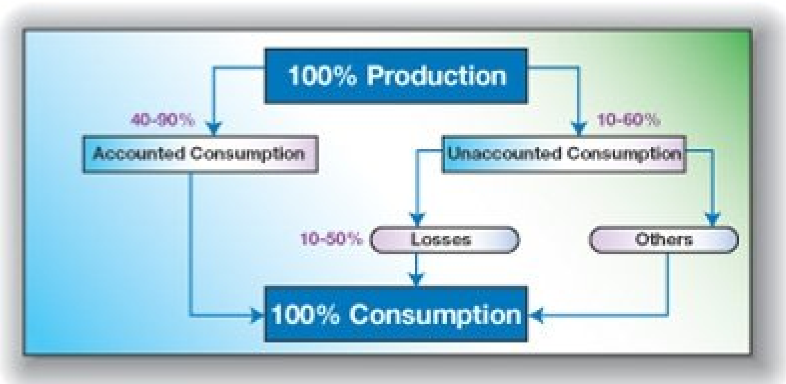
Managing Leakage
Pressure Optimization for Water Conservation

by Joseph H. Lipari

Since the advent of SCADA, water operators have been able to obtain vast amounts of data. Flows and pressures can be monitored over time to develop system profiles. This information allows the operator to optimize pressure and improve service to the customer. Pressure optimization can be achieved over a 24-hour period as the flow rates increase and decrease. The pressure can be increased as the demand rises and decreased as the demand diminishes. This methodology is defined as pressure modulation. Through pressure modulation a reduction in unaccounted for water that is lost directly to leakage can be achieved.

The water industry defines unaccounted for water as: *Water Purchased or Produced - Water Sold or Billed For*



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As shown in Figure 1, it is widely recognized that anywhere from 10 percent to 50 percent of a system's total consumption are real losses. Unaccounted for water is not a specific enough term to adequately define water loss though, so we will use the term non-revenue water herein.

Non-revenue water losses can be as high as 50 percent. At this rate the real losses are the largest customer. The goal is an overall reduction in non-revenue water. There are numerous causes that can be investigated. For example, consider losses due to system leakage. It is important to determine what portion of the total losses is actually related to leakage. Factors such as the system age and pressure will contribute greatly to this figure. Keep in mind that existing water resources play a key role in the effort to reduce the system's overall non-revenue water.

At this time water resources are becoming very limited. This trend is due in part to geologic or climatic conditions, conservation requirements, and environmental pollution. Water losses contribute to excess production and wasted resources. As the water industry becomes increasingly privatized, funds for improvements will also become limited. Thus it is imperative to utilize existing resources as efficiently and as economically as possible. It is also necessary to secure low cost methods to reduce water consumption and maintain low percentages of non-revenue water. *Are low cost* *water savings really possible?* They are, but resources and consumption must be key considerations. *How can a system avoid reaching a critical point were demand and consumption exceed available resources?* There are a number of strategies for reducing consumption. One such strategy is conservation through advanced methods of pressure control.

Pressure Management

Excessively high pressures and wide variations in pressure equate to greater leakage losses (Figure 2).

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Under-managed pressure creates undue mechanical stress on pipes and fittings. Frequent line breaks can occur, increasing leakage and inflating maintenance costs. As such, an operator must understand and control the distribution network. Obtaining critical data is the first step. The flows and pressures must be measured to develop a system profile. Then and only then can the pressures be optimized for maximum efficiency. Active pressure management provides stable and/or modulated pressures. The end results are reduced frequency of line breaks and repairs and lower leakage losses. Ultimately, when managing the distribution network the operator should be trying to achieve three main objectives:

- Reduce leakage and conserve water resources.
- Reduce the requirement for new resources.
- Provide consistent pressure at an adequate level for customers.

These goals can only be attained if the operator has a firm grasp of system performance. Advanced control schemes for existing equipment such as valves and meters must also be implemented.

Consider, for example, the basic hydraulics scenario in Figure 3. The system's maximum flow rate is 325 GPM with a 130 PSI static head. First it is necessary to calculate the friction loss at the critical point. The critical point is the furthest or highest connection in the network. Keep in mind that:

- The greater the distance the lower the pressure.
- Headloss rises exponentially with flow.

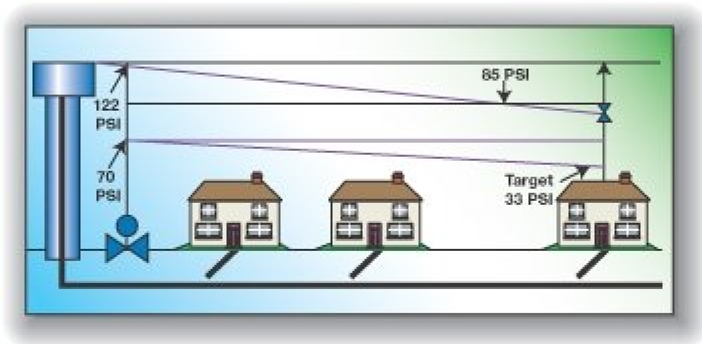

Figure 3. Pressure modulation in a basic hydraulic-based system.

Based on the location of the pressure-reducing valve and the maximum flow rate the inlet pressure in this example is 122 PSI. At the critical point there is a residual pressure of 85 PSI at 325 GPM. To obtain the system friction loss subtract 122-85 = 37 PSI. Thus, 33 PSI is required at the critical point to provide adequate service to the customer. By adding the two values 33 PSI (critical point pressure) + 37 PSI (loss), the first valve outlet setting of 70 PSI at 325 GPM is calculated. Then it is necessary to perform the same calculation for the minimum flow rate. With only a 5 PSI pressure loss at 80 GPM, the second valve outlet setting is calculated by adding the two values 33 PSI (critical point pressure) + 5 PSI (loss) = 38 PSI at 80 GPM. The pressure can be modulated between these values.

Sometimes a single set point pressure-reducing valve is not enough. Contemporary design leaves the system over-pressurized at all times, except during peak flow periods. A reduction in leakage losses can be achieved by lowering the downstream pressure during periods of low demand. Using a single set-point control valve dictates the valve outlet pressure for the maximum flow rate. In this case the valve setting would be 70 PSI to provide 33 PSI at the critical point due to system losses at 325 GPM. During the low demand period the valve outlet pressure would also be 70 PSI. Since there is a requirement of only 33 PSI at the critical point there would be more pressure than required to provide adequate service to the customer. Thus, without pressure modulation and 70 PSI in the system, at low demand periods there would be increased water loss due to leakage.

Complicating Factors

In water systems, pressure is a tricky factor. High pressure is necessary to ensure customers and fire departments have sufficient pressure and flow. Low pressure is required to reduce leakage and the frequency of line breaks. To address these conflicting interests, the operator can modulate the pressure as noted earlier. Using control valves with two set points can help operators achieve proper modulation by enabling a high pressure setting for periods of high demand and a low pressure setting for periods of low demand.

Modifications to the pilot system of a pressure-reducing valve and a valve controller allow the operator to provide dual-outlet set points. The control valve would then change the outlet pressure setting based on the time of day or demand in the system. A flowmeter is required to provide a feedback signal when operating in demand mode. The meter can be any type that produces a pulse or voltage output.

With the dual-outlet pressure setting modifications to the control valve, the operator has three variables that can be customized (Figure 4). The first is the initial outlet pressure setting of the valve. The second is the point at which the valve switches from the low-pressure setting to the high-pressure setting.

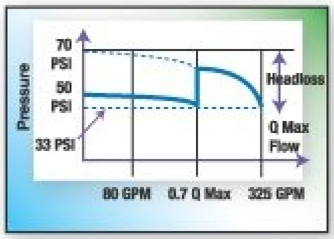

Figure 4. With the dual-outlet pressure setting modifications to the control valve, the operator has three variables that can be customized.

In the example in Figure 4, the pressure change occurs at 70 percent of maximum flow rate. Theoretically the switchover can occur at any flow rate percentage. The last variable is the amount of increase between the low and high pressure. As the valve controller varies the control valve outlet pressure there is an improvement in overall performance. Providing increased pressure only during high demands enhances the service to the customer. Pressure modulation can reduce water losses, decrease the incidence of pipe bursts, and optimize pressure.

To enact a pressure modulation system, a water operator should take the following four steps:

- ***System Audit —*** Study production capabilities and the distribution network.
- ***Metering —*** Log system pressures and flows.
- ***Optimizations —*** Improve actual pressure settings and/or modulate pressure.
- ***Training —*** Use the knowledge gained in the first three steps and apply it to entire system.

Supporting Evidence

There are definite gains to be made through effective pressure management. A recent experiment conducted by the Pennsylvania-American Water Company optimized a segment of its system with 140 PSI of uncontrolled pressure for modulation. Average flows ranged from 153 GPM during the day to 78 GPM at night. A pressure-reducing valve was installed. It was concluded that a valve outlet pressure of 80 PSI would provide adequate pressure for fire flows and customer service. After pressure regulation, the average day flows dropped to 122 GPM; the average night flows dropped to 38 GPM. As a result, there was a saving in delivered water of 53,000 gallons per day. Over a 30-day period, the total savings were figured to be 1.59 million gallons of water. This segment of the system was capable of supporting an additional 300 new connections without increasing resources based on the average family of four using 5,000 gallons of water per month.

As noted earlier, there are a number of different techniques currently being employed by water operators to control leakage. Each technique has advantages and disadvantages. Active leak detection and repair, main and pipe replacement, and pressure control are recognized methods to control leakage losses. Replacing every leaking water main is often not a cost effective approach. Leak detection and repair is a method that provides good results with a moderate cost. Pressure control is a particularly cost-efficient method of reducing water loss due strictly to leakage. This is based on the fact that existing equipment (pressure-reducing valves and meters) is being used to minimize leakage loss.

Advanced pressure control schemes require modifications to the pilot system of existing pressure-reducing valves. In addition, a battery-powered, microprocessor-operated controller is required. The controller can modulate the valve outlet pressure between two fixed set points based on time of day or demand. It does not require an external power source. If pressure change based on demand is selected, a single connection from a meter (pulse or electronic) to the controller is required for a flow feedback signal. When the demand mode is selected, the controller will change the valve outlet pressure as the flow rate varies. The valve outlet pressure will decrease as the flow diminishes. Reduced leakage losses will be realized during periods of low demand because the system is not over pressurized.

The solution is to manage the distribution network. Reducing system leakage can only be accomplished by establishing a pressure management system. To establish such a system, water operators must:

- Divide the network into zones or district metered areas (DMA).
- Measure demand and leakage in the zone.
- Control and optimize pressure in the zone.

The requirements for a DMA are:

- Closed Boundary Area
- Single Feed
- 800-1,000 Connections Maximum
- Significant Pressure Variations
- Area with Old Mains
- Existing PRV Installation with Meter

Starting the process dictates what action needs to be taken. This requires the selection of a DMA. The flows are logged and pressures are recorded for at least seven days at the critical point. Data gathered will provide a system profile. Once the control valve has been modified, the outlet pressures can be set to meet the pressure requirements at the critical point. Since this process is one of trial-and-error, the pressure at the critical point should be decreased in increments of 5 PSI. This procedure allows the system operator to work to an agreed pressure value at the critical point. If the pressure is adjusted too low, readjusting the control valve can change the value. Once the DMA is established, the information obtained can be used to develop other areas.

Studies have shown that significant savings in non-revenue water and total consumption can be realized through pressure management. Since the cost of new production facilities has increased dramatically, it makes economic sense to conserve our existing natural resources. Pressure management allows a system to obtain its greatest efficiency without spending additional funds on increased production.

About the Author

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