How Low Can You Go? A Practical Approach to Pressure Control in Low Pressure Systems

J Thornton*, M Shaw**, M Aguiar***, R Liemberger****

* Rua Arueira 370, Condominium Sausalito, Mairipora SP 076000-00 Brazil; thornton@water-audit.com
** 5, Jalan Astaka, Bukit Jelutong Ind.Park, 40150, Shah Alam, Selangor, Malaysia; martin.shaw@pd.jaring.my
*** Av. Antonio F. Ozanan, 9100, Pq. da Represa, Jundiaí SP 13214-001 Brazil, e-mail milene@vitalux.com.br
**** Bahnhofstrasse 24, A-9020 Klagenfurt, Austria; roland@liemberger.cc

Keywords: leakage management; low pressure systems; pressure management

Pressure management

Pressure management, in its widest sense, can be defined as the practice of managing system pressures to the optimum levels of service ensuring sufficient and efficient supply to legitimate uses and consumers, while reducing unnecessary or excess pressures, eliminating transients and faulty level controls all of which cause the distribution system to leak unnecessarily. In many cases pressure management addresses not only the effect of real losses but also the cause making it one of the most efficient tools for sustainable control of real loss.

As more or less pressure management is undertaken the current annual real loss volume (depicted by the larger square in the figure above) gets closer to or further away from the economic annual level of real loss.

It is worthwhile noting that pressure management can also have a positive effect on apparent loss management actions and revenue recovery programs.
**Pressure management in low pressure systems**

To some it may seem strange to even consider pressure management as a water loss intervention tool in systems which already have low pressure and in some cases intermittent supply, however a true pressure management programme addresses various types of control including:

- Implementation of controlled districts or DMA
- Pressure sustaining
- Altitude and level control
- Transient control
- Pressure reducing

A pressure management programme might actually improve levels of service in some areas of a low pressure system. Industry perception in many cases is that pressure management consists of just one of the actions above, *pressure reducing*, however this is not the case. The following discussion considers how each of the pressure management tools shown above might benefit a low pressure system.

**Implementation of controlled districts or DMA**

Systems which have low pressure and intermittent supply and do not have distribution districts or DMA should consider formation of these during a pressure management programme. Formation of controlled districts even when supply is scarce allows the operator to properly manage what little water there is available and as improvements are made to downstream districts and they become fully supplied excess water can be routed in a controlled manner to other districts. In the case that intermittent supply and water rationing have to be imposed pressures can be reduced in a controlled manner and re supplied in a controlled manner ensuring that the distribution system is protected from damaging transients.

**Pressure sustaining**

In systems with weak hydraulics and high head losses it is common that some areas may experience a deficit of water at the expense of another area. For example a large user such as an industry (or an informal settlement) which sits at a lower elevation may draw large quantities of water creating head loss across the system and starving other areas and users of water.

An integral part of a pressure management program is to evenly distribute water to a majority of the customers not just a lucky few. Pressure sustaining valves can be used to ensure that upstream district pressures are not reduced drastically in an uncontrolled way at the expense of downstream districts.

**Altitude and level control**

Even in systems with little or no pressure it is important to ensure that any storage has the proper altitude or level controls as in the event that pressures are improved in the system due to reduction in leakage and higher volumes of water become available storage tanks can easily overflow in many cases causing large volumes of real loss.
Transient control

Pressure transients are often found to be one of the main causes of high frequencies of new leaks. Systems with intermittent supply have a particular problem with destructive transients. Transient control is a very effective pressure management tool. Transient control can be undertaken by using efficient pump controls, by ensuring that delicate sections of the distribution system are protected by surge control valves and quite often by simply ensuring that valve operation is undertaken in a slow and smooth manner.

Pressure reducing

Significant gains can be made in reducing already low pressures as shown in the following simple example:

   Example - assuming a linear pressure/leakage relationship (as often found in large mixed materials systems), average pressure reduction from 15 to 12 m (20%) would consequently also mean a 20% reduction in leakage volume - without fixing a single leak! Additional benefits in reduced break frequency are also realized in low pressure systems. It is not recommended that pressure reduction be used in place of leak repair but rather in conjunction with a good quality leak repair programme. In many cases the two programmes allow the utility to regain control of the system. As leak frequency drops off maintenance crews can focus on proactive management of the system as opposed to what is often referred to as “fighting fires”, where crews are fully occupied chasing reported leaks.

   Pressure reduction comes in many forms some simple and some complex. Key control types may be classified as show below:

   • Pump control
   • Sectorization
   • Fixed outlet valve control
   • Time modulated valve control
   • Flow or demand based valve control
   • Remote node closed loop valve control

   Whichever type of control is chosen, special considerations need to be made for the low pressure or intermittent supply systems. While pump control and sectorization are key tools for pressure reduction the remainder of this paper is focused on what to do with automatic control valves in order for them to function in difficult situations.

Special considerations for valves operating in low pressure areas

If hydraulically operated control valves (probably the most common selection for water loss management projects as no power is required at the chamber) are to be installed in systems with low pressure or intermittent supply it is important to consider and remedy the following problems:

   • The valve needs a certain minimum pressure differential in order to function
   • If air gets into the valve head it may loose control
   • The pilot spring may not be sensitive enough to modulate very low pressures
The following sections discuss the correct selection of parts and retrofits to industry standard hydraulic control valves in order for them to work in these difficult conditions.

**Helping the valve recover when it is wide open and modulate towards closed**

One way to help a valve recover control even when there is very little pressure differential is to fit a heavier spring in the head of the valve (see Figure 25).

![Figure 25 Selecting the correct spring for difficult conditions](image)

The heavier spring helps the valve to move towards the closed position. A certain amount of pressure differential will however always be needed if using hydraulically actuated valves and this does need to be considered during the project planning stage.

**Purging air from the system automatically**

Another simple retrofit which helps the valve recover control especially from a rotation in supply is the installation of a small air release valve on the head of the valve in place of the stem indicator (as seen in Figure 26). Most water distribution system pressure reducing valves will open completely as water is taken off the system. As water comes back on to the system the air release valve purges air from the head of the valve allowing water pressure on to the diaphragm which allows the valve to modulate towards the closed position and regain control.
Selecting the correct pilot system for low pressure applications

The spring in the pilot system (as seen in Figure 4) modulates the pilot system and pushes water on to the valve head to close the valve or allows water to come off the valve head in order to open the valve. In this way the main valve maintains a constant outlet pressure which is a function of the force exerted by the pilot spring.

Most manufacturers of hydraulically operated control valves offer various ranges of spring pressure. Typical spring ranges offered are:

- 1 to 20 m (2 to 30 PSI)
- 10 to 50 m (15 to 75 PSI)
- 20 to 200 m (30 to 300 PSI)

A hydraulically operated pressure reducing valve working in a system with low pressure should not be fitted with a pilot spring which is designed to work with high pressure (or vice versa). It is necessary to properly understand the system conditions prior to making equipment selection decisions.

Alternative valves for control in low pressure situations

Other alternative valve types such as the plunger type valve seen in Figure 4b can be used in low pressure systems where the valve is required to have as little head loss as possible during peak demand periods. Plunger valve installations are currently being tested for suitability in low pressure situations in both Brazil and India. Future papers will report on the suitability of these valves and present detailed cases studies.
Measurements

In order to make informed decisions on the most appropriate type of control and control limitations it is necessary to monitor (as a minimum) the following points:

- Supply nodes
- Storage nodes
- Critical nodes
- Estimated average nodes

Supply nodes

A supply node could be considered as any point, which supplies a system or district within a system. A supply node could also be an outlet point from one district to another. In some cases it may be necessary to monitor bi-directional flows.

Storage nodes

A storage node would be any reservoir, tank, standpipe or location where water is stored.

Critical nodes

A critical node is a location point where supply may be at its weakest, for example a high level within the system or a point where there is high head loss in the supply pipe. Alternatively it could be a point where a user cannot be left without water, for example a production plant or hospital.

Estimated average node

An estimated average node is a location, which is chosen to be representative of the average condition, (ground level, pressure, head loss etc) within the system or district.

How to choose between fixed outlet or modulated valve control

There are many reasons why flow modulated control may be selected however the key reason is to combat changing head loss in the system to ensure smooth and constant pressure (as shown in the two diagrams in Figure 28 and Figure 29 below) at the critical
points which are often found to be the weaker points where more leaks occur on small pipes.

![Diagram of pressure control system](image)

**Figure 28** fixed outlet control does not combat the effects of head loss in the system

Usually the larger pipes and mains are stronger and can cope with some changing pressure. Flow modulation reverses the condition in the district putting more pressure into the district during times of peak or higher demand and reducing the pressure even further when the demand is lower, the high pressure setting is that of the fixed outlet control and the low pressure setting reflects that less the changing head loss, thus saving additional leakage volumes. The larger pipes in the district are exposed to some pressure fluctuation while the smaller more fragile pipes are protected.

Care should be taken when considering modulated control especially in systems where the main pipes are not in good condition as the change in pressure from the flow modulation could cause the leak frequency of the larger mains to increase.

![Diagram of pressure control system](image)

**Figure 29** flow modulated control ensures a smooth constant pressure at the critical point
Case studies

There is nothing better than a case study to prove that a methodology works. The following two case studies show that pressure management can be undertaken in areas with low pressure and the third shows an estimate of savings in a low pressure district.

**SABESP Sao Paulo Brazil**

The metropolitan region of São Paulo has seventeen million inhabitants settled in an eight thousand square km area. The landscape is mountainous, varying from 730 m to 850 m, above sea level. The São Paulo Water & Sewer CO. SABESP, supplies water and sanitation services through a distribution network of twenty five thousand KM of mains, with three million customer connections and through bulk sales to six neighbouring municipalities. The water system is totally metered and consumers have individual building storage roof tanks. Last years average production was sixty-four meters cubed per second (1,417 MGD) and, the water losses were 20.6 meter cubed per second (456 MGD).

SABESP has been undertaking pressure management proactively as a real loss control tool since 1996 and has made significant savings in the region of 4 cubic meters per second of sustainable reduction through installation of approximately 800 stations.

While SABESP has areas of the system with high pressure there are still benefits to be found in the areas with relatively low pressure. One example is the district “Vila Maria” key statistics can be found in the line diagram shown below in Figure 30.

**Vila Maria District**

Vila Maria is fed by two control valves. The lead valve is flow modulated.

---

![Figure 30 Vila Maria overview and key statistics](image-url)
Figure 31 remote node pressure is stable after flow modulated control

Figure 31 shows an example of pressure being shaved away at off peak times. This very limited pressure reduction reduced losses in the district by approximately 137 L/sec and greatly reduced the number of new breaks in the district.

Selangor Malaysia

The following case study serves to show that hydraulically actuated valves can be used in small districts that are under pressured however there may be a price to pay with unwanted head loss during the day. The business case will dictate if the price is right.

Klang Perdana DMA

Pressures are only controlled at night when there is excess pressure in the district however losses are reduced during the day by the inherent head loss created by the valve. This is not an ideal situation however the valve cannot be completely transparent in the system.

Figure 9 The valve is seen to operate with very small differential pressure
Savings were measured at around 2.7 cubic meters per hour. Even though there was some reduction in day time demand (estimated at around 5%) the business case showed that this installation was a success.

This DMA is one of several hundred DMA which have been installed during a large performance based contract.

**Ho Chi Minh City, Vietnam**

The Ho Chi Minh City (HCMC) Water Supply Company is in the process of developing a comprehensive Non-Revenue Water (NRW) Management Project that will be financed by the World Bank.

In the course of a feasibility study (by Soil and Water Ltd) 7 day pressure measurement data, recorded at 100 locations throughout the distribution system, were carefully analysed. Pressure varied widely between zero and 50 m, with a weighted average of only 12 m.

The pressure reduction potential (mainly by reducing excess pressures during night hours) was assessed and it was found that around 220,000 customers have more than 15 m pressure for 8 to 12 hours per day. If pressure in all these areas was actively managed and night pressures limited to 15m, savings of nearly 50,000 m3/d could be made without repairing a single leak!

The same approach was used to predict the potential increase of leakage in the low pressure areas assuming that in future these areas would also be operated at 15 m pressure. If done without improving the condition of the distribution system and without introducing active leakage control, some 100,000 m3/d would be lost through increased leakage levels in these areas.

After the necessity of pressure management became obvious, data from small (DMA size) study areas were analysed. Figure 32 below indicates that in a small area (550 service connections only) some 100 m3/day could be saved by reducing night pressure to daytime levels.

![Area: 1
Inflow Analysis - Day 1
Potential Savings: 107 m3](image)

**Figure 32** Potential savings in a low pressure situation

One of the key problems in situations like this is the potential head loss through the PRV during daytime - when no (or nearly no) pressure reduction could be tolerated. It will be interesting to see how this problem will be overcome in HCMC - but the results from
Brazil and Malaysia are encouraging and successful pressure management should be feasible if latest technology is used and PRV and accessories are properly specified, installed and maintained.

**Summary**

So, how low can you go? This will be very dependant on the methodology and equipment used and local system conditions but our first two case studies indicate that we can work with system pressures as low as 5 to 10 meters head or 7 to 15 PSI using standard hydraulically actuated valves, however there may be more head loss in the valve at the open position than can be tolerated by the district during peak demand. A business case must be made for each individual installation to ensure that the desired results will be achieved.

Clearly more studies are necessary to properly identify how low we can go with other technology such as the plunger valve however this paper serves as an awareness tool and initial guide to working in difficult low pressure or intermittent supply conditions.

**References**


Lipari J, “Claval training slides” Claval Automatic Control Valves, USA 2005

Murias J “VAG training slides” VAG Armaturen GmbH, Germany 2005

Paracampos F, De Freitas M, Thornton J “A Pragmatic Approach to Water Loss Control in Sao Paulo, Brazil” AWWA DSS conference proceedings Norfolk Virginia September, 1997
