Detecting leaks in water distribution pipes
Hunaidi, O.; Wang, A.; Bracken, M.; Gambino, T.; Fricke, C.

Publisher's version / Version de l'éditeur:

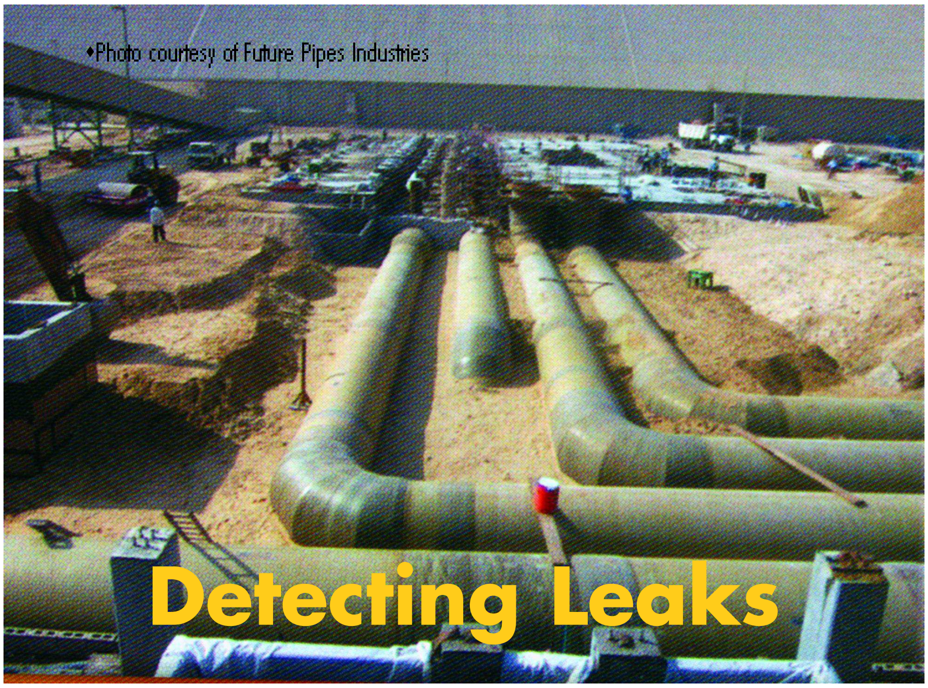
Arab Water World, 29, May/June 4, pp. 52-55, 2005-05-01

Detecting Leaks in Water Distribution Pipes

Hunaidi, O.; Wang, A.; Bracken, M.;
Gambino, T.; Fricke, C.

NRCC-48359

A version of this document is publishing in / Une version de ce document se trouve dans:
Arab Water World, v. 29, no. 4, May/June 2005, pp. 52-55



Detecting Leaks in Water Distribution Pipes

By: *Osama Hunaidi* and *Alex Wang**
Marc Bracken, *Tony Gambino*,
and *Charlie Fricke***

Water utilities in many parts of the world are facing growing challenges in their attempts to meet the demand for drinking water. Several factors are contributing to this situation. Climate change, manifested by extended periods of drought, is adversely impacting water resources. Population growth caused by migration to large urban centers and temperate regions is exerting increasing pressure on existing water supplies. The problem is compounded if water treatment infrastructure is operating near capacity and funds required for expansion are scarce. Limited treatment capacity can create drinking water shortages even in water-rich regions. In the face of these challenges, the recovery of water loss from leaks in transmission and distribution pipes can provide a solution, at least partially, to shortages caused by insufficient water resources and/or limited treatment capacity.

Water transmission and distribution networks deteriorate naturally with time and subsequently loose their initial water tightness. Causes of the deterioration include corrosive environments, soil movement, poor construction standards, fluctuation of water pressure, and excessive traffic loads and vibration. Water is lost due to leakage in different components of the networks that include transmission pipes, distribution pipes, service connection pipes, joints, valves, fire hydrants, and storage tanks and reservoirs. In addition to the physical losses due to leakage, many networks suffer from so called apparent losses. These are caused by under-registration of customer meters, accounting errors, and unauthorized water use.

The amount of water loss is typically between 20 to 30% of production, with leakage being the main component. For some distribution systems, the loss can be in excess of 50%. In addition to their help in meeting water demand, detection and repair of pipe leaks help to minimize water quality breaches that may result from the entry of contaminants via leaks. They also help to reduce the high cost of energy wasted on the treatment and pumping of leaking water. The energy-wasting aspect of leakage is important as significant savings can be realized. Energy to supply water is the second largest cost after labor for water systems in developed countries, and the cost may easily consume 50% of a municipality's budget in the developing world.

Acoustic equipment is commonly used to locate leaks in municipal water pipes. These include noise loggers, simple listening devices, and leak noise correlators. The economic viability and leak detection effectiveness of noise loggers is questionable. Also, they are not suitable for pinpointing leaks. The effectiveness of listening devices such as ground microphones for pinpointing leaks depends greatly on the experience of the user and the process is time-consuming. Leak noise correlators are more efficient, yield more accurate results and depend less on user experience than do listening devices. Existing correlators, however, require extensive training and can be unreliable for quiet leaks in cast and ductile iron pipes and for most leaks in plastic and large-diameter pipes. Correlators are also expensive and remain beyond the means of many water utilities and leak detection service companies. Recent correlator developments, see www.echologics.com, overcame these drawbacks.

Overview of Leakage Management

Management of leakage comprises four main components: (i) quantifying the total water loss, (ii) monitoring of leakage, (iii) locating and repairing leaks, and (iv) pipe pressure management.

Quantifying the total amount of lost water is achieved by conducting a system-wide water audit, known internationally as a water balance. Like financial audits that account for all the debits and credits of a business, water audits account for all water flowing into and out of a utility's water delivery system. An audit can be performed over an arbitrary period of time, but normally it is computed annually over a period of 12 months. Audits provide a valuable overall picture about various components of consumption and loss, which is necessary for assessing a utility's efficiency regarding water delivery, finances, and maintenance operations. Also, water audits are necessary for planning other leakage management practices.

Monitoring of leakage involves dividing the distribution system into well-defined areas that each can be supplied through a single pipe where a flow meter capable of measuring low flow rates is installed. These areas are known as district metering areas or DMAs. The boundaries of DMAs can sometimes occur naturally but generally they have to be created by the closing of appropriate valves. The size of a typical DMA can be between 500 and 3000 properties. Leakage in DMAs is monitored by measuring the minimum night flow rate monthly or quarterly or on continual basis if flow meters are connected telemetrically to a SCADA system. Leakage is suspected if the minimum night flow rate is greater than a previously measured level or if it exceeds a certain threshold. The latter is determined as the sum of the flow rate of water used by all night-time commercial and industrial users in the district, flow rate of water used by all residential properties based on average night flow rate per property, and unavoidable leakage rate. DMAs make it possible to quickly and efficiently identify areas of the pipe network that suffer from excessive leakage, which are then targeted for leakage detection and localization operations. Analysis of minimum night flow rates can also be used to refine (or check) the accuracy of water audits.

The exact positions of leaks are commonly pinpointed by using ground microphones and leak noise correlators and possibly by using non-acoustic methods such as thermography, ground-penetrating radar, and tracer gas. Pinpointing of leaks can be time consuming and therefore leak detection surveys are normally undertaken prior to pinpointing to narrow down the area of the leak to a pipe section(s). Step testing can identify pipe sections with leaks in a DMA. This involves the monitoring of the district meter's flow rate while successively closing valves within the DMA, starting with the valve that is farthest away from the meter. A significant reduction in the flow rate is an indication of leakage in the last shut- off section. Step testing has to be performed at night and can be time consuming and dangerous. In recent years, its use has dwindled in favor of acoustic surveys using noise loggers, acoustic listening tools, or leak noise correlators.

Pipe pressure affects leakage in a number of ways and a substantial reduction in leakage can be realized by pressure management. The lower the pressure, the lower the pipe break frequency. Also, pressure transients can fracture pipes and damage their joints. Frequent pressure fluctuations may cause fatigue failure in pipes, especially plastic ones. Most importantly, the higher the pressure, the higher the leakage rate. Theoretically, the flow rate of a fluid through an opening is proportional to the square root of the pressure differential across the opening, provided that the dimensions of the opening remain fixed. However, pipe leak openings may enlarge with pressure. Therefore, much greater reductions in leakage can be realized than predicted by the square root relationship, especially for small leaks from joints and fittings in most pipe types and large leaks in plastic pipes. A linear relationship between pipe pressure and leakage level is widely used by leakage management practitioners.

Leak Detection Equipment

- *Acoustic Equipment*

Listening devices. These devices include listening rods and ground microphones and may be either mechanical or electronic. They use sensitive mechanisms or materials such

as piezoelectric elements to sense leak-induced sound or vibration. Modern electronic listening devices incorporate signal amplifiers and noise filters to make the leak signal stand out. Leak inspectors conducting leak surveys work their way around the pipe network systematically and use listening rods at appropriate pipe fittings to detect the characteristic hissing sound created by leaking water. The leak detection effectiveness of listening surveys depends on the size of leaks, ambient noise from road traffic and water draw, and the degree of detail of the survey. General surveys, performed by listening at only convenient fittings such as fire hydrants and/or valves, mainly detect large leaks. On the other hand, detailed surveys conducted by listening at all pipes fittings, including curb-stops (or stop-taps), can detect small leaks. Ground microphones are used to pinpoint leaks by listening for leak noise at the ground surface directly above pipes at small intervals. This process is time consuming and its success depends on the experience of the user.

Noise loggers. These are compact units composed of a vibration sensor (or hydrophone) and a programmable data logger. They are used to leak survey large areas but they are not suitable for pinpointing leaks. Loggers are deployed in groups of 6 or more at adjacent pipe fittings, e.g., fire hydrants and valves 200 to 500 m apart, and left there overnight. The units are normally programmed to collect pipe noise data between 2 and 4 AM. The loggers are collected the next day and the stored data are downloaded to a personal computer before the loggers are deployed at the next location. The logged data are analyzed statistically, e.g., frequency analysis of leak noise levels, to detect the presence of leaks. Recent models of acoustic noise loggers can be deployed permanently - leak noise is processed using onboard electronics and the stored result is transmitted wirelessly to a roaming receiver. The economic viability and leak detection effectiveness of temporarily or permanently deployed noise loggers is questionable. Acoustic loggers can be advantageous over listening surveys in instances where the latter cannot be undertaken during daytime due to high ambient noise.

Leak noise correlators. These are portable microprocessor-based devices that can be used in either leak survey or pinpointing modes. They are based on the cross-correlation method, which involves the measurement of leak noise (either sound or vibration) at two locations on a pipe section. Measured noise is transmitted wirelessly to the correlator, which then determines the position of the leak based on the time shift of the maximum correlation of the two leak signals, propagation velocity of leak noise, and the distance between sensing points. The distance between sensors can be read from distribution system maps when the correlator is used in survey mode but it should be measured onsite accurately when it is used in pinpointing mode. Propagation velocities for various pipe types and sizes are programmed in most correlators, but they should be measured onsite to improve pinpointing accuracy, especially for non-metallic pipes. Leak noise correlators are more efficient, yield more accurate results and are less dependent on user experience than listening devices. However, existing equipment requires extensive training and can be unreliable for quiet leaks in cast and ductile iron pipes and for most leaks in plastic and large diameter pipes. Correlators are also expensive and remain beyond the means of many water utilities and leak detection service companies. The recently developed LeakfinderRT correlator, see www.echologics.com, overcomes these drawbacks.

- *Non-acoustic Equipment*

Tracer gas technique. In this technique, a non-toxic, water-insoluble and lighter-than-air gas, such as helium or hydrogen, is injected into an isolated section of a water pipe. The gas escapes at a leak opening and then, being lighter than air, permeates to the surface through the soil and pavement. The leak is located by scanning the ground surface directly above the pipe with a highly sensitive gas detector.

Thermography. The principle behind the use of thermography for leak detection is that water leaking from an underground pipe changes the thermal characteristics of the adjacent soil, for example, making it a more effective heat sink than the surrounding dry soil. Thermal anomalies above pipes are detected with a ground or air-deployed infrared camera.

Ground-penetrating radar. Radar can be used to locate leaks in buried water pipes either by detecting voids in the soil created by leaking water as it circulates near the pipe, or by detecting sections of pipe that appear deeper than they truly are because of the increase in the dielectric constant of water-saturated adjacent soil.

Ground-penetrating radar waves are partially reflected back to the ground surface when they encounter an anomaly in dielectric properties, for example, a void or pipe. An image of the size and shape of the object is formed by radar time-traces obtained by scanning the ground surface. The time lag between transmitted and reflected radar waves determines the depth of the reflecting object.

Factors Influencing the Effectiveness of Acoustic Equipment

The effectiveness of acoustic leak-detection equipment depends on several factors including pipe size, type, and depth; soil type and water table level; leak type and size; pipe pressure; interfering noise; and sensitivity and frequency response of the equipment.

Pipe material and diameter have a significant effect on the attenuation of leak signals in the pipe.

For example, leak signals travel farthest in metal pipes and are attenuated greatly in plastic ones for acoustical characteristics of plastic pipe leaks). The larger the diameter of the pipe, the greater the attenuation, and the harder it is to detect the leak. Pipe material and diameter also affect the predominant frequencies of leak signals - the larger the diameter and the less rigid the pipe material, the lower the predominant frequencies. This effect makes leak signals susceptible to interference from low-frequency vibrations, for example, from pumps and road traffic.

Soil type and the water table level influence the strength of leak signals at the ground surface significantly. Leak sounds are more audible on sandy soils than on clayey ones, and on an asphalt or concrete surface than on grass. Leak signals are muffled if the pipe is below the water table level. Acoustical characteristics of leak sounds vary with leak type and size. Splits and corrosion pits in pipe walls may induce stronger leak signals and higher frequencies than leaking joints and valves. Generally, the larger the leak, the louder the leak signal, but this may not be true for very large leaks. The higher the pipe pressure, the louder the leak signals.

The more sensitive and quieter the leak sensors, and the higher the signal-to-noise ratio of the signal conditioning and recording equipment, the smaller the leaks that can be detected. Modern acoustic equipment incorporates signal-conditioning components such as filters and amplifiers to make leak signals stand out. Filters remove interfering noise occurring outside the predominant frequency range of leak signals. Amplifiers improve the signal-to-noise ratio and make weak leak signals audible. If the frequency response of the equipment does not extend to sufficiently low frequencies, it can miss leaks in plastic and large-diameter pipes. ■

* **National Research Council Canada**, Ottawa, Canada K1A 0R6
** **Echologics Engineering Inc.**, Toronto, Canada M9W 1B3
A full version of this article is available at: www.nrc.ca/irc/fulltext/nrcc47062/nrcc47062.pdf

يُعتبر تسرّب المياه من شبكات التوزيع من أكبر المشاكل التي تواجه هيئات خدمات المياه وذلك من الناحية الإقتصادية حيث يُشكّل التسرّب هدر كمية كبيرة من المياه وبالتالي خسارة هذه المياه بالإضافة إلى تأثيرها على البنية التحتية من كهرباء وهاتف وطرق خلافه. كما أن تسرّب المياه يعني وجود انكسارات غير ظاهرة في شبكات المياه وبالتالي دخول ملوثات إلى الشبكة مما يؤدي إلى تلوث الشبكة العامة وما ينتج عن ذلك من التأثيرات الصحيّة والبيئية. لذا فإن تقليل الفاقد من التسرّبات له جدوى اقتصادية وصحية وبيئية.

هناك نوعان من التسرّبات:

أ- تسرّب مرئي: وهو الذي يمكن أن يُرى فوق سطح الأرض نتيجة انكسارات ظاهرة أو سوء استخدام المياه.

ب- تسرّب غير مرئي: وهو الذي لا يمكن رؤيته وهذا ناتج عن الإنكسارات غير الظاهرة والتي من خلالها يتم فقد كميات كبيرة من المياه تحت سطح الأرض دون ملاحظة ذلك.

يمكن تقسيم مسح التسرّبات إلى قسمين:

أ- المسح السماعي: وهو يتم عن طريق تمرير أجهزة الكشف عن التسرّب فوق خطوط المياه والتوصيلات المنزلية ويمكن من خلالها اكتشاف التسرّب.

ب- المسح القياسي: ومن خلاله يتم قياس التدفق لمجموعة من المنازل حيث يتم قياس الفرق بين كميات المياه الداخلة والمستهلكة والفرق هو المياه المفقودة.

Reader Inquiry #58