DEVELOPMENT OF A SUCCESSFUL UNTETHERED LEAK DETECTION AND PIPE WALL CONDITION ASSESSMENT TECHNOLOGY FOR LARGE DIAMETER PIPELINES

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ABSTRACT

Leak detection in large diameter transmission water pipelines has historically proven difficult for operators.

Traditional leak correlators have worked well on smaller diameter distribution networks but have limitations in detecting leaks on larger diameter pipe (> 300 mm). In many cases, large diameter transmission mains are the backbone to most utility systems and, as a result, have a high level of consequence of failure. Therefore, identifying leaks on a these large diameter pipelines can be of greater value when looking at the overall risk of failure.

Technologies that detect acoustic activity associated with leaks offer an inspection technique for transmission main assessments to occur during full operation of the pipeline. Identification of leaks along the pipeline allows the system owner to find and repair defects that are a source of non-revenue or, in some cases, can cause harmful environmental impacts.

The SmartBall® acoustical inspection technology allows for a unique, un-tethered inspection of many kilometers of pipeline during a single deployment. The technology is inserted into an operational pipeline and travels with the flow for up to 15 hours collecting the time and location of leaks as it traverses the pipeline. Once extracted from the pipeline, the data can be downloaded to a laptop computer to evaluate the number, size and location of the leaks. To date, the technology has been successfully deployed on over 2,000 km of water pipelines.

In more recent times the technology has been adapted to also complete pipe wall condition assessment by emitting a low frequency resonance into the pipeline.

This paper will discuss the challenges and solutions employed in order to successfully deploy, retrieve, and analyze data for an untethered device in pipelines for several utilities.

KEYWORDS

Leak Detection, Trunk Main Leakage, SmartBall, Pipeline Condition Assessment, Pipe Wall Assessment, Transmission Mains, Pipeline Inspection

1 INTRODUCTION

Until recently, identifying and quantifying leakage from trunk mains was not an important priority for water utilities or regulators. Most of the emphasis for loss prevention was on distribution systems. Part of the rationale for this state of affairs stemmed from two factors: first, the presumption, still quite prevalent, that if a trunk main springs a leak, it will be evident from water visible at the surface; and, second, the lack of effective leak detection technologies for trunk mains.

This situation is changing. Regulators are requiring water utilities to pay more attention to trunk main losses, and the implementation of asset management programs, such as AMP 5 in the U.K., emphasizes the need for high-quality condition assessment information so that rehabilitation or replacement programs can be focused and prioritised. The deployment of a recently-developed autonomous in-line inspection system, called SmartBall®, for locating and quantifying leaks in trunk mains, has greatly improved the quality of information available to utilities.

2 TECHNOLOGY OVERVIEW

The technique involves the introduction of instrumented sphere into a trunk main, which, when propelled by the water flow, collects acoustic data as it rolls along the pipeline. This approach is similar to the use of in-line inspection tools, or “smart pigs”, in the oil and gas industry with one important difference; the instrument is smaller than the pipe diameter, allowing it to roll along the pipeline without generating frictional or mechanical noise, thereby permitting optimal acoustic sensitivity. The small size of the instrument allows it to be deployed and retrieved through a 90 mm opening (usually an air-release valve), to pass through in-line butterfly and gate valves, as long as they are open sufficiently, and to negotiate any number of tight-radius bends. This permits very long runs with a single deployment (typically over 20 km with appropriate flows), and eliminates the need for significant modifications to the pipeline and accompanying civil works to facilitate the inspection.

The instrument is tracked during the survey at the surface with GPS tracking devices which detect a periodic ultrasonic pulse emitted by the instrument. At the end of the run, the instrument is captured in a net deployed in the pipeline and the data from the run is retrieved for processing and analysis. In addition to noise generated by leaks, the system can also detect noise from entrapped air (which is important in sewer force mains as a potential source of corrosive hydrogen sulphide gas), and from debris on the invert of the pipeline (construction debris or de-bonded mortar lining). Because the instrument travels directly past leak sites, the sensitivity is independent of pipe material or diameter. A schematic representation of how the system is deployed is shown in Figure 1. The instrument and tracking unit are shown in Figure 2, and typical insertion and retrieval arrangements are shown in Figures 3 and 4.

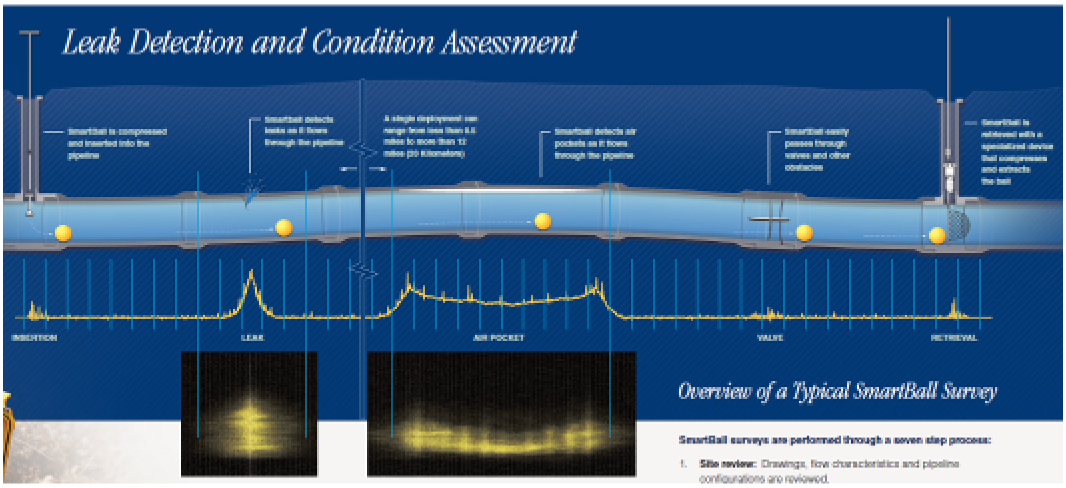

Figure 1. SmartBall Survey Schematic Representation

Figure 2. SmartBall with Foam Cover and Tracking Unit

Figure 3. Insertion Site

Figure 4. Retrieval Site

3 SYSTEM REQUIREMENTS

There are two primary requirements for a successful survey: flow and pressure. Depending on the maximum slope of the pipeline, flows as slow as 0.25 m/s can be accommodated. Flow velocity of 0.5 m/s is usually sufficient in most circumstances. Without sufficient positive pressure, leaks will not generate enough noise to be detectable. For this reason, the system is not normally used in gravity-flow lines; however small leaks have been detected in lines with pressures as low as 100 kPa.

Sufficient working space is required at the launching and retrieval sites to facilitate assembly of the components. Launching can be done through a side, invert or top-mounted valve, but retrieval must be done through a top-mounted valve. Because the instrument is autonomous, it is necessary to ensure that the device will not be diverted into an off-take or branch line. Flow into large-diameter off-takes, or invert off-takes less than 150 mm diameter, should be stopped or reversed while the instrument is passing. The location of invert scour valves should also be noted so that the instrument can be retrieved through the valve if it drops into one. This is not normally a problem if flow velocities are high.

It is necessary for the direction of flow in the line to be established prior to deployment and to avoid flow reversals during the survey. The instrument will stop if it encounters a sufficiently large obstruction in the line or a partially closed valve. However, as the location of the instrument can be determined by the tracking unit, the cause of the obstruction, which adversely affects the hydraulic performance of the line, can be identified and addressed.

4 SYSTEM PERFORMANCE

4.1 LEAK SENSITIVITY

Over the past two years of commercial experience, the system has proven to be a cost-effective, accurate and sensitive method of leak detection. As with all acoustic systems, the sensitivity of the system is determined by the signal-to-noise ratio in the pipeline, rather than theoretical leak sensitivity based on laboratory conditions, which is sometimes quoted by leak detection technology providers. Higher-pressure lines generally generate more noise at leak sites, and different types of leaks generate different acoustic signatures. Because the sensor travels directly past the leak, and because of the absence of frictional and mechanical noise, leak sensitivity of the system is optimized.

Leaks as small as 0.1 l/min have been detected in high-pressure oil pipelines, and small, weeping leaks have been detected in water pipelines with pressures as low as 100 kPa (Figure 5). The value of repairing very small leaks is questionable but, at least, the progression of leak size can be tracked over a period of time with repetitive surveys. Calibration of the system is undertaken on most surveys so that leak size can be estimated for a particular pipeline. Leaks sizes are categorized as Small, Medium and Large. A typical calibration chart is shown in Figure 6, and leak signatures for each class of leak are shown in Figure 7.

Figure 5. Small Leak in 900mm Pipe

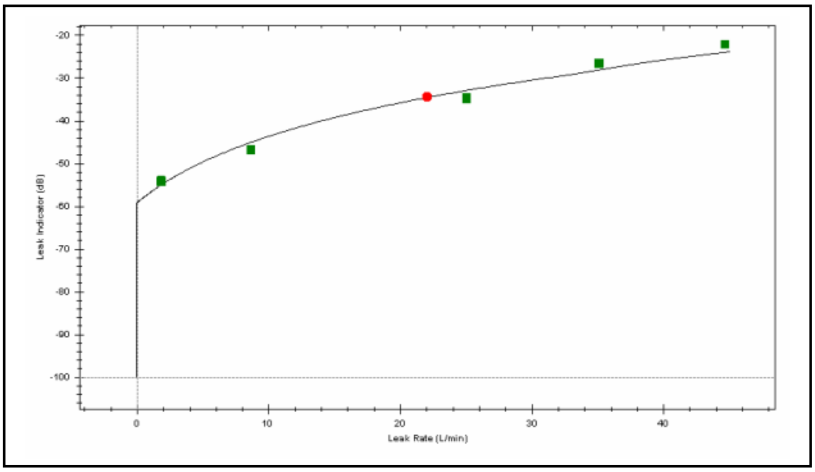

Figure 6. Leak Calibration Chart

4.2 LEAK LOCATION

Leak location is determined by two methods. The rate of rotation of the instrument as it rolls along the pipeline is measured by on-board accelerometers, which provides a velocity profile for the instrument throughout the full length of the survey. Also, the exact time that the instrument passes the above-ground reference points can be determined with the tracking units. As the acoustic data file uses the same time scale, the distance of a leak from a reference point (and hence, any known point) can be calculated, by interpolating between adjacent reference points. Figure 8 shows the velocity profile for a 12-km survey synchronized with the fixed reference points. This process results in location accuracy generally within one metre of the confirmed leak location. If the distance between reference points is greater than 2 km, or if the pipeline chainage information provided by the utility is inaccurate, the variance may be greater. If there is doubt about the accuracy of the pipeline information, locations can be refined by repeating the survey with reference points placed closer to the indicated location, or by using supplementary techniques to refine the leak location.

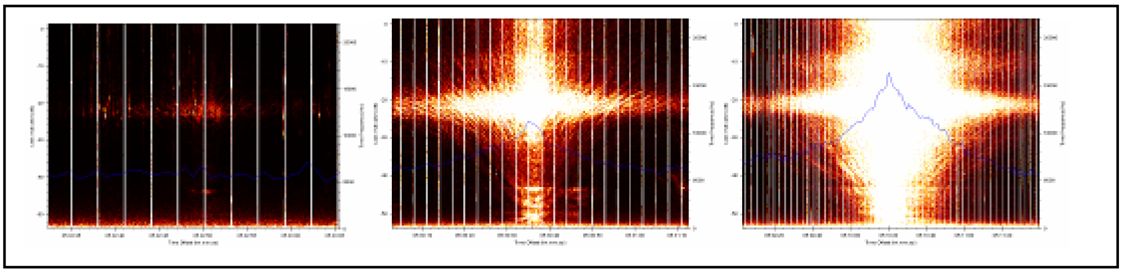

Figure 7. Leak Signatures from Small (<1 l/min), Medium (<40 l/min) and Large (>40 l/min) Leaks

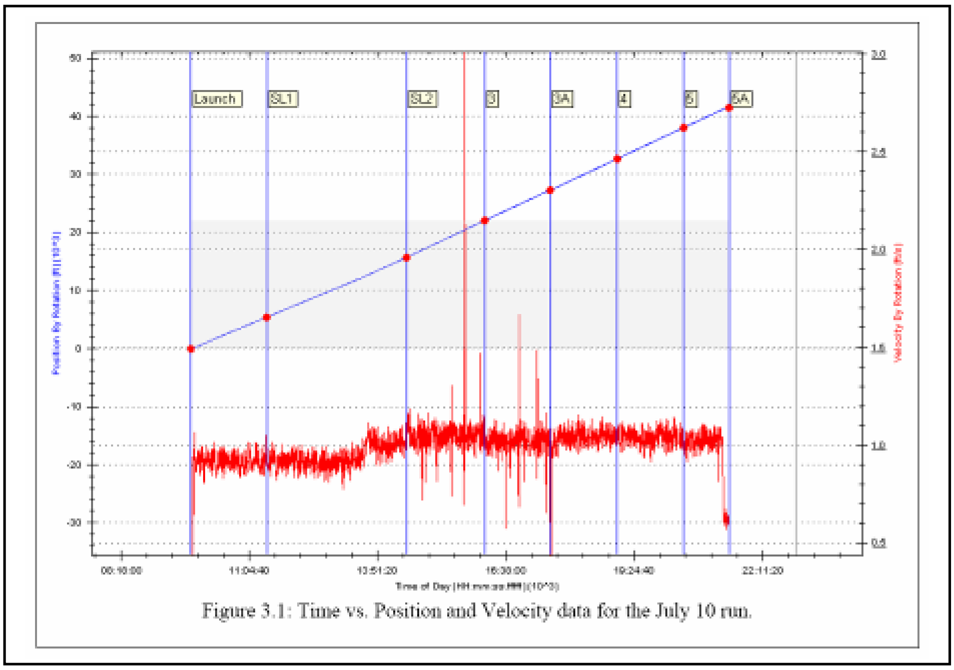

Figure 8. Velocity Profile (red line) and Fixed Reference Points (red dots)

4.3 PIPE WALL ASSESSMENT

While still under refinement; acoustic pipe wall assessment (PWA) takes advantage of the known relationship between the speed of sound in a pipeline and the structural thickness of a pipe wall. A high propagation value will indicate the pipe wall has a high stiffness value which will allow us to generally determine the condition of the pipelines.

PWA is a low resolution first pass which will allow pipeline owners and operators make more informed decisions about the use of higher value more intrusive technologies such as Magnetic Flux Leakage (MFL) and Broadband Electromagnetics (BEM).

The PWA platform is integrated with the standard SmartBall system by inducing low frequency acoustic pulses into the pipeline. Figure 9 shows the acoustic pulser and Figure 10 shows how this is attached to a pipeline.

Figure 9. Acoustic Pulser used for Pipe Wall Assessment (PWA)

Figure 10. The various methods for attaching Acoutic Pulsers to Pipelines

We continue to undertake inspections of various pipeline types to build up our database to allow us to make more informed decisions on pipe wall assessment. Additionally, laser profiling is now been used to overlay on top of our PWA output to quantify anomalies. Figures 10 and Figure 11 demonstrate the outputs we are currently getting from PWA.

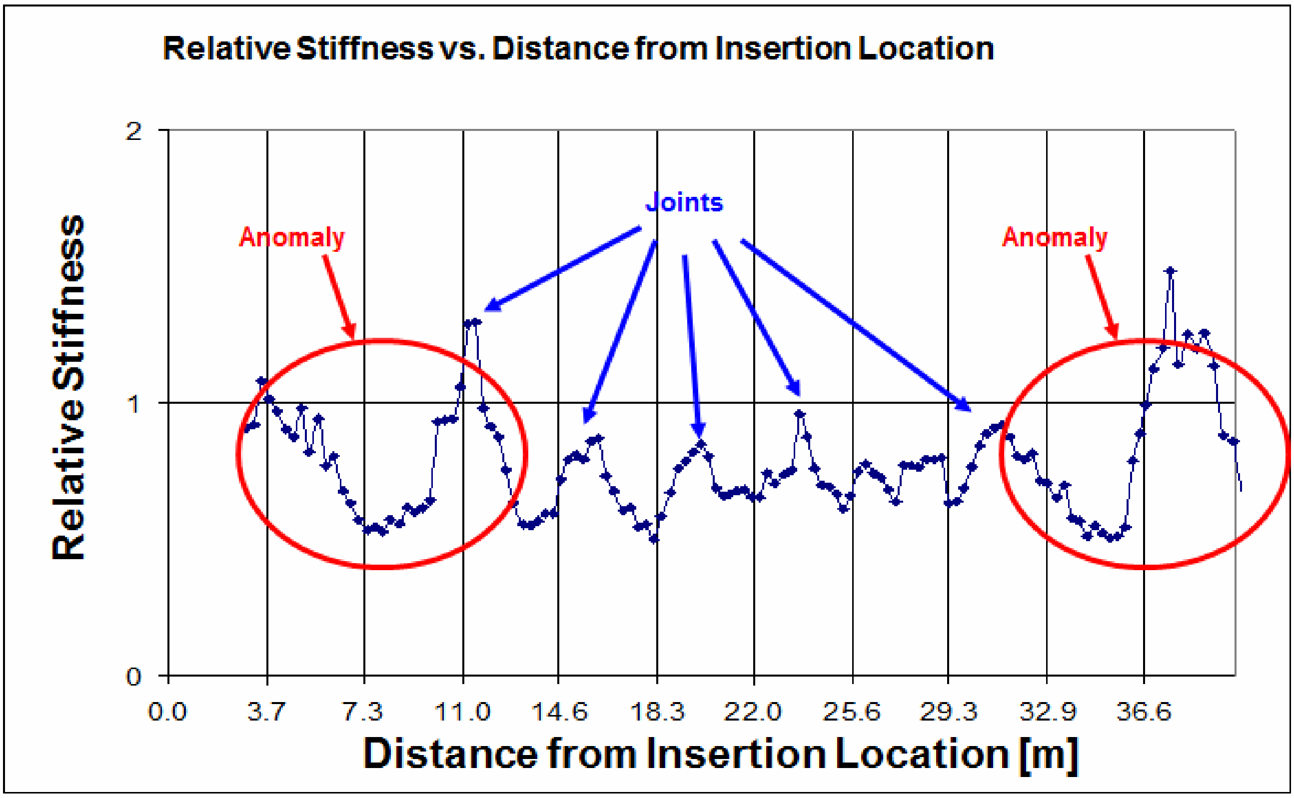

Figure 10. Identification of anomalies and joints in PWA data.

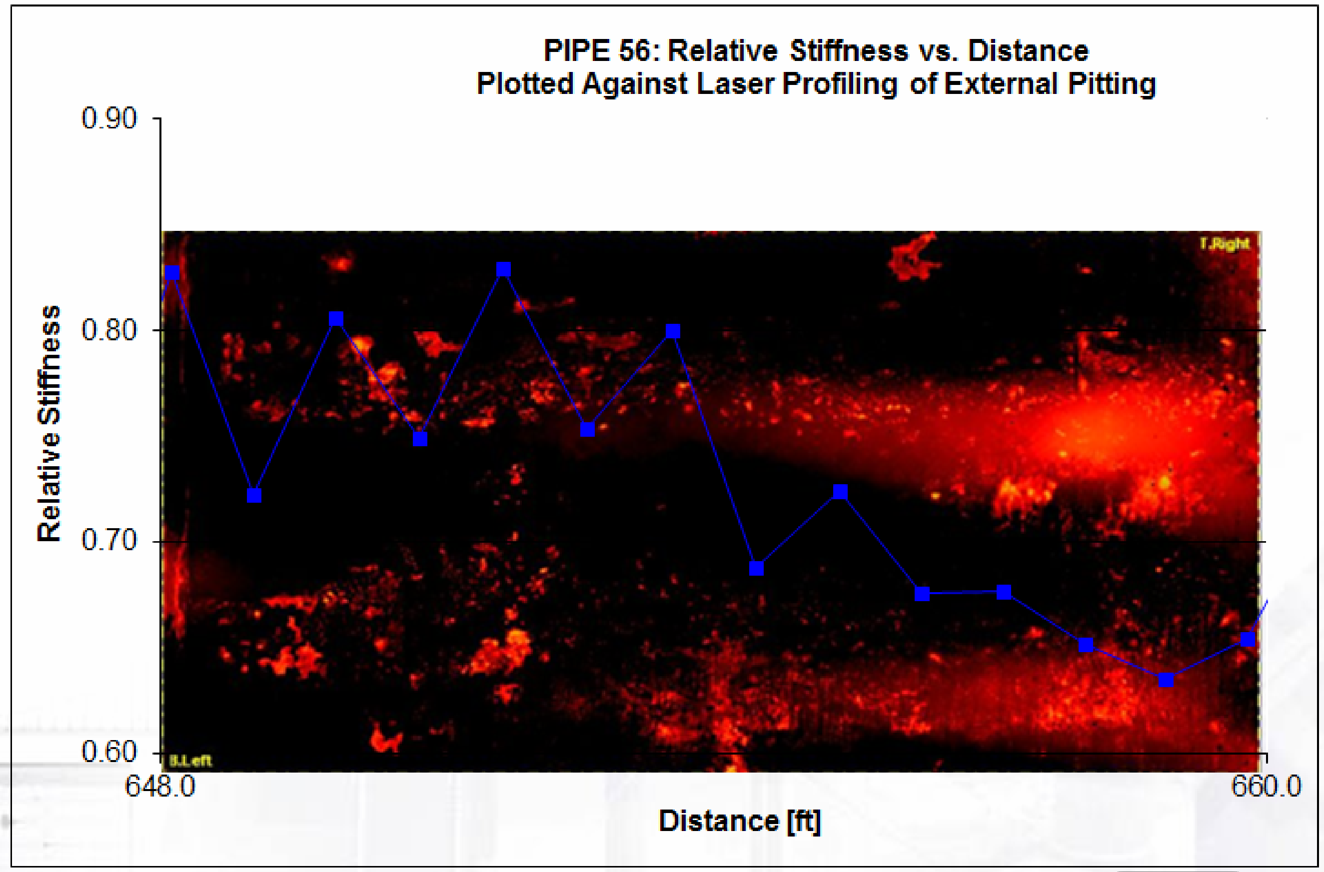

Figure 11. PWA data (relative stiffness) overlapped on laser profile of exhumed section of water main.

PWA continues to be refined by our dedicated R&D department. Under the current resolution we are getting a relative hoop stiffness data reading every 75mm but we are looking to increase the resolution so a data reading is obtained every 10mm of less. Currently undertaking pilot pilot projects in all regions with preference given to partners who are making a commitment to exhuming their pipelines.

5 SYSTEM COMPARISON TO OTHER SYSTEMS

5.1 CORRELATORS

Traditional correlators have generally proven to be unreliable for identifying and locating leaks in trunk mains and in non-ferrous pipelines such as asbestos cement, MDPE and PVC. This is because correlators rely primarily on the pipe wall material to transmit acoustic signals to sensors that may be some distance from the leak. The signals attenuate rapidly in large-diameter pipes and in non-ferrous materials, resulting in poor resolution. As stated previously, the autonomous instrument travels past the leak location and is not reliant on the pipe material to transmit the acoustic information to the sensor.

If multiple leaks exist between correlator locations, the signals from each leak will interfere with each other, thereby preventing the system from accurately locating each leak. The autonomous system avoids this problem as it logs each leak individually in a single pass. Correlators are also affected by surface noise sources, such as traffic or construction activity, whereas the autonomous system is not generally susceptible to this because the sensor is inside the pipeline.

5.2 TETHERED SYSTEMS (SAHARA)

Tethered systems use a hydrophone attached to the end of a cable deployed along a pipeline with a parachute. Once fully deployed, the cable is re-wound and the hydrophone transmits the noise from any leaks encountered through the cable to a receiver above ground. The location of the hydrophone is tracked from the surface using an electromagnetic transducer/receiver arrangement, a technique commonly used in the oil and gas industry.

Because the system uses a sensor that travels directly past a leak, it has similar advantages to the autonomous system in terms of leak sensitivity and indifference to pipe material. Leak location is done in real time and the indicated position of the leak is usually marked on the surface during the survey.

Tethered systems have a major disadvantage over the autonomous system. The survey length is limited by the extent to which the tether cable can be deployed inside the pipeline. This is determined by factors such as drag, friction at bends, and the presence of in-line valves, which the cable cannot traverse. In practice, this typically limits the survey length to less than 1.5 km. This compares to over 20 km for the autonomous system. It is usually necessary, therefore, to prepare the pipeline by installing hot-tapped access points every kilometer or so along the pipeline. The civil works required to facilitate these taps, combined with the lower survey productivity due to frequent re-insertion of the system over an extended distance, can have a significant impact on comparative cost.

6 EXPERIENCE TO DATE

Since the technology was introduced commercially in June of 2007, over 2,000 km of pipelines of different materials have been surveyed and approximately 1000 leaks have been detected. Many of the leaks have been confirmed and repaired.

The system's capability to identify the location and size of every leak on a pipeline provides pipeline owners with valuable asset management information. Utilities are using the information provided by the system to prioritize leak repairs or to determine if it would be more cost-effective to replace a trunk main rather than repair all of the leaks. The information can also be used to initiate a focused condition assessment program, as the resources can be concentrated on sections of the line where leakage is concentrated, which are likely to be the areas of greatest deterioration.

7 CONCLUSIONS

The introduction of an autonomous in-line leak detection technology for trunk mains has proven to be a valuable contribution to the efforts to address loss in large-diameter long distance transmission water mains.

The technology allows cost-effective inspection of long pipeline systems, with minimal modification or disruption to the pipelines. Its use has demonstrated that leaks in trunk mains are usually not apparent at the surface, thereby emphasizing the need for a programmed approach to leak detection in these pipeline systems.

Adding a Pipe Wall Assessment platform will allow a one-pass approach in pipelines and provide significant amounts of data to pipeline owners in a cost effective manner.

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