Leak Locating Method for Pre-Commissioned Transmission Pipelines: North American Case Studies

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Introduction

Any leak in a pressurized water pipe will generate noise; the magnitude and frequency of the noise will depend on a number of factors including the shape and size of the leak, the pipe material and the pressure inside the pipe. The most widely used leak detection method is the leak noise correlators. These are less reliable when used on pipes larger than 300mm (12 inch) and on non-metallic pipes (MDPE, PVC, asbestos cement or concrete) as the leak noise is attenuated very rapidly as it travels away from the source in these types of pipe.

When the limitations of correlators for larger pipes were recognized alternative methods of leak location in trunk mains were investigated. Based on these studies a group, led by the United Kingdom’s Water Research Council, decided in the early 1990’s that the most reliable method of detecting leaks, and pinpointing their position accurately, would be to pass an acoustic sensor along inside the pipe and detect the point where the leak noise signal was greatest. Thus, the Sahara system was developed.

Sahara® is normally used as a condition based asset management tool that identifies leaks in in-service operating pipelines of any material construction type greater than 300mm (12 inch) in diameter. In normal operation the Sahara assembly is carried through the pipe by the flow of water. An advanced application of this technology is the deployment of the system into a pre-commissioned line to pinpoint the location of any and all leaks that are causing the line to fail its pressure test(s).

Because the pipelines have not been placed in service and there is no water flow, a pulltape or dragline is used to pull the inspection equipment through each testing area. Specifically, the sensor head is pulled along until it reaches the Pull-site. In the cases presented, leaks were successfully located, verified and the pipeline leaks were repaired. The rehabilitated pipelines subsequently passed their hydrostatic pressure tests and were successfully accepted by the pipeline owners.

The Sahara System

**Normal Operating Conditions**

Sahara pinpoints the location and estimates the magnitude of leaks in water transmission mains. The Sahara system uses a highly sensitive acoustic detector unit, which is inserted into the main at any tap point 2” (50 mm) or greater in diameter while the pipeline remains under pressure between 0.3 and 13.8 bar (3 and 200 psi).
The insertion allows the cable to be inserted into a live main and incorporates a retractable guide which protects the cable from damage as it passes into the pipe. A winch and cable drum control the deployment and retrieval of the umbilical. The winch forces the umbilical into the pipe against water pressure and withdraws the umbilical from the pipe upon completion of the survey.

![Schematic representation of Sahara system in normal operations](image)

**Figure 1** Schematic representation of Sahara system in normal operations

In operation, the neutrally buoyant probe and data cable are disinfected before they enter the pipe. Normally, the system is then carried along the pipe by the flow of water (the flow rate must be greater than 0.3m/s or 1ft/sec). As the system travels through the pipe, the detector head continuously "listens" for the distinctive noise of a leak that is generated by the escape of under-pressure water. Leaks as small as 1L/hr (0.25 gallons/hr) are identified in real time by a processor at the insertion point.

Once a leak has been detected, the sensor head can be stopped at the precise position of the leak. The magnitude of the leak is then estimated by the operator through quantification of the acoustic signal recorded by the sensor. The location of the leak within the main is surface located using TUE's PipeSpy2000™ precision locator unit and accurately marked for subsequent excavation and repair.

**Sahara System Modifications and Setup**

Initially, the pipeline to be surveyed must be dewatered to allow for manned entry and the installation of "pulltape" inside the pipe. "Pulltape" is a 10mm (¼ inch) wide flat woven Kevlar material with a very high tensile strength. It is available in 1525m (5,000-foot) spools in North America and is normally used to pull data cable through conduit in the fiber optic and electrical industries.

A number of operational and physical modifications are required in order to insert the Sahara system into the pipe. A minimum 50mm (2 inch) inside diameter clear bore is required on the 12 o’clock position of the pipe for each insertion and pull-site location. A 50mm (2 inch) ball valve is preferred over other types of valves because the ball can be closed on the pulltape without severing the tape.
Pull-site

Each pull-site location requires the installation of a guide tube, which is used to protect the pulltape from severing against the inner weir of the pipe and/or flange. The guide tube consists of a 25mm (1 inch) poly water service tubing cut at a length that ensures a minimum penetration into the pipe of 300mm (12 inch) from the inner most weir of the pipe. The guide tube/sealing gland component is assembled by attaching to one end of the poly tubing, a 25mm (1 inch) compression x 25mm (1 inch) MIP NPT threaded brass coupling. The 25mm (1 inch) poly tubing is inserted through the ball valve into the pipe with the brass coupling sitting on top of the 50mm (2 inch) ball valve the coupling is large enough so that it will not pass through into the pipe.

Threaded onto the ball valve over the brass coupling is a galvanized nipple, a 50mm (2 inch) galvanized coupling is then installed on the nipple, a bushing is installed on the coupling and then a special electrical connector with a rubber grommet cut in half is installed on the bushing. The bushing and electrical connector are the components that make up the pulltape sealing gland, the rubber grommet seals the pulltape and will withstand pressures up to 20 bar (300 psi), this allows the pipeline to be filled and pressurized.

Insertion Site

Each insertion site does not require a guide tube because the insertion tube has an internal “trapper hose” that is inserted into the pipe during the insertion process. This acts as a guide tube to protect the umbilical. However, a pulltape sealing gland does need to be installed on top of the 50mm (2 inch) ball valve at the insertion site. The pressure in the line must be reduced to approximately 2.5 bar (35 psi) or line pressure whichever is achievable, which is dependant on elevation, in order to manage the disassembly of the pulltape sealing gland and the installation of the insertion mechanism’s.

Once the pipeline is depressurized and the pulltape sealing gland is removed, the pulltape is pulled through the insertion tube and tied onto the sensor head. At a predetermined distance away from the insertion point (Pull-site), the other end of the pulltape is attached to a cable retrieval assembly (capstan support equipment). At the insertion location, the insertion tube with the pre-loaded sensor head and cable is installed onto the ball valve with the pulltape slack pulled at the pull-site.
Installation of the hydraulic winch, encoder cable, hydraulic hoses and support legs completes the assembly of the insertion components at the insertion location. At this time the operator powers up the computer and prepares for the deployment of the sensor head. At the pull-site, a hydraulic capstan, spooler, pit rollers, generator and hydraulic power pack are employed to pull the Sahara system through the pipe. Once the equipment set-up is complete, the Sahara operator (at the insertion location) then instructs the capstan operator (at the pull-site) to pull the pulltape thus deploying the sensor head through the section of pipe to be inspected. Once the deployment is underway the Sahara operator instructs the host utility/contractor to pressurize the pipeline to test pressure.

**Locating Leaks**

When the sensor head reaches the pull-site the Sahara staff standby until the pipeline reaches test pressure. Once test pressure is achieved the Sahara operator instructs the capstan operator to re-configure for retrieval. The cable is then retrieved by the hydraulic winch at the insertion location. The Sahara operator in conjunction with the capstan operator stops the retrieval at 5m intervals to listen for leaks, this continues until the sensor head reaches the insertion location. This process requires synchronization between the Sahara operator and the capstan operator to keep the sensor head taut.

Once a leak, or anomaly, is found, the PipeSpy operator is dispatched to locate and mark the area on the surface. The precise location is triangulated by the PipeSpy tool detecting signal strengths between the sensor head and the tool. The location is tied to permanent reference points and also recorded using GPS technology. Logs are kept throughout the process to document all findings and events.

Upon completion and conclusion of the retrieval and inspection of the pipeline section the Sahara operator instructs the utility/contractor to de-pressurize the pipeline back down to 2.5 bar (35 psi) or line pressure whichever is less in order to safely remove the insertion.
equipment. The pulltape, upon completion of each section, is pulled out of the pipe by the capstan equipment at the pull-site and is re-spooled.

**Sahara Case Studies**

### 2700mm (108 inch) Prestressed Concrete Cylinder Pipe (PCCP)

Dallas Water Utilities (DALW), in Texas, USA, is currently constructing Phase III of the Lake Fork Raw Water Transmission Main, which is composed of approximately 40 km (30 miles) of 2700mm (108 inch) Prestressed Concrete Cylinder Pressure Pipe (PCCP). Approximately 11 km (7 miles) of Phase I of this line had been previously installed, but had failed a series of hydrostatic pressure tests. The failure of the pipeline to hold pressure above 13 bar (190 psi) suggested the presence of high pressure leak(s). Operators attempted to locate these leaks using a variety of methods including: visual inspection (internal and external), leak-noise correlators and excavation. None of these methods proved universally effective.

In August 2004 Wiss, Janney, Elstner Associates, Inc. (WJE), the forensic engineers contracted to assist in remediation of the pipeline, contracted with the Pressure Pipe Inspection Company (the North American Sahara licensee) to inspect Phase I of the Lake Fork Raw Water Transmission Main using the modified Sahara system.

Two substantial leaks were detected. Subsequently, WJE and a specialty contractor, JD Stevens, repaired the indicated leak locations by welding the bell & spigot joints. Phase I of the Lake Fork Raw Water Transmission Main subsequently passed its pressure test in October 2004.

### 2100mm (84 inch) & 1800mm (72 inch) Diameter PCCP

To meet the needs of a growing population, York Region, in Ontario, Canada has entered into a long-term water supply agreement with Peel Region, also in Ontario, called the York-Peel Water Partnership (YPWP). YPWP’s main goal is to establish a major east-west water supply line to York Region’s Maple Reservoir and will supplement York Region’s current water supply from Toronto, Lake Simcoe and underground aquifers, creating less pressure in periods of high demand.

The multi-million dollar design-build contract for York Region incorporates a 13 km, 1800 mm (72 inch) diameter PCCP feedermain and associated road works. Another design-build contract for the Region of Peel is an 8 km, 2100 mm (84 inch) diameter PCCP and an 1800 mm diameter PCCP feedermain which connects to the York Region contract. Construction of these feedermains was anticipated to be complete as early as spring 2005.

The project was awarded to three contractors, and was overseen by KMK Consultants. Each of the contractors was responsible for a section of the line. In each case the failure of the pipeline to hold pressure during a pressure test suggested the presence of high pressure leak(s). Therefore, between February and March, 2005, under separate contract to each of the contractors involved, the Pressure Pipe Inspection Company inspected these feedermains using its patented Sahara Leak Detection Technology.

Analysis of the data obtained during this inspection revealed two Small to Medium magnitude leaks in the first area of the feedermain that was tested; a single Medium level in the first area of the feedermain that was tested; and a single Small level leak in the final area. In all cases, the identified leaks were repaired and the 6 km of pipelines passed their respective pressure tests.
**1200mm (48 inch) Diameter Steel Pipe**

The success of the Dallas Lake Fork Transmission Main inspection has prompted JD Stevens to use the modified version of the Sahara leak detection system in similar situations.

The Williamson County Regional Raw Water Line (RWL) is located near Salado, in Bell County, approximately 80 km (50 miles) north of Austin Texas. The RWL is constructed of 1200mm (48 inch) steel pipe, and is owned and operated by Williamson County. The RWL had failed previous pressure tests required for the pipeline to be placed into active service.

The inspection was conducted in December, 2004 on approximately 6km (3.5 miles), of the RWL. As a result of the data obtained during this inspection when the pipeline was re-pressurized to approximately 15 bar (220 psi), five leaks were located in the pipeline, all of which ranged from medium to large in magnitude. As with the Lake Fork Raw Water Transmission Main, the presence of these leaks was verified, the line was repaired, passed its pressure test, and was successfully handed over to Williamson County.

**600mm (24 inch) Diameter Ductile Iron Pipe**

The Huguenot Transmission Line is being constructed as part of the W.L.Hailey-Richmond Water Supply Agreement. W. L. Hailey Company, Inc. (WLH) was contracted to install this Pipeline, which runs across the James River in Richmond, Virginia, USA. The pipeline is constructed of 600mm (24 inch) diameter cement lined ductile iron. Divers installed the joints in the sub-aqueous portion of the line.

The failure of the pipeline to hold pressure during a pressure test suggested the presence of high pressure leak(s). Therefore, in May, 2005, under contract by W. L. Hailey Company, Inc., the Pressure Pipe Inspection Company inspected approximately 1 mile of the line using the modified version of the patented Sahara Leak Detection Technology.

PPIC’s evaluation of the Huguenot Transmission Line in the area tested found two sub aqueous leaks. Normally, leaks are surface located using the PipeSpy 2000 location system. This system incorporates a powerful extremely low frequency (ELF) transmitter carried above ground. A miniaturized receiver, held behind the hydrophone head, within the pipeline, picks up the ELF signal. This receiver passes the transmitted signal up to the processor and onto the surface operatives. The frequency used allows accurate through-pipe communication, even within steel mains, and remains uncorrupted by adjacent services. In this way, the second operative can be positioned directly above the hydrophone head and accurately track its position and progress.

In this case, surface location was not possible. The location of the leak was approximated by gathering GPS points at visible above ground locations along the pipeline and then using the distance encoder on the Sahara equipment to estimate the leaks position. One leak was discovered approximately 67m (222 feet) south from Insertion Point 1, and was medium-large in magnitude. Another leak was found approximately 80m (262 feet) south from Insertion Point 1, and was also medium-large in magnitude. The leaks correlated exactly with two joints, which were then re-connected, tightened, and allowed for the pipeline to successfully pass the pressure test.
Conclusion

On most occasions, when a new pipeline is built it passes its hydrostatic pressure test and is handed over to its operator without issue. On occasion, however, it does not pass this test and the contractor is obligated to try and identify the source of the leak(s). This can be an extensive, and time consuming, process.

The Sahara transmission main leak detection system is normally used to precisely locate leaks, reduce non-revenue water, and as a condition assessment / risk management / asset validation tool for in-service pipelines. Therefore, deployment of the system into a pre-commissioned line required a variety of operational and physical modifications. Successful location of leaks for the case studies presented has demonstrated that the system can be successfully adapted to detect leaks in pre-commissioned lines.

In addition, the case studies verify the capabilities of the Sahara to detect leaks in various sizes of large diameter pipelines manufactured from various pipe materials such as concrete, steel, and ductile iron.

References