Reducing pressure surge water losses: combining air valves and bladder surge tanks

Pressure transients within pipelines can cause damage to components and over time weaken pipes and joints, leading to cracks and bursts and high levels of water loss. In the latest article from the IWA Specialist Group on Water Loss, **SHARON YANIV** outlines research undertaken into the use of air valves and bladder surge tanks to control surges.

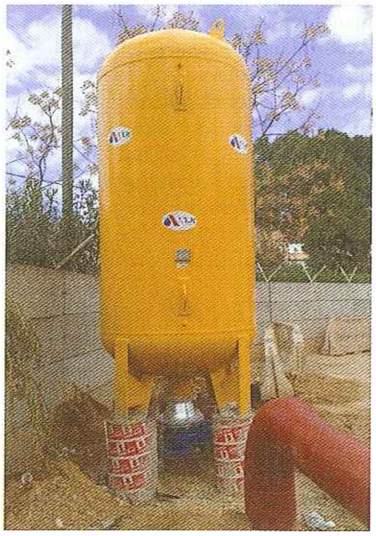
Many pipelines suffer from cracks and faulty joints, seals and gaskets, resulting in water losses. In potable water transmission the loss of often-expensive treated water results in loss of revenue for the water company or municipality. This loss, at times of drought, can even result in a shortage of drinking water.

Pressure management provides one important means of controlling water losses. Managing sudden changes in pressure within pipelines is a means of preventing or limiting leaks that are causing cracks in the pipelines in the first place. These so-called hydraulic pressure transients (surges) are one of the most prevalent causes of pipe damage, including pipe bursts, pipe collapse, pipe cracking and pitting, leakage and intrusion.

Pressure transients can be described as waves with both positive and negative amplitudes. They are caused by sudden extreme changes in flow velocity, brought about by events such as pipe bursts, sudden changes in demand, sudden pump start-ups and shut-offs, opening and closing of fire hydrants, rapid closing and opening of in-line isolating valves, flushing and draining operations, fire flow, feed tank draining, etc.

Pressure transient analysis has revealed the importance of both positive and negative pressure transients (up-surges and down-surges). Pressure surges that occur at the source (pump stations) have economic consequences as these extreme transient events cause pump damage. But surges can also occur along the pipeline when two or more waves of similar amplitude (positive or negative) meet, increasing their size.

Most pressure transient events are accompanied by water column separation. If water column separation occurs and nothing replaces the parting water column, a void is left behind, pressure drops and a down-surge occurs at the point of separation.



Pressure surge vessel installed at the case study location in Natanya, Israel.

When pressure drops below the vapour pressure of the liquid, some of the liquid vaporises, filling the void with vapour. This void is called a 'vapour cavity'.

After a series of recurring transient events (both up-surges and down-surges), the pipe will eventually rupture. These transients do not have to be extreme. Even very slight transients can induce this pipe deterioration process, and not only over long periods.

Restraining and controlling pressure transients

Air valves are the most cost effective tools for protection against damage from most of the common pressure transient events. There are three major types of air valves: air-release valves, air / vacuum valves, and combination air valves.

An air / vacuum valve (kinetic air valve) has a large orifice that discharges air during pipe filling and water column return (following water column separation), and during sudden, extreme pressure drops. Because of the size of the orifice, this type of air valve will not open when the pipeline is full and pressurized. It will only open when internal pipe pressure is lower than the external pressure. Because of its high capacity for air intake, this type of air valve is essential for down-surge control, and is sometimes called a 'vacuum breaker'.

An air-release valve (automatic air valve) has a small orifice that is capable of opening even when the pipeline and air valve are under pressure. The air-release valve releases small volumes of air that accumulate in its body, thus preventing the development of air pockets in the pipeline. When properly located and assembled along a pipeline, air release valves can prevent any air from accumulating.

A combination air valve (double orifice air valve) combines the functions of the air / vacuum valve and the air release valve either in one body or in two bodies connected via a pipe. This is the most commonly used type of air valve since in most cases both functions are required at the same location.

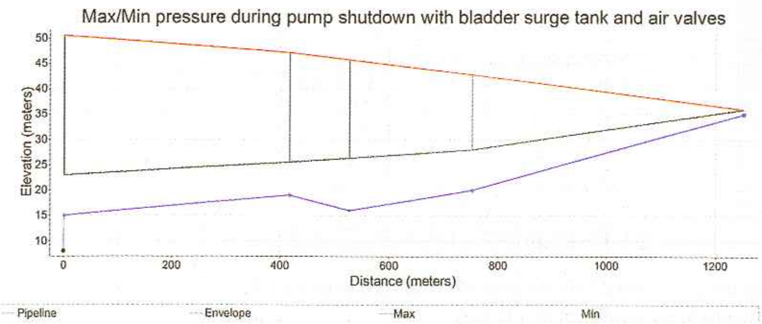


Figure 1: Case study simulation of max/min pressure during pump shutdown with bladder surge tank and air valves. See text for explanation.

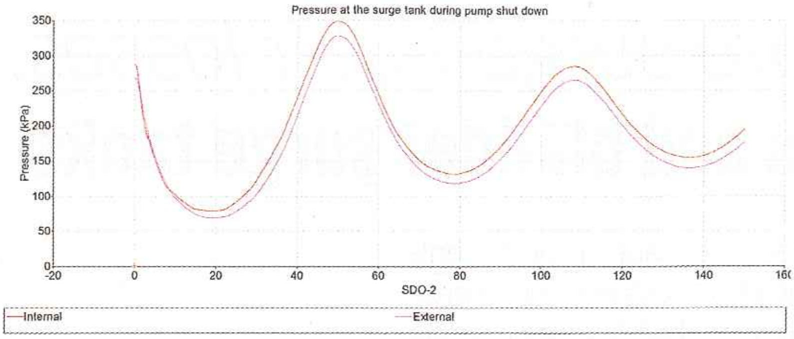


Figure 2: Predicted pressure at surge tank, showing maximum pressure of 34 metres (330 kPa).

A bladder surge tank is a large-capacity unit used in water pumping stations and municipal water applications. The purpose of a bladder surge tank is to absorb and control surges in pipelines, increasing the life of the components of water infrastructure systems and, together with air valves, reducing water losses.

Case study: bladder surge tank installation

A case study was evaluated to provide insights into the application of a bladder surge tank. It is difficult to carry out such an assessment, not least because of the need to shut down pumps – something that is not usually possible at a water supply installation. The assessment was carried out at the Pardes Hagedud sewage pumping station in Natanya, Israel. Despite being a sewage pumping station, this nonetheless provides insights that are equally applicable to water supply. The case study also allowed a comparison between design assessments and practical results.

The Pardes Hagedud sewage pumping station has two 1450 rpm submersible pumps, each with a capacity of $360m^3$/hour, with 35 metres of head. Either one pump operates or both in parallel. The station feeds a 1200 metre, 400mm diameter PVC PN10 delivery pipe which begins at an altitude of 7.5 metres and terminates at an altitude of 32.2 metres.

As a result of a surge analysis it was determined that a bladder surge tank with a volume of $5m^3$, diameter of 1.5 metres and a height of 3.2 metres (according to specifications from the manufacturer) was required at the site. According to calculations a bladder surge tank of this volume has a water level of 1.7 metres and the pre-charge pressure within the bladder is 0.5 bars.

A bladder surge tank and an air valve were then installed approximately 10 metres from the pumping station, before the water meter. The surge tank was installed at an elevation of 15 metres.

According to a surge analysis of a simulated electrical shutdown at the station with a bladder surge tank in place, the highest pressure at the pumping station is 43.5 metres and at the bladder surge tank is 34 metres, with no drop in pressure below the pipe profile. This is shown in Figure 1 (expressed as metres of elevation) as the difference between the maximum predicted pressure (red) and the pipe elevation (blue, starting at 7 metres and rising immediately to 15 metres, the elevation of the surge tank). The air valves will mainly discharge air during the filling of the pipe, release air when the system is under pressure, and admit air during emptying of the pipe. The predicted pressure at the surge tank during the pressure transient is shown in Figure 2.

A number of trials were then carried out operating and shutting down the pumps. Pressure readings were taken with a pressure transducer and data logger which gives a reading of a hundred readings per second.

According to a trial where both pumps were shut down, but without using the bladder surge tank, the pressure at the pump station reached 50 metres, where at this point the air valves admitted air during the pressure reduction in the pipe and discharged air when the pressure rose. The pressure in the pipeline is shown in Figure 3.

In a trial where both pumps were shut down but the bladder surge tank was connected, the maximum pressure reached only 35 metres, corresponding to the surge analysis simulation. There was a drop in pressure to three metres, meaning the bladder surge tank prevented the pressure from dropping below the pipe profile (vacuum). The pressure in the pipeline is shown in Figure 4.

Summary

The results indicate that the installation of a bladder surge tank prevents the sudden increase of pressure when both pumps are shutdown. Moreover, the bladder surge tank prevented a drop in pressure below atmospheric pressure (vacuum) of the system. The results also show that the air valves operated as required (admittance and discharge of air) and will continue to do so as long as the appropriate maintenance is carried out. The bladder surge tank requires minimal maintenance and is thus considered to be a worthwhile and efficient tool for surge protection in conjunction with air valves. Finally, the results of these field experiments conform very well with the surge analysis carried out using the analytical tool, Surge 2008, with air valves in combination with a bladder surge tank.●

About the author
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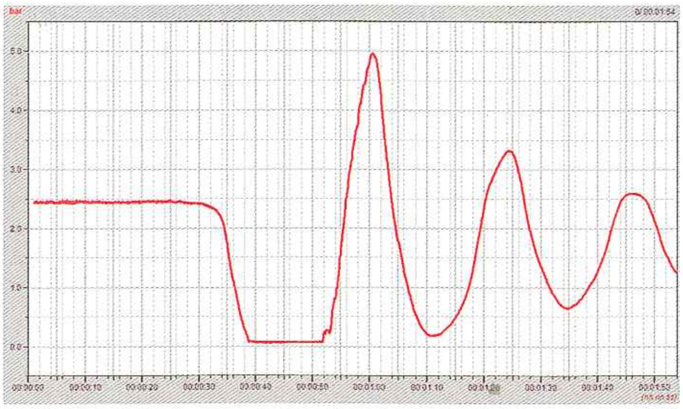

Figure 3: Pressure during shutdown of the two pumps without bladder surge tank, showing pressure peak of 50 m (5 bar).

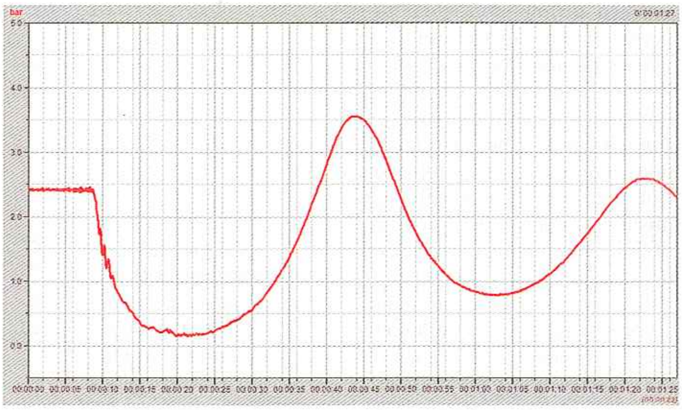

Figure 4: Pressure during shutdown of the two pumps with $5m^3$ bladder surge tank, with pressure peak of 35 m (3.5 bar) and pressure drop to 3 m.