine the level of investment necessary to make this a dependable force main.

Table 2. Western Missouri Overview

Project Two Pipeline Summary	
Diameter	24"
Material/Liner	Ductile Iron with Cement Mortar
Nominal Wall Thickness	.35" - .39"
Installation Date	Early 1990s
Total Distance Inspected	17,000 feet (5,000 feet analyzed)

There were several driversfor this project. The city wanted a follow-up investigation into the condition of the line after recent failures. Again, a clearer understanding would allow the pipeline owner to determine the remaining life and define a maintenance (or replacement) strategy. Prevention of future failures was of the utmost importance; PICA was committed to providing detailed results so any localized areas of distress could be addressed before they led to failure. Other challenges associated with this job included tight AWWA C153 elbows, a fragile internal cement liner and a limited window for force main shutdown, which requires good flow planning.

Again, by having access to line drawings, PICA was able to optimize the utilization of existing infrastructure. Ingress was built into an existing deadleg and egress was found at an existing manhole. In addition, PICA performed computer modeling and yard pulls to ensure safe negotiation of the tight elbows. Finally, a Progressive Pigging Program was employed and the SeeSnake tool was continuously monitored using above ground tracking equipment.

The area of inspection started at a pump station and finished in the parking lot of a local credit union. The first 2/5ths of the line ran under low level pasture and farm land. The last 3/5ths ran under residential and commercial property and partially along a local lake.

After completing the necessary civil work, step one of the inspection required a progressive pigging program. This program mimicked the Hong Kong program. The City started by pushing 22" diameter foam swabs through the line and gradually building up to 25.5" polyurethane swabs. Again, the last step was a gauging pig to ensure sufficient interior bore.

In order to generate the necessary flow rates for the inspection, a pump trailer was used to draw effluent from a wet well and propel the tool at the target rate of 15 feet per minute. While the tool was traveling through the pipeline, Above Ground Markers (AGMs) were employed to track the location of the tool. This information was used to verify appropriate tool speeds and in the Final Report will be used to help corroborate odometer information.

Figure 2. Picture of 24” SeeSnake tool (Pre-inspection)

One of the interesting facets of the inspection was the presence of 90 degree bends (elbows). As part of the inspection preparation, extensive computer modeling of the ILI tool was performed in sub 1D elbows (as per AWWA C153). The computer modeling led to design adjustments that allowed the tool to be pulled through an experimental yard setup by hand. Despite the computer modeling and resulting flexible tool design, it was necessary during the inspection to increase the flow rate at these bend locations to propel the tool with enough force.

Field technicians were able to track the tool from above ground as it approached the receive location. Once at the receive, the tool was hoisted out of a manhole, cleaned and sanitized, then prepared for download.

After the data download was complete, the tool was returned to PICA headquarters and analysis commenced. Although the inspection distance was 17,000 feet, the preliminary analysis focused on data the first 5,000 feet.
As for the initial 5,000 feet, 265 pipe sections were analyzed (256 of which were regular Bell & Spigot joints).

Notable is the discrepancy between Average Wall Thickness and the magnitude of localized pitting. The average wall thickness is 89% of nominal, meaning the pipe had corroded, on average, 11%. This 11% is of course not equally distributed throughout the 5,000 feet. Up to 30 locations experienced a measured 100% corrosion. Had average wall thickness been the sole determinant of future action, the pipeline owner would likely pursue an overly conservative approach towards pipeline life extention. Over half of the pipes experienced greater than five measured “pitting regions”. The inspection also identified 30 localized spots were remaining wall is 20% or less. Many of these are believed to be close to through holes which are prevented from leaking either through the internal liner or the graphite matrix remaining as part of the graphitization process. Almost 40% of the pipes experienced at least one defect classified as “Deep” or “Advanced”.

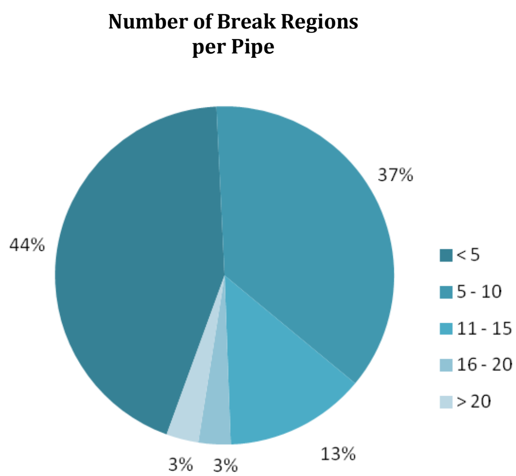

Figure 3: Number of Break Regions per Pipe

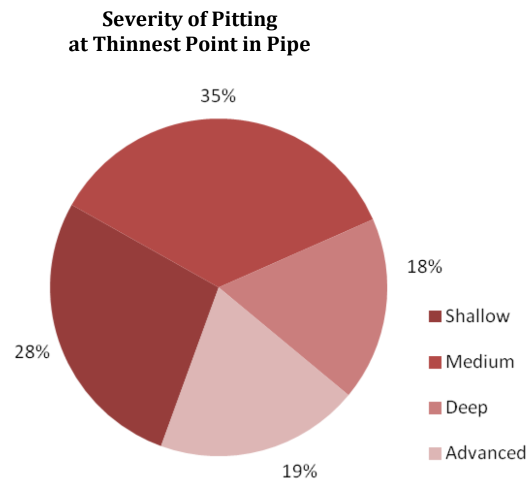

Figure 4: Severity of Pitting at Thinnest Point in Pipe

At the time of this paper, the Preliminary Report has been issued and the Final Report is being completed. Due to this fact, any decisions to perform verification digs or rehabilitate/replace section of pipe are pending.

As is the case with much pipeline infrastructure, at times records are not maintained as thoroughly (or as digitally) as would be convenient. PICA and the client had to work very closely to make sure the job parameters were clear throughout the inspection process. Ultimately this proved fruitful as the tool was successfully tracked in and out of all of the major features. The tool tracking played a significant role in the negotiation of the tight AWWA C153 elbows as operators were able to increase flow rates at the needed intervals.

4. CONCLUSION

One of the primary difficulties in developing an effective 10-15 year budget plans is the “invisibile” nature of underground assets. Traditional methods lack much predictive value as they seldom provide actual wall thickness measurements. An alternative approach would be to employ a Direct Condition Assessment, similar to the technology highlighted in two recent projects.

The recent inspection of 12” water lines in Hong Kong provided wall thickness measurements for two subaqueous lines. The near 19,000 feet of steel pipeline was inspected using an internal, free-swimming tool, resulting in a Final Report registering recordings of 515 pipe joints, 22 features (bends, elbows, ARVs, etc.). The average joint length was 39.48 feet with an average wall thickness of almost exactly the nominal .37” thickness (one line was about 5% over the nominal). Localized pitting was limited mostly to the areas around the welded joints and on the on-shore section of one of the two lines (possibly due to changing tidal levels). The tool was able to navigate the mitred bends with minimal damage to the internal liner.

A 24” ductile iron wastewater line was inspected using a similar technology. After an initial analysis of the 265 pipe sections (256 of which were regular Bell & Spigot joints) the original pipe breaks appear to be representative of much of the pipeline, and not isolated events. Even though the average wall thickness for the pipeline has experienced only 11% corrosion, much of the defects are deep and localized. The inspection identified 30 localized spots were remaining wall is 20% or less. Many of these are believed to be close to through holes which are prevented from leaking either through the internal liner or the graphite matrix remaining as part of the graphitization process. While parts of the pipeline seem to be worth salvaging, the results of the inspection will allow the pipeline owner to build a more educated budget and potentially capture long-term savings.

Although different in application (water vs. waste water), material (steel vs. ductile iron), terrain (off-shore vs. on shore), and size (12-inch vs 24-inch), the two inspection projects have many common aspects. Both projects benefitted from PICA having access to line drawings and optimizing the utilization of existing infrastructure for ingress and egress to the lines. Progressive pigging was implemented for both projects and careful planning led to successful smooth inspections.

From a tool design perspective, both projects had thin fragile liners that could not be damaged, requiring light "soft –touch" inspection tools. Both projects also required high sensitivity, with one of the drivers behind the waste water project specifically being the prevention of future failures. Municipal bends are extremely tight for conventional inspection tools employing UT and MFL. By utilizing RFT as the inspection technology and ensuring proper tool design, the severity of the mitred and AWWA C153 bends ultimately did not provide any significant issue.

5. REFERENCES

United States EPA; Drinking Water Infrastructure Needs Survey and Assessment, Fourth Report to Congress; EPA 816-R-09-001, February 2009.