BY ARIE BREGMAN

Don't Put Up with Water Hammer!

Did you ever shut off your kitchen faucet quickly at home and hear the piping rattle in the basement? What you're hearing is the common phenomenon of water hammer.

While that sound may be a minor annoyance in a home situation, expand the size of the pipes and the pressure they contain to an industrial level, and such a noise would mean a major problem on your hands. Water hammer has been known to break flanged connections and to burst pipes.

Water hammer is the result of pressure spikes generated within liquid piping systems. (Water hammer occurs not just in water, but in all liquids; however, not in gas or air flue streams.) For anyone dealing with water hammer, vital information is what factors are influencing the severity of the pressure spike or pressure transients (Figure 1). For more than 100 years, researchers have struggled to understand and define the parameters of that pressure and to develop equations that can predict water hammer pressure transients. Much of this research has been done at the Delft Hydraulics Laboratory in the Netherlands, The City University of London, and Utah State University to name a few.

In this article, I will highlight key factors that have been discovered as well as possible solutions for problems that result from water hammer. (A similar phenomenon often termed water hammer is "steam hammer." This is a different issue altogether, which is caused by steam condensing to a liquid. This article does not address "steam hammer.")

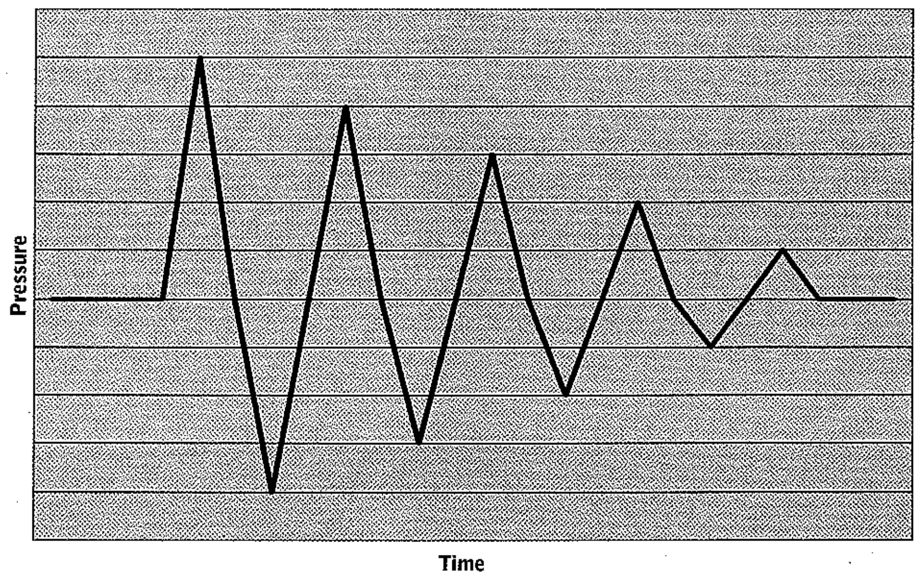

Figure 1. Graphical representation of the pressure transients over time

FUNDAMENTALS OF WATER HAMMER

Water hammer can occur either when flow suddenly starts or when it stops. It is far more common, however, for it to occur in situations when the fluid flow is suddenly stopped.

The fundamental law of physics known as Newton's first law ("A body in motion tends to stay in motion, in a straight line, unless it is acted on by another force") is important when dealing with water hammer because any mass of liquid flowing in a pipeline has momentum.

When a pump is shut off suddenly, the fluid, because of that momentum, wants to keep moving, but it can't. This moving column of water within the pipe then collides with whatever solid obstacles it encounters, such as a closed valve or a sudden change in piping geometry (e.g., 90-degree elbows or reducers). Most liquids are incompressible—the column of liquid cannot compress like a shock absorber to absorb the energy of the momentum. Therefore, a shock wave is generated within the liquid.

That shock wave is the "banging" sound you hear when the valve is closed or the pump shuts off. Depending on the design of the piping system, the intensity of that shock wave can create a pressure spike that could be three to four times the pressure of the liquid within the piping system.

When you suddenly stop the flow by closing a valve, the fluid's momentum will cause it to continue moving in the

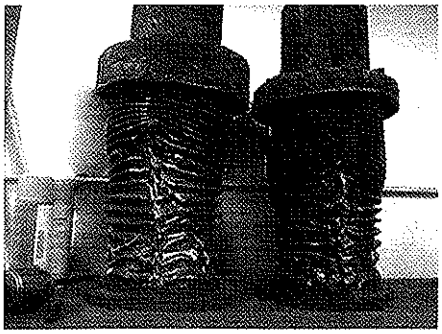

Figure 2. Expansion joints that have collapsed due to sudden valve closure

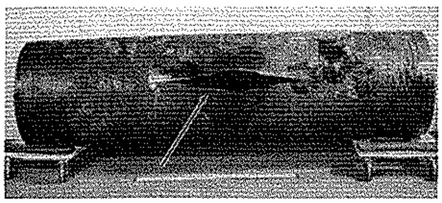

Figure 3. Typical pipe burst from over-pressurization

direction of the flow. That will then lead to a low-pressure area within the fluid column, just past the valve. This low-pressure zone created by the sudden valve closure could cause a pipe wall or expansion joint to collapse (Figure 2). If that does not happen, then the fluid pressure will recover suddenly, or "bounce back," causing a shock wave to be generated within the liquid. The sudden increase in pressure caused by the shock wave can cause the pipe or one of the many components in the piping system to rupture if it is severe enough (Figure 3).

PREDICTING AND PREVENTING

The analysis of pressure transients is complex and cannot be done through a few general equations. However, simple equations can be used to predict the pressure spike using key factors that influence the spike's potential. These factors include: fluid velocity, the rate of deceleration of the fluid, the speed of closure of valves and the acoustic velocity (speed of sound) of the fluid in the pipe.

The basic pressure transient equation, $h = av/g$, was developed by Nikolai Yegorovich Joukowski in 1904. In this equation; "h" represents the pressure transient, "a" is the acoustic velocity of the fluid, "v" is the fluid velocity and "g" is the gravitational constant. Small amounts of entrained gas in the fluid can dramatically reduce acoustic velocity. In the case of sudden pump stoppage, some gas may come out of the fluid solution, which, because it reduces the acoustic velocity, will also reduce the pressure spike. This is one of the factors that makes the analysis and prediction of pressure transients very complicated.

SOLUTIONS FOR WATER HAMMER

Although mixing a gas into the liquid stream would reduce acoustic velocity, this obviously is not a solution in many cases. However, there are other elements of a piping system that can absorb part of the pressure surge. Air pads, surge tanks, valve speed controls and check valves are potential solutions for water hammer problems. Understanding the underlying root cause or source of the shock wave will help in finding the best solution.

As previously noted, a fast-closing valve could be the root cause of the water hammer problem. Quarter-turn and other valves that are quick to open or close can be slowed down through speed controls such as solenoid valves.

Sometimes slowing down a valve's closure speed is not an option, however, as in emergency shutdown applications. In this case, a hydrodynamic device such as an air pad or surge tank can act like a shock absorber to dampen the energy of the shock wave. Air pads are often a solution for domestic plumbing systems. However, a surge tank may need to be employed on a larger, industrial piping system.

The other primary root cause of water hammer is a pump suddenly shutting down. Common places this might occur would include sump pumps that are eliminating water from a low collection point, as in a mine dewatering application, pumping water to a cooling tower or raw water intake into a manufacturing facility. In this case, a cost-effective solution might be to install a non-slam-type check valve that closes before flow stoppage or reversing flow occurs (Figure 4).

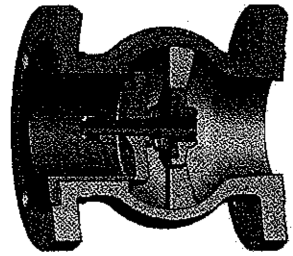

Figure 4. A typical configuration of a non-slam, axial flow check valve

Check valves come in a wide variety of styles and configurations, most of which are not easily adapted to a non-slam technology. In-line, axial flow check valves, also known as nozzle check, non-slam or silent check valves, are specifically designed to reduce or eliminate water hammer.

Spring designs can be critical to eliminating water hammer. The "cracking pressure" of a check valve will describe the differential pressure at which the valve will begin to open. Cracking pressure also can be used to determine the flow rate at which a check valve will close. Closing the valve before the flow stops or reverses is key to reducing and eliminating water hammer.

A reputable check valve manufacturer can guide persons concerned with water hammer through the process from this point forward. Determining the proper spring is one part of that process along with other design and safety considerations. The check valve manufacturer also can help with any valve parameters that will be needed to model valve closure times and pressure transients.

Water hammer is not something anyone should have to live with. Eliminating it can improve worker safety as well as eliminate environmental concerns related to noise and leaks. **VM**

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