INCREASING EFFICIENCY WITH PERMANENT LEAKAGE MONITORING

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Abstract

In this paper information from Water Authorities in the USA, Europe, Middle East and Australia that have purchased permanent monitoring leak detection equipment is reviewed and the findings are presented in a structured format that covers the following:

- Justification for permanent monitoring
- Evaluating the different product offerings
- Selecting the deployment zone
- Installation challenges
- Collection and validation of the data
- Handling false Alarms
- Managing the change in operational procedures
- Calculating the payback period
- Viability to expand the program
- The operational benefits to permanent leakage monitoring

The objective is to share knowledge, experiences, operational benefits, economic benefits and water loss results.

Introduction to permanent monitoring

Permanent leakage monitoring is a concept that has been practiced by a number of water authorities over the last five years. Acoustic loggers are deployed with a magnetic connection on valves and hydrants. They are programmed to log noise levels in the early hours of the morning when pressure is highest and background noise is lowest. With careful analysis of the data the probability of leakage can be calculated based on the level and consistency of the noise. This data is sent daily to a host pc or webserver by SMS or GPRS (depending on the system). Some systems have a modem in every logger and others use repeaters and data collection units to minimise the cost of data transmission. Most systems display the data on a map, colour code the loggers and keep the results in a table. Some systems provide a correlation showing the exact leak position. ***[See Fig. 1.1.]***

Figure 1.1 Screen capture of a permanent leakage monitoring system

Justification for permanent monitoring

There are many justifications for permanent leakage monitoring and this is truly an individual evaluation exercise for a utility. Points to consider include the following:

- Reducing leak run-time with more frequent leakage data.
- Identifying leaks when they are small so they can be repaired in a controlled and scheduled method without interrupting customer supply.
- Monitoring critical locations to ensure there are no bursts that cause disruptions.
- A grant or research budget to experiment with new technology to ensure current operation methods are optimal.
- A desire to reduce water loss quickly. Not interested in DMA's or prepared to wait for DMA's to be implemented before starting leak detection.
- The cost of desalinated water is too expensive to waste.
- Reduce the leakage to defer the investment of a new water treatment plant or reservoir.
- The environmental protection agency will not permit increases in water allocations until water loss is reduced.

Evaluating the different product offerings

Acoustic loggers have been deployed permanently for many years with "drive-by" being the most common form of data collection. There are a number of logger brands available with the ability to transmit data via radio to a moving vehicle. This technology is effective if the data is collected regularly. However with reducing numbers and job rotation of operations staff and increased traffic levels it has been difficult to ensure this data is collected frequently enough to reduce leak run time. After the rate of rise is calculated for an area the survey frequency is usually determined on an area by area basis. This usually varies from weekly to quarterly.

In the last few years more utilities have started to install leakage monitoring systems that transmit data to the office or hosted website every day. The advantage of this system is that it is un-manned and there is no reliance on operational staff to collect the data. With data arriving daily the response time is increased significantly, thus reducing the run time. This has a highly desirable effect on water loss. Additional advantages to many of these un-manned systems is that self-learning algorithms can be introduced to increase the intelligence of the system. This enables quieter leaks to be found and reduces false alarms. When evaluating un-manned leakage systems there are a number of points to consider:

- Noise loggers or correlating noise loggers?
- Individual SMS communication or radio communication to a GPRS collector.
- Acoustic loggers versus acoustic loggers with frequency logging

Noise loggers will typically localise the leak position within one hundred metres however a correlating noise logger will produce an exact location of the leak position within one metre. In busy areas correlation is not possible during the day. The correlating logger will provide a massive reduction in pinpointing costs associated with finding leaks and reduce the run-time by a few days. Correlating loggers collect data daily to find difficult leaks that cannot be found with noise loggers. These are usually the significant leaks. Repeated correlations over consecutive days in a similar location increases the confidence level and reduces the chance of a false alarm.

SMS loggers require a SIM card in every logger and can be programmed to send the data daily, weekly, monthly or on alarm. SMS loggers are the quickest and easiest to deploy and ideal for temporary monitoring. SMS loggers cannot correlate and the amount of data they transmit is limited. The costs associated with having a SIM in every logger can be high when considered over a five year deployment period.

Logger systems using radio in the loggers, repeaters on street lamps and data collectors on water towers or high buildings can economically transmit large amounts of data via GPRS. With an average of thirty to forty logged points to each data collection unit the communication costs are a fraction of the cost incurred by SMS loggers. This communication method enables additional data such as sound recordings for correlation and frequency analysis to be performed. Installation is a little slower and more expensive than SMS loggers however it is still possible to install a system with eighty logged points within three or four days. The initial capital investment for this system is usually more expensive as more hardware is required. However the increased operating efficiency soon outweighs the additional cost.

Acoustic loggers have historically generated many false alarms from a multitude of constant noises in the network being interpreted as leaks. The more advanced systems monitor the frequency of the noise in addition to the noise level to determine whether the noise is mechanical, electrical or a leak.

Cold weather increases the burst rate. Some of the more advanced systems include temperature ***[c.f. figure 1.2]*** for analysis.

Figure 1.2 Screen Capture showing Logger Details including temperature

A more recent customer driven development has been to adapt the data collection units to interface with a city wide wi-fi network. This removes the need for GPRS SIM cards and their associated costs. ***[This is shown in figure 1.3.]***

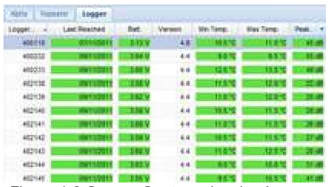

Figure 1.2 Screen Capture showing Logger Details including temperature

Selecting the deployment zone

Water utilities often have individual motives for selecting the deployment zone for their permanent monitoring system. If the system is a trial for evaluation purposes it is important to have a flow meter and data logger capturing the data before and during the trial. A reservoir zone may be the ideal location for a trial. It is large enough to find at least one leak during a short trial and should be a secured zone enabling flow to be monitored.

Leaky zones are often selected. The cost of regular survey is higher in these areas and the probability in reducing water loss and increasing efficiency is high. It should be ensured that Minimum Night Flow is the bench mark used for defining a “Leaky Zone’. A zone with a high ILI (Infrastructure Leakage Index) may not have leaks.

Many water utilities who do not practice “Active Leakage Control” do not know where their “leaky zones” exist and actually suspect them to be in the area where the leaks often surface. If a trial is to be performed it is recommended to perform a water balance at a reservoir zone level before selecting the leaky zone for a trial.

Figure 1.3 Data Collector connected to the Wi-Fi Network

Leak detection in remote areas represents the greatest cost to a utility due to increased site travel. Permanent leakage monitoring in these areas will produce a large saving in operational costs if the number of visits required to locate and repair the leak is reduced.

Residential areas are the easiest areas to install permanent leakage monitoring systems. They usually have fittings and hydrants at regular intervals, good GSM signal for the SMS loggers and plenty of street lamps to install radio repeaters.

It is often harder to install leakage monitoring systems in a CBD. Tall buildings bounce and shield communication waves. However due to the complex network and high level of background noise this is also the location in which it is most difficult to perform an effective leakage survey in any other way.

Installation challenges

Valve boxes are often very small without room to place a logger on top of the valve spindle or on the side of the valve spindle. In this instance an angled bracket should be purchased to magnetically join the logger to the side of the valve spindle. ***[c.f. Figure 1.4]***

It is difficult to find a good location to deploy acoustic loggers on above ground fire hydrants. A custom logger design may be required to fit inside the hydrant so the logger is securely connected and invisible. ***[c.f. Figure 1.5]***

If theft is a concern camouflage of the loggers or an innovative locking device may be needed. ***Figure 1.6*** shows an acoustic logger with a stainless steel eyelet and a steel cable tie securing the logger to the hydrant.

Figure 1.4 Acoustic logger deployed on a valve spindle with a bracket

The standard GSM wavelength is approximately 30cm from peak to peak. Therefore moving the antenna of an SMS logger underground can make a big difference to the signal quality. Maintenance work is performed periodically on GSM network towers and the alignment of the signal peak can shift a few centimetres. In cases with marginal signal the antenna will need to be moved. There will often be some locations where the signal is too weak for communication from underground and the logger has to be deployed in another location. Otherwise there will be a small gap in the monitoring network.

Permission is often required to install radio repeaters on other utilities “furniture”. Each municipality will have their own setup. In some places it is one company managing all the utilities. In other places the local government body manages all the utilities. In some places a private company manages each utility. The objective is to have as many options available as possible and to install the repeaters at a height of five to fifteen metres. Typical radio repeater installation points include:


Figure 1.5 Pictures of an acoustic logger developed to fit onto above ground hydrants

- Street lamps
- Power poles
- Traffic signs
- Over pass bridges
- Flood lights for sports fields
- Sewer vents
- Water towers
- Buildings

It is very unusual to find a chamber where radio communication to a logger is not possible. The depth and construction of the chamber will determine whether the signal radiates upwards or outwards. If the signal radiates upwards the radio repeater needs to be installed within fifteen to twenty metres from the logger. If it radiates outwards the radio repeater can usually be installed one hundred to one hundred and fifty metres from the logger.


Figure 1.6 Correlating noise logger secured on hydrant with a steel cable tie

Installing the Data Collection Units in high locations like the top of water towers and tall buildings will significantly reduce the number of units required. With these perfect installations one data collection unit can serve forty or fifty monitoring points. This reduces the capital outlay and on-going operational cost of GSM communication. The data collection unit shown in ***Figure 1.7*** is an example of one of these ideal installations.


Figure 1.7 Deployment of a data collection unit

Collection and validation of the data
It is usual to set some objectives at the start of a permanent leakage monitoring project so the success of the project can be reviewed. Reliability of data and optimum deployment distance are likely to be major points of these criteria.

Events occur which prevent every logger from transmitting data every day. It would be un-realistic to set such a high target. It is important to identify the different conditions and identify the weakness of the equipment. Typical reasons for communication problems may include:

- Logger and antenna are submerged
- A car or truck is parked over the logger
- There is a thick layer of snow above the logger
- Faulty SIM card
- Marginal signal strength

The data should be validated with an acoustic listening stick that has a numeric value showing the minimum noise to confirm anomalies in the results. Sometimes the leak noise is louder at points that are further from the leak. This occurs when repairs have been made in another pipe material or there are errors in the map.

The history of the data should be reasonably consistent or form a pattern. The pattern does not need to be explained however this is helpful. When there is no consistency or pattern the reliability of the data should be verified by deploying another logging device in the same location to draw comparisons. The example in figure 1.8 shows consistent data.

Figure 1.8 Historical data from an acoustic noise logger

The project objectives should specify the criteria for the type of leaks the system is expected to find. An example of this objective might be "to find all leaks above 10 litres per minute on the main pipe." The deployment distance from logger to the next logger is dependent on the project objective, pressure pipe diameter and pipe material. This deployment distance can vary from 80 metres to 500 metres. The deployment interval changes the number of loggers required and can alter the economic viability of a project significantly. Once an objective is defined leaks should be simulated to evaluate the performance of the equipment and experiment with different deployment distances until the optimum range is found.

Handling false alarms
False alarms are inevitable at some point even with the most advanced leakage monitoring system. Care should be taken evaluating the data to avoid chasing mechanical and electrical noise instead of leaks. If an operator goes to site searching for a leak and finds a constant noise source that is not a leak, they should provide details of the noise and location of the noise. This way the system intelligence can be increased to prevent re-occurrence.

The more advanced loggers analyse the frequency in addition to the noise level to reduce the number of false alarms. In figure 1.9 the logger records a high level of constant noise but after analysing the frequency data shown in figure 2.0 calculates the leak probability at 1%.

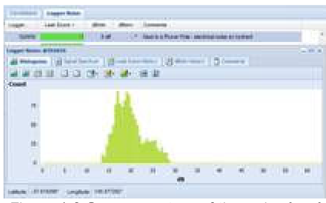
Figure 1.9 Screen capture of the noise level and consistency of noise recorded by an acoustic logger

If there are flow meters in the reservoir zone deployed in strategic locations the data from these monitoring points can be cross referenced with the acoustic data to confirm the presence of a leak before sending out the repair team. This flow monitoring can be performed without closing the system into smaller zones.

Managing the change in operational procedures
Operational procedures will need to be introduced to reflect the changed working conditions.

- Leaks reported in a call centre should go to the engineers or technical officers with access to the leak monitoring system before jobs are issued to field staff.

Information about the deployment method and maps with logger positions should be provided to field staff so they know where the loggers belong.

Contractors that may use hydrants need to be advised about the loggers so they do not take them as a souvenir or leave them deployed incorrectly.

Field crews should be educated on the purpose of the leakage monitoring system. If these crews will be responsible for locating leaks they should also be taught how to interpret all of the data.

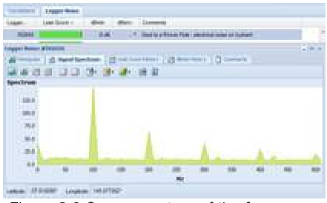
Figure 2.0 Screen capture of the frequency spectrum detected by an acoustic logger

Managing the change should be performed delicately so the workforce feel the system will help them do their job, not replace them. A reporting system should be introduced or modified to identify the exact location, size of leak, method of repair, visibility, pipe material and pipe diameter. This information should be collected for all leaks and used to evaluate the performance of the equipment. It should be stored in a leak database. Which may be used at a later date to prioritise pipe replacement.

It is usual for the pipe to be re-checked for additional leaks after the repair has been made, with the leakage monitoring system this procedure can be eliminated.

What are the operational benefits?
The operational benefits from leakage monitoring depend on the objectives set by each organisation. Typical examples of operational benefits include:

- Reducing the run-time of a leak
- Reducing the man hours spent searching for leaks
- Focusing on looking for leaks in the areas with leaks
- Increasing knowledge of the network
- Raising awareness of a leak when it occurs and before it becomes a major incident
- Reducing the amount of night-work and over-time
- Finding quiet leaks that are inaudible during the day or are masked by smaller leaks
- Saving every drop of water including customer leakage
- Reducing repair costs through earlier intervention
- Improving public relations

Testimonials on operational benefits from engineers with leakage monitoring systems:
“With an acoustic logging system that correlates the leak position, providing both the localization and location steps of localize, locate and pinpoint we have reduced the effort and cost of localization by 98% and reduced the average run time of a leak event to 1.5 days.” -- Frank Tantzky, Albstadtwerke Germany.

“We have reduced the number of leakage operators employed to survey for leaks and reduced the amount of overtime. This helps us comply with the current push to reduce working hours and provides a financial saving.” -- Wish to remain anonymous, France.

“The operational benefits include identifying leaks before they surface and providing a more intelligent network by comparing current results against previous data to identify any change.” -- Malcolm Hill, South East Water, Australia.

“Significant improvements in speed of response to leak sites.

Identification of incorrect working practices for service connections. Education and formal procedures will improve standards and reduce tendency for leakage due to incorrect practices. ... Much better knowledge of network infrastructure – good and bad areas. ... Customer side issues have also been addressed such as leaking tanks. This improves customer relations and provides added value and reduces billing complaints.” -- Wish to remain anonymous, Middle East.

Calculating the payback period
At the end of a trial or after the roll-out of a project, it is usual to calculate the payback period for the investment made and predict payback period on extending this project. The accuracy of this calculation will be reflected by the quality of data collected before and after the project. If a leakage survey was recently performed in this zone prior to installing the monitoring system the natural rate of rise should be applied to the base value over time to reflect the true saving.

The common components to be considered are:

- Cost of equipment purchased
- Cost of communication
- Cost of installation
- Saving in water (calculated at production cost and retail price)
- Reduction in labour costs for leak detection and repair
- Reduction in energy and carbon emissions

When a selection of engineers was asked about the water savings delivered by their leakage monitoring system, the responses included the following:

“With this technology we have been able to continue to maintain our MNF at 0.4L/S with an average run-time of a leak event being 1.5 days enabling us to reduce our water losses to lower levels than ever before.” -- Frank Tantzky, Albstadtwerke, Germany.

“Although leak calculations are not complete, many leaks have been found and repaired. Leaks are now being measured and classified to give better understanding of leak sizes and water loss from leaks found via the permanent monitoring system. DMAs are being installed to help provide more accurate leak reduction figures.” -- Wish to remain anonymous, Middle East.

“Acoustic logging is our only water loss strategy and we find it provides the quickest and most cost effective solution to reduce water loss. In the first three months we reduced the water loss by 30% in our trial area. Now we have ordered acoustic logging equipment to cover our entire network.” -- Karl-Heinz Beißwänger, Zweckverband Eislingen, Germany.

“With desalinated water in a city with one million people, two thousand kilometres of pipework and thirty per cent water loss, we only have to make a two point five per cent reduction in water loss for the leakage monitoring system to be economical.” -- Wish to remain anonymous, Middle East.

Viability to expand the program
Utilities with high water costs, high labour costs or high water loss will find the payback period of a permanent leakage monitoring system to be relatively short. Feedback from utilities in Europe indicate the payback period can be as short as three months for utilities that have not practiced Active Leakage Control (ALC) and eighteen months for utilities with good ALC.

A leakage monitoring system will be an attractive alternative to constructing new treatment plants, dams or reservoirs if it can deliver the saving to defer this investment.

During periods of drought or in countries with little rainfall the viability will shift in favour of permanent leakage monitoring.

There is political merit to reducing water loss and protecting the environment which can be a driver to install permanent leakage monitoring.

Combining two or more monitoring systems with one set of infrastructure can make the roll-out of a permanent leakage monitoring system more attractive. We already see a number of acoustic logger manufacturers working with AMI manufacturers to provide un-manned meter reading and leak detection systems. ***(c.f. Figure 2.1 STAR Zonescan by Aclara and Gutermann)***


Figure 2.1 Acoustic logger modified to transmit results on a fixed AMI network

The ultimate decision on the viability of leakage monitoring systems is usually based on a combination of environmental, political and economic factors. With such short payback periods and the ability to change leak run-time from weeks or months to hours or days should be sufficient to convince those with an environmental conscience.

Conclusions
The information collected shows that permanent leakage monitoring has been practiced for a number of years and that many technological problems have already been resolved.

There are both operational savings and water loss savings generated from permanent leakage monitoring. These savings include:

- Reducing the leak run-time
- Reducing the manpower required to perform leakage surveys
- Reducing the manpower required to pinpoint leaks
- Finding quiet leaks that would usually be missed in a leakage survey
- Identifying and repairing small bursts before they become large incidents
- Finding some customer side leaks improves customer relations
- Improved knowledge of the water distribution network and its problem areas
- A fast and effective solution for reducing water loss
- Maintaining low levels of water loss

There is a large capital investment required to set up permanent leakage monitoring, however it is often comparable or cheaper than DMA creation. Pipe augmentation work, design engineering and hydraulic modelling are large costs associated with DMA construction and are not required in a permanent leakage monitoring system.

The water balance can be calculated by reservoir zone and the zones with high leakage could have a leakage monitoring system installed within weeks to deliver immediate savings without waiting two years to install DMA's.

Several of the water authorities assisting with the research in this paper calculate the return on investment period for permanent leakage monitoring to be twelve to eighteen months.

It is good practice to vary Non-Revenue Water strategies according to the zones within each network. Permanent Leakage Monitoring will provide the fastest results and quickest payback in leaky zones, while DMA's and pressure management provide good solutions for zones with less leakage.

References

Permanent Monitoring is the fastest way to reduce water loss in Eislingen; *by Karl-Heinz Beißwänger / Zweckverband Eislinger Wasserversorgung (Case Study Not Published Yet)*

Operational Efficiencies from Permanent Leakage Monitoring; *by Frank Tantzky, Network Operations Manager at Albstadtwerke (Presented at Global Leakage Summit, London 2011)*