Surge Protection can Minimize Damage to Pipes, Valves, Pumps

By Joe Cheema

Any type of fluid distribution system can be seriously damaged by sudden changes in flow and the resulting water hammer. Though the topic has been known for as long as there have been pumped systems, the research into the mechanism and how to mitigate it continues.

The first thing to understand is that surge is very different from pulsation.

Surge protection devices.

The latter is the regular acceleration and deceleration of the fluid, typically caused by the cyclical actions of a reciprocating pump. While pulsation can be solved by installing a properly sized pulsation dampener at the pump outlet, surge is less predictable and can cause severe damage to pipes, valves, fittings and pumps.

Water systems never operate at a constant pressure. Pumps going on and off line, changes in temperature, demand and tank levels alter system flow rate and pressure at any given time. A mild change, called a surge, results from water pressure oscillations within the system and can damage pipes, valves and fittings.

The more severe waterhammer, on the other hand, comes about when there is a sudden change at either the inlet or outlet of a system. Pumps suddenly going on or off line or valves rapidly closing are the most common causes.

When an outlet valve suddenly closes, the energy contained in the water flow compresses the water nearest the valve. Like a spring, this energy then reverses flow, sending a shockwave at the speed of sound back upstream until it hits an obstruction: a joint, another closed valve or the impeller in the pump. Most of the energy from that shockwave then bounces off that obstruction and returns to hammer the valve. The wave travels back and forth between the obstruction and valve until friction finally dissipates the energy.

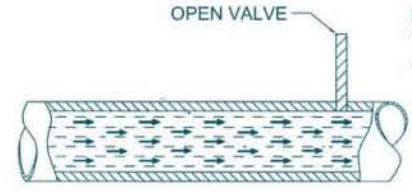

Fig. 1. STEADY STATE FLOW WITH OPEN VALVE

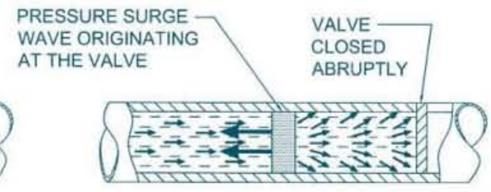

Fig. 2. SURGE SUPPRESSOR DURING ABRUPT VALVE CLOSING

Surge Mitigation

While it is theoretically possible to build a water distribution system strong enough to withstand the stresses caused by water hammer, it is neither practical nor necessary. Rather, one must locate the potential trouble spots, determine the possible damage and implement a cost-effective strategy to mitigate the effects.

Engineers can model their own system (pipes, valves, pumps, turbines, surge tanks) using the free Windows-based Water Hammer and Mass Oscillation 3.0 (WHAMO) desktop application developed by the U.S. Army Corps of Engineers' Construction Engineering Research Laboratory (www.cecer.army.mil/usmt/whamo/whamo.htm). The software calculates the changes in flow and pressure in the system based on variations in operation of the pumps and valves. It can be used to locate problems in the current setup as well as help in designing methods to eliminate or mitigate water hammer.

Since there are multiple sources of water hammer, a comprehensive approach is needed to address each of the sources. There are several strategies for reducing pressure changes at the pump. Using multiple pumps minimizes the affect of a single pump starting or stopping. Having a spring loaded check valve near the pump outlet prevents backflow and pressure drop in the pipe while the pump is starting. Using a discharge valve that is slowly opened and closed during startup and shutdown will eliminate rapid flow and pressure changes.

A relief valve installed at a critical point in the line can also be used to bleed off excess water during a surge, thus limiting the impact of the water hammer event. Since the valves may not open quickly enough on their own, the valves can be equipped with anticipators so they start opening prior to the pressure increase.

Another key factor to consider is the speed at which outlet valves open and shut. The speed (called the "critical period") is determined by the length of the pipe between the outlet valve and the nearest upstream obstruction. The pressure wave from the shutting valve will travel upstream from the valve, bounce off the obstruction and then return to the valve. What you want to do is ensure that the valve has not fully shut by the time the wave returns, so the pressure can continue downstream through the pipe rather than slamming back and forth inside it.

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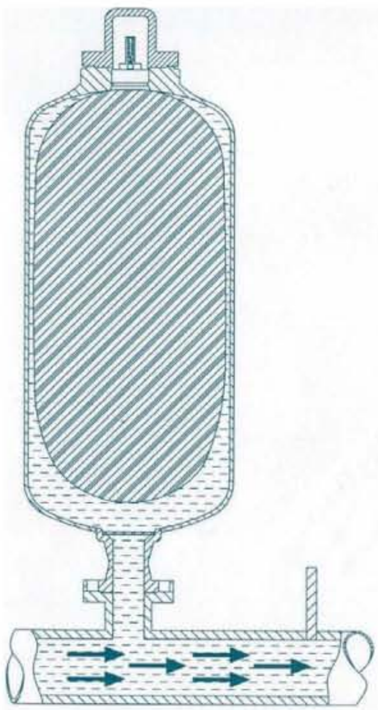
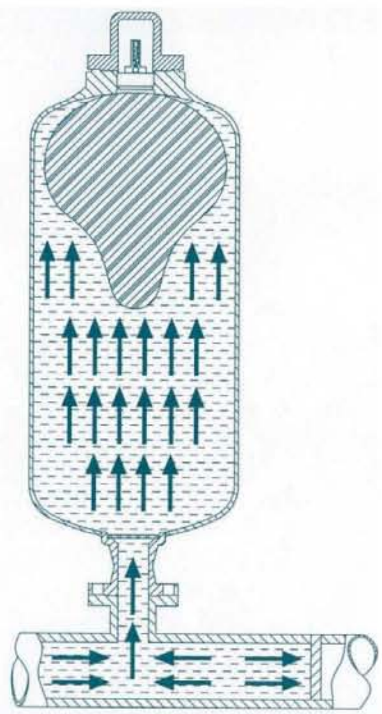


SURGE SUPPRESSOR DURING NORMAL FLOW WITH OPEN VALVE



SURGE SUPPRESSOR DURING SUDDEN VALVE CLOSING

The formula to use is $t=2L/\alpha$ where t is the minimum amount of time in seconds for closing the valve, L is the pipe length in feet and α is the speed of sound in ft/sec. For a one mile long pipe, t would equal just over 2 seconds. Ensuring that the valve takes more than 2 seconds to close will mitigate the damage.

Surge Suppressors

One of the more cost effective options to combat surges and water hammer events is to install surge suppressors at the right points in the system. These are similar in design to pulsation dampeners, but are built to address much larger pressure and volume fluctuations. The basic elements are a cylinder containing a bladder. The bladder is attached to a charging valve and pressure meter so it can be precharged with nitrogen to the desired pressure. The other end of the cylinder is attached to the water system.

The bladder is precharged to a level lower than the minimum allowable system pressure, so there will always be some liquid within the suppressor. Then, when there is a pressure surge, since the nitrogen is more compressible than the water fluid, most of the fluid above the average system flow goes into the surge suppressor, rather than creating a compression wave. When there is a sudden drop in pressure, the gas expands to force the water back out of the surge suppressor, so there is no danger of causing water column separation.

The elasticity of the rubber and the compressibility of the gas work together to eliminate greater than 95 percent of the flow and pressure variations, prolonging the life of the equipment. This does require, however, that the system be properly designed, installed and maintained. To begin with, the right materials must be selected for the diaphragm/bladder and the vessel. The diaphragm or bladder is typically made using Buna-N, however other materials (neoprene, Nordel, Viton, Hypalon, silicon, Teflon, EPR, butyl, and Hydrin) are also available depending on the material being pumped. Carbon steel, 304 or 316 stainless steel are normally used for the vessel, though other materials - including Alloy 20, Hastelloy C, polypropylene, PVDF, Teflon and Nylon - can also be used as appropriate.

Next is properly sizing the surge suppressor. This would depend on the size of the pipe, the normal water flow velocity and the water pressure, as well as other conditions that would contribute to surge or water hammer.

Other than size, one key difference between a pulsation dampener and a surge suppressor is where they are installed. The dampener should be placed as close to the pump outlet as possible. Surge suppressors, on the other hand will be needed at various points throughout the system. They can be installed at the pumps to prevent damage if the pump loses power. Others can be installed at critical points in the piping network where modeling or experience shows the possibility of damage.

Because each municipal water system is designed to meet the unique needs of its community, there is no single, off the shelf solution to eliminate transient pressure changes. Taking the time to develop and implement a thorough plan that matches your system can eliminate or at least minimize water hammer damage, extending pump and plumbing life, and eliminating costly downtime.

About the Author: Joe Cheema is a Senior Project Engineer for accumulator manufacturer Fluid Energy Controls Inc. in Los Angeles, CA For more information contact Cheema via emails: jc@fecintl.com or visit www.fecintl.com