Acoustic detection technology can convert 'Out-of-Sight, Out-of-Mind' attitudes about leaks into proactive ones.

By Don Talend

The challenge of locating leaks in underground pipes is daunting enough to make many managers put the problem out of their minds until the leaks are in plain sight. As acoustic leak-detection technology evolves, however, accepting a certain amount of waste while adopting an out-of-sight, out-of-mind philosophy may soon become a mindset of the past.

When a pipe ruptures and allows water to escape, it creates a significant amount of vibration that can be detected by highly sensitive acoustic leak-detection sensors, facilitating timely repair. Current technologies consist of listening devices that locate leaks within a general area, correlators that pinpoint those leaks, and acoustic data loggers that offer potential for monitoring of entire water systems.

Financial Benefits: A Tough Sell

The practice of detecting leaks with acoustic methods before they become major problems has not achieved general acceptance to date, notes Tom McGee, who has worked in this niche field for more than 25 years, currently as director of operations for acoustic leak-detection technology provider Fluid Conservation Systems.

McGee has a good idea of where most leaks occur and where the most water is wasted. "If you took a look at a leak survey, you would find that 50% to 75% of leaks would be service leaks. Where the smaller-diameter, normally copper pipe taps into the main line and feeds into your house or your business—that's the weakest link in the distribution network," he says. "Then you'll find another 20% that are joint leaks, and then you'll find 5% to 10% that are what we call main breaks, where the pipe is actually cracked. They make up the smallest number of leaks, but the number of gallons that are being lost in those leaks is quite a bit higher." He estimates that service leaks account for a little less than 50% of total water losses, main breaks for 20% to 30%, and joint leaks the remainder.

"Acoustic leak detection is well-accepted by almost all utilities for dealing with problem leaks and wet spots on the ground and water running down the curb, but there are very, very few utilities in the country doing proactive leak detection," adds McGee, referring to leaks that are not necessarily small but, more importantly, are hidden. "Utilities around the country are losing 10%, 15%, 20% of their water every day to leakage, and it's just been accepted by the industry over the years that that's OK; there's nothing you can do about it, it's just part of the business. But it doesn't have to be that way; there's technology now..."
that can find those leaks, and it's been around for quite a while."

In recent years, however, several water-management entities in the desert southwest have taken a more proactive approach to detecting leaks because a sustained drought—coupled with sustained high population growth—has forced them into it, McGee points out. "We've gotten quite a bit of business from Phoenix, El Paso, Denver, and Las Vegas because they're in a critical supply of water right now," he says. But in most areas, says McGee, water is plentiful and inexpensive enough to keep water utility managers' waste-management efforts minimal.

"These cities know that [acoustic leak-detection technologies] are out there and they're using it every day; they're just not hunting for the hidden leaks because first of all, no one's forcing them to, and secondly, if they go hunt for leaks, they've got to fix them and they just don't have the manpower and the time to do it," McGee is noticing that automated monitoring technology such as the data logger is starting to catch on, however. "The utilities that are getting more proactive are very quickly noticing that their overtime budgets are going way down because they're not constantly reacting," he says. "They're fixing these leaks when they're small and manageable and the public doesn't even know about them."

Andy Crocker, water products specialist for Metrotech Corp., gives a presentation titled "Financial Justification for Implementing a Leak Detection Program" for water utility officials. He argues that, in determining the need for leak-detection programs, water utilities underestimate the true cost impact of leaks by calculating a percentage of unaccounted-for water and comparing total metered and unmetered usage with total production. When usage increases, the percentage of unaccounted-for water may appear to decrease, distorting management's assessment of the true cost impact of leaks. He cites a hypothetical example of a utility with a production of 300,000 gallons per day and unaccounted-for water volume of 90,000 gallons a day, or 30%. If a new factory is built that consumes 300,000 gallons per day, it appears that the percentage of unaccounted-for water decreases to 15%.

Crocker cites the International Water Association (IWA) model for calculating specific water loss as a more appropriate method of determining the impact of leaks from a financial perspective. The model allows apples-to-apples water loss comparisons among water systems of various sizes by calculating losses per mile of pipe per year. However, the losses are categorized as high, medium, or low according to the level of consumption. Revealing the losses in volume rather than percentage and categorizing the losses in relative terms brings out a true indication of the impact of the losses, argues Crocker.

Using an example of a groundwater system with a 2.5-million-gallon-per-day (mgd) capacity that pumps an average of 2 mgd, or 80% of capacity, Crocker illustrates the financial benefit of purchasing leak-detection equipment—even when the traditional percentage-loss calculation method is used. Significantly for this system, 40% of the water, which must be treated with chlorine and a corrosion inhibitor, is unaccounted for, meaning 1.2 mgd of the water are utilized.

Crocker details the multiple financial benefits that would result from purchasing the leak-detection equipment in this example. The percentage of unaccounted-for water declines to 25%. Production can decrease by 20%, from 2 mgd to 1.6 mgd. Variable production costs of treatment chemicals, energy for pumping, and equipment replacement and maintenance costs will likely decrease as well. Assuming that the system's annual water budget is $150,000, $60,000 of which is production costs, 20% reduced production would likely result in $120,000 in immediate savings.

Perhaps most significantly, reducing the daily production from 2 mgd to 1.6 mgd means that the system is using only 64% of its 2.5-mgd capacity, allowing it to delay expansion plans. (Crocker argues that in many states, when a production facility reaches 80% of capacity for three consecutive months, it must submit plans for expansion.) So the savings that result from leak-detection equipment, combined with any rate increases, can be applied to other areas of need such as system repairs or improvements, salary adjustments, hiring, or equipment purchases.

One notable exception to the prevailing philosophy about water leakage, besides the Desert Southwest, is the Chicago area, McGee says. He began his career with Associated Technical Services Ltd., a Villa Park, IL-based engineering firm that was the first to use correlator technology in the early 1980s and has done leak-detection surveys for the City of Chicago ever since. Chicago's suburbs get their water from Lake Michigan via a pipeline that was very expensive to build. "Towns like Villa Park and Lombard and Schaumberg—it costs them $2,000 for a million gallons of water, that's some of the most expensive water in the country, so they've had a motivation to get on their leakage a lot more than most of the country," he says. But in general, acoustic leak detection has not progressed much beyond the original method of excavating around a pipe after a wet spot in the soil has appeared, indicating a major leak.

Listening devices called geophones were first used for tunneling surveillance by militaries during the first half of the 20th century, and acoustic leak detection equipment has become increasingly specialized since the 1970s. Using acoustics remains, by far, the most common method of detecting leaks. Gas
sensing—injecting a water main with lighter-than-air gases and using special equipment to detect leaks—thermal imaging, and ground-penetrating radar have, to date, proven to be far less reliable methods.

Audits Uncover Hidden Leaks
One way to uncover hidden leaks throughout a water system is to perform a comprehensive leak-detection survey on the entire system. American Leak Detection, which has a nationwide network of franchises that conduct comprehensive leak detection surveys, recommends that a survey is warranted when a water audit reveals that a leak in the system might be present. Telltale signs of a leak might include customer reports of low pressure or dirty water, an unexpected spike in the utility’s electric use, or an unusually high volume of water loss.

The company also recommends that water systems that conduct leak surveys on their own follow several steps. These include conducting a preliminary survey by checking for leaks in malfunctioning pumps, valves, meters, and other appurtenances; dividing the system into zones and listening for leaks, testing pressures, throttling valves, and watching meters and tanks in each zone; locating leaks with acoustic leak-detection equipment; recording leak locations with GPS equipment; and documenting the repairs, cause of leak, amount of water lost, and date of maintenance. Alternatively, managers might choose to outsource this fairly specialized task to a specialist.

Acoustic leak detection technologies are also available for direct use by water system personnel to locate leaks with a high level of confidence using equipment that either detects a leak within a general area of a water system or pinpoints the precise location of the leak.

Identifying Problem Areas
The portable listening device allows the user to verify that a leak is present within a general area. This equipment consists of a base unit that contains batteries and electronic components that amplify leak noise and filter extraneous noise and an acoustic sensor that attaches to the road surface or pipe itself, as well as to a pair of headphones. The price range is $1,000 to $5,000.

According to McGee, the relatively low cost of listening devices entices some utilities to try to use them to pinpoint the precise location of leaks, although this is not easily achieved. This may have to be done at night, when traffic volume is low. “It’s called ground miking,” he says. “You can hope that you can hear the leak through the road surface, so if the conditions are good—meaning there’s not a whole lot of traffic noise in the area and if the pipe is not too deep—you might get lucky and be able to pinpoint the leak. It’s not easy; it takes a skilled technician. It’s an art form; it takes a year or two of practice before you get good at it.”

Listening devices that can be set on both the ground and the pipe surface are available from Fluid Conservation Systems. Its Lmic electronic surveying and microphone device can be set on the ground or attached directly to the pipe surface or fittings using different attachments for the microphone. The microphone is connected to a handheld listening stick that is operated by a trigger mechanism and has an output to operator headphones. Another device, the Xmic, is a ground microphone with pinpointing capabilities. This device uses a graphic display that reveals histograms of comparative leak noise levels to increase the operator’s confidence of the precise leak location.

Using portable listening devices is a reactive approach to confirming that a leak exists along a given stretch of pipe, but earlier this decade technology was developed that allows managers to detect problems throughout an entire water system proactively. Acoustic data loggers consist of a vibration sensor, a microchip for storing noise data, and a radio frequency transmitter. The data are collected by a receiver that is either handheld or mounted in a vehicle. “Nighttime is the best time to listen for leaks because there’s less traffic noise, fewer people are using water, and pressures are a little higher at night so leaks actually make a little more noise at night,” McGee says in reference to data loggers, which can monitor pipes unattended. The price is about $300 per unit; the total cost depends on the size of the water system.

Metrotech Corp. offers the MetroLog HL-7000 Digital Sound Logger, which is promoted as freeing up labor to perform other tasks besides leak detection. The device can be set up either temporarily or permanently to automatically activate at night and records both noise and frequency data as well as leak probability and leak status. The sensitive device provides 2,000- to 2,500-foot lineal and 250-foot radial reading capability. The operator has the ability to radio-program multiple loggers throughout the system.

The MLOG sensor from Flow Metrix Inc. is a waterproof, battery-powered unit that is permanently installed near a water service meter by field crews at about every 500 feet of water main, or at about every 10th service. The unit records vibrations for four hours every night. Vibration data are stored and processed to reveal a noise pattern over days and months, and the data can be transmitted by radio on demand.

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Specialized software, into which the data are downloaded, assigns each unit a leak status. The software can run reports that rank each unit in the network according to leak status and other factors, and it can visually plot out leaks within the network on water distribution system maps. A particularly powerful function of the software is its computation of a “Leak Index,” which indicates the likelihood of a leak in the vicinity of each sensor. This is computed according to historical sound patterns at each sensor, groups of sensors showing unusual or changing activity, and attributes of leaks discovered previously—which provide a "leak signature" and improve accuracy.

Fluid Conservation Systems is offering the third version of its Permalog product, which can acquire leak data either manually or via drive-by collection. The loggers are attached to the pipe exterior roughly every two blocks—for a total of five loggers per mile of pipe—and automatically take nightly readings. For drive-by collection, the radio transmitter can be mounted on the underside of a manhole cover, and a wire connects the logger to the transmitter. While it collects data, the receiver indicates whether or not a leak is present at a given location via an LED display. When it is uploaded to specialized software at the office, the noise data correspond to the reading locations in the form of charts. The software displays the noise data as historical leak and no-leak statuses as well as in a histogram of the previous night’s status.

A natural progression of drive-by acoustic leak data collection is piggybacking this function onto fixed-network automatic meter reading systems, which eliminate the need for personnel to collect the data. This technology, which allows leak monitoring of entire water systems every night, is starting to become available, as in Flow Metrix’s MLOG system.

**Pinpointing Leaks**
The proper device to use for picking up where listening devices leave off and ascertaining the exact location of a leak is the correlator. Typically, a listening device is used to determine the general area of a leak and a correlator is then deployed in the general area to pinpoint the exact location of the leak. Prices range from about $18,000 to $40,000.

The correlator was invented in the 1970s and Fluid Control Systems subsequently purchased the patent. This device has two identical sensor units that magnetically attach to either end of a pipe and detect any vibration. A transmitter connects to one of the sensors and sends data from both sensors to a handheld receiver unit via radio frequency. The receiver displays the precise location of the leak both in a graph and in numerical distance from each sensor.

"The correlator is sort of like a sophisticated stopwatch," McGee notes. "The correlator waits for the leak noise to arrive at one sensor at one end of the block and then it waits for the identical sound to arrive at the other end of the block. The difference in arrival time is measured in milliseconds and every millisecond of difference equals so many feet depending on the size, the type, and the length of the pipe. So every correlator needs to know what diameter the pipe is, what material it is made of, and the exact length between the two sensors. It basically compares the two sound waves arriving at each end of the block and times them, puts a stopwatch on them," by using algorithms to calculate the distance.

McGee points out that inputting the correct pipe diameter and material and distance between the sensors into the receiver is important for obtaining an accurate measurement. “Some [measurements] are more critical than others,” he says. “For instance, if the operator made a mistake between 8-inch and 6-inch pipe when he was entering the data, that would make hardly any difference at all, but if he punched in cast-iron and it was really a PVC mate, that would be a huge mistake and he probably missed the leak by 15 or 20 feet.”

PVC makes it much more difficult to obtain accurate measurements, McGee points out. “PVC is a softer, less dense material, and when you’re dealing with acoustics, you’re counting on the pipe wall to echo sounds down the street, and if the pipe is soft, it actually absorbs the sound instead of transferring it,” he says. Fluid Conservation Systems’ new AccuCALL (Computer Assisted Leak Locator) fifth-generation correlator utilizes a personal computer as the receiver, and the computer’s high processing power is better suited to accurately detect leaks in PVC. "Ten years ago, our success with the correlator on PVC pipe was maybe 10%; now we’re closer to 50% or 60% on PVC."

The system is said to be the first that uses digital technology, which is designed to prevent signal degradation that occurs when the signal passes through sensors, cables, and radios. The signal is immediately converted to digital at the sensor, a process intended to maintain signal integrity.

Metrotech Corp. offers its HL 6000 High-Performance Water Leak Correlator, which features 500-MW radio power for maximum range. Active piezo ceramic accelerometers are designed to provide accurate readings on plastic pipes. Both manual and automatic calculations are available to provide accurate readings in all conditions. The base model features a pinpointing function, which is not available in two other models.
Implementing a fixed-network leak-detection system that uses one of two types of logger is particularly beneficial to water utilities that have aging underground pipe networks, argues Steve Carson, general manager at Subsurface Leak Detection Inc. in San Jose, CA, distributor of listening devices, correlators, and correlating loggers. Noting that the current American Water Works Association threshold for leak detection requirements is a 10% water loss, says Carson, "There are some cities in the older parts of the US, particularly in the North and Northeast, that actually have 20% and 25% or even 30% and 40% water loss."

Another type of data logger records audio data during defined periods, and highly sophisticated software groups data from loggers that are nearby or in similar locations in order to double-check the existence of leaks.

Correlating loggers are a totally new technology that's opened up all new areas and opportunities for water utilities, says Carson. "This is a powerful technology that's taken off in the past four or five years. Traditional correlators use two points: two transducers and two radio transmitters to transmit the sounds simultaneously from two different locations. The logger uses the same technology, except that we're using a logger as opposed to using a sensor with a radio transmitter. The loggers are programmed from your PC as to when you want them to turn on. So the beauty of the correlating loggers is that they turn on in the middle of the night and they'll collect their data multiple times. When you download the sounds the next morning, then the loggers will perform correlations in pairs to try and pinpoint the exact locations of the leaks."

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