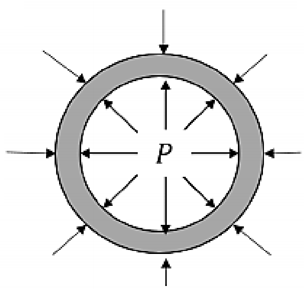
Solutions for Surge Alleviation

30" pipe burst - Fisher Road, Kingswood Bristol (Kevin Henderson Bristol Water)

INTRODUCTION

The Cause of surges in pipelines

Transporting water from source to tap requires energy in the form of a pressure differential. This is either provided naturally by gravity or artificially with a pump. Pipelines are subjected to varying degrees of axial (hoop) stress due to dynamic changes in pressures and flow.



Premature failure can arise when pressures either exceed the rating of the pipeline, or the cumulative effect of pressure variability over time.

This document focuses on pressure transients and surges in pipe systems and offers some practical and cost-effective CLA-VAL product solutions for either preventing or limiting the severity of pressure variability.

When specifying pipelines, several factors are taken into consideration including flow capacity, maximum pressure, loss coefficient (K factor), Materials of construction, components (valves etc).
For pumping applications, safeguard against the risks of transients and consequential asset failure should be considered. Surge or transients are caused by a sudden change in fluid velocity. This can be caused by a variety of reasons such as: pipe failure, air entrapment, human intervention e.g Valve Ops, incorrect product selection (or set up) and pump start/stops.

Pressure and velocity changes in a pipeline are inseparably related in accordance with the Joukowski equation :-

$$\Delta h \quad \frac{c\Delta v}{g}$$

Where $\Delta \boldsymbol{h}$ = Head change (m)
$\boldsymbol{C}$ = Wavespeed (m/s)
$\Delta \boldsymbol{v}$ = Velocity change (m/s)
g = Acceleration due to gravity (m/s^2)

Example: *ΔV of 1 m/s in metal pipe will produce a ΔP of 100 Mhd (10 bar!)*

A change in flow will directly cause a change in pressure and vice versa. When pumps are started, sudden pressure changes are propagated through the pipe system as the water accelerates from rest to its design flow. When the pumps are switched off, there is a change in velocity as the system de-pressurises. An illustration of these effects is illustrated on the next page. Variable Speed Drives (VSD) help to mitigate the effects of sudden pressure changes by controlling pump start and stop speeds, however these dampening controls are rendered useless in the event of a power failure, exposing the pipe system to the risk of surge and possible failure.

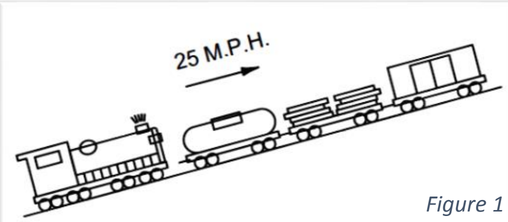


Figure 1

A locomotive is pushing a train up a gradient. This compares with a pump delivering water to a higher elevation through a pipeline. The locomotive has stopped abruptly (fig.2) but the momentum carries the train forward up the gradient. The same condition exists at the pump discharge upon power failure to the pump. The momentum of the water column continues to carry it forward, creating a downward pressure wave at the pump discharge.

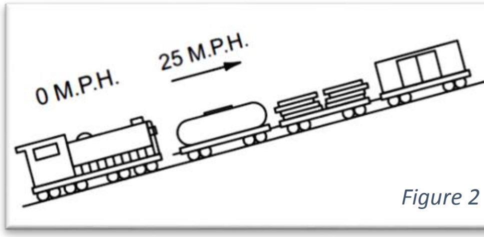


Figure 2

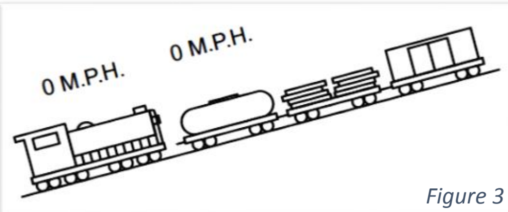


Figure 3

The train stopped (Fig.3) after expending its energy in moving up the gradient. The water column in the pipeline has likewise come to rest.

The train has now started coasting backward (fig.4) down the track and is about to collide with the locomotive. The same is true in the pipeline, the water column reverses and flows back down the pipeline toward the pump with approximately the same velocity as before the pump failed.

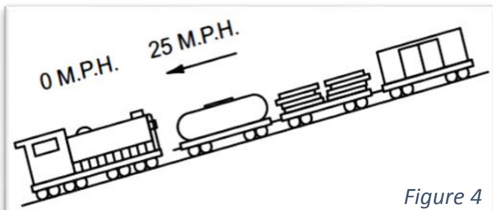


Figure 4

The moving train collides with the stationary locomotive with disastrous results (fig.5). When the water returning back down the pipeline is stopped by the closed system check valve, a high-pressure wave develops. The sudden stopping of the pump can be damaging to the pipeline and the pumping equipment, similar to the wrecked train. The magnitude of the high-pressure surge is directly proportional to the rate of change of the velocity of the fluid. A 10 bar surge will occur for each meter/sec change in the velocity of the fluid. A surge anticipator valve can control the high pressure at the check valve. The returning train being switched to a side track, averting collision with the locomotive.

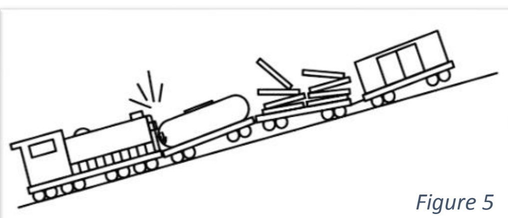


Figure 5

A CLA-VAL Model 52-03 surge anticipator valve acts in the same manner as the side-track and the train (fig.6) directing the surge to atmosphere, protecting the pump and the system. figure 2 mentioned the creation of a low-pressure wave. This was the result of the abrupt stopping of the pump and the water column rushing away from it. The surge anticipator senses the low-pressure wave, then opens. This prevents the high-pressure wave from building up against a closed system check valve. Eliminating damage to the pump and system. This type of action is how the valve derives its name. Anticipating the high-pressure wave and effortless bypassing it from the system.

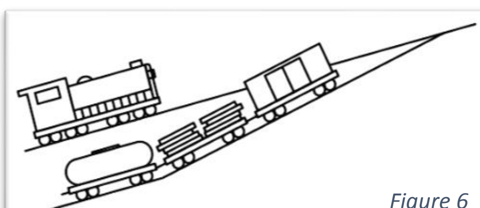


Figure 6

CLA-VAL Model 52-03 Surge Anticipator and Pressure Relief Valve

This valve is typically installed near a pump on a discharge line to atmosphere. When pumping systems are started and stopped gradually, harmful surges do not occur. However, should a power failure take place, the abrupt stopping of the pump can cause dangerous surges in the system which could result in severe equipment damage.

When the pump trips, the subsequent low-pressure wave (black line in Fig.1) is sensed by a low-pressure hydraulic pilot which triggers the control valve to begin opening in anticipation of the returning positive pressure.

The high-pressure hydraulic pilot triggers the valve to open further if the subsequent high pressure exceeds its pressure setting (red line in Fig 1.) Once steady state is restored, the valve closes drip tight. If hydraulic modelling identifies the risk of sub atmospheric pressure, the Cla-Val NUVENT Anti-Shock air release and vacuum breaker valve will prevent pressure falling below atmosphere by admitting air into the pipeline. As the pressure starts to rise again, air is discharged slowly to minimise the magnitude of the pressure transients throughout the transition to steady state.

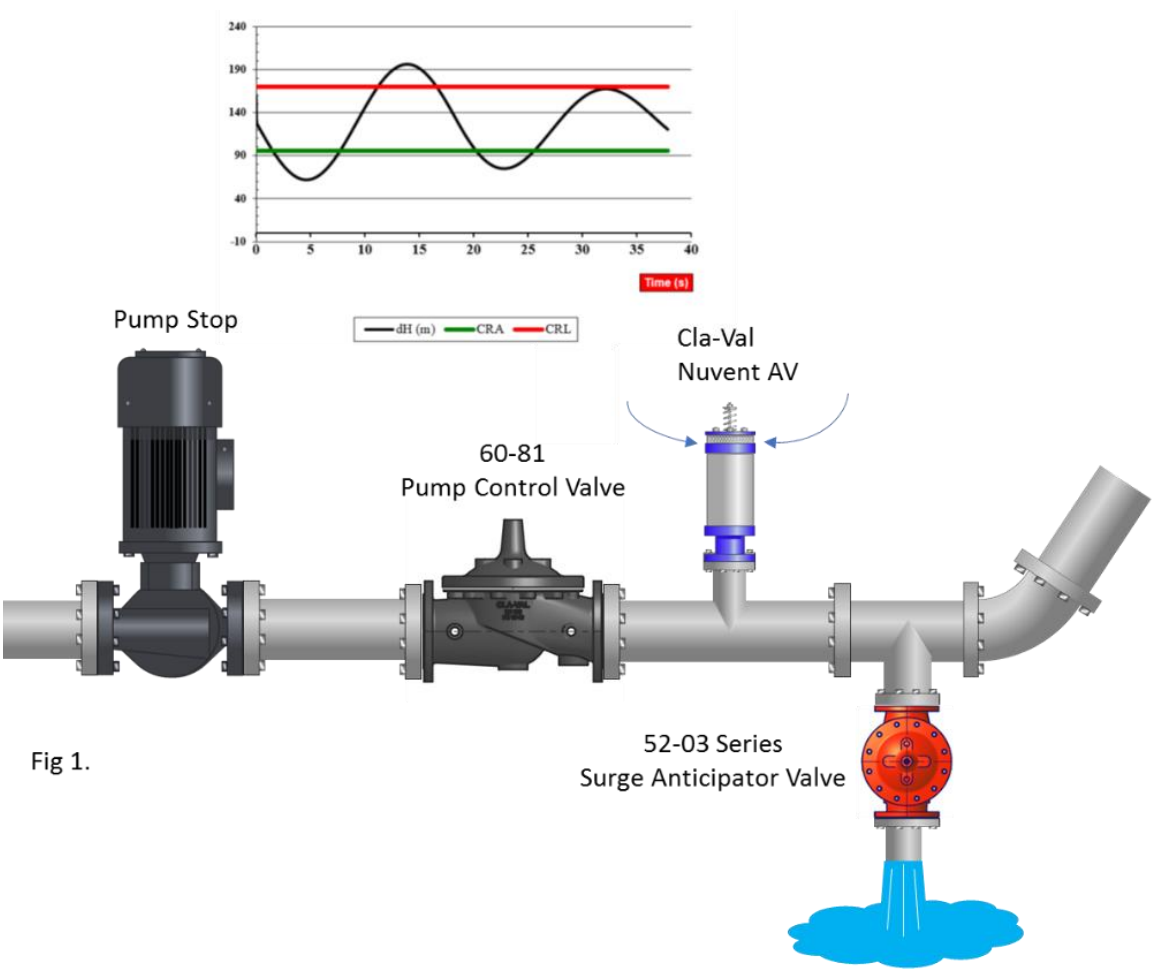
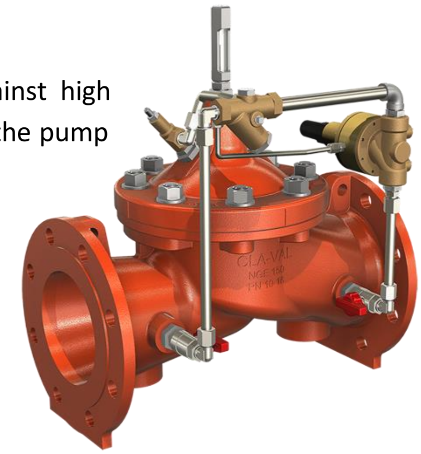
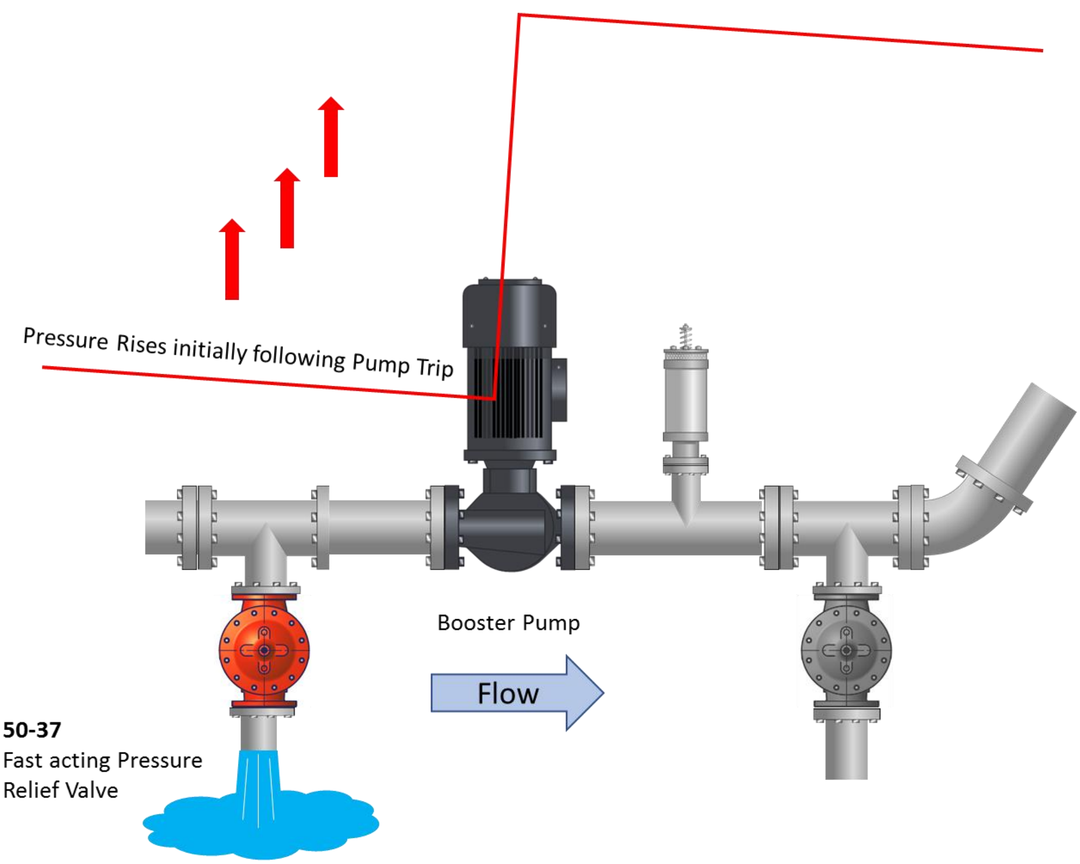


Fig 1.

CLA-VAL Model 50-37 Fast Acting Relief Valve

This valve type is installed to protect the system or installations against high pressure surges when pumps are shut down. The valve is installed near the pump suction, providing rapid opening and progressive closing.





CLA-VAL Model 60-81 Pump Control Valve

Fixed speed pumps without adequate surge protection or controlled starts can cause a positive shockwave on start up as it suddenly pushes against a static volume of water in the pipeline.

The CLA-VAL model 60-81 Pump Control Valve provides a controlled opening to facilitate a gradual pressure rise on pump start up. The valve also provides a slow closure on the pump stop sequence and incorporates an integral check feature.

<u>Operating Sequence</u>

The pump starts against a closed valve. The valve mounted solenoid is energised and the valve begins to open slowly, gradually increasing line pressure to full pumping head.

When the pump is signalled to shut-off, the solenoid is de-energised and the valve begins to close slowly, gradually reducing flow while the pump continues to run. When the valve is closed, a limit switch assembly (which serves as an electrical interlock between the valve and the pump) releases the pump starter and the pump stops. Should a power failure occur, a built-in lift-type check feature closes the valve as soon as flow stops, preventing reverse flow regardless of solenoid or diaphragm assembly position.

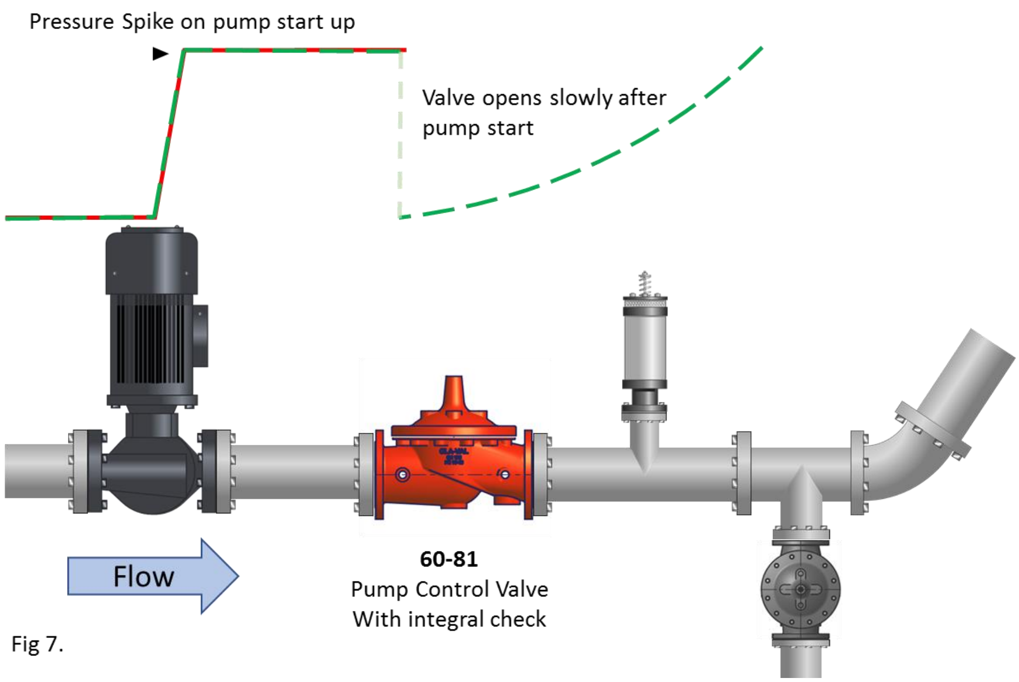


Fig 7.

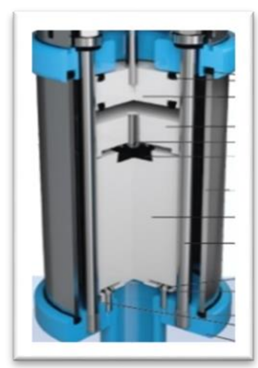
AIR VALVES

Trapped air in pipelines can result in a variety of problems including surge and water hammer. These can result in premature pipe failure and loss of pump efficiency. Although these factors alone are sufficient justification for an air valve installation, the presence of air can also result in organic growth and risk of internal pipe corrosion.

Many traditional air valves rely on hollow spherical floats for buoyancy and sealing. During a surge/transient event, floats are susceptible to jamming or deformation as they are slammed into their seat. As a result, damage can prevent them from sealing effectively resulting in leaks.

When venting air under normal operation, the floats can also be dynamically drawn (sucked) up onto its seat (called the venturi effect) leading to premature closure, preventing further discharge of air. This can result in longer pipeline filling times and loss in pipeline efficiency.

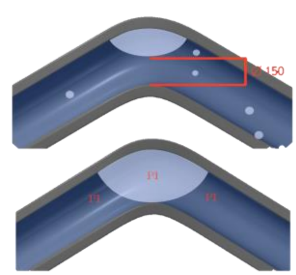
The CLA-VAL NUVENT Is an ‘Anti-Shock’ Air Release and Vacuum Breaker Valve that provides an effective solution to overcome these design deficiencies. It provides high-capacity air discharge, for example during pipeline filling. Then, as water enters the valve the three internal floats are buoyed and compressed together closing the valve drip tight.



However, If the air discharge velocity is too high, the sudden impact of the water on the floats can result in damaging surges in the vicinity of the valve. The NUVENT overcomes this by automatically and hydraulically switching into ‘**Anti-shock**’ mode, reducing the approach speed of the water and minimising the risk of water hammer. This is particularly relevant at high points along pipelines prone to column separation in the event of pump trip around the discharge of booster pumps and borehole pumps.

In the event of burst pipe or when the pipeline is being drained, the air valve provides full vacuum breaking capability to allow rapid ingress of air into the pipeline to prevent pipe collapse.

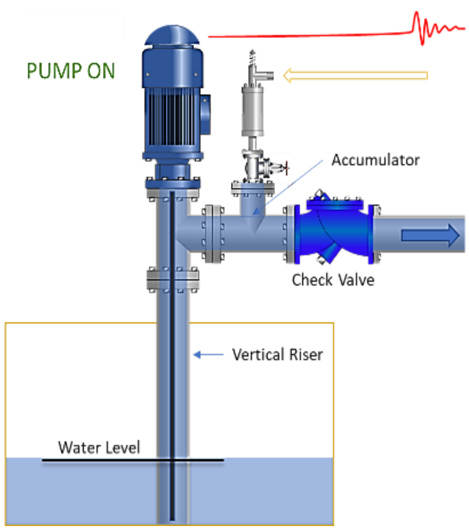
When water is pumped, entrained air can accumulate at high points along the pipe.



If air is not vented, it can lead to pump inefficiency, pipe corrosion or water quality problems. Along pipeline high points, air locks and possibly surge/water hammer events can occur as the air pocket is dragged downhill with the flow of water. The NUVENT collects air inside the valve body. Eventually, the air pressure displaces the lower ‘large’ float exposing a small orifice and releasing this residual trapped air.

200mm Pipe shows loss of efficiency as air accumulates eventually leading to an air lock. This means the pumps are forced to work harder or longer to meet the flow demand.

Air valve placed subsequent to a pump but prior to a check valve on a borehole pump



An air valve is essential to prevent large volumes of air entering the pipeline during pump start-up and to prevent a vacuum when the pump stops. A conventional air valve is not suitable for this application as it will either induce water hammer on closure of the large orifice or, not close at all due to the rapid water velocity, or close prematurely and trapping large pockets of air resulting in operating problems.

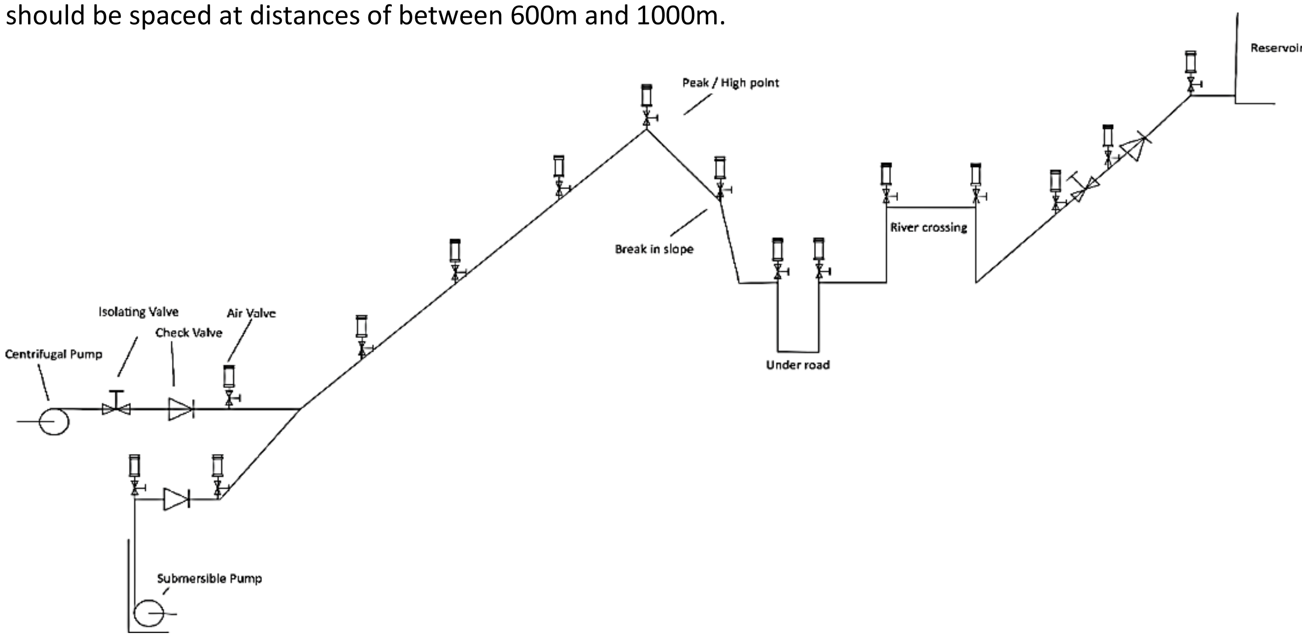
CLA-VAL NUVENT model 70-516B

controls the discharge of air to eliminate water hammer problems as well as adequately protect against vacuum conditions. The air valve selected, should be sized on pump discharge velocities.

Sizing and positioning

Air valves should be located at high points or changes in an upward or downward slope as shown in the figure below. Valve sizing is based on pipe diameter, velocity.

In horizontal sections of pipe, air pockets are less likely to be transported along the pipe therefore, air valves should be spaced at distances of between 600m and 1000m.



CHECK VALVES

Check valves play an integral role in alleviating surge events in pumped water systems. Their primary role is to stop flow reversal when a pump stops, however, little thought is often given at design stage into the right choice of check valve for the application.

In higher velocity applications, check valves have the potential to cause water hammer as the column of water travelling backwards gains speed before the check valve has time to close. This is a phenomenon known as check valve slam.

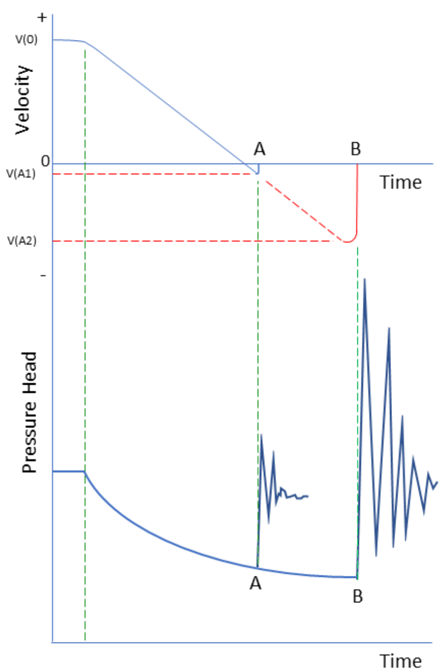


Fig1. – Taken from Fluid Transients in Pipeline Systems:
Author A. R. D. Thorley.

The graph in Fig 1 shows the difference that time makes to the resulting surge wave when the returning velocity is kept to absolute minimum. To overcome this phenomenon the ideal check valve must close quickly to avoid flow reversal. Section '**A**' illustrates the performance of a fast-closing valve relative to a valve with a slow reaction speed (section '**B**').

Secondary, though just as important, check valves create resistance thereby adding friction losses to the pipe system. This is can sometimes be overcome by increasing pumping pressure albeit at the expensive of additional energy costs.

CLA-VAL Model Aqua 30-601

This is a spring loaded axially guided check valve with a resilient sealing mechanism which combines a valve with very low head-loss whilst operating in the normal direction of flow coupled with a fast-closing characteristic on flow reversal to mitigate water hammer when the pump is off. This is achieved using a conical rear section, connected to the valve plunger. When fully open, vortices and frictional losses are reduced within the valve, minimising the risk of cavitation in the attached pipework.

Swing-Flex®

This Check Valve has a non-slam closing characteristic achieved by utilizing a "Short Disc Stroke" in conjunction with the unique "Memory-Flex™ action" of the valve's disc. The 35° stroke, a result of the angled seat, is less than half the typical 80° to 90° stroke of a conventional swing check valve. The streamlined contour of the Swing-Flex® body provides 100% flow area with no restrictions at any point through the valve and typically halves the head loss of a conventional swing check, plus significantly reduces pressure transients.

Surge Buster & Nozzle Check Valves are available on request

It is extremely beneficial for the check valve to close quickly, however in some applications a slow closing valve with linear characteristics can provide a similar effect by slowing the returning column of water gradually and in controlled manner to minimise the effects in causing water hammer. Typically used in conjunction with a CLA-VAL 52-03 series Surge Anticipator Valve.

CLA-VAL Model 81-01/81-02

This valve is to be used when a positive shut-off is required. It is typically installed on the discharge of pumps or well pumping systems to prevent backflow when the pump is off.

This type of check feature is often added as a secondary function other Cla-Val control valves including: Pressure sustaining, pressure reducing or flow control.