Engineering Technologies for Pipeline Asset Management

Bryon L. Livingston, Ahmad Habibian, and Dan Kugler

There are many technologies available for managing the condition of underground infrastructure, or buried pipe. This article will review a few of the non-destructive technologies commonly used in conducting condition assessments in water systems.

The condition assessment step is a key component of the asset management process, and knowing what technology to use is important. Asset management principles are not a new concept for most utilities, except that using a formalized approach provides a more efficient use of the data collected. The formalized process provides for converting data from condition assessment to implementation of projects based on priorities.

This article will identify why utilities should be proactive in determining the condition of the pipe in their system—especially those located in critical areas. The condition-based assessment will show why it is beneficial to have information on the actual condition of the pipe based on field evaluations, versus information based on statistical methods.

Managing buried infrastructure requires balancing the performance of the system; the associated risks; and costs required with operational efficiency, planning requirements, affordable rate structures, security, and regulatory requirements. The decisions made to replace or repair/rehabilitate pipe should be made based on the actual condition of the pipe in the system.

The service life of pipe is variable and is affected by many factors. The "wave" of reinvestment is just beginning, and utilities that take steps now to prepare for reinvestment needs will reap the benefits of early planning.

News reports are full of many incidents describing catastrophic events and disruption to traffic and lifestyle resulting from breaks in water lines. It is impossible and impractical to try to prevent all the line breaks, but it is practical and also sound management to prevent failures on critical pipelines that can result in catastrophic events.

Effective planning and condition-based assessment are required to minimize the number of such events. With aging infrastructure, they are becoming more common. Now is the time to take action.

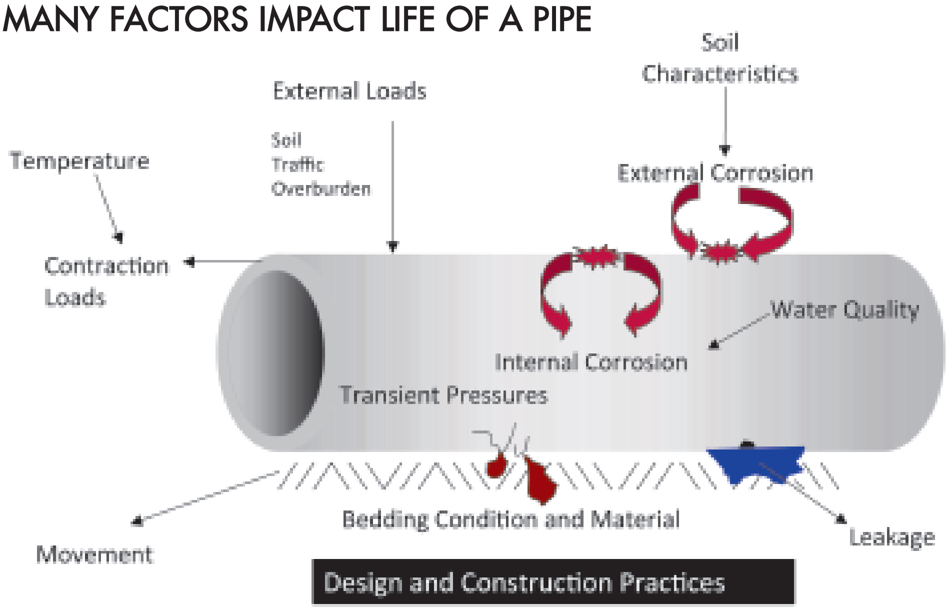
Developing an inventory of the type(s) of pipe in a system and the year(s) the pipe was installed will help determine the future investment needs, but not all pipes installed in the same year will fail during the same year in the future. Evaluating these factors will provide the necessary data that is useful in the condition assessment.

There are several factors that impact the length of the service life of pipe, including:

- Third-party damage
- Temperature, which creates contraction loads
- External loads from overburden and traffic
- External corrosion from oil characteristics
- Internal corrosion from water quality characteristics
- Transient pressures that affect the structural integrity of the pipe
- Design and construction practices
- Bedding condition and material
- Ground movement
- Groundwater and leakage

Bryon L. Livingston, P.E., is an engineering manager in the Kansas City, Missouri, world headquarters of the engineering firm Black & Veatch. Ahmad Habibian, P.E., PhD., is the national practice leader for pipeline rehabilitation in the firm's Gaithersburg, Maryland, office. Dan Kugler, P.E., is an engineering manager in the firm's Colorado Springs, Colorado, office. This article was presented as a technical paper at the 2010 Florida Water Resources Conference.

MANY FACTORS IMPACT LIFE OF A PIPE



Understanding that these factors exist and how they affect the service life of pipe is important in knowing how to manage the risk associated with buried infrastructure. Such factors can not be eliminated, but they can be managed.

Several models have been used in the past to predict the condition of pipe, including:

- Prioritization Model
- KANEW Model
- Economic Analysis
- Risk-Based Model (Monte Carlo Simulation)

These models are useful in developing a plan to identify areas to focus repairs in a replacement program. This article is focused on the engineering technologies, so these tools will not be discussed but are presented for information.

The technologies we will discuss are:

- Visual Inspection and Closed Circuit TV
- Electromagnetic (Remote Field Eddy Current and Broad Band)
- Ultrasonic, including G-Wave
- Remote Field Eddy Current/Transformer Coupling

Continued on page 32

Continued from page 30

- Acoustic Monitoring
- Leak Detection
- Magnetic Flux Leakage (Currently used in oil and gas)

This is only a partial list and there are a number of technologies or variations of these that are available. The following sections are summaries of the technologies listed.

Visual & Closed-Circuit TV (CCTV)

Visual inspection by entry into pipe has been used in the past as a standard method to inspect pipe interior. This method is not as cost-effective as it was in the past because of OSHA requirements.

The technology for CCTV is making dramatic improvements. It has been used primarily in the gravity sewer lines, but improvements in the technology are making it applicable for water lines as well. Unless your pipes are full of tuberculation, there are some potential benefits from using CCTV inside a water line. If the pipe line can be cleaned, then CCTV would be a valuable tool to identify internal corrosion problems.

The CCTV technology used to identify internal corrosion problems is similar to that used in sewer lines; the camera can pan and tilt to identify lost valves, build-up in the pipe, zebra mussel, and various repair needs. The value of this technology could be used to enhance a repair program to investigate the condition of a pipe following a line cleaning.

Broadband (BEM) Electromagnetic Technology

This technology is used for inspecting metallic pipe; it measures wall thickness and pits using near-field electromagnetic. The inspection can be completed by using an internal survey by droid and an external scan by "blanket."

The pipe must be exposed and out of service in order for the inspection to be conducted. Also for this inspection, the pipe must be very close to round and the survey must be performed in a straight line. The inspection provides the average thickness based on spot measurements at nodes. Based on the results, an ultrasonic inspection can be used to confirm the findings.

Remote Field Eddy Current

This technology inspects the pipe wall from the interior of the pipe and is used to assess the wall thickness of metallic pipe. This pipe includes:

- Ductile Iron
- Cast Iron
- Steel

The inspection process detects internal & external defects equally well and can identify pits (20mm) with metal loss or cracks. The application of this technology is limited because of the use of linings in water piping systems.

This technique is used in conjunction with ultrasonic inspection to confirm findings. It was developed for oil and gas pipelines and has limited applications in the water industry. As the need for assessing metallic water pipe increases, this technology has the potential to provide the information required.

Ultrasonic Inspection Technology

This technology is used for metallic pipes and requires an external inspection to determine wall thickness by measuring the transit time of sound waves through pipe wall. One of the limitations of the technology is that it can be used for spot measurements only. This requires a detailed evaluation of the pipeline to determine the area most likely to contain wall loss or pitting.

The pipe wall must be very clean to provide a good contact between the sensor and the pipe wall. A couplant is normally used to improve contact. The instrument used is a handheld and is not expensive. Some cities have purchased the equipment and have conducted tests, known as B-scans, whenever there is a leak or access to the pipe.

Advantages of the B-scan are:

- It is accurate to three thousandths of an inch.
- It uses water as a couplant.
- It displays the cross-sectional thickness of the material.
- It is very portable.
- It is five to 10 times faster than a conventional point-to-point ultrasonic.

The limitations of the B-scan technique include:

- It can scan only surfaces that can be reached by the technician.
- It can not scan pipes with heavily corroded exterior surfaces.

Impact Echo

Impact echo is a simple test that is used on concrete. This principle is the same as using a hammer to strike the concrete and listening to the sound. The test measures the sound waves that result from striking the concrete with a measured force. A hollow sound indicates the possibility of separation in the concrete.

Remote Field Eddy Current/ Transformer Coupling

This technology was developed to identify broken wires in prestressed concrete cylinder or non-cylinder pipe (AWWA C-301 and C-303). The electromagnetic waves are used to evaluate the condition of the prestressed wires.

The tool uses the prestressed wires as an antenna, and the exciter in the tool transmits a signal that is recovered by the receiver. The technology measures the signal to identify wire breaks. Normally this technology is used prior to acoustic monitoring to establish a baseline, but it can be used following acoustic monitoring if the situation requires it.

There are several factors that affect the electromagnetic signal, including:

- Wire anchoring methods
- Variation in wire spacing
- Variation in wire diameter
- Variation in cylinder thickness
- Wire splices
- Shorting Straps
- Joint configuration
- Insulation in joints

Knowledge of the pipe is required to improve the accuracy of the evaluation. Calibration of the pipe prior to the investigation greatly improves the results. Evaluation of the signal is an art as well as a science, and interpretation of the data requires experience.

Acoustic Emission Technology (AET)

AET detects areas of active deterioration by measuring the frequency and number of distress-related acoustic events that occur along the monitored PCCP pipe section over a defined period of time. This technology is used for PCCP to monitor for prestressed wire breaks. If any breaks in the wire have been detected, monitoring can indicate if the wire breaks are active.

Acoustic monitoring evolved in the mid 1990s and has been used to detect wire breaks while the pipe remains in operation. If a prestressed wire breaks, or releases tension (slips), it will generate an acoustic energy that will propagate into the water and move down the pipeline.

The energy from a break or slip generates a unique acoustic signal that is detected as it passes the hydrophone or accelerometer installed along the pipeline. The location of the "event" is determined based on the arrival time of the sound at the site of the accelerometer or hydrophone.

Continued on page 34

Continued from page 33

Leak Detection Technologies

There are several methods used to detect leaks in distribution systems. Older acoustic methods can not identify the location of leaks smaller than 125 gallons per hour or 3000 gallons per day—1.1 million gallons per year.

Acoustic methods perform better in smaller diameters no larger than 12 inches; the signal attenuates and weakens in large-diameter pipe. The accuracy of these tools limits locating the leak usually to within 10 feet or more. Another complication is that multiple leaks tend to distort signals.

The question "Why find leaks?" has an obvious answer. Leaks contribute to accelerating pipe corrosion, weaken the bedding support material, and can lead to a "catastrophic failure." The number of leaks is also an indicator of pipe condition. It is important to recognize that not all leaks surface—at least, not right away. Leaks can go on for years, depending on the soil condition in the surrounding area.

This is how sink holes are formed—a potential dangerous situation where water lines are under roadways or other structures. The leakage from the system is classified as "non-revenue" water, and systems should recognize this will become a significant issue if not addressed. With emphasis on sustainability and water scarcity, the amount of water from leaks can be a significant concern.

As mentioned, not all leaks surface right away. The process of water moving through soil porosity provides the erosion of the soil and for potential failures by the formation of sink holes.

Often a sink hole will develop when a small leak goes unattended. The water pressure from the leak washes away the soil and bedding around the pipe. The water and soil moves through existing cracks and voids in the ground around the pipe. The erosion of the soil through the cracks will eventually form a cavity. In time the size of the cavity increases until the weight of the soil and roadway cause a collapse.

The primary goal of condition assessment is to avoid the major failure of a critical pipeline. If a utility has experienced a catastrophic failure on a critical pipeline, there is a good chance that the utility will probably have or will be receptive to an ongoing aggressive asset management plan.

The failure of a major pipe line can cause a lot of damage. Sink holes are created because the pipe has been leaking for a long time. There are stories about sink holes in the news all the time.

Sahara® Leak Detection Technology

Developed in the United Kingdom, this technology uses an acoustic monitor and com-

Continued on page 36

Continued from page 34
pliments the other leak detection technologies, such as Noise Correlation, Acoustic Leak Detection, and Metering.

Sahara® Leak Detection Technology can be used on any pipe of any material; the data results are identified in real time. The significant difference in this technology is that it can detect and precisely locate leaks as small as 0.5 gallons per hour. The inspection is limited to 5,000 feet of 12-inch or larger pipe.

A recent project found a medium leak that, when excavated, revealed that a large area had been washed away. Finding the leak prevented a potential catastrophic incident and allowed a scheduled repair rather than an emergency repair.

Complete the Condition Assessment

With the data obtained from a condition assessment, it is possible to identify the right pipe to be replaced or repaired. The use of a risk analysis will determine the right time required and engineering principles will determine the right material. Using asset management principles, it is possible to incorporate knowledge of pipe condition into a program for managing pipeline assets.

With knowledge from the technologies to properly manage infrastructure, a process must be developed. The condition assessment is the first step and results in documented results.

These results are used to identify projects in which cost can be estimated to incorporate into a capital improvement. The projects are then prioritized based on the risk evaluation and are ranked using risk criteria. They can be implemented through the capital improvement plan, which includes a schedule of the projects.

The amount invested in pipeline infrastructure constitutes a large portion of utilities infrastructure assets. It is the major driver for altering investment needs. In contrast to treatment works, pipe replacement and rehabilitation require a sustained flow of expenditures, not a periodic capital expense followed by years of service. As stated previously, all pipes "born" in a given year will not "die" during the same future year.

The focus on buried infrastructure is ***balancing performance, risk, and cost***. The basic steps to managing pipeline infrastructure are:

- Conducting a condition assessment
- Developing a program
- Prioritizing based on risk analysis
- Implementing the plan

The approach is summarized by the following equation:

R3 = Replace the Right Pipe
at the Right Time
with the Right Material