THE VALVE CHRONICLES

Volume One

CLA-VAL

Cla-Val Automatic Control Valves

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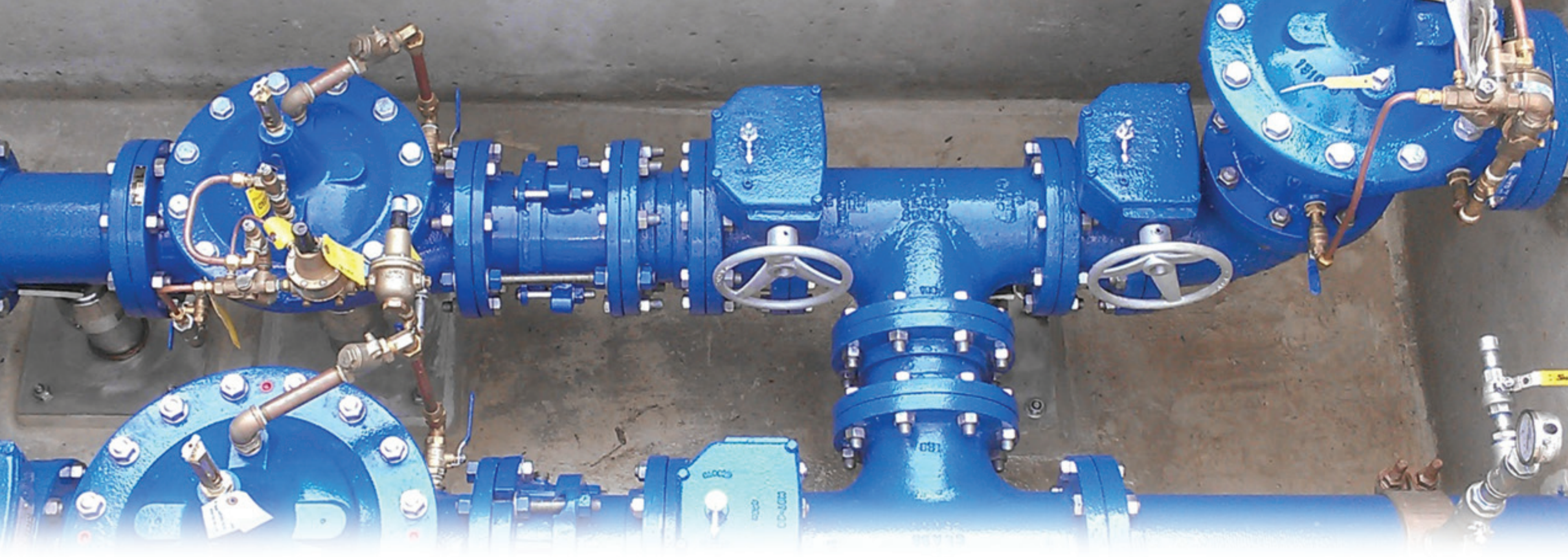
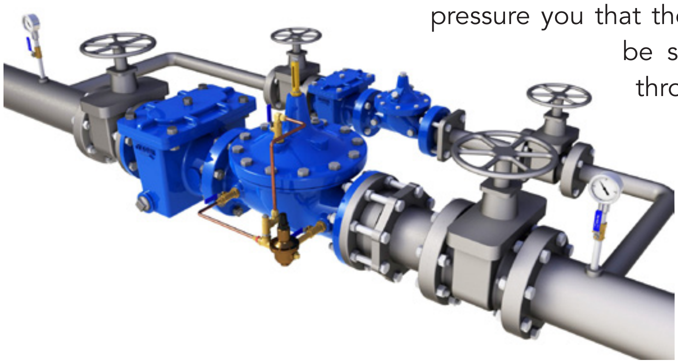


Valve Stations 101

The decision has been made that a control valve is required in the pipeline and now the task is to select the correct size of valve and design a valve station that will provide the necessary accessories for years of trouble free operation, while providing a well-designed environment for the operational personnel that will have to maintain this valve. Where does one begin?

Firstly, it is assumed that at least the size of the water main in question is known. With that in mind, and armed with the knowledge of the maximum, average and minimum flow demands, one can move forward in the valve size selection. For the purpose of this paper, assume that this valve is to be a pressure reducing valve, a Model 90G-01 or 690G-01, as that is what most valve stations in municipal water situations are. Sizing a pressure reducing valve is important, as problems can arise from incorrect sizing. Rather than sizing the valve based on line size, it is necessary to consider flows, pressures and velocities being dealt with. Using the Cla-Val sizing calculator is certainly the simplest way to arrive at a valve size but having an understanding of what the calculator is considering is useful.

A calculator will select a valve size based on maximum required flow the valve has to pass, based on the minimum system differential pressure. This will be the upstream pressure minus the required downstream pressure you that the reducing valve will be set at. The program will consider the velocity passing through the valve as it is best to limit this to 20 feet per second, (6 m/s) in valves operating continuously.

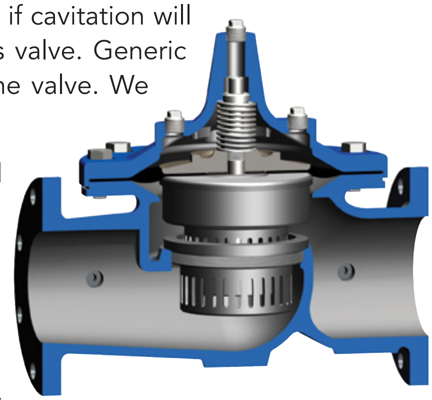


In valve stations it is very common to have two control valves in parallel. The larger valve on the main line is designed to take care of peak flows, while the smaller second valve on a bypass will take care low flows. Typically, the smaller, bypass valve will be sized to handle approximately 20% of the peak flow.

The smaller valve is also set slightly higher in pressure than the large valve. This allows the smaller valve to open first in the sequence, followed by the large valve as flow increases. The smaller valve is also the last to close as flow diminishes. This bypass line also offers redundancy as either of the valves can be used to supply the network while the other is being serviced. This is really important where it is not possible or practical to shut off the main water supply for periods of time.

Anytime there is an application where reductions from a higher pressure to a lower pressure, and that ratio is greater than 3:1, there is a real risk of cavitation. This phenomenon will destroy a valve over time due to erosion and will create noise and vibration in the pipeline that may be a problem for nearby residents to the station. However, unlike in days past where multiple valves would have to be installed to stagger the pressure drops, this can now be achieved through the use of anti-cavitation trim. This is a specific trim consisting of two stainless steel cages with slotted openings or drilled orifices, that contain the cavitation in the center of the cages, eliminating the disastrous erosion issues.

It is always recommend running a cavitation software program to determine if cavitation will be a problem, and this should be a program specific to the manufacturer's valve. Generic programs are available but do not account for the actual body shape of the valve. We recommend using Cla-Cav to software to review the specific application.



As for the pilot system of the valve, the real advantage of diaphragm actuated globe valves is that they can be a pilot system can be tailored to a specific application. There are numerous features that can be added to really give a custom solution that provides real operational benefits.

Firstly, what materials should the pilot system to be constructed from? Is brass/bronze and copper suitable or would it benefit by looking for something that may last longer due to aggressive water or a harsher environment. Stainless steel pilot systems are becoming very popular and the price differences these days are not restrictive. Another important point regarding pilot systems - these can be installed on either side of the control valve so please give some thought as to the location of ladders etc. and also maintenance clearances required. Sadly, pilot tubing is frequently stepped on or knocked through poor placement and with a little forethought this is totally avoidable.

The pilot system should always be installed with a strainer and this can either be the flow clean, internal style or an external Y strainer style. In tough applications, a water filter can be used.

Pilot isolating valves are vital for maintenance and troubleshooting of the valve and we would always recommend these even on the smallest of valve sizes.

This would take care of the basic pilot system, but also consider other options that may be required.

An X101 valve position indicator is very useful for operations personnel as it gives the ability to see the exact position of the valve during operation. If a remote signal is required this can be upgraded to a position transmitter, supplying a 4-20 mA signal via SCADA or a limit switch can be added to give an output for a X117D position transmitter. Pressure transmitters can be added to give 4-20mA signals for both inlet and outlet pressures. This option is very useful if the intention is to utilize a pressure management program in the future.

Also, consider options to give more system control. A second pilot control can be added to give the ability to have upstream pressure sustaining (Model 92-01 or 692-01) – very useful in situations where there is a need to protect the upstream from being starved of pressure by high downstream demand. If downstream surge could be an issue, (maybe an application where the line dead ends and if a valve is closed to quickly, high pressure could get locked into the downstream piping). In this instance, a downstream surge pilot can be added to the reducing valve that will close the control valve quickly should the downstream pressure rise slightly above the pressure reducing pilot set point (Model 94-01 or 694-01).

A Model X144D insertion flowmeter can also be added to the control valve, allowing a reducing valve to also be a flowmeter, giving either pulse or 4-20MA outputs, without the typical space requirements of a conventional meter.

The possibilities of the additions are numerous and specific requirements should be discussed with the control valve supplier to ensure you get the full benefit of all that is available.

So now the valve size and type are decided, it is time to consider the actual layout of a valve station. There are some key items that every valve station requires, namely isolating valves, upstream and downstream of the control valves. These are required to allow maintenance for isolating the control valve when it is necessary to work on the control valve. These valves can be either butterfly valves or gate valves and can be installed with handwheels or operating nuts depending on whether it is required to operate these valves from above ground. Typically, most utilities will use non-rising stem gate valves as these are the valves that are typically located throughout the network so everyone is familiar with them, however is space or cost is an issue, butterfly valves can certainly be used, as long as there is space between the butterfly and the control valve to allow for clearance for any equipment in the control valve such as insertion strainers or flow meters.

It cannot be stressed enough the importance of protecting the control valve from foreign objects in the pipeline and this is where a line strainer is an excellent addition to the station. While most water supplies do have screening at the intake point, it is not uncommon for objects to be introduced into the network, either by insufficient flushing after piping work or even open pipe ends during projects attracting animals. Everything from welding rods, fish, rodents, pieces of wood and even expensive tools, have been seen so it important none of these things find their way into the control valve. A Model X43H strainer certainly eliminates that possibility and is good insurance against foreign objects.

Each station should be installed with pressure gauges, and these can be installed on the pipeline or even supplied with the control valve. It is necessary to know the outlet pressure in order to set the reducing valve and having an inlet gauge allows the operator to also observe what the conditions are upstream also.

Air valves are something that should be strongly considered for every valve station. The operation of reducing pressure naturally allows air to form in the pipeline and if this is not removed down stream of the control valve, this will move down the pipeline and potentially cause issues elsewhere. Good practice is to install an air release valve on the upstream side of the control valve – this will eliminate the possibility air entering the pilot system, which can be a source of problems. We recommend a Cla-Val Model 34 Air release valve upstream and a Model 36 downstream.

Lastly, there are some practical and functional additions, that are best considered before a valve station is installed as these items are easier to install before the station is operational.

1. Lifting eyes in the ceilings above major pieces of equipment. If this is a concrete chamber, these need to be decided upon before the concrete is cast to ensure correct capacity, but these will certainly make maintenance a much easier task for the operations crew.

2. Spare pipeline connections – possibly for a hose bib connection. It is much easier to install before the line is pressurized!

3. A sump drain. Chambers can flood and getting water out of these chambers can be an issue. This may be as simple as a daylight drain or a sump with an electric pump may be required.

4. Protection for the downstream network from over-pressure. It may be prudent to consider adding a relief valve on the downstream piping inside the valve station. Typically, this valve is going to be a much smaller valve than the main line valve and an angle style is most common. The outlet from this valve will require a drain connection to eliminate the flooding of the chamber, should the valve ever be utilized. However, that is a small cost compared to the potential damage that a burst water main may cause downstream.

In closing, while valve station design is not necessarily difficult, poor design can certainly lead to operational issues down the road and by giving a few moments of thought ahead of time, can certainly win friends in the operations department later.

Why Pressure Management?

There are many ways and reasons that pressure can and should be managed in a network from source to tap. The aim is to create a network where pressure in the pipe system is managed in such a way as to mitigate the rise of transients, which can cause pipe bursts and weaken pipe systems. The goal is to efficiently and effectively control pressure fluctuations, keeping the water network calm, and at serviceable pressure levels and reducing leakage.

This article will focus on one of the solutions the water industry employs to reduce system pressure and manage leakage; namely the Pressure Reducing Valve, (PRV). PRV's have been a huge asset to the water industry as they are a very simple and effective solution to take a problematic higher-pressure source to a controlled fixed outlet pressure, regardless of flow demand.

However, it must be recognized that a PRV alone will not eliminate the issues surrounding leakage and water utilities should repair as many leaks in the network as possible. When the pressures are at their highest, the leaks are easier to identify. At this point, a PRV installation will maintain the pressure in the system at serviceable levels and also reduce the amount of water lost through leaking pipework and also help to eliminate any new leaks.

Why Pressure Management?

Before a PRV is selected it is important to gain as much information as possible about the distribution network the valve will be servicing. The following outlines the elements that need to be considered in choosing the correct reducing valve.

1. Determine a zone or area that the PRV will feed into and ensure that the zone can also be monitored.
2. How many properties fall within the zone and identify the areas which suffer the lowest pressure. This is usually the property or properties located at the highest altitude, the furthest away from the water source or perhaps due to poor infrastructure issues, has the lowest pressure. This is called the Critical Point or Critical Node (C.P.)
3. Determine where the PRV will be located.
4. Ensure this new zone can be a serviced through a single pipe source and all interconnecting boundary valves must be closed off.
5. At the point of entry into the zone, a flow meter must be installed allowing flow readings to be taken of water entering the zone. (Typically, the flow meter will be located close to where the PRV will also be located.)

Data Acquisition - DMA

Once the zone has been defined, the most crucial element is data acquisition. Both flow and pressure must be logged and data collected over time to gain the intelligence and understanding of how the new zone operates hydraulically under various flowing conditions. These newly defined zones now become what we refer to as a DMA – District Metered Area or Demand Management Zone.

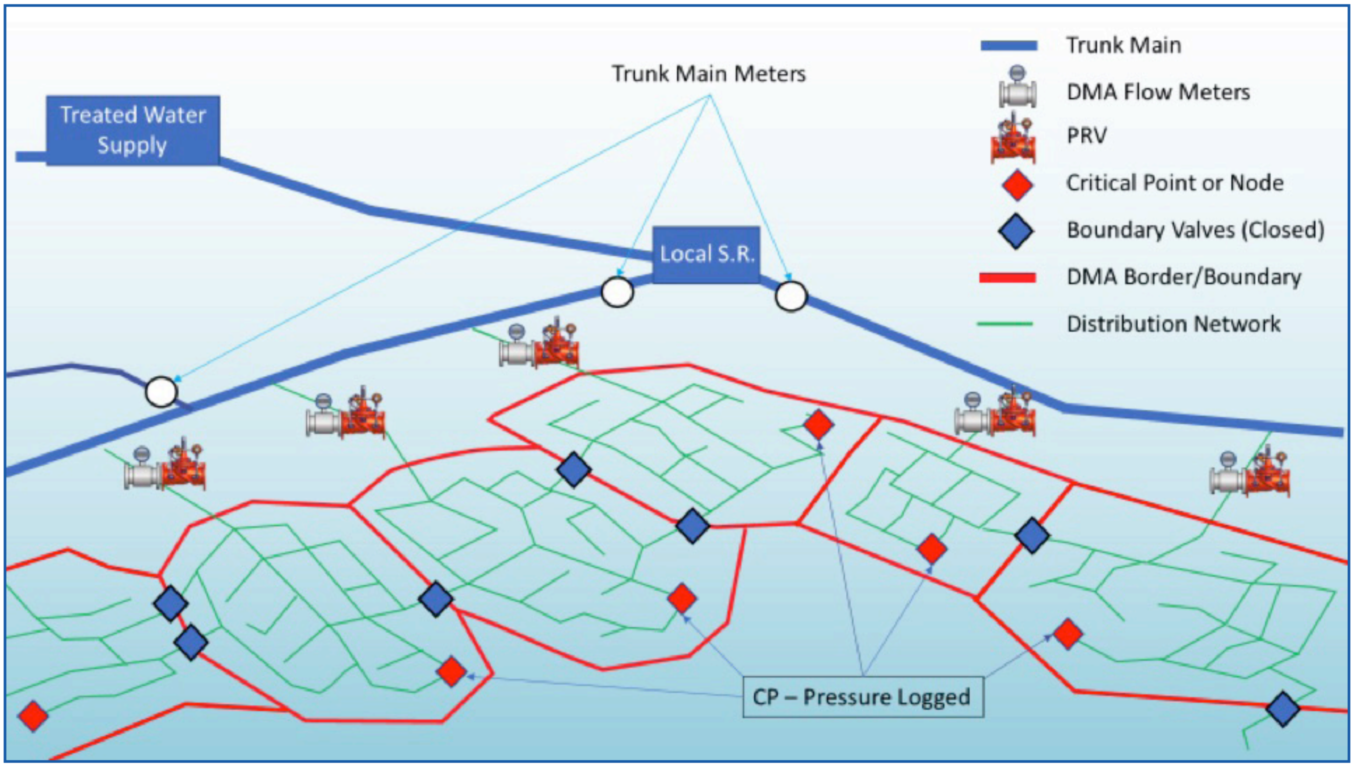
It is recommended the following be data be collected using some system of data logging:

1. Flow rates – through the single feed into the area
2. Pressure – where the PRV is to be located (nearby DMA Flowmeter)
3. Pressure point in the network that suffer lowest pressure – C.P.
4. Pressure at zonal boundaries

**Quick guide to determine the average flow rate into a DMA:

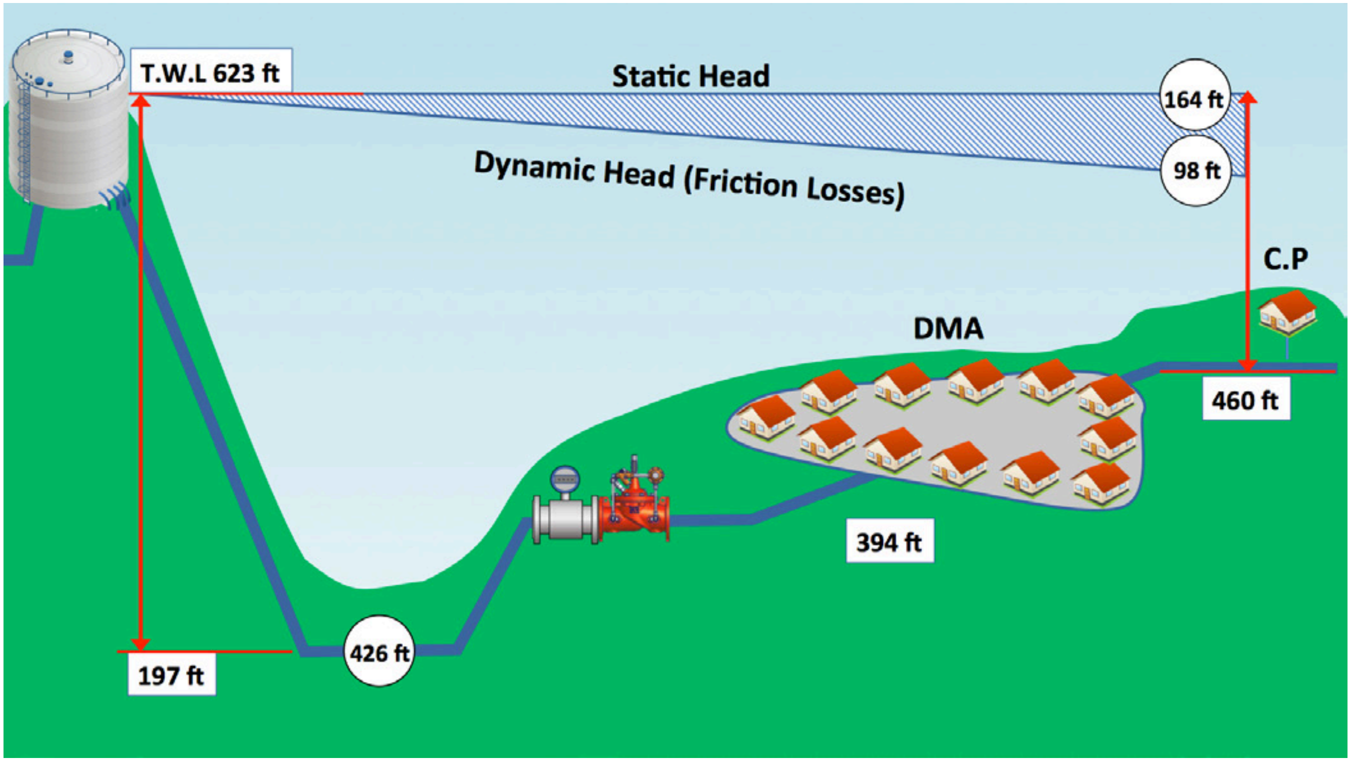
Number of properties in DMA	= 1,000 (example)
Av. People per property	= 2.5
Av. Water usage per person/per day	= 100 gallons
Formula:- (1,000 x 2.5) x 0.15 / 24 hours	= 10,416.6 gph (173.6 gpm)
Max Flow x 2	= 347 gpm
Min Flow / 2	= 87 gpm

**Does not consider fire flows or seasonal variations



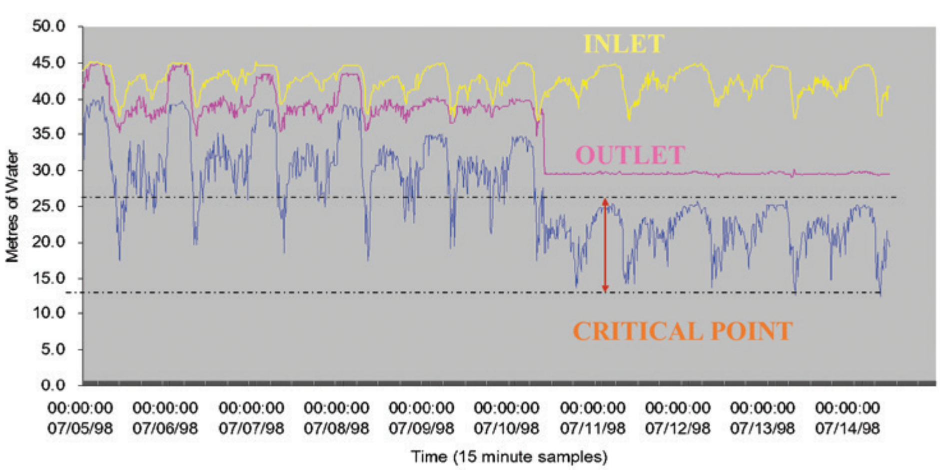
Using the data

Once the DMA data has been collected for a sufficient time frame (minimum 7 days plus incorporating fire flows and seasonal variations), the data can be analysed and will begin to provide the hydraulic characteristics of the area.



The collected data will show the variation in inlet pressure and flow into the DMA, together with the critical point pressure data which will also vary throughout the day/night as a result of the dynamic head losses caused by the increase and decrease in flow demand across the network.

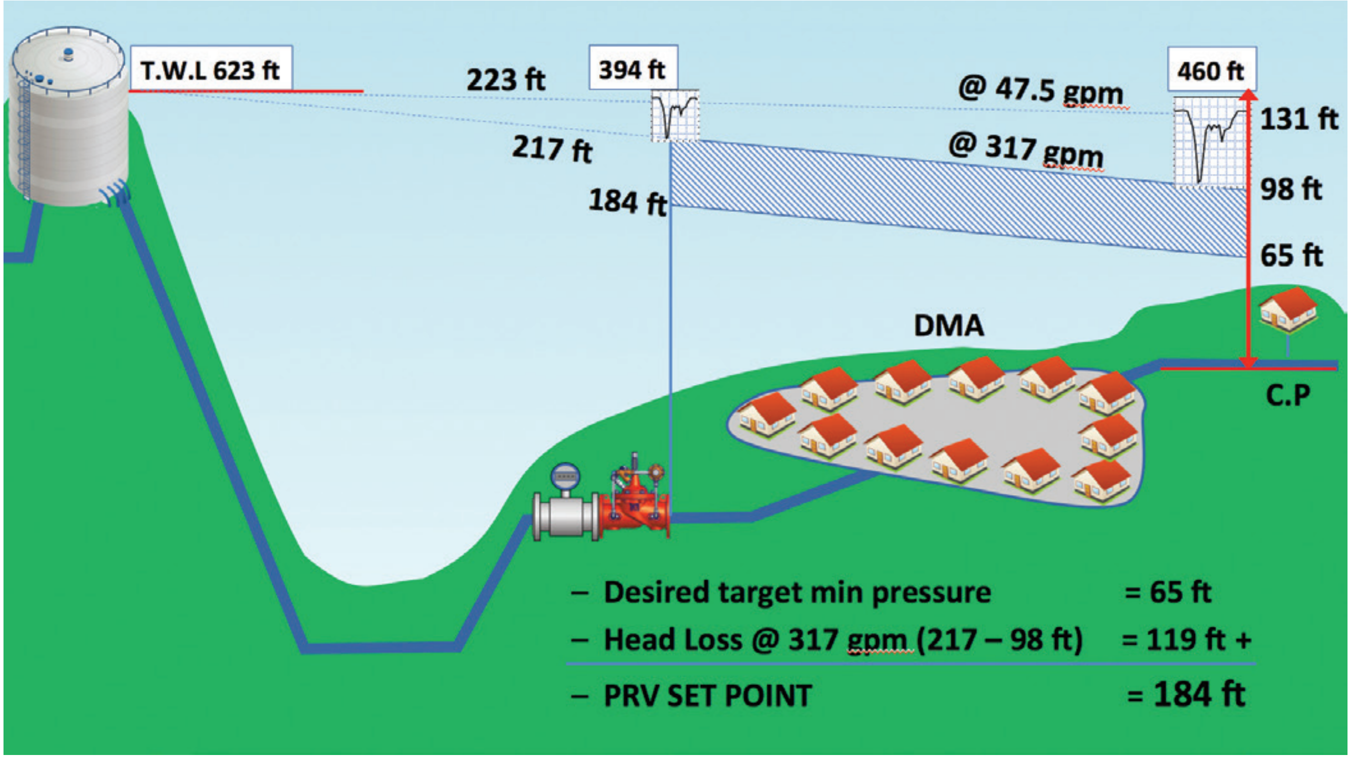
The above image shows the hydraulic gradient of a typical water supply network at maximum flows. The top water level in the service reservoir provides the head of pressure into the pipe system and the topography of the pipework shows the height of the DMA and Critical Point, but more importantly the resulting pressure at the Critical Point due to the friction losses along the pipeline. These friction losses will vary and increase as flow demand increases through the network. This is caused by many factors including; pipe age, condition and size variation across the network but also an increase in flow velocity.



The Graph shows an example of logged pressure data into a DMA.

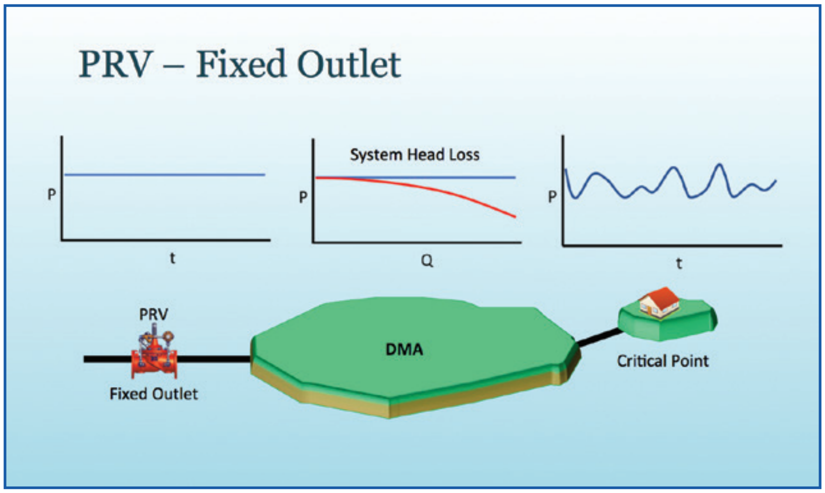
It shows the erratic inlet pressure, (yellow), before the PRV is brought online, and how the CP mirrors this, (blue) being lower pressure because of the friction losses.

After the PRV outlet pressure has been reduced to a fixed lower pressure, (pink), the effect on the CP can be seen.



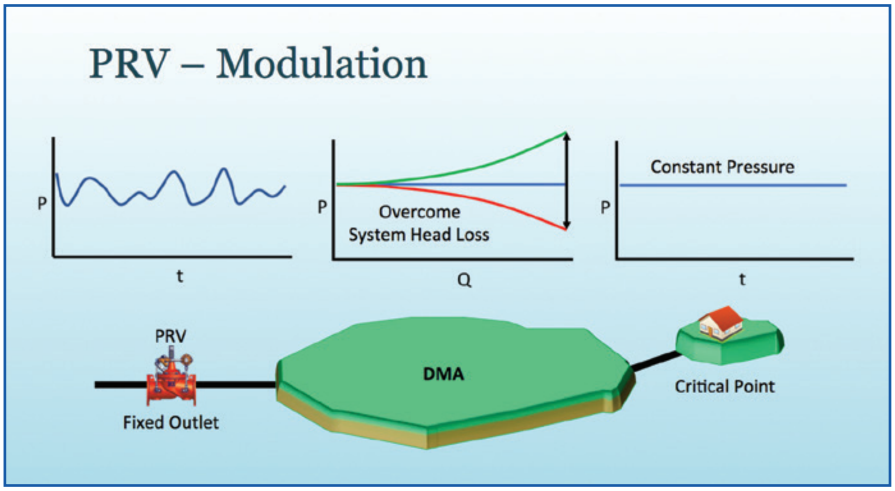
The above image represents the new hydraulic gradient after the PRV has been installed and set at the desired outlet pressure. The Critical Point has been protected so that the minimum pressure at the maximum flow will not drop below 65 ft. It is common practise to drop outlet pressure in stages over a period of time whilst continuing to monitor the CP and reduce the potential for customer complaints during this process (5m each time at no less than 7 day intervals).

Pressure Modulation



Understanding the hydraulic characteristics of the network and installing a PRV to a fixed outlet pressure can save leakage up to around 70%. Although this is an impressive payback, the water industry is looking for new and innovative ways to reduce this figure further. To achieve this, PRV's can be modified to modulate the outlet pressure according to changes in flow or time. Again, understanding the hydraulic gradient across the DMA and looking for differences in PRV outlet pressure comparative to the CP pressure.

In most cases a fixed outlet PRV is set to protect the minimum pressure requirements at the CP at peak flow demand. Any other time the system is not at full demand the PRV in effectively providing excessive pressure, this can be a huge percentage over a 24-hour period, particularly at night when the system is at its lowest flow demand. The term 'pressure management' as far as PRV's are concerned is modulating the outlet pressure in order to maintain a relative constant minimum pressure at the CP and overcoming the difference in system head loss.



The solutions are quite simple to the more complex; 2 stage pressure control to complete closed loop control.

In economic terms, this can be quite simple to break down and categorise in providing the most cost-effective solution for the most potential in the return on investment.

SMALL VALVES (1.5"-3")

- 2 stage outlet pressure according to time (night & day) <1500 properties

MEDIUM VALVES (3" – 8")

- Large DMA's utilising flow modulation, low or self-powered open loop pressure controllers >1500 properties, usually with P1, P2 and Flow logging capability and 2-way comms.

LARGE VALVES (8"+)

- Critical PRV's (ie Trunk Main PRV's) Closed Loop or Open Loop, sites that have 24VDC and remote comms/control via SCADA

Many water companies prefer quite simple and inexpensive solutions that they institute with little training and support, that simply drop the pressure throughout the night. Other companies prefer a more complex solution such as flow modulation that also provides a means of data logging and more recently, the addition of two-way communication. Data acquisition is becoming more focussed with the industry wanting to see real time data by increasing the frequency of communication to 15-minute intervals, as opposed to a single daily update.

In some established areas of the world it is becoming increasingly difficult and expensive to find and benefit from the extra savings of pressure management and the ROI is getting longer. Five years ROI is generally acceptable.

Zones may become 'Rezoned' for pressure optimisation, with more and more small PRV's being installed for those small benefits rather than the expense, support and maintenance of a full pressure management solution. Basically, increasing the number of smaller DMA's.

Water companies are beginning to invest in Smart Network solutions where they can interlink DMA's with intelligent valves and controllers to automatically manage pressures across a much larger scale and where they can build resilience into their networks to protect against issues relating to low water pressure, quick rezoning after pipe bursts, water quality issues etc.

Internationally, there is still a long way to go in attacking leakage on a primary level with PRV's with fixed outlets. Moving into true 'Pressure Management' is the secondary stage.

Sadly, there is generally a huge knowledge gap in in the industry from understanding basic hydraulics in a network to ascertaining when and where to install a PRV, and at what pressure setpoint. Therefore, water companies must engage with knowledgeable and experienced control valve partners.

Control Valve Cavitation

Causes & Prevention

Cavitation prevention and protection is an important consideration in the design and operation of valves used in water distribution systems. One should be able to determine if cavitation exists, and if so its intensity and effects on the system. Cavitation in valves is a destructive condition that seriously affects the operation and service of the valve and occurs when fluid passing through the valve lowers to the vapor pressure of the fluid causing vapor cavities (bubbles) to form. When the fluid passes out of the low-pressure area into a higher-pressure area, the vapor cavity becomes unstable and collapses. This collapse is what can sometimes be heard or seen and is the reason we must be concerned about its presence in pipeline systems. The collapse can be violent and is accompanied by noise, vibrations, and possible erosion damage to the valve or surrounding pipeline.

ORIGIN OF CAVITATION

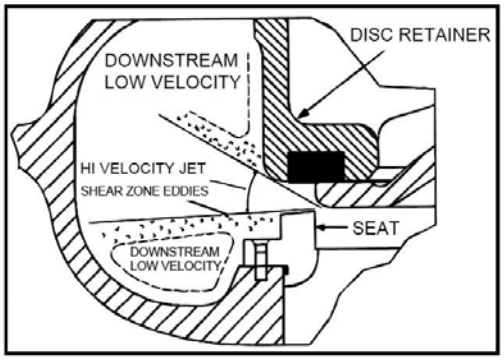
There are three fundamental requirements for cavitation to occur. First, there must be gas bubbles (nuclei) or voids in the fluid that serves as a basis for vaporization to occur. Second, the internal pressure in the fluid must drop to or below vapor pressure. Third, the pressure surrounding the vapor bubble must be greater than the vapor pressure for it to collapse.

For cavitation to occur, there must be nuclei present. If the water was completely de-aerated and there were no contaminant's, voids or entrapped air, either in the water or in the boundary of the valve, the water could sustain tension and would not cavitate when the pressure dropped to the normal vapor pressure.

Therefore, nuclei are one of the primary requirements for cavitation to occur. The primary sources of nuclei are from free air bubbles and air bubbles trapped in crevasses of suspended material and crevasses in the valve body material (boundary).

SOURCES OF LOW PRESSURE

The mean pressure at the inlet to a valve is equal to the static head or pump pressure, minus the dynamic head. The local pressure in a valve is the sum of the mean pressure, which is uniform over a certain flow range and the dynamic pressure which depends on fluid motion which causes friction losses and local accelerations due to changes in the cross-sectional flow area and on the formation and dissipation of eddies and vortices in turbulent shear zones. Flow at the inlet to a valve for example, has a relatively low velocity and high pressure.



As the flow approaches the partially open valve, the velocity must increase to maintain the same flowrate, and this causes the pressure to drop. When the high velocity jet enters the larger downstream area of the valve, a shear layer is created along the boundary of the high velocity jet and the lower velocity in the larger downstream area. The high velocity gradients created along this shear area creates eddies is considerably less than the already lower pressure of the high velocity jet. If nuclei are entrapped inside these eddies and the pressure drops to vapor pressure, it will begin to grow. If the pressure remains at vapor pressure long enough for the nuclei to reach a critical diameter, it then begins to grow rapidly through vaporization. As the size of the vapor pressure cavity increases, the strength of the eddy is rapidly destroyed, the rotational speed reduces, and the pressure is no longer vapor pressure.

Since surrounding pressure is above vapor pressure, the cavity becomes unstable and collapses inward. The time that a nucleus is subjected to low pressure inside the eddy is important. If the time is so short the bubble can- not reach its critical diameter, it will not become cavitation event.

PRESSURE RECOVERY

In the third phase of cavitation there must be a pressure in the cavitation zone greater than vapor pressure for the cavity to collapse. If the bubble collapses before reaching the boundary areas there will be no cavitation damage, only noise, vibrations and possible reduction of flow.

DAMAGE

If the vapor cavities are carried to the solid boundary of the valve before they collapse, erosion damage will occur. Prior research has indicated that the collapse must occur approximately one bubble diameter from the boundary to cause erosion damage. Since the bubbles are generally small, this indicates that only collapses near or on the surface of the boundary will cause erosion damage. High pressure shock waves are generated by the collapse of the vapor cavities and in severe cases have been estimated to be over 1,000,000 psi. No material can withstand this type of beating very long. Once a system reaches a point where erosion damage occurs, damage increases very rapidly as the velocity of the system is increased. Because of this it is important that when selecting conditions corresponding to the onset of erosion or cavitation damage, one should be conservative because a slight increase in velocity could cause a large increase in the damage rate.

EFFECTS OF CAVITATION

There are five basic problems associated with cavitation: noise, vibrations, pressure fluctuations, erosion damage and loss of flow capacity. The type and intensity of noise in a valve usually depends on the size of the valve. Cavitation in a small valve is usually identified as a hissing or a light crackling sound. In large valves, the noise may sound more like small explosions and can vary with the design of the valve. The shock waves generated by the collapsing vapor cavities can produce pressure fluctuations and system vibration. As the intensity of the cavitation increases, the magnitude of the vibration increases many times over and can cause serious damage to mounting bolts, pipe fitting and structural failure. If the vapor cavities collapse close to a boundary inside the valve, erosion damage can occur. In many cases cavitation damage has eroded holes through the side of valve bodies and in some cases has eroded holes in the bridge wall and valve seat areas. This is one of the most common types of failure.

During advanced stages of cavitation, large vapor cavities form, which can alter the flow characteristics of the valve and drastically reduce the efficiency. This is referred to as Choking cavitation and represents the condition at which the flow coefficient (Cv) is drastically reduced because of the large vapor cavities. Just prior to choking cavitation, erosion damage, noise and vibration are at their maxi- mum, then will start to drop off rapidly. Once the valve fully chokes, the vapor cavity will extend out beyond the dis- charge of the valve and into the down- stream piping where the collapsing vapor cavities can cause major damage to the downstream piping and fittings.

DESIGN PARAMETERS

If we understand cavitation, its causes and effects, we can probably think of several ways to prevent damage to the valve. One easy method would be to limit operation of the system to a level that would not produce enough energy to carry the vapor cavity to the boundary of the valve and there would be no cavitation damage.

Another method would be to change the internal geometry of the valve to remove the boundary out of the immediate damage cavitation zone. A number of years ago, Cla-Val took the data obtained from 25 years of studying cavitation and associated problems and changed the internal geometry of the valve. This allowed an increase in the operating differentials of the valve without causing cavitation damage.

DETERMINING CAVITATION LIMITS

Historically there was no analytical solution for determining the cavitation characteristics of a valve. Every valve design has its own “footprint” and for this reason the only way to properly evaluate the cavitation parameters is by laboratory experimentation. (This all changed with the advent of Computational Fluid Dynamics). Once these parameters are obtained for a specific valve geometry then it is possible to develop empirical relationships for predicting the various levels of cavitation. If the internal geometry is changed, then new experimental data must be obtained to develop new empirical relationships. For this reason, the empirical data developed for one company’s products cannot be transferred to another manufacturer’s products.

Most any laboratory instrument that can detect noise, pressure fluctuations, vibrations, pitting or loss of efficiency can be used to detect cavitation. An important factor in determining the cavitation parameters is to do the experimentation in a laboratory that is relatively free from other noises such as pumps, control valves and vibrations that could affect the data obtained. Probably the most common instrument used to detect cavitation is the accelerometer because it is easy to use and is sensitive to the lightest and heaviest levels of cavitation. To obtain the flow conditions for incipient damage, polished soft aluminum plates were installed flush with the inside surfaces of the valve, in the proper locations to record the pitting.

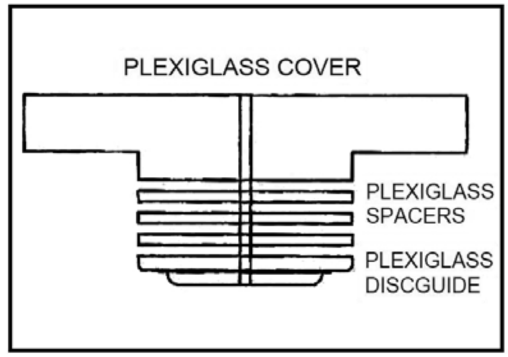
Nearly all the experimental data taken in the laboratory is taken at reduced pressures and flows from actual applications and for this reason just scaling the experimental data up to actual conditions in the field will not give true cavitation data. Therefore, pressure scale effects for a given valve geometry must be determined in the laboratory.

CAVITATION DAMAGE STUDIES

Testing of valves in conjunction with reputable flow laboratories have been undertaken by certain manufacturers to determine the maximum operating limits without incurring cavitation damage. Tests were conducted to determine the flow conditions where cavitation noise first begins (Critical Cavitation), the pressure scale effects on critical cavitation, the flow conditions where cavitation damage begins, (Incipient Damage) and the flow conditions where choking cavitation begin to occur.

A dimensionless cavitation parameter sigma was used to quantify the intensity of cavitation at different flow conditions. The most common formula for determining sigma is (= (Pd - Pvg)/Pu - Pd) where Pd is the downstream pressure, Pvg is the gage vapor pressure and Pu is the valve inlet pressure. Data were collected at every 10 percent of opening to provide a valve opening versus Cv curve. The intensity of cavitation at critical level consists of steady light popping sounds. This level of cavitation does not cause erosion damage or reduce the service life of the valve and for most applications is recommended for what could be termed “cavitation free operation”. The critical cavitation levels were determined by ear during these tests.

To determine the sigma value at incipient damage, it was first necessary to determine the location inside the valve where actual cavitation was occurring. This was done by making a valve cover and valve disc from Lucite with spacers for each 10 percent of valve opening. When installed, one could observe where inside the valve, cavitation occurred when operated at various percentages of opening. Polished soft aluminum plugs were then inserted through the walls of the valve body and positioned flush with the inside wall in the locations where cavitation was observed. Plates were also fastened flush with the bridge wall boundary inside the valve.



The internals were then re-installed in the valves and the valves operated at each 10 percent opening at various differentials and flow rates until pitting was observed on the soft aluminum plates.

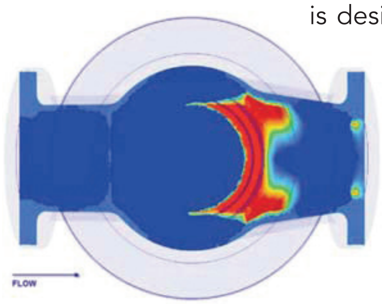
This was a very time-consuming test because the valve had to be operated at a known condition for 10 to 20 minutes, then disassembled and the plates examined to see if there were any pits in the soft aluminum plates. If there were no pits the valve was re-assembled, and the process repeated at a lower sigma value until the proper number of pits were obtained. Incipient damage for these tests was taken as one pit per square inch per minute on the soft aluminum plates. This procedure was then repeated at each 10 percent of valve opening.

At the end of the cavitation damage studies, the cavitation program was modified to include the condition of incipient damage and it was found that certain body designs would tolerate a much higher degree of cavitation than others before the onset of cavitation damage.

Over the years, different series of valves have been developed and much of the information obtained from the cavitation studies has been incorporated into the design. When designing a valve with a reduced seat diameter to eliminate the need for reducing flanges that are required in many installations, it gave the opportunity to design a valve that had improved cavitation characteristics.

The results of these reduced seat valves in testing were far better than expected and this series of valves will operate at much greater velocities without experiencing cavitation damage.

Valves that operate intermittently such as some relief applications may be able to operate at a higher degree of cavitation. In this type of service, erosion damage may not be the deciding factor. If the system is designed to withstand the vibration and noise the valve may be able to operate at choke flows. The intensity of cavitation, noise, vibration and erosion damage is usually at their maximum just before the valve chokes and the flow may be very unstable. The cavitation program shows the occurrence of choking cavitation.



In the past ten years, Computational Fluid Dynamics (CFD), has significantly evolved using numerical methods and algorithms to analyze complex fluid flow problems. Utilizing this process allows an analysis to be seen on valve designs, clearly indicating areas of cavitation.

VALVE APPLICATION

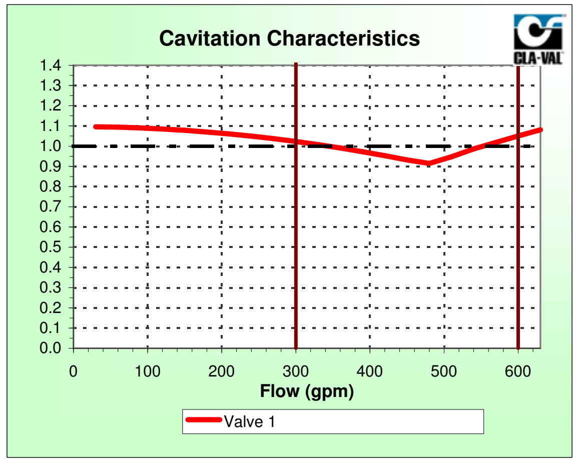
When specifying a valve, a manufacturer supplied calculator can be used to determine the cavitation characteristics of the valve for the specific application. As in example 1, let’s say we have a 4 inch main valve, located at the end of a long pipeline flowing from 300 to 600 gpm. The long supply pipeline has a pressure loss of 20 psi at 600 gpm. The static inlet pressure is 100 psi, the outlet pressure is 20 psi and the valve is at 800 feet elevation. The cavitation program shows cavitation damage starting at 300 gpm and again at 550 gpm.

Valve 1		
Valve size	4" 100-01	
Maximum flow rate	600	gpm
Minimum flow rate	300	gpm
Static inlet pressure	100	psi
Static outlet pressure	20	psi
Elevation above S.L.	800	ft
Water temperature	60	deg F
Dynam. inlet pressure	80.0	psi
Dynam outlet pressure	20.0	psi
Backpressure orifice	None	
Orifice backpressure	0	
Orifice discharge to	Downstream piping	

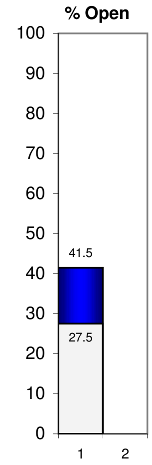
Valve operation

Continuous (>50%)

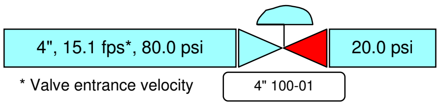
Avoid operation near (within 10 %) cavitation damage level of 1.0.



If the lines go above 1.0 there will be cavitation damage.



No damage
Caution - near damage
Damaging cavitation



* Valve entrance velocity

Valve 1 Flow Rate GPM	Inlet (psi)	Outlet (psi)	% Open	Pipe Vel. (ft/s)	Cav Damage
30	100.0	20.0	5.5	0.8	Yes
150	98.8	20.0	20.1	3.8	Yes
300	95.0	20.0	27.5	7.6	Yes
450	88.8	20.0	34.2	11.3	Near
600	80.0	20.0	41.5	15.1	Yes

Now that we know there will be cavitation damage, what can we do about it? One method of combating cavitation damage is to add back pressure to the valve.

This is done in the cavitation program by entering a value for the back pressure, which must be greater than the normal outlet pressure. As the flow rate increases, the pressure at the outlet of the valve increases causing the valve to open further which reduces the velocity of the jet through the partially open valve and increases the outlet pressure which may raise the internal pressure above vapor pressure.

In example 2, a back pressure of 37.8 psi was added and the cavitation damage was completely eliminated. Adding back pressure to a valve can be accomplished by adding an orifice plate downstream of the valve. In a pressure reducing valve application, the pressure regulating pilot must sense the pressure downstream of the orifice plate. If there is considerable resistance in the discharge line of the valve, then the back pressure on the valve will automatically increase as the flow increases and this must be taken into consideration when entering the data. If the discharge line is long and the valve is anything but a pressure reducing valve, then the dis- charge pipe Cv must be entered which will automatically raise the outlet pressure as the flow increases. This should be done before entering back pressure to eliminate damage cavitation. Still another method of reducing cavitation damage in a valve installation is to use two or more valves in series. Using the cavitation program, one can determine the maximum pressure conditions for each valve that will permit them to operate free of cavitation damage.

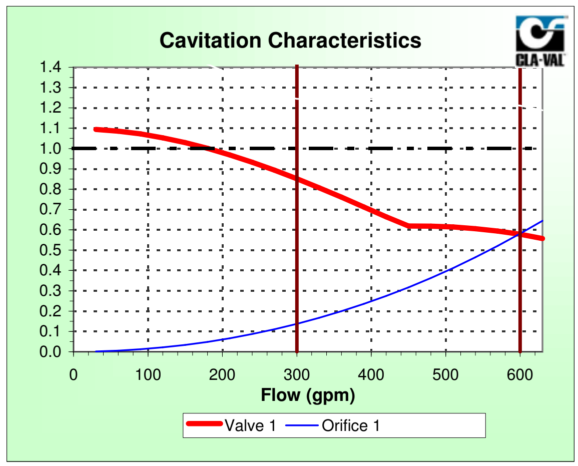
Valve 1

Valve size	4" 100-01	
Maximum flow rate	600	gpm
Minimum flow rate	300	gpm
Static inlet pressure	100	psi
Static outlet pressure	20	psi
Elevation above S.L.	800	ft
Water temperature	60	deg F
Dynam. inlet pressure	80.0	psi
Dynam outlet pressure	20.0	psi
Backpressure orifice	Single	
Orifice backpressure	37.8	psi
Orifice discharge to	Downstream piping	

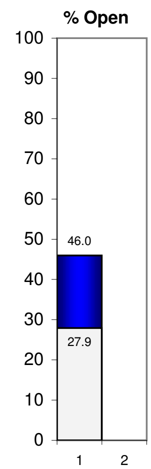
Valve operation

Continuous (>50%)

Avoid operation near (within 10 %) cavitation damage level of 1.0.

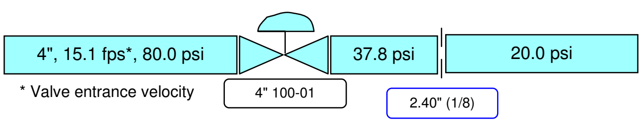


If the lines go above 1.0 there will be cavitation damage.



No damage
Caution - near damage
Damaging cavitation

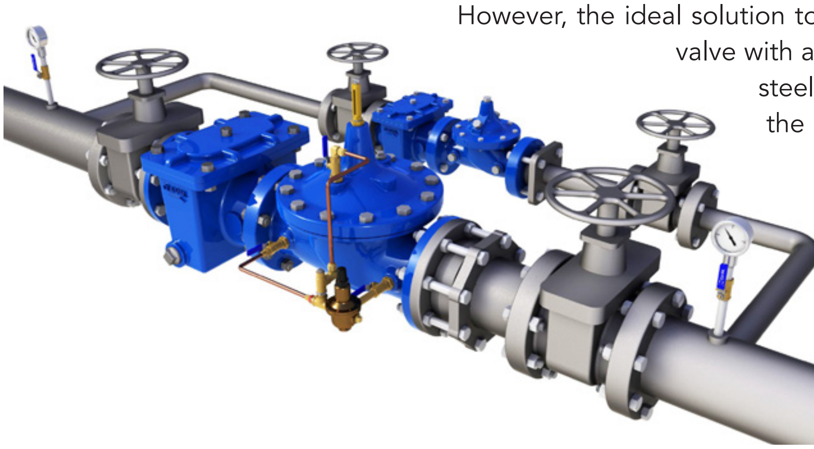
Valve damage occurs <15 psi.



Valve 1 Flow Rate GPM	Inlet (psi)	Outlet (psi)	% Open	Pipe Vel. (ft/s)	Cav Damage
30	100.0	20.0	5.5	0.8	Yes
150	98.8	21.1	20.2	3.8	Yes
300	95.0	24.5	27.9	7.6	No
450	88.8	30.0	35.7	11.3	No
600	80.0	37.8	46.0	15.1	No

Orifice plate thickness shown in parentheses

Anti-Cavitation Trim



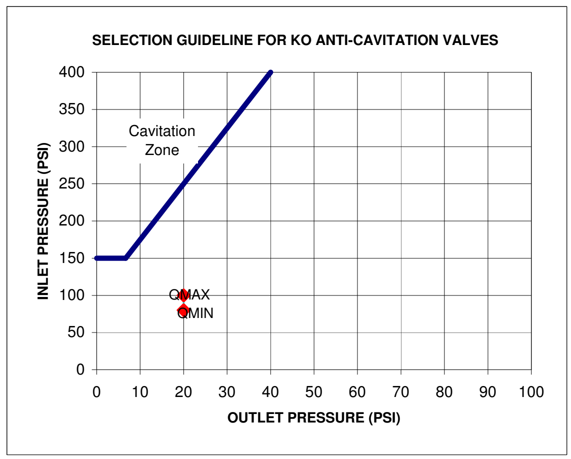
However, the ideal solution to cavitation occurrences is to install a control valve with anti-cavitation trim. This involves two stainless steel cages, the inner cage being free to move with the valve stroke. The cages are either slotted or drilled, and control where cavitation occurs in the valve. Essentially the cage openings create enough back pressure to keep the cavitation inside the center of the cages where no damage can occur. This solution guarantees that cavitation damage will not migrate downstream and cause pipework damage, whilst also ensuring the control valve gives years of damage free operation.

Valve 1		
Valve size	4" 100-01	
Maximum flow rate	600	gpm
Minimum flow rate	50	gpm
Static inlet pressure	100	psi
Static outlet pressure	20	psi
Elevation above S.L.	800	ft
Water temperature	60	deg F
Dynam. inlet pressure	80.0	psi
Dynam outlet pressure	20.0	psi
Backpressure orifice	None	
Orifice backpressure	0	
Orifice discharge to	Downstream piping	

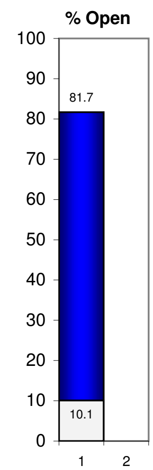
Valve operation

Continuous (>50%)

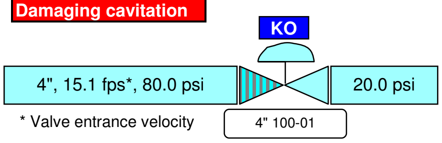
Avoid operation above 18 ft/sec.



Published Cavitation Chart.



No damage
Caution - near damage
Damaging cavitation



Valve 1	Flow Rate GPM	Inlet (psi)	Outlet (psi)	est. % Open	Pipe Vel. (ft/s)	Cav Damage
	30	100.0	20.0	7.4	0.8	No
	150	98.8	20.0	19.9	3.8	No
	300	95.0	20.0	36.8	7.6	No
	450	88.8	20.0	56.5	11.3	No
	600	80.0	20.0	81.7	15.1	No

CONCLUSION

When dealing with cavitation it is always important to select the correct valve for the application and having computer programs to assist in this process certainly is beneficial. It is prudent to request copies of these computer reports, ensuring that the reports are specific to the valve manufacturer you are evaluating, rather than a generic program to ensure a correct analysis is performed.

Electrical Energy Savings using Anti-Stagnation Valves

The City of Hamilton is a port city situated at the west end of Lake Ontario in the Canadian province of Ontario. It is the 10th largest municipality in Canada. It has an elevation of 298 ft (91m) above sea level and is defined by unique geographical features like the Niagara Escarpment and the Hamilton Harbor. The City of Hamilton's water distribution system is one of the oldest and most complex water distribution systems in Canada. The City's water distribution network consists of:

- 6 separate water systems
- 1,262 miles (2,031 km) of water mains
- 144,691 water services
- 16 Pressure Reducing zones
- 145 Pressure District Level Valves

The City's distribution system must maintain a minimum operating pressure of 20 psi (1.38 Bar) at ground level at all points under maximum day demand plus fire flow conditions. The normal operating pressure within the network is 40 to 100psi. (2.76 to 6.89 Bar)

This is a difficult undertaking due to a unique, local geographic feature, namely the Niagara Escarpment. This steep rock face that runs through the middle of the city across its entire breadth, bisecting the city into 'upper' and 'lower' sections. This vertical wall ascends an average of 328 feet (100m) and presents a unique challenge in the conveyance of water at acceptable flows and pressures. Due to this elevation change coupled with the sprawling geography of the City, the water distribution system is divided into 25 distinct pressure districts, both open and closed.

In an open district, continuous pumping is not required to maintain pressure due to the provision of floating storage, such as an elevated tank or reservoir. In a closed district, continuous pumping is required to ensure that the required flows and pressures in that portion of the distribution network are met.

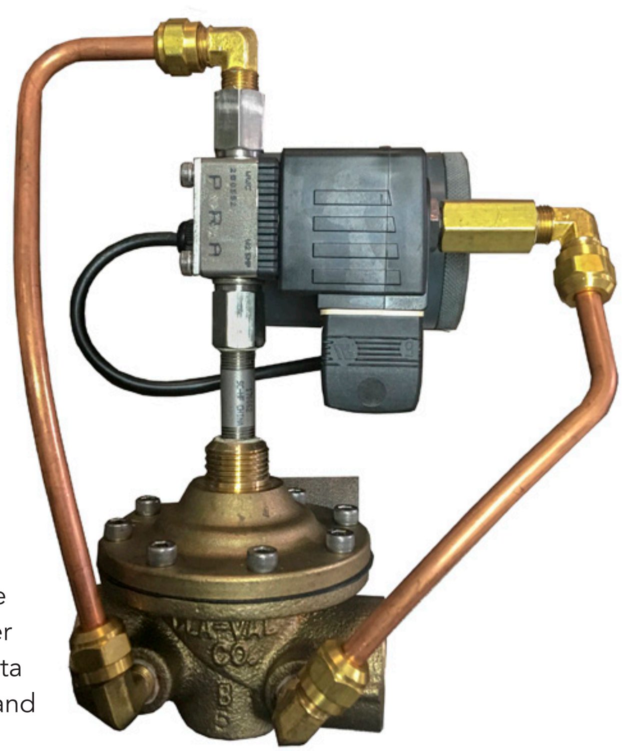
In areas where a facility such as a reservoir or elevated tank is not present, pumping station discharge head must be enough to overcome system losses and to maintain the appropriate hydraulic gradient.

The placement of floating storage within the distribution system not only provides sufficient amounts of water to equalize demand, but also translates into energy savings when supplying the network via gravity.

The various pressure district zones are inter-connected via level valves and an open ¾” (20 mm) by-pass line. Typically, by-pass lines allow a continuous flow of water from the high to low pressure zones to provide a mixing of water to maintain acceptable residual chlorine levels. These by-passing flows consume significant pumping energy.

The mission of Hamilton Water is to provide quality water services that contributes to a healthy, safe and prosperous community, in a sustainable manner. Hamilton Water is one of the largest energy users within the City of Hamilton and has started to implement measures to lessen electricity expenditures. In 2017, Hamilton Water spent over $13,000,000 on power costs (6.2% of the total operating budget) and the goal of the Hamilton Water Leadership Team is to drastically reduce these costs.

In late 2017, a pilot project was implemented to review and investigate the significant increase in flow from two reservoirs (PD4 – Greenhill Avenue and PD8 – Dewitt Road), in comparison to the trends from previous years. It had been determined that it was acceptable and feasible to significantly reduce water flow through the by-pass lines from a 24/7 continuous flow to approximately 15 minutes per day, and still maintain water quality, while using a timer controlled, anti-stagnation valve. These valves significantly reduced the required water flow from pumping stations.



Each valve is a ¾” (20 mm) Cla-Val Model 139-10A, a programmable timer control valve, and is an on/off control valve which can be programmed to operate on a time schedule. It utilizes a long life 9-volt lithium battery and the whole assembly is IP-68 submersible.

The pilot project focused on 37 water distribution level valves and open by-pass lines that separate two pressure districts. The 37 valves were all installed and operational by the end of June 2018. The previous one-year historic pumping station electrical demand (kW) and energy consumption (kWh) were used as a baseline for the pilot project.

The Post-Retrofit period (after June 2018) is being continuously monitored using the City of Hamilton - Office of Energy Initiatives Energy Management System to gather electrical demand (kW) and energy consumption (kWh) data to verify actual project energy savings and electrical demand reduction.

The results of the pilot study were that total demand reduction in power for the pumping stations in the two pressure zones was 497 kW. If a continuous 24 hour per day, 7 day per week operation is taken into consideration, that equates to 4,353,720 kWh per year of energy use reduction.

Conclusions:

Based on the product calculations, it was estimated that each valve saves 44,000 kWh of energy, or 1,628,000 kWh per year in total for 37 valves. This is based on a 185-kW reduction in electrical demand and a 24/7 process operation. Preliminary pilot study results have indicated an actual (average peak) electrical demand reduction of 497 kW.

In addition, the valve timers were set for 15 minutes which is shorter than the original time used to estimate savings, providing even more water flow energy savings.

Also, since electrical demand varies significantly in these pumping station processes, moving forward the actual power consumption (kWh) will also be compared between baseline period and post retrofit data collected for the stations. Savings in the order of $200,000 per year are expected for this Phase 1 (Pilot) study and with a total installed project cost of under $90,000, the simple payback is under 6 months for this technology.

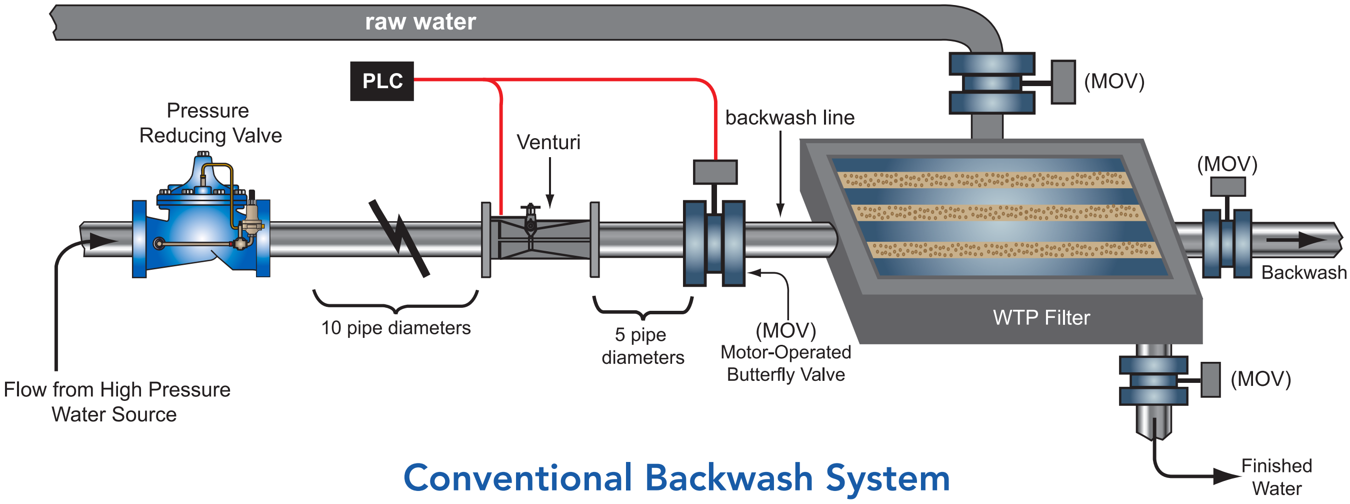
The pilot project has demonstrated that very significant energy savings and demand reduction for the City of Hamilton is achievable using the Anti-Stagnation valve technology in its pumping district zones.

Two more phases (2 and 3) are now in the process of being developed based on these preliminary findings. Phase 2 will involve the installation of an additional 37 valves providing an energy savings estimated at 400,000 kWh per year or a cost savings of $56,000. A Phase 3 project will also be initiated following this which involves the installation of a further 36 valves.

Hybrid Electronic and Hydraulic Valve Control

Plant and Network Lifesavers!

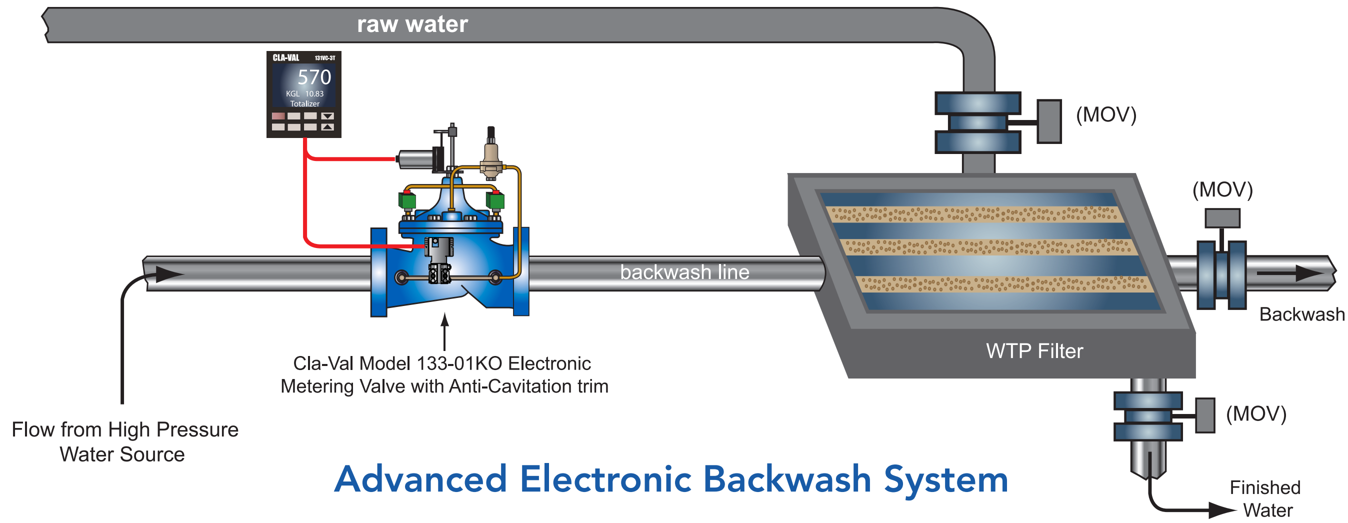
A recent visitor to our facility described the lengthy process that entails when a power failure occurs and what that means to his utility's water treatment plant operator. The operator has to quickly close fifteen motorized valves manually in order to prevent water overflowing onto the plant floor. The valves are usually controlled by a Programmable Logic Controller (PLC), to control flow into a filtration backwash process, utilizing venturi flowmeters. These types of valves are susceptible to cavitation problems and therefore a hydraulic Pressure Reducing Valve is normally installed upstream to reduce the pressure and prevent cavitation.



Conventional Backwash System

This traditional arrangement requires significant piping space for two valves and a venturi flowmeter. Furthermore, power failure to the motor operated valve can cause significant problems.

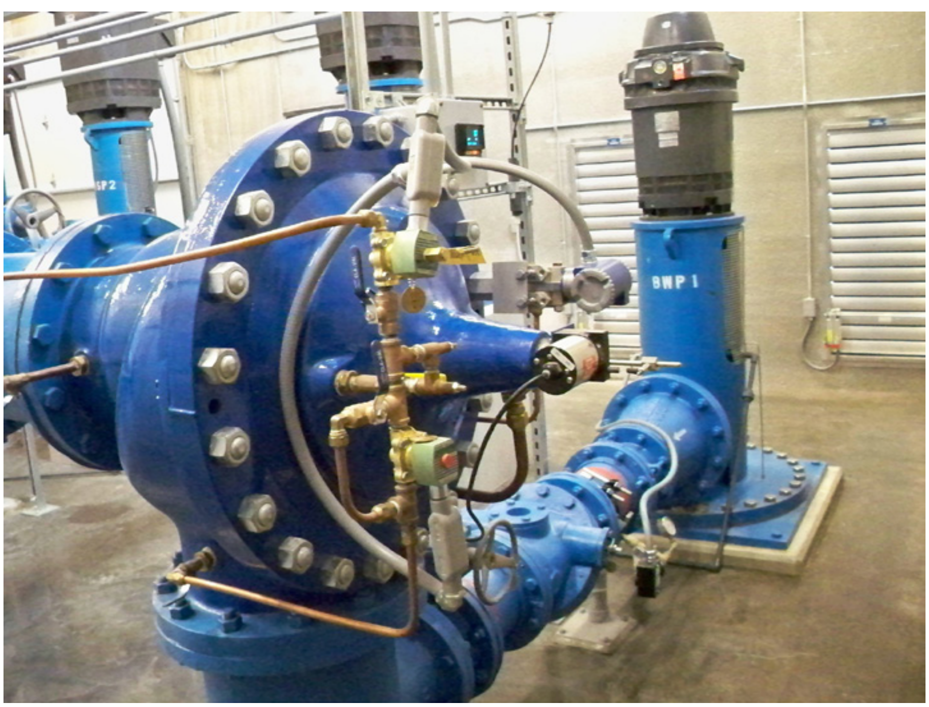
Fortunately, the hydraulic Pressure Reducing Valve can now be replaced with a hybrid multi-function electronic and hydraulic Metering Valve. This valve is capable of measuring and controlling flow based on valve position and differential pressure sensors installed on the valve. It also incorporates Anti-cavitation trim to prevent cavitation due to the high pressure drop into the filtration process.



Advanced Electronic Backwash System

The electronic Metering function utilizes dual solenoids and simply changing the upstream closing solenoid from Normally Closed to Normally Open will result in hydraulic valve closure when a power failure occurs. This allows the plant operator to handle other important duties when the inevitable loss of power happens. The single Metering Valve replaces the previous lengthy piping arrangement, saving significant space. And because the replacement valve discharges directly into the filtration process, a hydraulic pressure limiting function can be added to provide a "hydraulic guarantee" against over pressurizing the system.

Metering Valve with Anti-cavitation trim and "Power Failure Close" Solenoid

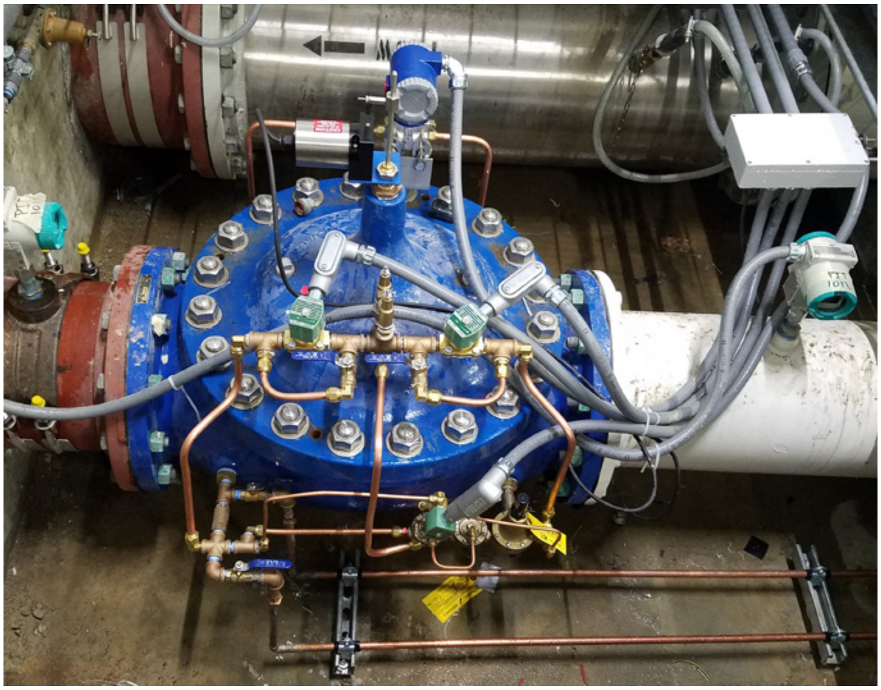


Hydraulic Pressure Reducing with Electronic "Time of Closure"

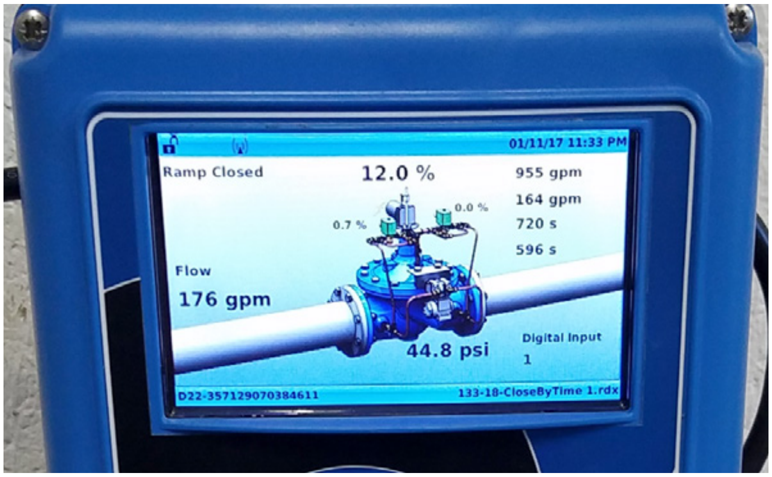
In another treatment plant application, this time utilizing prefabricated treatment equipment, a hydraulic Pressure Reducing Valve is used to limit the pressure into the process. A Relief Valve provides protection for a long, ten mile pipeline feeding into the plant, when a fast closing butterfly valve, shuts down the process.

The engineer's surge analysis determined that the Pressure Reducing Valve was required to close in twelve minutes when this occurs and a standard closing needle valve is really incapable of controlling these long closing times. The simple answer was to modify the pilot control system to perform a switch between the normal pressure reducing function and electronic controlled closing of Metering Flow to zero flow, in a programmable time period.

Hydraulic Pressure Reducing Valve with Electronic Controlled Time of Closure



A third solenoid installed, switches between the normal hydraulic control to electronic control when the system shuts down. Operators can easily see on the valve controller screen the status of the closing sequence. They are also able to adjust closing times, if the required closing time requires amendment.



This valve therefore accomplishes two very important functions. A hydraulic pressure reducing function during normal operation, and an electronic "Time of Closure" function to prevent surging in the long upstream pipeline.

Numerous Hybrid Electronic and Hydraulic Combinations

Many other hydraulic and electronic functions can be combined onto one valve, which can reduce the number of valves in an installation, protect aging and sensitive pipes, or prevent overflow of tanks and reservoirs. A particularly popular combination is an electronic flow control with a hydraulic pilot control to limit downstream pressure. This example of hybrid electronic and hydraulic control allows normal electronic flow control unless downstream pressure exceeds the limit of the hydraulic pilot setpoint.

Electronic Flow Control Valve with Hydraulic Protection of Downstream Piping

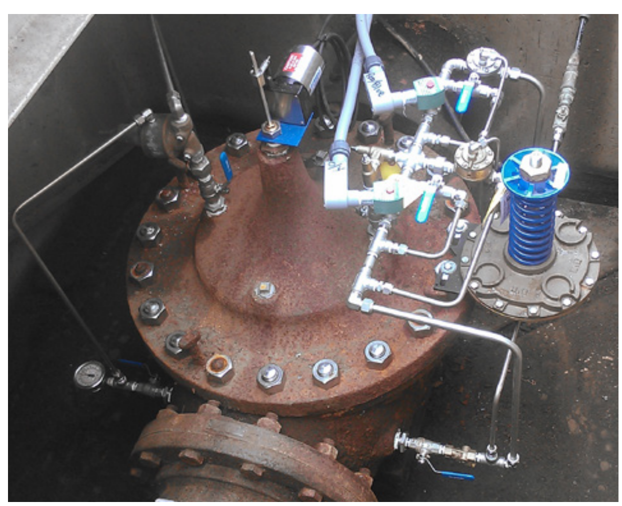
At one recent project startup, an electronic flow control valve began to open, but was unable to barely crack open. A check of the downstream pressure gauge revealed that downstream pressure had already reached the setting of the pressure limiting pilot control. It transpired that the water district had forgotten that an isolation valve had been closed some distance downstream. In effect, the hydraulic control system prevented a pipe break from occurring.

In fact, the electronic control system is capable of multiple functions such as flow control and pressure reducing. In this instance, the hydraulic pilot can be used as "backup insurance" where the pilot control adjustment is set to not interfere with normal electronic multi-function control. Normal operation consists of electronic flow control and electronic pressure reducing control and seamlessly transfers between functions with specialized software. In the event of power failure, or solenoid malfunction, the hydraulic pilot will take over and limit downstream pressure, preventing pipe breakage.

Up to four modulating electronic functions are possible, including flow, pressure sustaining, pressure reducing, and level control. Reservoir level control for example, can include flow control and pressure sustaining control. Conversions of existing Altitude Control valves often include the hydraulic Altitude Control pilot for backup control to prevent overflowing of a tank. Often there is a long pipeline upstream of these valves which is susceptible to surging during valve closure. A hydraulic "Surge Relief Override" pilot control prevents this in case of faster than normal valve closure.

Hybrid Electronic Multi-function Valve Conversion with Altitude and Relief Override Pilots

Motorized valves are typically used to control a single function and offer limited or no capabilities to provide multiple electronic functions with hydraulic backup functions. Replacing these valves with hybrid electronic and hydraulic control can certainly reduce the number of valves required and can offer very useful "insurance" against power failures and costly line breaks.



Multi-Functional Control Valves!

The Mount Pleasant Experience

Mount Pleasant is a charming, historic town just across the Cooper River from Charleston, South Carolina. The Charleston harbor, rivers and creeks infuse a coastal spirit so unique that it lures people to visit and live in its wonder. The area boasts a variety of water recreational activities, wonderful restaurants with great views, as well as inspired golf courses. English settlers arrived in 1680 sparking a tidal wave of patriotic activity during the Revolutionary War as well as the Civil War. Significant military landmarks and museums pay tribute to the CSS H.L. Hunley and USS Yorktown located at Patriots Point Naval and Maritime Museum. The region's historic landmarks and natural beauty coupled with the friendly people, attract many visitors each year as evidenced by being designated "America's Most Friendly City" and "World's Best City" by Travel & Leisure

Mount Pleasant's growth is unmatched in South Carolina, making it the largest town in the state with a population of 87,710. Nestled in this booming coastal region is Mount Pleasant Waterworks, a public utility that serves the town by providing potable water from two sources; ground water from the Middendorf Aquifer is pumped from six deep-wells and treated at four Reverse Osmosis Treatment plants, and surface-treated water from Charleston Water System. Water is stored in six ground storage tanks, and one elevated tank. Two active aquifer storage and recovery (ASR) wells also provide water during high demand periods.

The Water Department at Mount Pleasant Waterworks was experiencing some control issues with two booster pump stations, Wando Park, and Highway 41. Filling the reservoir at a desired rate had to be done manually. This made it difficult to peg the exact flow necessary to manage water moving to storage and what was needed in the distribution system. At this point, MPW staff to include Chris Martin, SCADA and Electrical Supervisor, and Tony Hill, Operations Foreman, decided to improve control capabilities involving these assets. The utility already had a state-of-the-art SCADA system utilizing cellular technology so the ability to control a valve remotely seemed like a good solution. The valve would need the capability to control flow based on an operator setpoint while ensuring that system pressure is maintained above a critical operating point. Also, a method to prevent cavitation was necessary due to the high-pressure differential from filling a low-pressure tank from a high-pressure water distribution system.

After doing some research, it was determined that an existing valve could be retrofitted to suit the new requirements. However, MPW had to decide between two options for the controlling pilot system; mechanical or electronic. A mechanical system would require a motorized rate of flow control pilot with an orifice plate and sensing element to achieve adjustable flow control, and a pressure sustaining pilot to maintain system back pressure. The electronic system was a much simpler option; requiring only two electronic solenoids and an electronic controller to achieve the desired flow control and back pressure sustainability. The less complex electronic system would also make future valve maintenance easier when compared to the mechanical. The electronic pilot system was the clear choice and was installed with an anti-cavitation trim to prevent cavitation.

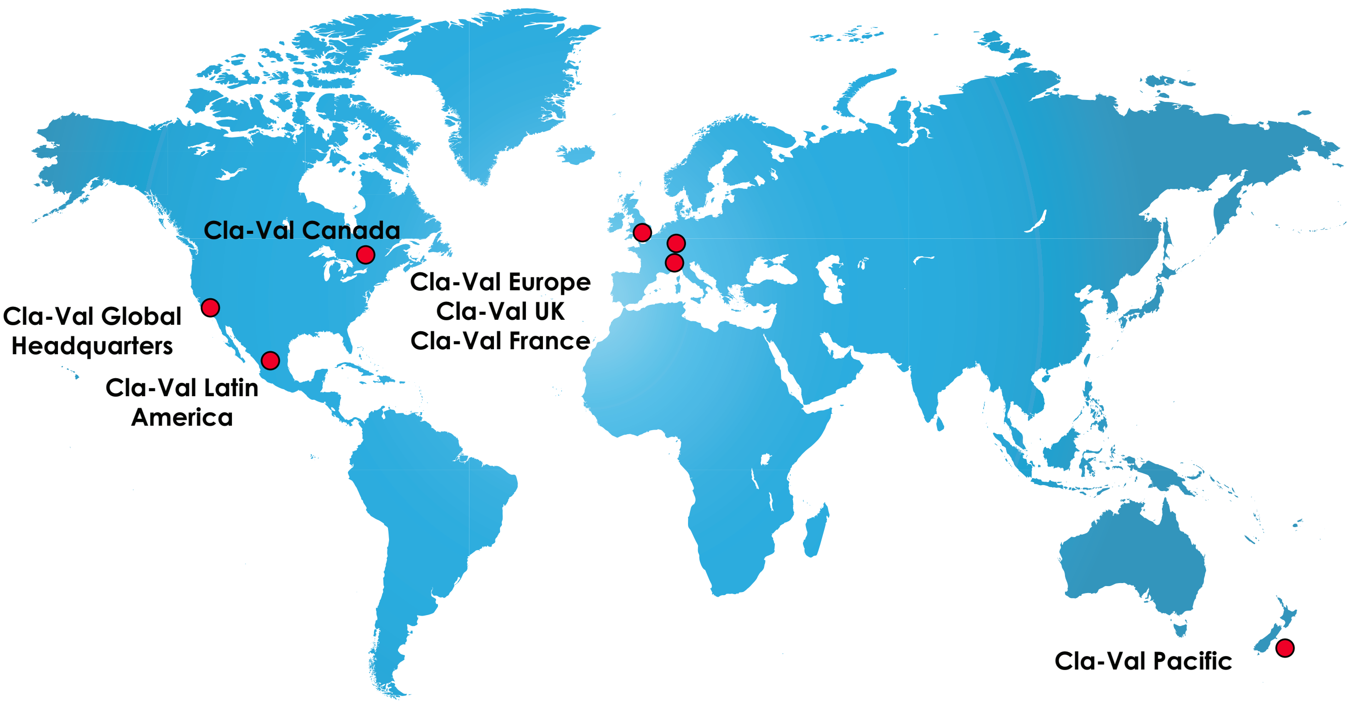
The burden of installing a supporting flow meter and a pressure instrument was also avoided by utilizing the electronic control system. Inlet and outlet Model X141-PT Pressure Transmitters along with a Model X117D valve position transmitter were retrofitted to the existing ports on the valve. The transmitters were wired into the supplied VC22D electronic controller, which allowed the controller to see upstream distribution pressure for sustainability and to determine flowrate through valve for adjustable flow control. This all-in-one solution bypassed the need to reconfigure existing piping for additional instruments.

The VC22D electronic controller came preloaded with a variety of typical valve control applications including valve characteristic flow calculations, adjustable flow control, and pressure sustaining control—all the desired control features for MPW's application. The controller was wired back into MPW's SCADA system through a local PLC--giving full remote valve control and feedback. The commissioning of the tank fill system was simplified by the controller's full color graphical display and preloaded applications which alleviated the need for custom programming and loop tuning.

Chris Martin, the SCADA and Electrical Supervisor, was pleased with the fact that the new controller was extremely easy to set up, with loop tunings being performed right on the unit. This saves his department valuable time. In fact, it can be tuned remotely with factory support which was a real benefit during the learning curve. He is also very pleased with the multi-functionality of the new generation of control valves using dual solenoid control that can be controlled remotely and can perform multiple duties, all electronically.

This initial installation proved so successful that the Water Department has added three other valves with the same configuration, also supplied with valve controllers. Tony Hill, the Water Operations Foreman, states that he is "very happy with the new valves. They get great control and are very easy to maintain".

THE VALVE CHRONICLES
Volume One



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