xylem
Let's Solve Water

Increasing visibility of pressure distribution in a drinking water network with Cordonel®

SENSUS
a xylem brand

Pressure management is a balance and improves with increased visibility of the pressure distribution across the whole network.

Introduction

Virtually all modern water distribution networks are pressurised to a level set by industry practice or regulation, and measured at the connection pipe to the end-customers property. Sometimes, the pressure requirement is also set to meet the needs of the fire service, who need a minimum pressure of water to deal with fires in standard residential dwellings.

Pressurised water ensures the water entering the property will be able to rise to a height of typically 10 metres or more, without the need for ancillary pumps. The utilities also need to ensure that there is sufficient pressure in the network irrespective of the terrain it traverses. Areas with hills and valleys are harder for water distribution, and typically rely on booster stations that contain large pumps to increase pressure downstream.

Having enough pressure to meet the needs of the end-customer and move sufficient water around the network are major needs of the utility. However, exceeding these requirements can be detrimental to overall network performance, as water loss due to leaks increases and the stresses on pipe junctions, valves and bends also grow, leading to a greater risk of pipe bursts or new leaks. Excessive pumping also wastes energy and can generate harmful pressure transients which shorten the working life of the pipes.

Pressure management is a balance between these sometimes-conflicting objectives, and it improves with increased visibility of the pressure distribution across the whole network.

Key benefits of effective pressure management include:

- Reducing water loss through leaking pipes and joints
- Extending the service life of pipes in the network
- Lowering the overall pipe failure rate
- Minimising energy use by pumps, thus reducing operational costs
- Ensuring pressure delivery is compliant with legal minimums or better
- Ensuring any Service Legal agreements relating to pressure are being met
- Improving overall water distribution management

Pressure measurement capabilities within Cordonel®

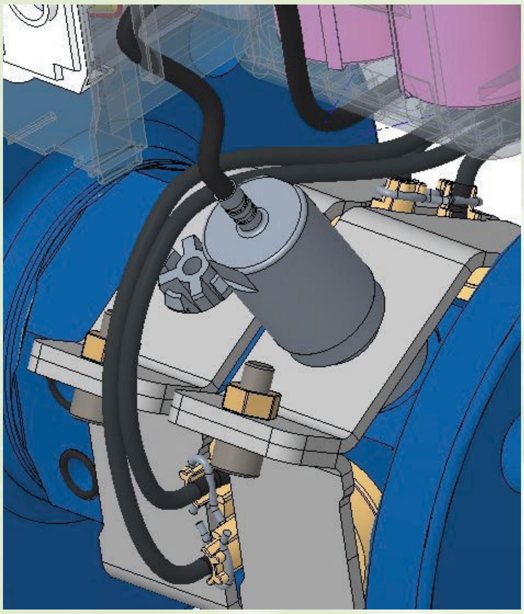
Cordonel® is the only mainstream ultrasonic bulk meter to offer in-built pressure sensing.

The pressure sensor (optional) is enclosed within the body of the meter during manufacture.

Being integrated, the pressure sensor must be robust enough to last for the entire lifetime of the meter, which is up to 20 years of standard use. The integrated sensor also enables the whole meter to be IP68 rated, which means it can be used in situations where it is fully immersed in ground water, for example at the bottom of a flooded inspection pit.

Integration of the pressure sensor also helps prevent some issues which have been observed in field deployments of separate pressure devices that connect via short pipes to the water distribution network via an access point, such as a hydrant. As there is no flow in these sensor pipe connections, they can freeze in very cold weather, leading to erroneous measurements. As water regularly flows through the meter, an integrated pressure sensor is not affected by these conditions and so provides very reliable readings.

Xylem worked closely with its component supplier to ensure that the design would make Cordonel® capable of operating for this long while maintaining the same degree of reliability and accuracy.



Cutaway showing internal pressure sensor

Relationship between hydraulic pressure and leakage

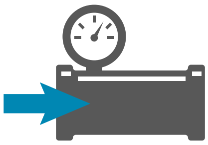
Pressure reduction valve

Water pressure management is the primary method of water leakage management, as the leakage rate increases in proportion to water pressure. Moreover, pressure management is generally more cost-effective than replacing leaking pipelines.

Water pressure management is often performed by installing a Pressure Reducing Valve (PRV) in the pipeline to achieve a certain degree of decompression. However, if the water pressure is lowered too much, it may be insufficient to supply customers who are at higher elevations, at the end of the network, or have insufficiently sized network pipelines. Therefore, the key objective of water pressure management is to ensure the right amount of pressure.

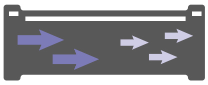
Factors that affect the pressure in a clean water distribution network

There are several factors that can affect pressure distribution across a water network including:



Inlet pressure

Higher inlet pressure is always considered to improve the outlet pressure, reducing the pressure drop along the pipeline.



Flow rate changes

As the flow rate increases, pressure decreases – this is often known as the Bernoulli effect.

Transport distance

The outlet pressure of a pipe gradually decreases as transport distance increases (excluding changes in elevation).

Roughness of the pipe walls

Under certain inlet pressure conditions, the pressure drop in the pipe increases as the roughness of the internal pipe wall increases.

High volume consumers

High volume consumers can decrease the network pressure when they are consuming water, making it important to measure the consumption and usage of water by large Commercial and Industrial (C&I) users.

Pressure Measurement

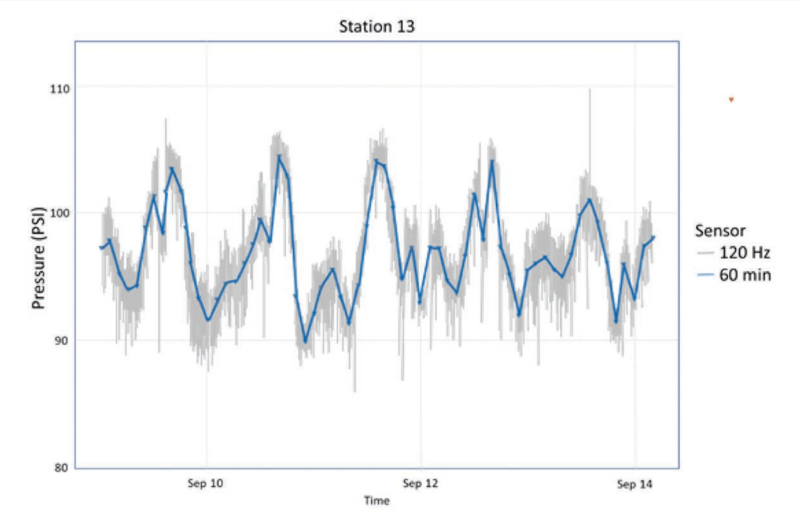
To date, standard network pressure monitoring has been synonymous with low-sample-rate transient capture at a limited number of sample locations across the network, or in many cases at a single sample location at the highest point of elevation in a District Metered Area/Zone. Its primary purpose is to measure the lowest pressure in the network (i.e. typically the pressure at the highest elevation).

Measuring the PRV outlet pressure using pressure transient sensors enables the monitoring of its operation status, as well as the identification of its maintenance requirements if the outlet pressure starts to vary. These variations in pressure result in the downstream pipeline being unduly stressed. Ultimately, the PRV can "lose control" and move to a fully open/non pressure reduction state, thus restressing the downstream network.

However, there is now increased awareness of the benefits of utilising many tens/hundreds of sensors distributed across a DMA and embedded within C&I meters, such as Xylem Cordonel®. Rather than expensive high-sample rate devices in a few locations, there is the chance to use cheaper, lower sample-rate pressure sensors, widely distributed across a DMA. By monitoring the actual pressure at the point of distribution to the customer, the network operator gets a much more detailed view across all their network, and not simply at the few locations chosen for the high-sample rate pressure measurement.

Low sample-rate pressure sensors typically take readings in a range between 5 minutes and 1 hour, depending on the needs of the utility, but can still provide real insight into the pressure distribution across the network.

The graph below shows the difference in sampling rates between a device designed for transient detection and analysis, and one which is providing sufficient detail to ascertain trends and envelopes in the pressure across a given area.



High Speed Transient Pressure Sensing

Other specialised pressure monitoring exists, which is designed to capture rapid pressure transients, typically at a rate of 64 Hz or higher. By doing so it is possible to determine the "fingerprint" of the cause of the pressure failure and if two other similar pressure sensors are available then it is also possible to triangulate the location of the fault to a certain level of accuracy, typically 10m's, determined by the construction of the pipe materials and complexity of the pipe routes. Unfortunately, due to their cost and the additional opex of deploying and maintaining these sensors, the number of pressure sensors used of this type is limited.

The distribution and location of pressure sensors across a network

There are three primary types of pressure sensors distributed at various points across the water distribution network:

Dedicated low sample rate pressure sensors

- These are the industry norm and can be installed at various locations with the widest distribution across the water network.
- They are typically installed at the highest elevation, lowest elevation and the average elevation within a DMA or Zone, and on occasion at representative areas distributed across the water network.

Dedicated high sample rate pressure sensors

- These are more specialist in nature and are typically installed in the following locations:
  - » Sites where pressure transients and/or water hammer may occur, such as at the outlet of pumping stations, pressure reducing valve outlets etc.
  - » Downstream of large diameter valves that are operated regularly
  - » On extremely large customer connections

Low-sample rate pressure sensors integrated within DMA bulk meters and customer meters (e.g Cordonel®)

- Indicated when data is used to understand customer consumption vs network pressure.
- Ideal to help validate contractual Service Level Agreements (SLAs) and regulatory Key Performance Indicators (KPIs).
- Useful to provide pressure data for network model calibration and to assess digital twin emulation coefficients.

Benefits of low-sample rate pressure management and control

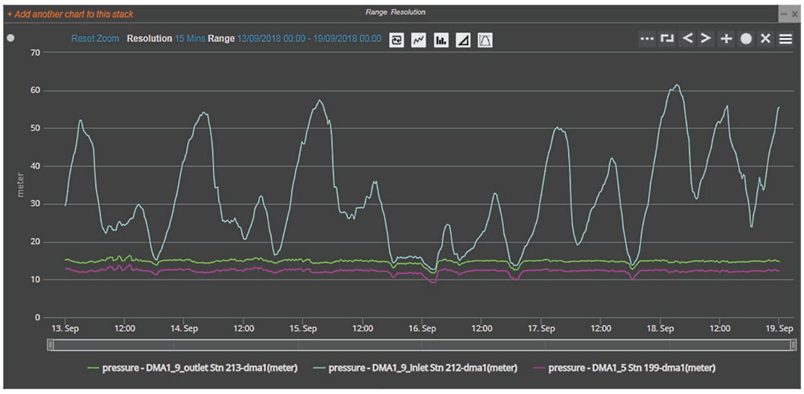
Low sample rate pressure measurements can be used by public utilities to support many different network operations and processes. These include:

1 Trend measurements for diurnal (daily) and seasonal pressure levels

- Trends highlight changes to the network over time and as the network evolves to accommodate changing customer use, new housing, business parks etc.
- They can show where additional boosting stations may be required and where trunk/distribution mains may need to be enlarged.

2 Determining how safe the pressure service levels are currently set

- Pressure can vary if there is increased consumption without a corresponding improvement in the network infra-structure to deliver it.
- In a worst-case scenario, this may lead to a drop in pressure below regulatory/ service level limits.
- Conversely, blockages, faulty pressure release valves, water hammer due to rapid valve closures etc. can all lead to over-pressure in the network – and subsequent leaks and bursts.



Pressure logging measurement across a DMA

- Measuring at many points across the water network enables operators to more closely determine the margin they have , and to assess any changes that need to be made to rebalance the network.

3 Measuring the effects of system maintenance or change in the pressure balance across the network

- Water networks are complex structures with many interde-pendencies. A change made in one part of the network can have an unforeseen effect on other areas. By measuring the pressure at many points across the network, it is easy to see the effects of a change by comparing with previous data records. Any negative effects can then be rapidly mitigated before any damage occurs.

4 Monitoring the standard operational performance of pressure-regulating assets – from booster stations, pressure release valves, water storage etc.

- High sample-rate pressure sensors are often an overkill in terms of performance and cost when used to provide standard operational performance data. It makes more sense to have more widely distributed lower-cost, low-sample rate sensors to provide a more complete picture across the network. This is not to say that high sample rate sensors do not have their uses, especially for determining the cause of a pipe burst or pressure surge. Low sample-rate pressure sensing is therefore complementary to existing high sample-rate pressure sensors.

An example of a large water distribution Pressure Reduction Valve (PRV) installation

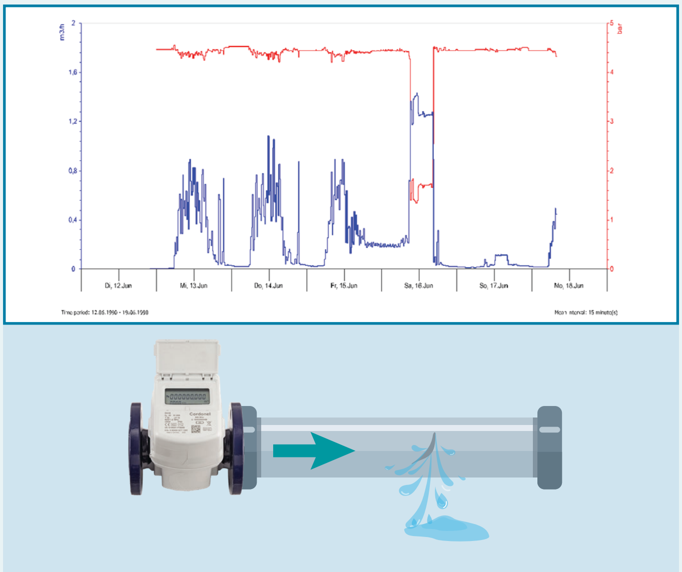
5 Determine the impact of topology and geography on major burst incidents

- By having many more sample points for pressure measurement across the network, it is possible to see if there are patterns across the network which indicate incorrect pressure settings – e.g. abnormal measurements that may indicate a new/developing leak or a precursor to a pipe burst.
- Meters with in-built pressure sensing, such as Cordonel®, can also provide the flow and volume data associated with a major incident, highlighting any unusual consumption demands placed on the network which may have acted as a precursor to the incident occurring.

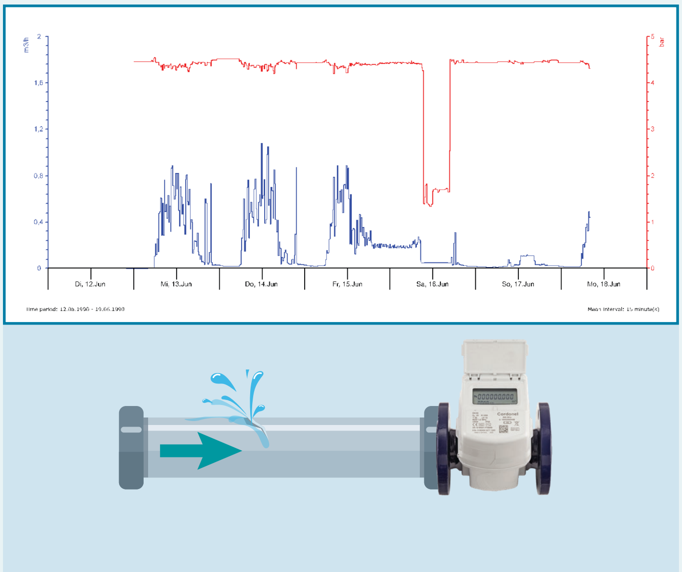
6 Extended leakage/ burst detection

- By combining pressure and flow-rate information from a pressure sensor in a meter, it is relatively simple to determine if the leak/burst is upstream or downstream of the meter. If pressure drops with the meter registering a lower flow, the leak is upstream of the meter. If the flow rate increases and pressure drops, the leak/burst is downstream of the meter.

Meter in front of the leak:
Flow increases (blue), pressure drops (red)



Meter behind the leak:
Flow drops (blue), pressure drops (red)



- C&I meters are usually near the boundary of the pipework that is the responsibility of the utility, and that which is owned by the customer. So, an early indication and warning to the end-customer could save a huge amount of water damage from flooded basements, damaged stock, undermined foundations etc.

7 Water pipe network and system design

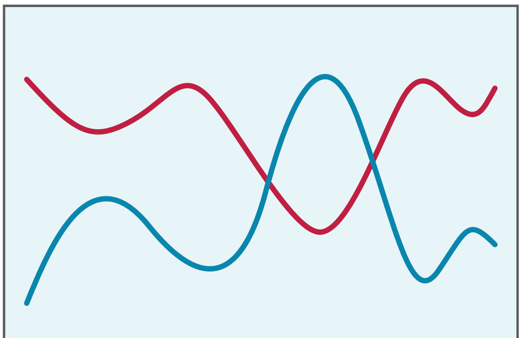
- The flow rate and pressure values recorded serve as basic data for system planning and design, which is needed to meet changing demographics and business dynamics – helping to answer questions such as:

  i. Will the existing pipe system be able to maintain the required mains pressure with increased water consumption?

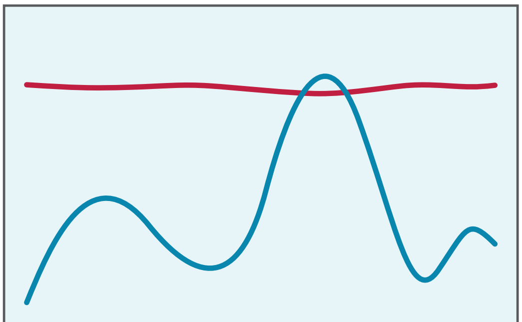
  ii. Will the pressure drop be unacceptable?

  iii. Will investing in a new trunk main alongside an existing one bring sufficient capacity and reduce the stress on the existing infrastructure?

- DMA boundaries are not necessarily static. Operators may feel that a different DMA configuration and boundary would be more operationally efficient, based on the pressure and flow data they receive over a given timeframe.



EXAMPLE 1 - If pressure drops with increasing consumption, capacity is limited.



EXAMPLE 2 - If pressure is constant with different consumption, capacity is sufficient.

Pressure   Flowrate

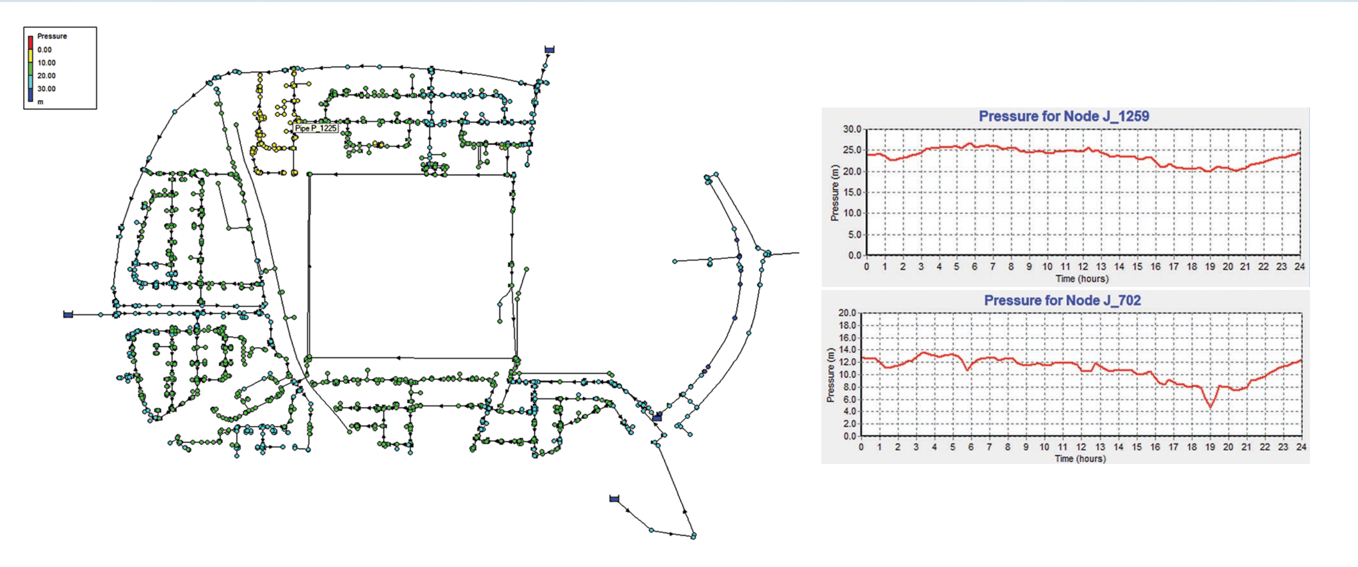
8 Pump control and energy minimisation

- Measuring the pressure across many points across the network enables the operator to balance it, providing enough pressure to meet ongoing demand. At the same time, this ensures a sufficient buffer to avoid going below permitted pressure levels.

- Measuring the pressure at several locations also allows the network operator to minimise pressure across the network when use is lower, for example late at night or early in the morning. It also allows operators to ramp up the boosters to meet increasing demand as the working day begins. By having many data points, the network engineer can be confident that they are running the network as efficiently as possible. Of course, any reduction in the time a pump has to operate leads to a direct saving in energy costs. With energy prices rising, and climate change and sustainability targets becoming a key consideration for public utilities, this is a key strategy to meet energy saving and CO_2 reduction goals.

9 Digital twin model adjustment

Changes to digital twin models can be made by comparing predicted model performance with real-world measurements via distributed pressure sensing Cordonel® meters, with multiple data sets measured over different metrological and demographic demand changes. The quantity of measurements made and the ability to collate them and correlate them against model data allows for complex, self-adapting machine learning algorithms to be implemented in the digital twin models, significantly improving the models over time.



Pressure modelling of a network (using EPANET)

Measuring at lower sample rates is sufficiently power-efficient to allow integration into battery-only powered meters such as Cordonel®. Crucially, this does not degrade the meter's performance, or its 20 years of operational life. Actually, wide-spread pressure and temperature sensing becomes one further capability that is available for little or no up-front additional capex, and no additional opex.

What causes low water pressure?

There are many potential causes of low water pressure that are the responsibility of the water utility to manage and rectify. These include:

- Insufficient pumping facilities and/or control
- Short-term reductions in pressure caused by routine pipe maintenance
- Distribution valves left closed after maintenance works
- Distribution valves that "drop" i.e. partially closed
- A water main that is too small in diameter to supply the necessary service load
- Network issues such as leakages, equipment failures (especially in pressure reduction valves) or blockages of the service pipes

There are other factors that commonly affect water pressure to the end-customer, such as topological issues, where the pressure is affected by the relative height of a customer's property. For example, properties at the top of a hill receive lower pressure than properties at the bottom of the hill, especially if there is high demand between the pumping station and properties at the highest point of elevation. Boosting the pressure to meet the demand of the properties at the highest elevation can cause problems at night or when demand is lower, causing overpressure that could, in extreme circumstances, lead to a major burst.

Houses at the top of a hill will receive lower water pressure than those at the bottom.

Pressure varies during the day depending on the demand for water placed on the supply system. When demand is high, such as in the morning and early evenings, pressure can be lower than during the rest of the day. There can also be problems during dry spells when people use garden sprinklers and hose pipes.

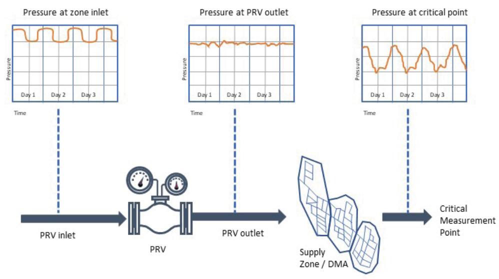
In some cases, pressure problems are caused by the end-customer's own pipework, for example due to a damaged or leaking pipe or a partially closed valve/tap. Alternatively, the customer's pipes may be very old and corroded, to the extent that water flow is restricted.

Methods of controlling pressure in a water network

There are many different methods that can be used to control the pressure across a water network. Each varies in complexity, skills and investment required to deliver varying degrees of pressure management and associated leakage reduction benefits.

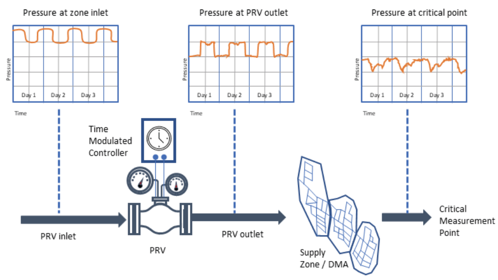
Fixed Outlet Pressure Control

Fixed outlet pressure control utilises a Pressure Reduction Valve (PRV) with no additional equipment, and is the simplest method of pressure management. PRVs are easy to operate and maintain, but usually lack the flexibility to regulate water pressures at different times of day. Excessive pressure in pipes downstream of the PRV increases the chance of leakage or breakage if pressures are not decreased when necessary, resulting in water loss, potential contamination, and increased repair costs.



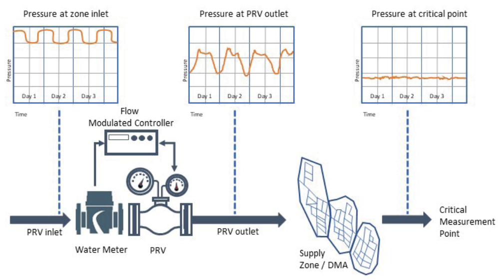
Time Modulated Pressure Control (TMPC)

The TMPC approach offers greater flexibility by using a controller to adjust the pressure at specific times of the day. The controller is usually low-cost and simple to operate. A notable limitation of TMPC is that it cannot respond to unforeseen water demands, such as firefighting or large events. During firefighting, full pressure is usually required to tackle fire as effectively as possible. Higher levels of expertise are required to operate and maintain devices using these systems, compared to the fixed outlet pressure control approach.



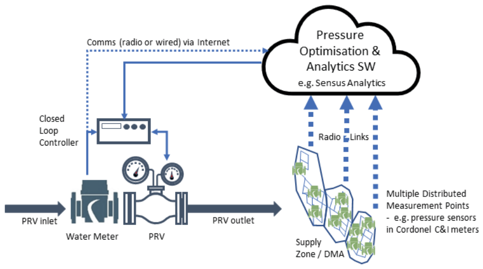
Flow Modulated Pressure Control (FMPC)

FMPC provides greater control and adaptability than TMPC. This method uses an electronic controller which interacts with a correctly sized meter and PRV to make sure adequate water pressure is always maintained, even if there is unforeseen demand. The increased flexibility generally offers greater savings over the system's operational life, compared to fixed outlet and TMPC systems.



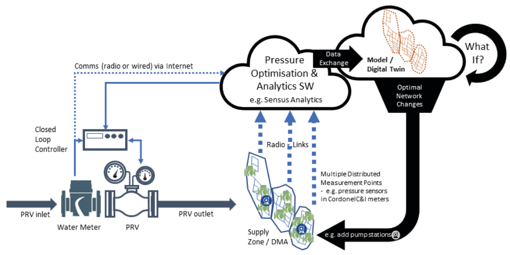
Closed Loop Pressure Control (CLPC)

Pressure control is achieved by adjusting the parameters of the PRVs and booster pump sets, based on the pressure measured at critical point(s) in the network. In this technique, a pressure sensor placed at the critical point(s) of the network is used to provide live data to the pressure controller at the inlet of a DMA. so that the pressure valves or pump booster settings can be adjusted accordingly. The more pressure sensors there are, for example within meters distributed across the network (e.g. Cordone®I), the greater is the visibility of the pressure distribution across the network. In this way, settings can be finessed to achieve an optimal result. This pressure control technique is more complex to manage but maximises the benefits achievable through proactive and continuous pressure management. It provides the ultimate level of control over an existing and established WDN.



Modelling and Network Optimisation

Modelling and network optimisation is a powerful tool that is increasingly being used to achieve the best possible operational settings of the Pressure Reduction Valves, Pressure Control Valves (PCVs) and Booster Pump Set controls throughout a WDN. It enables the determination of the optimal valve and booster station locations and configurations to provide the most effective pressure management. AI, Machine Learning and Genetic Algorithm optimisation techniques can all be used to develop models of the network that enable engineers to test "what-if" scenarios. It has been claimed that network leakage can potentially be reduced by more than 30% using these techniques, although this is obviously dependent on a variety of factors, including the complexity of the network and the topology of the area.



What actions can be taken to optimise pressure levels across a water distribution network?

The objective for any water utility should be to minimise the pressure in the system while still maintaining the regulatory requirements and needs of the fire services, without allowing too much margin. This is necessary to minimise the volume of water lost due to leakage in the network, and minimise the electrical power needed by the pumping stations. In this way, it is possible to reduce energy waste and CO_2 emissions, as most electricity is still derived from fossil fuels such as natural gas, oil or coal.

Reducing the operational pressure margin requires a much tighter monitoring and closed-loop control process than exists in most networks today. By combining a minimal number of high sample rate transient detectors with many more slower sample rate pressure sensors, either discretely or within DMA boundary meters augmented with additional meters in larger C&I customers, the operator will have sufficient data to profile and control the pressure across the network. While walk-by/drive-by AMR systems would allow problem detection and correction daily, AMI systems would allow pressure correction and balancing to occur within hours or even minutes. Using Xylem smartpoint technology, it is also entirely possible to transform an AMR system and migrated it to an AMI system in the future. In this way, the utility can scale its operations to meet its needs as this technology is rolled-out at scale.

Example pump booster set (Lowara - a Xylem brand)

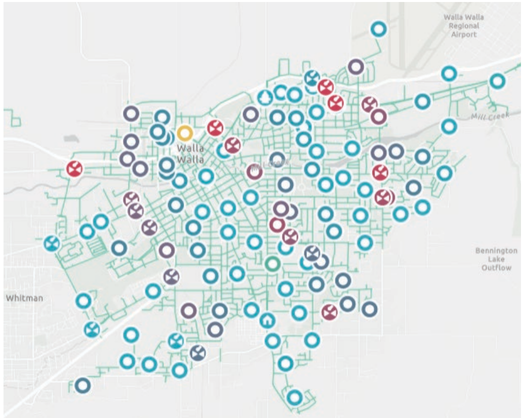
Of course, there may be a requirement for a utility to increase pressure in an area of its network to meet increasing demand, or to remedy an issue caused by ageing infrastructure. Some options include:

- Renovating the water main by scraping away any corrosion and putting in a new lining.
- Replacing the main with a larger one, if the main is found to be undersized for the number of customers it must serve.
- Installing pump sets to boost the pressure at strategic points across the network.
- Temporarily boosting network pressures during firefighting emergencies.

As a provider of in-built pressure measurement, trunk main condition assessment and high-efficiency booster pumps and services, Xylem is a well-resourced and capable partner that can offer guidance and advise on the best and most cost-effective pressure measurement strategies.

Case study: Distributed pressure management resolves low-pressure events with a simple, low-cost fix

The city of Walla Walla, WA, USA began a programme to get more out of its investment in AMI RF networks. The city created a pressure sensor placement plan to provide a network of sensors broad enough to cover its whole distribution system. This was accomplished with a mix of 22 water meters with integral pressure sensors, 10 pressure sensors placed in the test port of C&I meters communicating through a gateway, and 29 Pressure Reduction Valves (PRVs) monitored with pressure sensors on the inlet and outlet sample ports communicating through the gateway.



Overview of Walla Walla network showing a wide distribution of pressure measuring water meters and pressure distribution measurements.

The effectiveness of this setup was firstly appreciated when a chronic low-pressure complaint was received. The hourly data exposed a 35 psi (2.41 bar) drop daily between 5:00 am and 8:00 am, with some areas falling below 40 psi (2.76 bar). Based on the geospatial analysis performed through the mapping function in the monitoring software, the correlation between sensor reading and pressure drops was easy to identify and isolate. Irrigation timing turned out to be the root-cause, so the utility worked with the local residents to delay their start and run times and adjusted the upstream PRV to ensure no service dipped below 45 psi (3.10 bar) during high-flow times.

Walla Walla, WA, USA

In addition, the Walla Walla operations team began monitoring the pressure profile in each area before and after maintenance events. Looking at the pressure profile after one particular maintenance task on a PRV, the operations team realised a Boundary Valve had been left open, causing an increase in pressure in that area of 30 psi (2.07 bar) above normal levels. Without a proper monitoring system in place, this issue would have likely gone unnoticed for weeks or months, leading to increasing wear and tear on the pipes, and potentially to bursts caused by the additional loading on the distribution network infrastructure.

Using Cordonel® to implement distributed pressure sensing in clean water networks

An embedded pressure sensor Cordonel® enables a much wider distribution of pressure sensing capability across a clean water network.

Coupling this information with a near real-time capability provided through Advance Metering Infrastructure (AMI) communication networks enables the detection of anomalies with greater clarity. In this way, network operators and engineers can obtain a more detailed view of the whole network, reacting sooner to counteract disruptive events such as pipe bursts and major leaks.

As well as pressure sensing, Cordonel® provides volume, flow rate and temperature sensing. It also incorporates many forms of alarm condition detection, including backflow, pipe burst, tamper detection etc.

Other features, such as its innovative True U0D0 capability, ensure that it is easy to install, maintain and operate over its long 20-year lifetime.

Using Cordonel® pressure sensing in other vertical markets and applications

The innovative pressure sensing capability of Cordonel® can be used in many other markets and applications to deliver tangible benefits.

Non-critical industrial processes

Most industrial processes that require pressure to be maintained at a given level or within certain limits will use dedicated high-resolution pressure sensors. However, there are often less critical feeder systems that were traditionally not monitored, but now can be monitored in a cost-effective way. Doing this enables more comprehensive leak detection, earlier discovery of equipment issues, detailed tracking of pipe degradation, and more.

Irrigation and agriculture applications

Cordonel®'s low sample-rate pressure sensing, along with its highly accurate measurement of volume and flow rate of raw water from rivers and aquifers, enables much greater control and detection of faults in the irrigation network. Unprocessed water contains many more particles and contaminants than the processed water in a utility's potable water network, making irrigation systems more susceptible to wear-and-tear. Cordonel® has no moving parts or intrusions into the measurement channel, making it very resistant to damage caused by particulates in extracted raw water.

Building Systems

Distributing water in a large building, especially high-rises and skyscrapers, requires tight control to maintain sufficient pressure without creating an undue risk of pipe bursts, or to avoid excessive energy use by the booster pump sets that raise the water to the higher floors.

Water leaks and pipe bursts can be especially damaging in buildings. Early detection of pressure issues enables building managers to respond much more quickly, potentially saving thousands in costly insurance claims.

Xylem |'zīləm|

1) The tissue in plants that brings water upward from the roots;
2) a leading global water technology company.

We're a global team unified in a common purpose: creating advanced technology solutions to the world's water challenges. Developing new technologies that will improve the way water is used, conserved, and re-used in the future is central to our work. Our products and services move, treat, analyze, monitor and return water to the environment, in public utility, industrial, residential and commercial building services settings. Xylem also provides a leading portfolio of smart metering, network technologies and advanced analytics solutions for water, electric and gas utilities. In more than 150 countries, we have strong, long-standing relationships with customers who know us for our powerful combination of leading product brands and applications expertise with a strong focus on developing comprehensive, sustainable solutions.

For more information on how Xylem can help you, go to www.xylem.com

xylem vue

Digital transformation starts with Xylem Vue

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