Water Management and Water Loss

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Chapter 1

Introduction

Water losses from municipal reticulation systems are becoming a serious problem throughout the world and particularly in developing countries where lack of funds often results in poor maintenance of the water infrastructure. In some areas, the water losses are now estimated to be higher than the actual legitimate water use and the situation is gradually deteriorating to such an extent that intermittent supply is now the norm rather than the exception in some parts of the world.

The International Water Association has identified water loss from municipal systems as one of the most important issues facing a world where the ever increasing population is placing additional strain on systems which are already failing to meet the current demands. In response to these problems, the Water Losses Specialist Group was formed and has emerged as one of the most active and significant groups within the IWA. Its key function is to share the knowledge from specialists throughout the world to assist water suppliers to manage and reduce their water losses. Through the efforts of the group, many new and innovative techniques have been developed to measure, monitor and analyse water losses from municipal water supply systems. A standard water balance has been developed which is now widely accepted worldwide and enables water suppliers to quantify the magnitude of their water losses in a standard and pragmatic approach after which they can select the most appropriate interventions for a specific area. No "one-size fits all" solution is appropriate when trying to deal with water losses and it is important to understand that each area has its own set of problems, some of which may be common to other areas and some of which may be unique to a specific region. It is therefore necessary to identify the key problems and to implement the appropriate interventions.

This book provides a basic overview of the key issues frequently experienced by water supply managers in both developing and developed countries. It is designed to assist water supply managers to understand the problems experienced in their own systems and provides advice on how the problems can be addressed through examples and practical case studies. The book is non-academic and is aimed at providing information and advice in a practical and easy to understand manner. The book is basically a collection of case studies and practical experience from numerous water loss specialists who have worked around the world and have experienced both 'best practice' and the opposite extreme. It is hoped that by providing such examples and case studies, water supply managers and those employed to assist them, can benefit from both the successes and failures discussed in the book.

1.1 THE TECHNOLOGY MATRICES*

The choice of a particular leak detection/location technique and technology depends on the operating conditions and construction material of the pipeline in question. To assist in making this determination, four different matrices have been developed.

(1) Mains fittings only – high pressure
- For leakage detection on mains fittings only (no house connections) with pressures greater than 10 m head or 15 psi. Fittings are at a minimum distance of 200 m apart and maximum 500 m

(2) Mains fittings only – low pressure
- For leakage detection on mains fittings only (no house connections) with pressures less than 10 m head or 15 psi. Fittings are at a minimum distance of 200 m apart and maximum 500 m

(3) Domestic and mains fittings – high pressure
- For leakage detection on all property and mains fittings with pressures greater than 10 m head or 15 psi. Fittings are at a minimum distance of 10 m apart and maximum 50 m

(4) Domestic and mains fittings – low pressure
- For leakage detection on all property and mains fittings with pressures less than 10 m head or 15 psi. Fittings are at a minimum distance of 10 m apart and maximum 50 m

The matrices consider the following pipeline materials:

- Metallic
  - Includes steel, ductile iron and other ferrous materials
- Concrete
  - Includes reinforced concrete, pre-stressed concrete pipe (PCP)
- Asbestos cement
- Glass-reinforced plastic (GRP)
- Polyvinyl chloride (PVC)
- Polyethylene
  - MDPE medium density poly ethylene
  - HDPE high density poly ethylene

The technologies available are discussed in more detail later in this document. The equipment has been placed in the selected categories where it is reliably successful. The equipment may sometimes be successful in other categories but not reliably so.

Note that new equipment is continuously being developed: these matrices only take into account equipment that was available during the preparation of the matrices (up to December 2012).

1.1.1 Main pipelines only – high pressure

This matrix is for leakage detection on mains fittings only (no house connections) with pressures greater than 10 m head or 15 psi. Fittings are at a minimum distance of 200 m apart and maximum 500 m.

*This section is from Chapter 2 of *Leak Detection: Technology and Implementation* by Stuart Hamilton and Bambos Charalambous, Published in 2013 by IWA Publishing.

Diameter		75	100	150	200	250	300	350	400	450	500	600	700	800	900	1000+
	inches	3	4	6	8	10	12	14	16	18	20	24	28	32	36	40+
Material																
Metallic all		A,B, C,D, F,G	A,B, C,D, F,G	A,B, C,D, F,G	A,B, C,D, F,G	A,B, C,D, F,G	A,C, D,E, F,G	A,C, D,E, F,G	A,C, D,E	C,D,E	C,D,E	D,E	D,E	E	E	E
Concrete all		A,C,D	A,C,D	A,C,D	A,C,D	A,D	A,D,E	A,D,E	A,D,E	E	E	E	E	E	E	E
Asbestos Cement		A,C,D	A,C,D	A,C,D	A,C,D	A,D	A,D,E	A,D,E	A,D,E	E	E	E	E	E	E	E
GRP		A,D	A,D	A,D	A,D	A,D	A,D,E	A,D,E	A,D,E	E	E	E	E	E	E	E
PVC		A,D	A,D	A,D	A,D	A,D	A,D,E	A,D,E	A,D,E	E	E	E	E	E	E	E
Polyethylene all		A,D	A,D	A,D	A,D	A,D	A,D,E	A,D,E	A,D, E	E	E	E	E	E	E	E

Method A Gas Injection
Method B Traditional Techniques with Manual Listening Stick
Method C Non-Intrusive Acoustic Techniques that is Standard Correlator, Correlating Noise Loggers (Accelerometers)
Method D Intrusive Acoustic Techniques that is Standard Correlator or Correlating Noise Loggers (Hydrophones)
Method E Inline Inspection Techniques (Tethered and Free-swimming)
Method F Noise Loggers (Non-Correlating), Non-Intrusive Magnetic Connection
Method G Electronic Amplified Listening Ground Microphone

1.1.2 Main pipelines only – low pressure

This matrix is for leakage detection on mains fittings only (no house connections) with pressures less than 10 m head or 15 psi. Fittings are at a minimum distance of 200 m apart and maximum 500 m.

Diameter	mm	75	100	150	200	250	300	350	400	450	500	600	700	800	900	1000+
	inches	3	4	6	8	10	12	14	16	18	20	24	28	32	36	40+
Material																
Metallic all		A,D	A,D	A,D	A, D	A,D	A,D,E	A,D,E	A,D,E	E	E	E	E	E	E	E
Concrete all		A,D	A,D	A,D	A, D	A,D	A,D,E	A,D,E	A,D,E	E	E	E	E	E	E	E
Asbestos Cement		A,D	A,D	A,D	A,D	A,D	A,D,E	A,D,E	A,D,E	E	E	E	E	E	E	E
GRP		A,D	A,D	A,D	A,D	A,D	A,D,E	A,D,E	A,D,E	E	E	E	E	E	E	E
PVC		A,D	A,D	A,D	A,D	A,D	A,D,E	A,D,E	A,D,E	E	E	E	E	E	E	E
Polyethylene all		A,D	A,D	A,D	A,D	A,D	A,D,E	A,D,E	A,D,E	E	E	E	E	E	E	E

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1.1.3 Domestic and mains fittings – high pressure

This matrix is for leakage detection on all property and mains fittings with pressures greater than 10 m head or 15 psi. Fittings are at a minimum distance of 10 m apart and maximum 50 m.

Diameter	mm	75	100	150	200	250	300	350	400	450	500	600	700	800	900	1000+
	inches	3	4	6	8	10	12	14	16	18	20	24	28	32	36	40+
Material																
Metallic all		A,B,C, D,F,G	A,B,C, D,F,G	A,B,C, D,F,G	A,B,C, D,F,G	A,B,C, D,F,G	A,C,D, E,F,G	A,C,D, E,F,G	A,C,D, E,F,G	C,D,E, F,G	C,D,E, F,G	C,D, E	C,D, E	D,E	D,E	D,E
Concrete all		A,C, D,F,G	A,C, D,F,G	A,C, D,F,G	A,D	A,D	A,D,E	A,D,E	A,D,E	E	E	E	E	E	E	E
Asbestos Cement		A,C, D,F,G	A,C, D,F,G	A,C, D,F,G	A,C, D	A,C, D	A,D, E	A,D, E	A,D, E	E	E	E	E	E	E	E
GRP		A,C, D,F,G	A,C, D,F,G	A,C, D,F,G	A,C, D	A,C, D	A,D, E	A,D, E	A,D, E	E	E	E	E	E	E	E
PVC		A,C, D,F,G	A,C, D,F,G	A,C, D,F,G	A,D	A,D	A,D, E	A,D, E	A,D, E	E	E	E	E	E	E	E
Polyethylene all		A,C, D,F,G	A,C, D,F,G	A,C, D,F,G	A,D	A,D	A,D, E	A,D, E	A,D, E	E	E	E	E	E	E	E

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1.1.4 Domestic and mains fittings – low pressure

This matrix is for leakage detection on all property and mains fittings with pressures less than 10 m head or 15 psi. Fittings are at a minimum distance of 10 m apart and maximum 50 m.

Diameter	mm	75	100	150	200	250	300	350	400	450	500	600	700	800	900	1000+
	inches	3	4	6	8	10	12	14	16	18	20	24	28	32	36	40+
Material																
Metallic all		A,C, D,F	A,C, D,F	A,C, D,F	A,C, D,F	A,D	A,D,E	A,D,E	A,D,E	E	E	E	E	E	E	E
Concrete all		A,D	A,D	A,D	A,D	A,D	A,D,E	A,D,E	A,D,E	E	E	E	E	E	E	E
Asbestos Cement		A,D	A,D	A,D	A,D	A,D	A,D,E	A,D,E	A,D,E	E	E	E	E	E	E	E
GRP		A,D	A,D	A,D	A,D	A,D	A,D,E	A,D,E	A,D,E	E	E	E	E	E	E	E
PVC		A,D	A,D	A,D	A,D	A,D	A,D,E	A,D,E	A,D,E	E	E	E	E	E	E	E
Polyethylene all		A,D	A,D	A,D	A,D	A,D	A,D,E	A,D,E	A,D,E	E	E	E	E	E	E	E

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Chapter 2

Leak detection technologies*

There are a vast number of techniques to detect where leakage is occurring in the network. Location accuracy depends on many factors, and the subsequent portions of this document provide further detail. Some techniques are able to approximate or localize the position of a leak while others can find exact locations. Often a tool-box approach is used, where multiple technologies are deployed.

2.1 METHOD A: GAS INJECTION METHOD

This method uses a gas detector to find the presence of a tracer gas that has been injected into a pipeline. While helium can be used, the most common tracer gas is hydrogen due to its lower cost and high performance.

Hydrogen is the lightest gas and has the lowest viscosity. This makes it easy to fill, evacuate and dissipate. Typically diluted 5% in nitrogen, the gas can be injected into buried and ducted cables, pipelines and also small diameter in-house heating pipes.

The gas injection method can be used to detect leaks in all pipe materials from 75 mm to 1000 mm in diameter. It can be used on pipes of greater diameter but for obvious reasons a considerable amount of gas would be required. The pipeline can be empty of water or full, however with the pipeline full of water, less gas is required to be used to find the leak.

To accurately locate the leaking gas which comes to the surface after leaving the leak in the pipe, the direction of the water flow must be known and the gas should be kept within the pipeline in which the leak is suspected. This requires the closure of any branches/off-takes which may cause the gas to be diluted or transferred away from the pipeline in question. The mixing of the gas with water does not affect the water quality. This methodology can be used in all types of sealed tubes including cables and pipelines. The material has no effect on the gas injected.

2.2 METHOD B: MANUAL LISTENING STICK

The stethoscope or listening stick has an earpiece and is used to listen to leaks in fittings and to pinpoint the location of a leak. It is a widely used piece of equipment for many water utilities. The

*This chapter is modified from Chapter 4 of *Leak Detection: Technology and Implementation* by Stuart Hamilton and Bambos Charalambous, Published in 2013 by IWA Publishing.

material of the listening stick can be metal, wooden or plastic. This technique is dependent on the ability of the engineer to hear the leak and uses no electronic equipment to enhance the sound.

This technique is best suited for use on metallic pipelines between 75 mm and 250 mm and with pressures above 10 m (15 psi). The material or pipe size does not prevent the listening stick from being able to pinpoint the leak from the surface, but what does affect this is the type of leak, ground backfill material, pressure of the water leaving the pipe, background noise and the ability of the engineer (Figure 2.1).

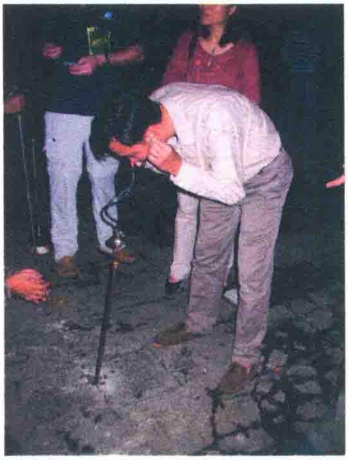

Figure 2.1 Manual listening sticks.

2.3 METHODS C AND D: LEAK NOISE CORRELATION

Leak noise correlation works by comparing the noise detected at two different points in the pipeline. Assuming consistent pipe material and diameter, the noise travels from the leak in both directions at a constant velocity, so that if the leak is equidistant between two sensors then these sensors will detect the noise at the same time. Conversely, if the leak is not equidistant, then the sensors will detect the same noise at different times – this difference in arrival times is measured by the correlation process.

The following diagram illustrates this principle (Figure 2.2):

The sensors are located on valves A and B (convenient access points for underground pipes), and as shown, the leak position is closer to A.

By the time an instance of noise from the leak has reached A, the same noise heading towards B has only travelled as far as point X. The distance from X to B causes a time delay (t) before the noise arrives at B. The correlation processing detects the delay (t) between the arrival of the noise at A and its arrival at B. If the velocity of sound is V and the distance between the loggers is D, then as the distance from X to B $= V * t$.

Then $D = (2 * L) + (V * t)$.

This equation may be rearranged to give L, the distance from the nearer logger to the leak site:

$$L = \frac{D - (V * t)}{2}$$

Correlation measures the time delay (*t*). The distance between the sensors must be determined by accurate measurement.

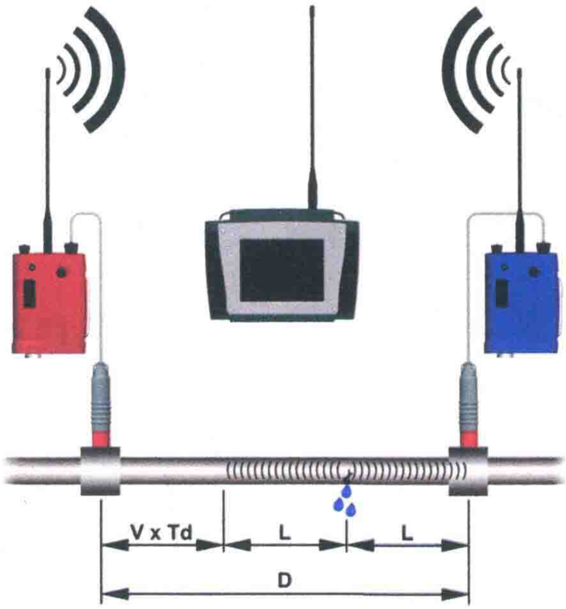

Figure 2.2 Principle of correlation (*Source*: Halma Water Management).

The sound velocity depends upon pipe material, pipe diameter and, to a lesser extent, on surrounding soil. Often, theoretical values of sound velocity are used and this is fine for a first approximation of the leak position. However, the velocity will vary due to many factors, and significantly so if a repair section of a different pipe material exists. Sound velocity must therefore be measured or, alternatively, multiple correlations carried out.

With all correlation techniques, practitioners should be aware that any noise source can result in a correlation peak and all results should thus be treated as 'points of interest' until confirmed. Confirmation is usually done using a ground microphone.

It is important to note that the capability of correlators is dependent on the pressure and level of background noise within the network. Furthermore, correlation can become impossible, because it requires two monitoring points, one on each side of the leak and the attenuation often causes leak signals to disappear at one or both points.

Leak noise correlation requires a noise signal. There are two types of noise transducer in normal use: accelerometers and hydrophones. These have significant differences in their deployment and uses, and have hence been identified as two different methods in the sections below.

2.4 METHOD C: CORRELATION USING ACCELEROMETERS

To perform correlation using accelerometers, two sensors are deployed on pipe fittings, so no access to the water inside the pipe is required. The sensors are then positioned on either side of the suspect leak position. Accelerometers respond to acceleration and so tend to be more responsive to higher frequencies