Vol.3 会員からの投稿：UAE での漏水管理

PE 日野さん(PE0009)からの紹介で Mr Andrew Wedgner さんに中東における漏水管理について寄稿してもらいました。

Mr Andrew Wedgner is a leading infrastructure engineer based in Abu Dhabi, the capital of the United Arab Emirates. He is a chartered member of both the UK Institution of Civil Engineers and the Chartered Institution of Water and Environmental Management. He has 20 years experience in the design, supervision and project management of water supply and wastewater projects, together with other subjects such as leakage management.

Having joined the Abu Dhabi Distribution Company, the local water and power utility, in 2006 to establish their Asset Management Division, he is currently the manager of the Projects Division, managing an annual capital budget of US$ 439 million.

The following paper was prepared by Mr Wedgner whist he was working for international consultant Mott MacDonald as their manager for water and environment activities in the Persian Gulf region. He has a strong commitment to the training and development of young engineers of all nationalities and would be happy to respond to any queries that you may have concerning his paper. I recommend you to contact him at <arwedgner@addc.ae>.

(written by Takashi Hino, P.E. (PE0009)

▪ Leakage Management In The Middle East

Andy Wedgner (CEng, MICE, MCIWEM)– Projects Division Manager, ADDC
formerly of Mott MacDonald Ltd.

Introduction

The aim of this paper is to introduce the reader to leakage management practices in general and illustrate some of the points by making reference to leakage management projects that Mott MacDonald have undertaken in the Middle east, particularly in Oman and the UAE.

Leakage Management Terms

Leakage management (sometimes referred to as leakage control) is the process by which the losses and wastage of water from a water supply system are identified, quantified and reduced down to an acceptable level. As with any field of engineering, leakage management has developed various technical terms, several which are defined as follows:

Unaccounted For Water (UFW)

This represents the difference between net production and consumption. Whilst this is a simple definition, determining the true figures can be a difficult, expensive and time consuming process. For the purposes of this paper, UFW will be referred to as leakage.

Net Production

This is the volume of water delivered into the network by the water treatment works, supply boreholes or other sources. This is normally measured by a meter on the source outlet.

Consumption

This is the volume accounted that can be for by legitimate consumption, whether metered or not. Where all domestic, commercial and industrial consumption is metered and the data collected, an allowance should also be made for such activities as fire fighting and mains flushing. In situations where the consumption of water is not effectively metered, the figures have to be estimated by undertaking a consumption survey or relying on published data for guidance.

Categorisation of Leakage

Leakage losses can be broken down into physical and non-physical categories. Physical losses ie. the loss of water from the system through leakage. This is a resource loss and is reflected in the cost of production.

Non-physical losses are water that is consumed but not metered or accounted for. It includes the under reading of low flows, flow not measured due to meters being damaged or tampered with and illegal connections. This cost of this water is reflected in lost revenue.

Measurement

The most common way in which to express leakage is in terms of a percentage of the total water production, a term that is both easy to derive and understand. The problem with using a percentage figure is that it is dependent on the level of production. Therefore even if the quantity of leakage remains constant over a period, the percentage figure will vary. Most organisations within the water industry therefore now quantify leakage in litres per property per hour and cubic metres per kilometer of mains per day.

The Benefits and Economics of a Leakage Management Programme

In environmental terms, most people would accept that water is a valuable and scarce resource that should be managed effectively. Water that is not leaking away into the ground can be used to irrigate crops and parkland, supply consumers and generally improve the quality of life. One should also remember that the production of cubic metre of desalinated water typically requires around 300,000 kJ of energy, normally created by the burning of fossil fuels and so contributing to the increasing level of green house gases in the atmosphere.

In economic terms, leakage that is lost through whatever means has a cost associated with its production, treatment and transmission up to the point where it is either lost or drawn from the system. This is especially the case in countries such as the UAE that use predominately desalinated water, which has high production costs. In leakage management terms, the economic cost of the water is usually expressed as the unit rate of water delivered to the consumer, inclusive of all production, storage, transmission, distribution and associated costs eg. AED per cubic metre of water delivered.

However, the establishment and undertaking of a leakage management programme also involves significant expenditure. This is normally made up of fixed costs such as purchasing equipment, hiring and paying staff, maintaining equipment and providing facilities, together with costs that are dependent on the amount of detected and repaired eg. hire of construction plant, repair materials and pavement reinstatement.

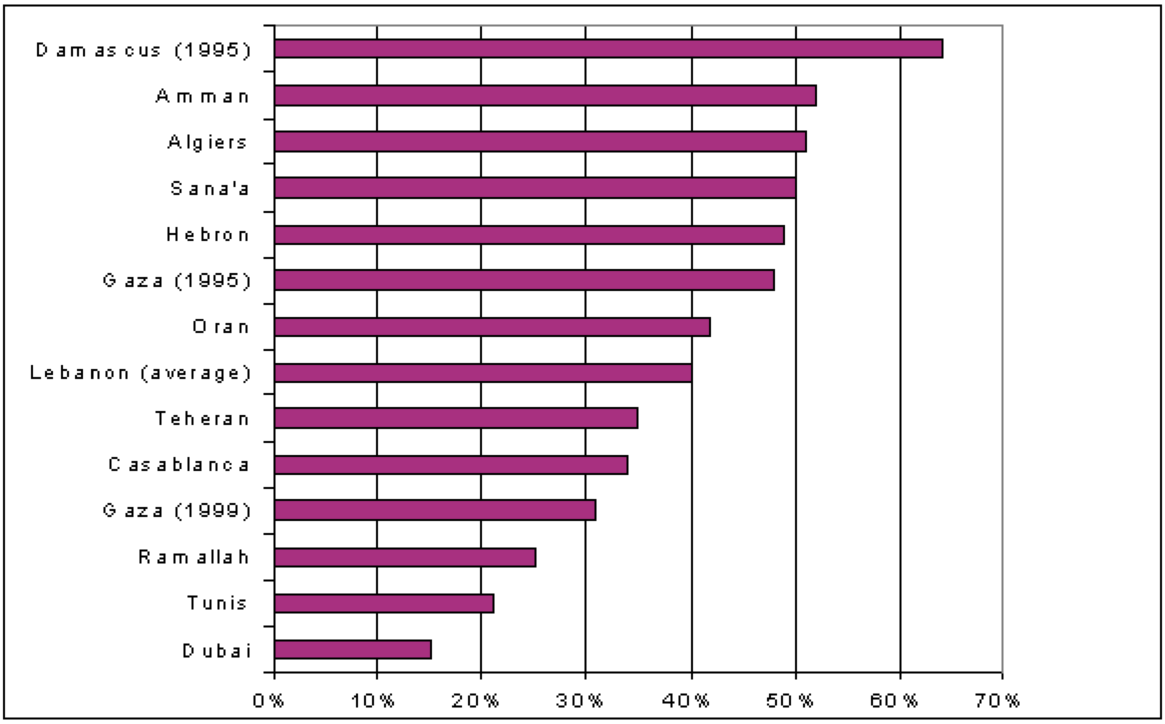
Experience has also shown that whilst it is comparatively easy and cost effective to tackle high levels of leakage, the unit cost gets higher as the level of leakage gets lower. This is best illustrated by considering the example of large pipeline bursts, which are much easier to locate than smaller leaks on individual house connections.

As the level of leakage is gradually reduced, the increasing cost of tackling the leaks eventually reaches the point at which the leakage management unit cost is equivalent to the unit cost of delivering water to the consumer. This balance point is called either the economic or optimum level of leakage and is the level down to which efficiently managed companies should be looking to reduce their leakage.

Another benefit not always considered by some organisations is that by reducing the level of leakage the operator is able to reduce the overall demand and defer the construction of new capital works such as desalination plants. A study of the data published by OFWAT, the UK Water Regulator, has shown that over a three year period between the 1996/97 and 1999/2000 operational periods, the water companies in the UK were able to reduce the quantity of leakage by 1195 Mld (263 MIGD). This was a reduction in the level of leakage by 27% and equivalent to constructing several major water supply and transmission projects.

The lessons that have been learnt in the West can also be applied to the Middle East. A World Bank comparison of leakage rates around the Middle East has shown that many cities suffer from very high levels of leakage, but that a leakage management programme, if actively pursued, can have a significant effect on the level of loss, as shown in the following chart.

Chart No. 1 – Findings of the World Bank Study into Levels Leakage



The low level of leakage in Dubai and the reduction of leakage over a four year period in Gaza are good demonstrations of what can be achieved.

Three Leakage Management Techniques

Following the development of leakage management techniques over the last decade they can now be grouped into the following three categories.

Passive Control

Passive control involves only repairing those leaks which become self evident, either through water showing on the surface, depressions in the pavement or as a result of customer complaints about a lack of supply or low pressure. This technique is by far the least effective of the three. It is only adopted when the operator believes they have very low levels of leakage or where there are insufficient resources to effectively undertake a leakage management programme.

Regular Surveys

This technique covers sounding, correlator and waste meter surveys. Sounding, as the name suggests, involves teams of inspectors seeking out leaks by the systematic sounding of hydrants, valves and other accessible fittings. Correlator surveys are carried out on a similar basis, but involve the use of leak noise correlators to identify leaks. Waste meter surveys involve dividing the network into areas of between 500 and 3,000 properties and then supplying these isolated areas through a mobile meter, which is normally positioned between two fire hydrants.

This technique has the advantage that it involves comparatively small capital cost, but is very intensive in its manpower requirements and hence operational costs. Whilst not as effective as leakage monitoring, it is often the most appropriate in developing countries where a large labour force is available and construction costs are high when compared to staff salaries.

Leakage Monitoring

This technique involves the regular and often constant monitoring of flows within the distribution system, through a system of district or sector meters. The operator analyses the data for indications of leakage, such as unusually heavy demands or sudden rises in the level of demand within an area. Once a sector has been highlighted as probably having a leakage problem the operator then employs such techniques as step tests, sounding and correlator surveys to identify the point or points of leakage.

Leakage monitoring is the most effective technique as the leakage detection teams are only employed in areas that are believed to have high levels or leakage or where a sudden rise in the level of demand indicates that a pipe burst has occurred. Due to the cost of installing the numerous meters it does however involve substantial capital investment, especially if the output from the meters is to be monitored by a telemetry system. This technique is however the benchmark that is now adopted throughout Western Europe and is being increasingly used around the world. The remainder of this paper will therefore give a overview of a typical leakage monitoring programme, together with typical details drawn from some of the projects that Mott MacDonald have been involved with.

Establishment and Operation of a District Metering Programme

The term “district metering” is used to describe the method whereby flows within the distribution system are monitored through a system of district meters, each typically supplying between 500 and 3,000 properties. A diagrammatic representation of a typical metering scheme is shown in Figure

No. 1.

If possible, flows are recorded on a continuous basis by the use of data loggers and/or a telemetry system. Where only loggers are used they are either collected for downloading in the office or downloaded at site at regular intervals, with the downloading period varying between a week and a month. When a telemetry system is employed, the data can be continuously transmitted to a control room by a dedicated line. The hire of such lines from the local telecommunications operator is however expensive and most systems rely on a arrangement whereby the logger modem calls the control room on a regular basis, say every 30 minutes and down loads the data for that period. If for some reason the connection is lost, the logger can store the data in its scrolling memory until the connection is reestablished.

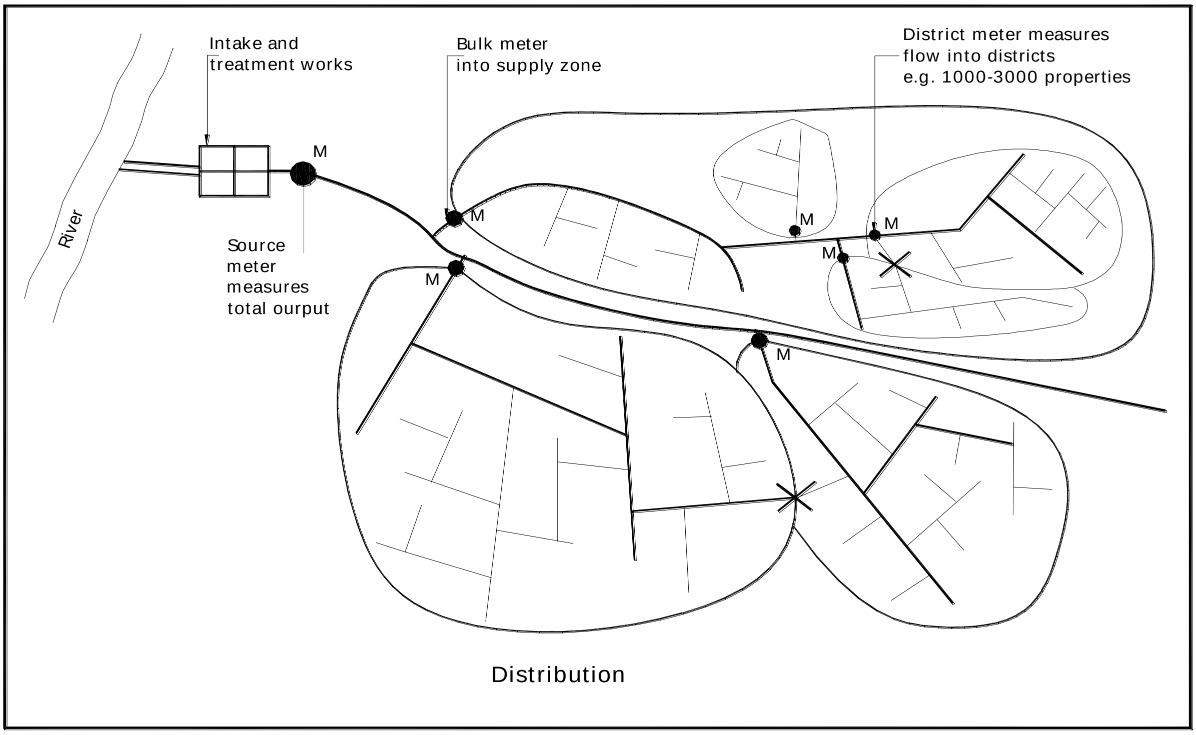
Depending on the sophistication of the control system, the logger can also be programmed to immediately call the control center if there is a sudden large jump in demand.

As previously explained, the downloaded data is used to monitor the total integrated flow into each district and/or the minimum night flow into the sector, with the flow being divided by the number of properties get a unit demand in litres per property per hour. Minimum night flow monitoring has the advantage that the leakage will comprise a much greater proportion of the flow into the district and that variations in the level of leakage can more easily be detected. In urban localities such as Abu Dhabi and Dubai, that contain large numbers of apartment blocks, together with a substantial number of villas, it may be more appropriate to measure demand litres per person per day, rather than litres per property.

A typical pilot project involves the establishment of at least 10 districts, that will cover a minimum of 10% of the all the distribution system area. such a number is required in order to accurately estimate the level of leakage within the system as a whole. Typical meter installations would comprise an inline ABB Aquamaster (or similar) electro-magnetic flow meters, which are housed in concrete chambers, with the meter instrumentation and data logging facilities being housed in a small adjacent GRP cabinet.

It should be pointed out that most meters are designed to be backfilled with sand and buried, but most clients in the middle east take a more conservative approach and house them in chambers, despite the additional cost and construction period.

Figure No. 1   Diagrammatic Representation of a Typical Metering Scheme



Water demands recorded during the projects have varied widely, depending on the type of habitation in the area concerned, age and construction of the distribution system, affluence of the society and the means by which consumers pay for their water, if at all. The range of demands is surprisingly wide, varying from 120 and 1070 l/h/d. By comparison, it is very unusaual for demands in the UK to be lower than 130 l/h/d or higher than 300 l/h/d.

Step Testing

Once analysis of the district metering data indicates that a district (or sector) has a high level of leakage the management organisation allocates a leakage detection team to do a survey of the area. Depending on operational practices of the organisation and other factors such as size and composition of the area, available resources and presumed level of leakage, the team may straight away commence a correlator survey of the area or instead undertake a step test.

A step test essentially involves the gradual isolation of the distribution system down stream of the district meter by the closure intermediate gate valves. The closures are programmed in such a way as to isolate the system in a series of steps, which gradually make their way back to the meter. In an ideal situation, the last valve to be closed and hence the last step to be isolated is located immediately downstream of the meter and the flow through the meter should fall to zero as the last valve is closed.

As the undertaking of a step test involves major disruption the water supply within district or sector the work is normally undertaken during the early hours of the morning. As with minimum night flow monitoring, this approach has the additional advantage that leakage flows normally make up the majority of system demands at these times.

Figure No. 2 shows a typical example of a small step test that was undertaken during one of Mott MacDonald's projects. The number of steps will varying depending on the size and complexity of the distribution system, but typically varies between six and twenty steps, with the average being around twelve steps.

Whilst the isolation of each step is taking place, the flow through the meter is continuously recorded on a data logger. As can be seen in Chart No. 2, which shows the step test flow profile for the area shown in Figure No. 2, there tends to be a decrease in flow each time one of the steps is isolated. This decrease in flow is then divided by the number of properties located within each step to get a unit decrease in flow in litres per property per hour etc. The magnitude of this unit decrease in flow gives the leakage team a very strong indication as to where within the area the leaks are located and hence where they should concentrate their initial investigations.

Leak Detection and Repair

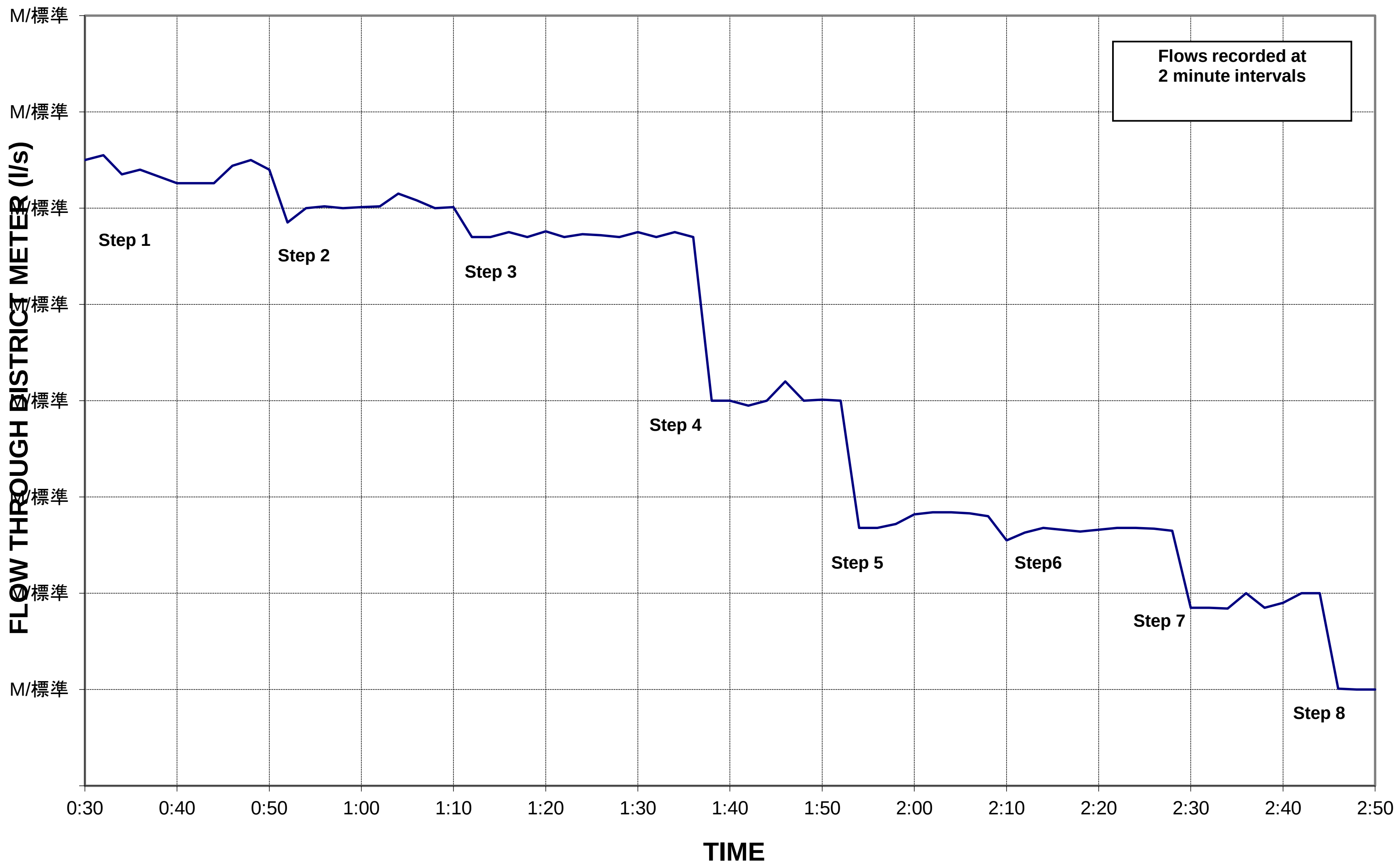
Virtually all the equipment used to detect the location of a individual leak rely on picking up and amplifying the small noise made by the water as it escapes from the pipe or fitting. The surrounding level of ambient noise is therefore of great importance and most leakage detection work in urban areas is therefore undertaken during the early hours of the morning.

Whilst the leak noise correlator is now the principal equipment used in locating individual leaks, it is normally used in conjunction with other equipment and techniques. The following is a list of the most commonly used equipment.

Listening Stick

As the name suggests, this item normally comprises a 1.5 – 2.0 m long steel rod of up to 10 mm diameter with a simple ear piece, through which the user listens to the sounds transmitted through the rod, when it is placed in contact with a accessible fitting or exposed pipe. More advanced designs replace the ear piece with a small amplification box. The listening stick is the minimum basic equipment employed by virtually all leakage teams.

Chart No.2 -Typical Step Test Record



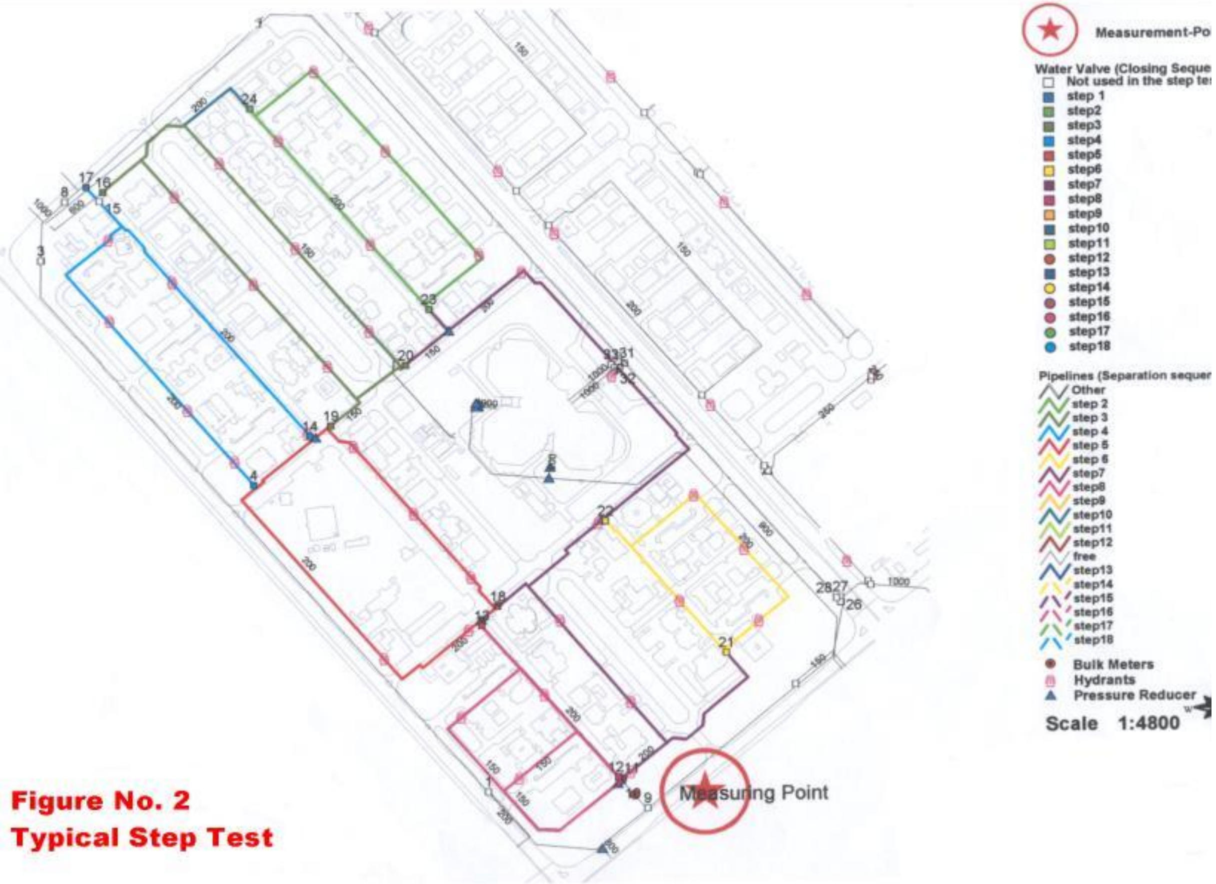
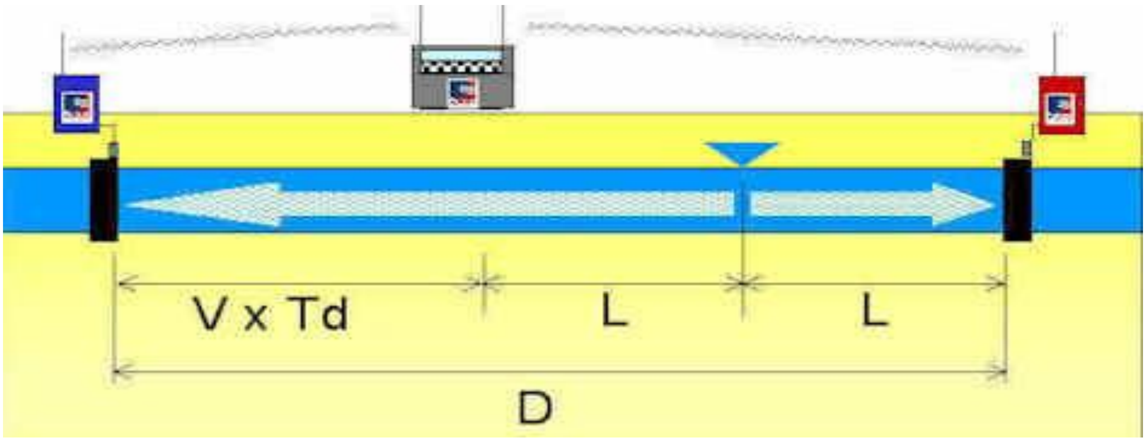


Figure No. 2
Typical Step Test

Leak Noise Correlator (LNC)

LNCs have developed over the last 15 years to the point where they are now the principal means by which the location of most leaks is pin pointed. Originally developed by the WRc and Palmer Environmental in the UK, LNCs are now produced by several companies in Europe, USA and Japan. The equipment shown opposite comprises a Palmer MicroCorr 6 LNC with its basic ancillaries ie. accelerometers, radio transmitters and headphones.

As shown in the following diagram, a correlator works by detecting the sound from the leak when it arrives at two sensor points on the pipe, either side of the suspected leak position. The sound arrives at the closer of the two sensors first; then there is a "time delay" (Td) before the sound arrives at the farther sensor. This time delay, combined with knowledge of the distance (D) between the sensors and the velocity (V) of the sound in the pipe, enables the correlator to calculate the leak position (L).



The correlation formula

$$L = \frac{D - (V \times Td)}{2}$$

The correlator detects the sound waves using either accelerometers that are magnetically held in contact with the pipe and pick up the sound energy carried along the pipe wall or hydrophones that are installed at fire hydrants and pick up the sound energy carried through the water. The correlator is constantly comparing the sound waves picked up by the sensors and trying to establish the time delay, so that it can apply the correlation formula.

Electronic Listening Stick

This device, a photograph of which is shown opposite, is used in essentially the same manner as the traditional instrument. Due to the electronic amplification of sound waves transmitted along the steel rod the user can pick up much fainter sounds that the traditional instrument, together with high pitched sounds that are normally outside of the human range of hearing.

Some experienced leakage operatives prefer not to use these devices, complaining that they are too sensitive and pick up large amounts of background noise, which can hide the sound of the leak itself.

Ground Microphone

The ground microphone is designed to be placed on the pavement a pick up and amplify the noise of the leak that passes through the earth, rather than along the pipe. It has an outer housing which shield the sensitive microphone from surrounding ambient noises. Unfortunately this is only partially effective and the equipment is therefore best used at night.

Leak Repair

Once the location of each leak has been confirmed the position is marked on the ground and the position informed to the repair team.

The repair of the leaks is the last step in the leakage control process and must be undertaken using the correct techniques and materials if the efforts of the detection team are not to be wasted. With regard to pipelines, this normally involves cutting out the damaged pipe and replacing it with a new section that is held in place by a coupling at each end. In the case of small leaks and perforations in the pipe barrel, the repair team can make use of repair clamps, such as the shown opposite.

In the case of old cast iron pipelines, the leakage sometimes takes place at the spigot and socket joints that were corked (made tight) using a lead run joint. This leak typically occurs because the pipe settles, so compressing the lead and opening up the joint. The traditional repair method was to cut out the joint and replacing it with a new piece of ductile iron pipe. However, using a special repair collar such as the one shown opposite speeds up the repair time and considerably reduces the cost. Such special fittings are typical of the new techniques that have been developed in the UK since the privatization of the water industry in 1989, as they are driven by the industry's need to reduce costs and work more efficiently.

Typical Results

Analysis of the projects undertaken by Mott MacDonald has shown that once established, an experienced three man leakage team can undertaken the survey of up to 15 km of distribution mains per week. Typical results for such a survey include the identification and repair of up to 15 leaks per week and the saving of up to 10 l/s (0.2 MIG) of potable water.

Conclusion

We hope that this short paper has given the reader a good introduction into leakage management theory and practice. It should be emphasised that leakage management is a continuous and repetitive process that has much in common with painting the famous Forth Bridge. A situation where the maintenance crew starts at one end of the bridge and works their way to the far end, only to find that by the time they get there, the first section needs painting again. Experience has however shown that despite the unglamorous nature of the work it is an essential part of operating an efficient water supply system.

Whilst the UAE and other countries around the Middle East Gulf are currently undertaking the construction of several major desalination projects in order to supply their ever growing demands, it should be remembered that increasing production is not the only means of tackling the problem. Effective leakage management and reducing the level of leakage down to economic levels should not be viewed as an alternative to undertaking the construction of new plants, but as ensuring that the best use is made of the expensive water.

References

1. Leakage Control Policy and Practice. WSA/WRc Standing technical Committee on Sewers and Water mains, Report No. 26.
2. Managing Leakage Reports A – J. UK Water Industry/WRc Technical Working Group on Waste of Water, Leakage Control Policy and Practice.
3. The reduction and Control of Unaccounted for Water. World Bank Technical Paper No. 72. Philip Jeffcoate and Armukham Saravanpavan.