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Discovering Actual Wall-Thickness in a 12–inch Steel Pipe in British Columbia, a 22-hour Journey

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1. ABSTRACT

In April 2013, PICA Corporation inspected a 300mm Steel bitumen lined steel pipe for BC Hydro in Port Moody, BC. The inspection was 6.8 km in length and done in 22 consecutive hours. Although the inspection was performed in one day, three days were required on-site to complete the assessment. Prior to commencement BC Hydro employed a local cleaning company to pig the line.

PICA Corporation was selected by BC Hydro for our patented Remote Field Testing (RFT) technique which would allow BC Hydro to determine the actual remaining wall-thickness.

The paper presents the results and verification of the inspection and the benefits of actual wall-thickness as opposed to average wall-thickness and leak detection. PICA concluded that this line has significant holes, areas of pitting and graphitization were identified and through a subsequent verification our results were confirmed by an Ultra Sonic Testing Gauge with their exact location on the pipeline and clock position.

2. INTRODUCTION

In November 2012, PICA was contacted by John Kohut and Bonifacio "Boni" dela Cruz from BC Hydro due to concerns regarding the status of their intake-line. They had observed some leaks and were interested how many there were and if they were any "leaks in waiting" so they opted for a "full-line" condition assessment was initially recommended for the 300mm pipeline. However, due to budgetary limitations, PICA analyzed only 2.2kms of the 6.8km line (160 pipe segments). PICA ran the See-Snake tool the entire pipeline because logistically it made sense to inset the tool at Buntzen Lake as opposed to where the inspection started (see Figure 1) There was no available access point where the analysis commenced, therefore it was decided to insert at the pumping station to reduce excavation cost.

The inspection was performed over three days: a gauge run was completed on April 16, and a Remote-Field-Testing (RFT) inspection was completed on April 17 and 18, 2013.This paper documents PICA's RFT condition assessment results for a subset of the inspected pipeline.

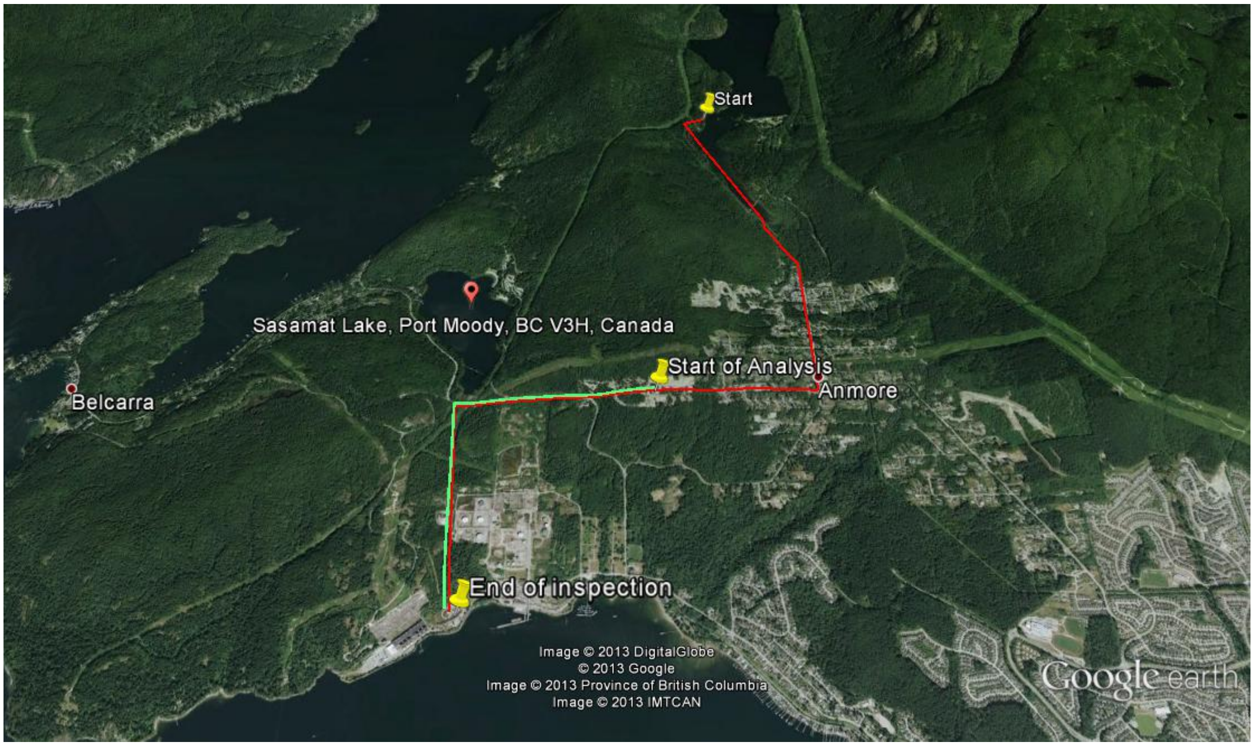

Figure 1: Inspection overview for project

3. REMOTE FIELD TESTING (RFT) TECHNOLOGY

RFT tools work by measuring the "time of flight" (phase shift) and the signal strength (amplitude) of a signal emitted by an exciter coil and detected by an array of receivers. The receivers are positioned circumferentially so that they are sensitive to the many clock locations of the pipe circumference. For each cycle of the exciter frequency, a clock is started and the arrival time of the signal at the detector is used to re-set the clock. The time interval is a measurement of the time of flight, and indirectly, the wall thickness of the pipe. There are many important considerations affecting in-line RFT inspection results. These can be subdivided into four categories:

1. **The physical quantities measured by the Inline Inspection Tool**
   Most ILI tools indirectly measure the wall thickness and infer the wall thickness though a calibration. Ultrasonic (UT) tools measure the "time-of-flight" of sound, while Magnetic Flux Leakage (MFL) tools measure the magnetic field. RFT tools measure both the time-of-flight and the signal strength of a varying electromagnetic field.

2. **The design of the tool:**
   Pipe inspection tool design is a compromise between countless design criteria. Lift-off and resolution are important considerations, but so are bend negotiation ability, battery life, pipe size range, centralization, wall thickness range, suspension, etc.

3. **The delivery procedure:**
   Most tools have an optimal inspection speed and provide the best results when the speed is consistent. Going faster or slower means less than optimal results. This is an especially important consideration when tools are run in gaseous media.

4. **Noise and other interference sources:**
These can be caused by both internal sources and external sources. A major problem for many tools is the cleanliness of the pipe. A dirty pipe can cause artifacts in the data that may mask flaws.
Physical Parameters Measured by RFT Tools.

RFT technology measures three quantities: wall thickness of ferromagnetic pipes, magnetic permeability electrical conductivity. These three factors are measured simultaneously and convey different, important information. For steel pipes, the electrical conductivity remains fairly constant over the length of a pipe segment, meaning that any RFT signal changes along the length of a pipe are mainly due to wall thickness and permeability changes.

Magnetic permeability is not usually a factor of interest. However, in lines that are subjected to soil load stresses, the permeability variations can be significant. For lines known to be under external stresses (for example due to geological ground movement) the permeability variations measured by an RFT tool can be very valuable. Permeability variations produce signals that generally lie just outside the RFT wall loss reference curve that analysts use to differentiate between wall loss and permeability; while wall loss signals lie inside the reference curve.

In the data from cast and ductile iron water lines, we generally notice significant changes in wall thickness along the length of a pipe segment. This appears to be fairly typical, even for brand new pipes that come straight from the foundry. The variation is believed to be the result of the manufacturing process. To capture the spread in wall thickness, we generally report both the minimum and maximum wall thickness per pipe (measured circumferentially without local defects).

Table 1. Pipeline Background Information

Client	BC Hydro – Burrard Generating Station
Location:	Port Moody, BC
Pipe Diameter	300mm
Year Installed	1967
Nominal Wall Thickness	8.34mm
Material	Carbon Steel
Access (Launcher)	Buntzen Lake Pump House
Access (Retrieval)	Storage Tank
Internal Linear	Coal Tar Epoxy
Cathodic Protection	Impressed Current
Analyzed Length	2209.15m
Inspection Direction	North to South-West
Break History	Observed Leaks

3.1 SeeSnake Tool Description

PICA Corp's See Snake line of RFT tools are highly flexible tools that employ Remote Field Testing (RFT) technology for measuring pipe wall thickness. RFT technology works by detecting changes in an AC electromagnetic field generated by the tool that interacts with the metal in the encompassing pipe, becoming stronger in areas of metal loss.

The SeeSnake tool used in the Burrard Water Line inspection employs an articulated mechanical design that gives it flexibility to negotiate 90-degree short radius elbows. The hard diameter of the tool is significantly smaller than the ID of the pipe to allow for protrusions, lining and scale. Centralizers maintain a uniform annulus between the tool and the pipe.

The tool detects wall thinning caused by corrosion or erosion (both internal and external), as well as line features such as joint couplings, branches and elbows.

Figure 2: Picture of the See-Snake inspection tool

4. INSPECTION DETAILS

Weeks prior to the RFT inspection BC Hydro contracted a local cleaning company to “swab” the pipeline. This was done in an effort to remove sediment and organic matter that had settled in the line. Cleaning runs were conducted over several days using incrementally increasing diameters of cleaning swabs. Pipeline access was granted via an existing launcher at the Buntzen Lake pump-house.

Due to the length of the 300mm SeeSnake tool, the existing launcher was insufficient in providing pipeline access for the RFT inspection. PICA provided an appropriate launcher that was installed at the pump-house. An existing receiver at the storage tank was deemed suitable for tool extraction.

Prior to the inspection, PICA’s gauge pig was run through the line to identify any restrictions that could impede or stop the passage of the RFT tool. This tool additionally cleaned the remaining sediment in the line. The gauge run indicated clear passage for the SeeSnake tool.

The SeeSnake tool was propelled through the line using flow induced from the Buntzen pump-house. Progress was tracked using Above Ground Monitors (AGMs) spaced at regular intervals. After approximately 22 hours, the tool arrived at the storage tank where it was removed from the pipeline. A data download was initiated and the data quality was confirmed to be acceptable. The data was then uploaded from the tool to PICA’s Edmonton office where it was analyzed and the report produced

4.1 Calibration

For the best possible RFT accuracy, a calibration is performed using a short section of pipe with the same nominal pipe properties (wall thickness and grade) as the pipe being inspected. Under ideal conditions, a full pipe section with a half pipe on each end (to create two full connections and eliminate any “end effect”) in good condition are provided by the client. PICA creates artificial defects of varying depth and diameter in this pipe and run the RFT tool through it several times at various frequencies. The signal produced during this process is then compared to the signal produced during the field surveys to better quantify remaining wall calculations.

In the absence of such a calibration pipe or to confirm the accuracy of the calibration (especially in the case where the test sample is not representative of the majority of the pipes in the inspected line), calibration test results are supplemented by mathematical calibrations. Simply, the analyst will build a histogram of the thickest RFT phase reading per inspected pipe section and create a calibration from this histogram. This assumes that the thickest phase readings are unaffected by possible corrosion. Using this method, defect sizing accuracy is expected to be ±20% for short (local) wall loss and ±10% for long (general) wall loss for pitting above the limit of detection and sufficiently removed from major features (such as flanges or girth-welds).

PICA relied on the latter (mathematical) calibration method for corrosion assessment. A calibration pipe was still used, but due to differing wall thickness and grade its purpose was simply to confirm that the tool was operating within acceptable parameters.

5 ANALYSIS RESULTS

A 2209.15m section of data was analyzed at the request of BC Hydro spanning from the insertion point up to the flange pair connecting the last 45° elbow and the receiver-wye. As the predominant features in the pipeline were below ground (i.e.: bends) no additional scaling was performed. Nineteen AGM locations spaced at convenient intervals were used to track tool progress through the line and were used as reference markers for later verification of inspection results.

5.1 Velocity Information

The RFT inspection method requires meticulous control of tool velocity to obtain optimal data quality. The Burrard water line was inspected by propelling the See Snake tool using fresh water pumped from the Buntzen lake pump house. To restrict abrupt changes in tool velocity, the flow was choked at the receive-end in an effort to maintain a steady flow. As the tool approached the receive barrel, the choking valve was completely opened to allow tool passage. This resulted in tool acceleration through a short section of line at the end of the run.

At the 35Hz inspection frequency the optimal tool velocity is 5m/min. Velocities up to 10m/min provide acceptable RFT data quality. Velocities above 10m/min result in compromised data quality. Acceptable velocities were maintained for a majority of the Burrard water line inspection.

5.2 General Wall Condition

Pipe sections longer than 1.2m were analyzed to obtain the average wall thickness, as well as the minimum and maximum circumferential thicknesses.

The average remaining wall thickness (Tavg) calculated over the length of the section is called the "PARW" value (Pipe Average Remaining Wall). A plot of each pipe's individual PARW with the line's average PARW is shown in Figure 3. Because no calibration standard was provided to PICA, a free-air calibration assigned an *average wall thickness* of 100% to the Burrard water line. This is generally a safe assumption when very little corrosion is observed as was the case in this instance.

The PARW value usually varies ±15% due to tolerances in manufacturing. Variations outside the normal 15% spread can be an indicator of a different nominal wall thickness or pipe type, or point towards a problem like aggregate pitting or general wall loss.

A minimum circumferential thickness of 85.6% has been noted for the Burrard water line. This can signify early signs of corrosion and can be indicative of naturally thinner pipe. This value falls within manufacturing tolerances.

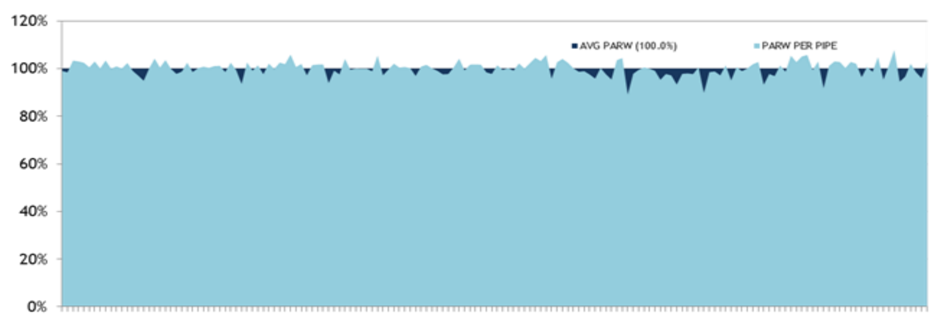

Figure 2: Pipe Average Remaining Wall (PARW) for each inspected pipe

5.3 Local Wall Loss

A total of 19 wall loss indications, spread over 12 pipes, were identified. Five of these indications measured as through holes with another three measuring less than 25% remaining-wall. Most corrosion appears concentrated in the area between air vent/vacuum brake #5 and the receiver.

The presence of through holes was suspected as surging water and air bubbles were observed at these sites during the inspection.

Table 2: Pipeline Summary:

Analyzed Length	2209.15
Thinnest Circumferential Wall Thickness	85.6% in pipe 1410
Number of Analyzed Pipes	160
Number of Vertical Bends/Elbows	2
Number of Horizontal Bends/Elbows	3
Number of Permeability Anomalies	60
Number of pipes without localized wall loss indications	148
Number of pipes with localized wall loss indications	12
Number of pipe with Through Hole (TH) indications	3

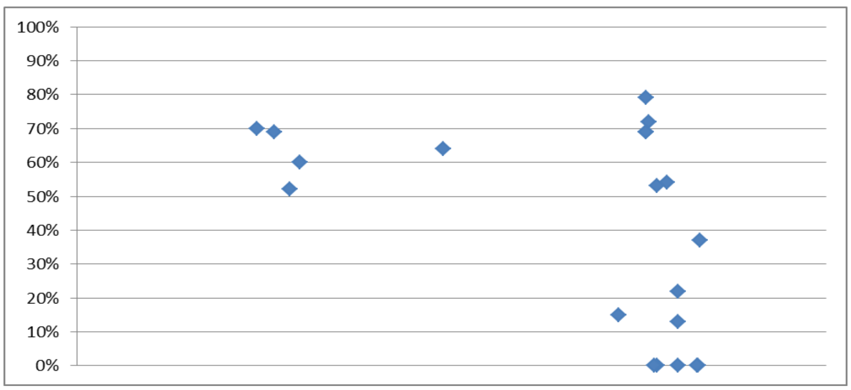

Figure 3: Plotting areas of corrosion and estimated pit depth along the pipeline (start – finish along x axis)

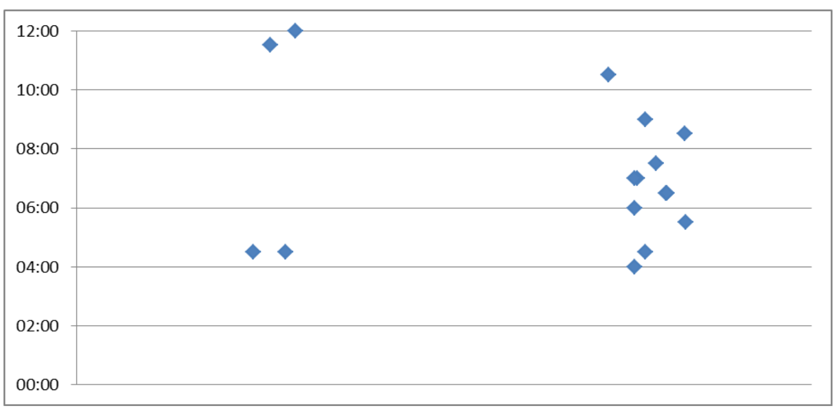

Figure 4: Showing clock position of detected corrosion pits (start to finish along x axis)

5.4 Dig Verification

At the request of BC Hydro, PICA provided three dig sheets (Figures 5, 8 and 9) containing Indication of Wall Loss, Area of Interest (AOI); Position; Clock Position Looking Downstream; Estimated Depth of Defect and the Distance from the upstream AGM. In July 2013, BC Hydro decided to perform three excavations for dig verification and pipeline repair. Since all three reported areas of wall-loss were located in close proximity of each other BC Hydro decided to excavate all three. The first verification dig PICA identified two areas of concern (3a and 3b) shown in Figure 5. The first one was 3.4m from Above Ground Marker A3 and the second was 12.77m. In both cases holes were identified and in the proper clock position {circular anomaly and through-hole on 3a (Figure 7); 9 o'clock position and through-hole on 3b (Figure 8)}.

Indication	AOI #	Position [m]	Clock Position Looking DS	Estimated Depth	Distance From US AGM A3 [m]
Localized Wall Loss and Mechanical Stress measuring ~356mm in length.*	AOI 3a	1927.61	CIRC	100%	3.4
Localized Wall Loss Anomaly measuring ~150mm in length.*	AOI 3b	1936.98	9:00	100%	12.77

Figure 5: Dig sheet 1 identifying areas of to examine for eveidence of corrosion

Figure 6: Examining AOI 3b showing a through hole at the 9 o'clock position

Figure 7: AOI 3a identifying a circumferential crack in pipe.

Indication	AOI #	Position [m]	Clock Position Looking DS	Estimated Depth	Distance From US AGM A3 [m]	Location of US AGM A3[m]
Localized Wall Loss Anomaly measuring ~96mm in length.*	AOI 4a	2007.8	6:30	87%	83.59	1924.21
Localized Wall Loss Anomaly measuring ~82mm in length.*	AOI 4b	2007.91	6:30	78%	83.7	1924.21
Localized Wall Loss Anomaly measuring ~153mm in length.*	AOI 4c	2008.07	6:30	100%	83.86	1924.21

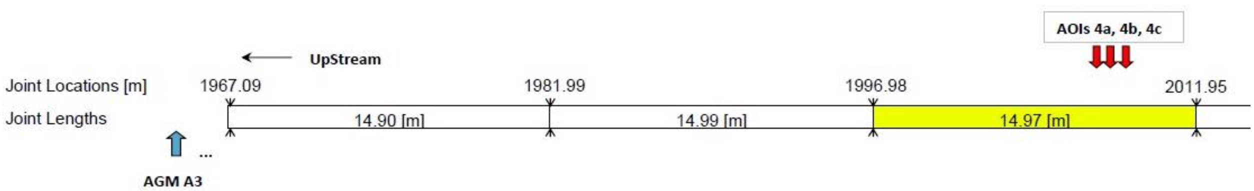

Figure 8: Dig Sheet 2 identifying 3 Areas of Interest (AOI's)

Indication	AOI #	Position [m]	Clock Position Looking DS	Estimated Depth	Distance From US AGM A2 [m]
Localized Wall Loss Anomaly measuring ~137mm in length.*	AOI 5a	2071.37	8:30	100%	34.34
Localized Wall Loss Anomaly measuring ~135mm in length.*	AOI 5b	2073.92	5:30	100%	36.89
Suspected external metal object measuring ~262mm in length.*	AOI 5c	2074.59	11:30	n/a	37.56

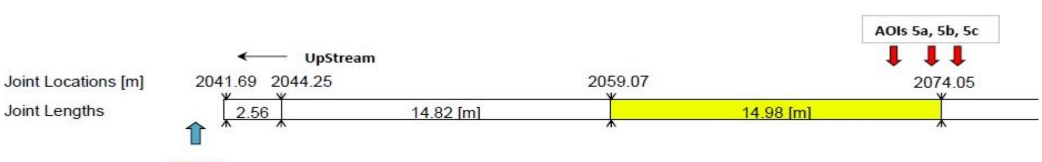

Figure 9: Dig Sheet 3 identifying 3 AOI's and 2 through holes.

6. CONCLUSION

A total of eight AOIs were noted during this pipe wall-thickness inspection and each was verified by BC Hydro during dig verifications. John Kohut, Sr. Mechanical Engineer commented “the measurement were very accurate.” BC Hydro determined that the defects located to-date were due to improper installation of yellow jacket shrink-sleeves. Water got underneath the sleeve and locally attacked the pipe, eventually lead to leaks. A leak detection survey was performed in 2012 and only one leak was detected, where PICA was able to locate five through holes (with active leaks?) and other areas where pitting was as deep as 85% of the initial wall thickness. These locations represent the potential for future failures and water loss.

Since the pipe wall-thickness investigation provided accurate pipe failure locations as well as locations for potential future failures, BC Hydro contracted with PICA to analyze the remaining 4.6 kms of pipeline in April 2014.