THE IWA WATER LOSS TASK FORCE
Water 21 - Article No. 3

Managing Leakage by Managing Pressure – A Practical Approach

- This article, by JULIAN THORNTON, is the third in a special series of articles for *Water21* by the IWA Water Loss Task Force, highlighting practical developments over the last decade in managing water losses in public water supply distribution systems.

The scope of this series of articles ‘A Practical Approach to Water Loss Reduction’ was recently outlined in Water 21 by Ken Brothers[1], Chair of the Water Loss Task Force

This article outlines the importance of proactive pressure management as part of a demand management strategy; as a pre-requisite for effective management of Real Losses and as an option for managing components of Consumption and Apparent Losses.

THE FUNDAMENTAL IMPORTANCE OF PRESSURE MANAGEMENT

In some countries – notably Japan and the UK - it has been recognised for over twenty years that effective management of pressures is the essential foundation of effective leakage management. However, recognition of this fact is not universal. A recent IWA International Report[2] showed that proactive pressure management was taking place in only 5 out of 20 Countries, and in 8 out of the 20, it was not widely practiced to manage leakage.

In part this is because, in leakage management practice, it has not been traditional to measure operating pressures, or to take pressure into account when analysing leakage data, comparing performance or setting targets. Many practitioners still believe, incorrectly, that system leakage is relatively insensitive to pressure, and that the effects of pressure management cannot be predicted with any degree of certainty. In some systems where pressure management has been introduced, selection of inappropriate control valves and/or inadequate maintenance has resulted in problems.

Recently there have been notable advances in analysing diverse sets of experimental and field test data, and in understanding pressure:leakage relationships. There have been many success stories, from the savings of 24 Ml/d of unwanted demand and leakage in Khyeletsia township, South Africa[3] , through installations of hundreds of PRVs in Sao Paulo[4], Brazil saving 260 Ml/d, to numerous single installations in individual systems. Some major NRW reduction contracts consider it best practice to include pressure management in all newly installed district metered areas, even those with low pressures[5].

The purpose of this article is to stimulate wider international interest in pressure management, to realize some or all of the following practical benefits:

- Ensure minimum standards of service for pressure are achieved

- Identify and minimise surge
    - Reduces new leak frequencies and extend infrastructure working life
- Reduce excess pressures
    - Reduces flow rates from existing leaks
    - Reduces some components of consumption (if appropriate)
    - Reduces new leak frequencies and natural rate of rise of leakage
    - Extends infrastructure working life

It is also important to acknowledge, and deal with, some of the practical concerns of utilities that are considering introduction of pressure management, for example:

- Potential changes in consumption and Utility revenue
- Minimum fire-fighting and automatic sprinkler systems requirements
- Irrigation system capacity
- Potential dead ends and water quality problems
- Hydraulic capacity and distribution storage fill cycles

INFLUENCE OF PRESSURE ON FLOW RATES OF EXISTING LEAKS

The hydraulic equation for flow rate (L) through a hole of area A subject to pressure P is

$$L = Cd \times A \times (2gP)^{0.5}$$

Cd is a discharge coefficient and g is the acceleration due to gravity. However, for some types of individual leakage path, Cd and A (and the effective area Cd x A) can be pressure-dependent. This is the basis of the FAVAD (Fixed and Variable Area Discharges) concept[6]. For practical predictions of pressure: leakage rate relationships[7, 8] the best practice equations are:

$$L \text{ varies with } P^{N1} \quad \text{and} \quad L_1/L_0 = (P_1/P_0)^{N1}$$

It is important to note that the ratio of pressures (P_1/P_0), not the difference in pressures is influential in this predictive equation. The value of the exponent N1 may vary from 0.5 for ‘Fixed Area’ leaks to 1.5 or more for ‘Variable Area’ leaks where effective area (CdxA) varies with pressure.

In general, large leaks from metal pipes have N1 exponents close to 0.5. However, small ‘background’ leaks at joints and fittings, and large leaks from flexible non-metal pipes, usually have N1 exponents of 1.5 or more. Consequently, whilst the N1 exponent may be anywhere between 0.5 and 2.5 for individual small zones, the average pressure:leakage rate relationship for large systems with mixed pipe materials is usually close to linear (N1 = 1.0), Figure 1.

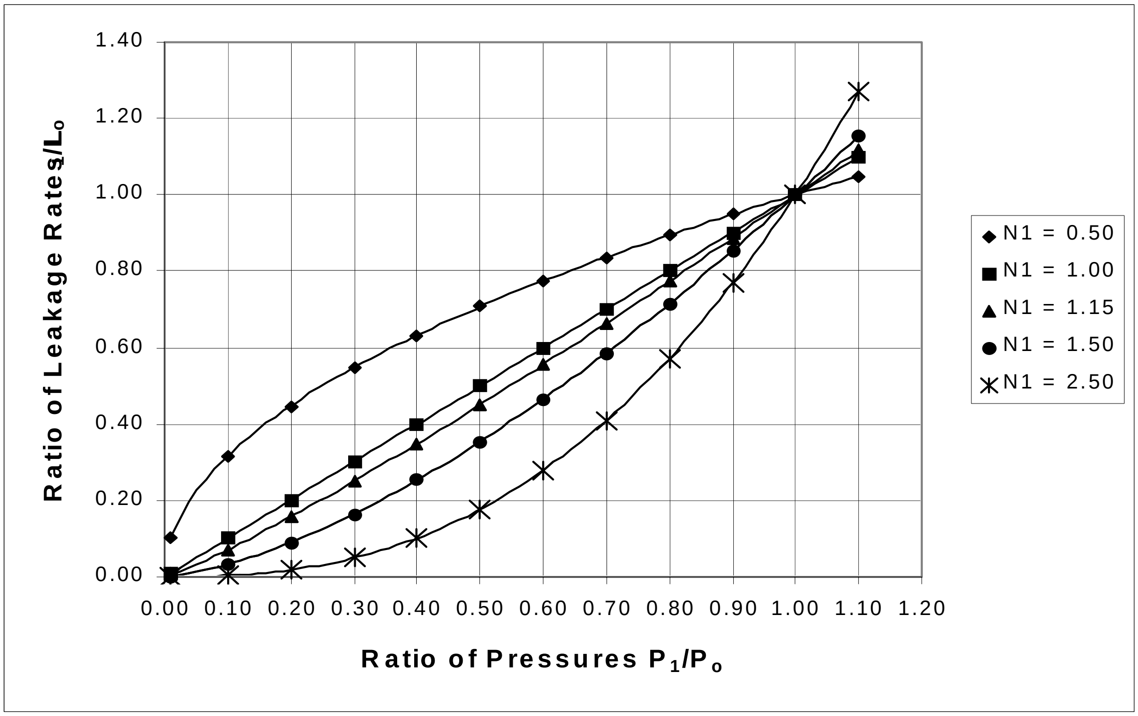

Figure 1P1/Po vs. L1/Lo relationships

The N1 exponent for individual small systems is calculated from a night test where inlet pressure is reduced, and reductions in inflow rate and average zone pressure are measured. Practical guidance to predict N1 for different systems, given the current leakage rates and the pipe materials, is now being tested by the Task Force.

For quick calculations and small changes in average pressure, the predicted reduction in leakage rate will be N1 times the % reduction in average pressure. So a 10% reduction in average pressure for a system with an N1 of 1.5 gives a 15% reduction in current leakage rate.

INFLUENCE OF PRESSURE ON SOME ELEMENTS OF CONSUMPTION

Consumption consists of components with different N1 exponent values, ranging from 0 (pressure independent for example after a storage tank) to 0.5 (open tap) or possibly higher (for sprinkler systems with numerous small orifices each equivalent to a 'background leak'). The FAVAD concept can be used to predict the effect of pressure management (at different times of day) on different elements of consumption.

INFLUENCE OF PRESSURE ON FREQUENCY OF NEW LEAKS

Maximum pressure has a considerable influence on the frequency of new leaks. Surges are particularly damaging[9]; higher new leak frequencies have been observed in parts of a system with direct pumping, compared to parts supplied by gravity from a service reservoir. Systems with intermittent supply may suffer 10 or even 20 times the annual numbers of new leaks that would be expected if the system operated at steady pressure[8].

IDENTIFYING OPPORTUNITIES FOR PRESSURE MANAGEMENT

In order to properly asses if pressure management will be suitable for a particular system a series of tasks should be undertaken prior to implementation and usually include the following[10, 11]

1. Desk top study to identify potential zones, installation points and issues
2. Demand analysis to identify consumer types control limitations and issues
3. Field measurements of flow and pressure (the later usually at inlet, average zone point and critical node points)
4. Modeling of potential benefit using specialized models
5. Identification of correct control valves and control devices
6. Modeling of correct control regimes to provide desired results
7. Cost to benefit analysis

At this stage it is normal to analyze requirements for maintenance and post installation monitoring to ensure sustainability of results.

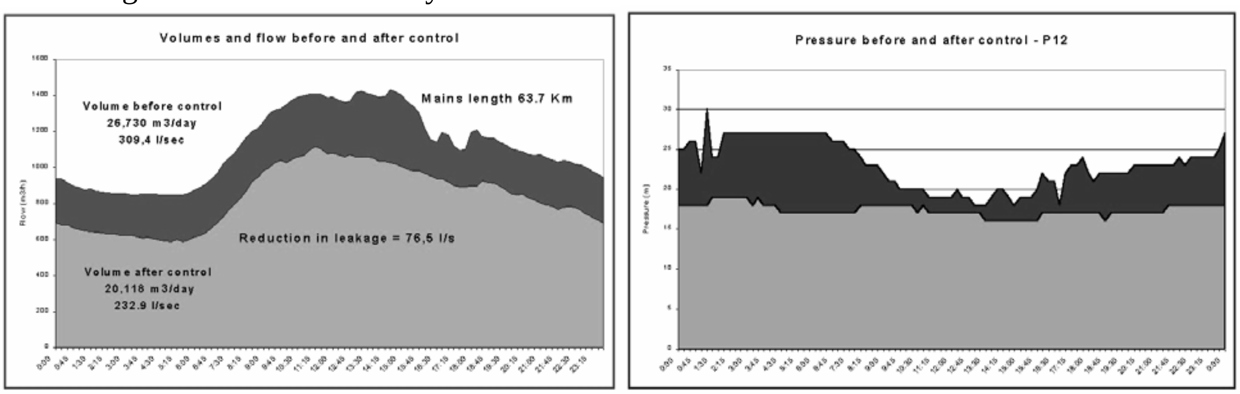

Figure 2 Reduction in leakage and unwanted demand even at low pressures

METHODS OF PRESSURE MANAGEMENT

Pressure management for leakage and demand reduction usually falls into the following categories:

- Pressure reduction/sustaining
- Surge anticipation/relief
- Level/altitude control

While all three methods can form part of a proactive water loss and unwanted demand management program, the most common form of control is pressure reduction.

Pressure reduction can be undertaken using various methods. The level of sophistication usually depends on the economic level of leakage and the ability of the utility to maintain the equipment. The most common methods of pressure reduction are listed below:

- Zonal boundaries
- Pump and level control
- Fixed outlet control valves

- Time modulated control valves
- Flow modulated control valves
- Remote node control

All methods should be considered during the economic analysis.

The pressure management team will be presenting an international review of methodology and technology at the IWA World Water Congress in Marrakech 2004.

NEXT ARTICLE IN SERIES

Richard Pilcher, Leader of the Leak Detection Practices and Technology Team in the IWA Water Loss Task Force, will outline the practical approach to 'Leakage Detection Practices and Technology – A Practical Approach'.

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