Avoid water hammer

Even mild water hammer can weaken and eventually destroy piping, gauges, floats, heat exchange equipment, etc.

J. Kremers, Armstrong Machine Works,
Three Rivers, Mich.

WITH A BETTER UNDERSTANDING of the nature and severity of the water hammer problem, we can avoid its destructive forces. This greater understanding should also help with the introduction of more preventive measures into system designs and installations, which will help provide maximum safety for personnel, lower maintenance cost and reduce system downtime.

Where water hammer occurs. Water hammer can occur in any water supply line, hot or cold. Its effects can be even more pronounced in heterogeneous or biphase systems. Biphase systems carry water in two states, as a liquid and as a gas. Such a condition exists in a steam system where condensate coexists with live or flash steam: in heat exchangers, tracer lines, steam mains, condensate return lines and, in some cases, pump discharge lines.

Effects of water hammer. Water hammer has a tremendous and dangerous force that can collapse floats and thermostatic elements, overstress gauges, bend mechanisms, crack trap bodies, rupture fittings and heat exchange equipment and even expand piping. Over a period of time, this repeated stress on the pipe will weaken it to the point of rupture.

Water hammer is not always accompanied by noise. Some types of water hammer, resulting from localized abrupt pressure drops, are never heard. The consequences, however, may be just as severe.

Conditions causing water hammer. Three conditions have been identified that can cause the violent reactions known as water hammer. These conditions are hydraulic shock, thermal shock and differential shock.

Hydraulic shock: Visualize what happens at home when a faucet is open. A solid shaft of water is moving through the pipes from the point where it enters the house to the faucet. This could be 100 pounds of water moving at 10 feet per second, about seven miles per hour.

When the faucet is shut suddenly, it is like a 100-pound hammer coming to a stop. There is a "bang." This shock wave is similar to a hammer hitting a piece of steel. The shock pressure wave of about 600 psi is reflected back and forth from end to end until the energy is dissipated. Similar action can take place in the suction or discharge piping of a pump when the pump starts and stops if check valves are in the line. Slow closure of the valve or faucet and slow-closing check valves along with water hammer arrestors are solutions to these problems. If the column of water is slowed before it is stopped, its momentum is reduced gradually and, therefore, damaging water hammer will not be produced.

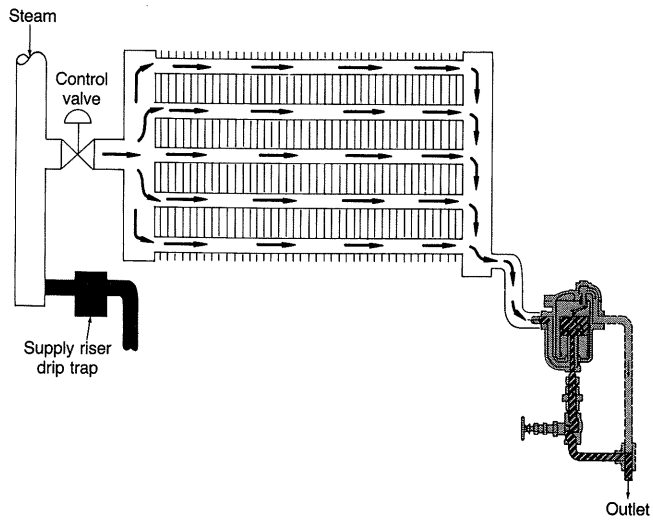

Fig. 1—Condensate controller maintains a positive pressure differential across all the tubes.

Water hammer arrestors, if correctly sized, placed and maintained, will reduce water hammer by providing a controlled expansion chamber in the system. As the forward motion of the water column in the pipe is stopped by the valve, a portion of the reversing column is forced into the water hammer arrestor. The water chamber of the arrestor expands at a rate controlled by the pressure chamber and gradually slows the column, preventing hydraulic shock.

If a check valve is used in a system without an arrestor, excessive pressure may be exerted on the system when the reversing water column is violently stopped by the check valve. If a float-type air vent is located between the check valve and the closing valve, the float could easily be ruptured.

Thermal shock: In biphase systems, steam bubbles may become trapped in pools of condensate in a flooded main, branch or tracer line, as well as in heat exchanger tubing and pumped condensate lines. Since condensate temperature is almost always below saturation, the steam will immediately collapse.

One pound of steam at 0 psig occupies 1,600 times the volume of a pound of water at atmospheric conditions. This ratio drops proportionately as the pressure increases. When the steam collapses, water is accelerated into the resulting vacuum from all directions. This happens when a steam trap discharges relatively high-pressure flashing condensate into a pump discharge line.

Another cause of water hammer is lack of proper drainage ahead of a steam control valve. When the valve opens, a slug of condensate will enter the equipment at a high velocity, producing water hammer when it impinges on the walls. In addition to this, the mixing of the steam that follows with the relatively cool condensate will produce water hammer from thermal shock. This condition can be corrected by dripping the supply riser as shown in Fig. 1.

Reprinted from HYDROCARBON PROCESSING®, March 1983

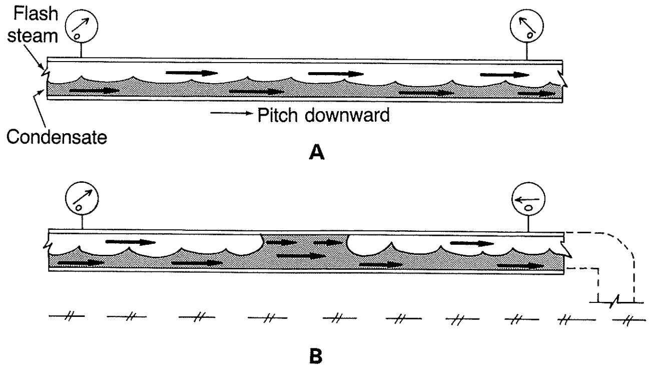

Fig. 2—Formation of a condensate seal.

Water hammer can also occur in steam mains, condensate return lines and heat exchange equipment where steam entrapment can take place (Fig. 1). A coil constructed and installed as shown here, except with just a steam trap at the outlet, permits steam from the control valve to be directed through the center tube(s) first. Steam then gets into the return header before the top and bottom tubes are filled with steam. Consequently, these top and bottom tubes are fed with steam from both ends. Waves of condensate are moved toward each other from both ends, and steam can be trapped between the waves.

Water hammer results from the collapse of this trapped steam. The localized sudden reduction in pressure caused by the collapse of the steam bubbles has a tendency to chip out pipe and tube interiors. Oxide layers that otherwise would resist further corrosion are removed, resulting in accelerated corrosion.

One means of overcoming this problem is to install a condensate controller, which maintains a positive pressure differential across all the tubes (Fig. 1). A condensate controller provides a specialized purge line, which assures a positive flow through the coil at all times.

Differential shock: Differential shock, like thermal shock, occurs in biphase systems. It can occur whenever steam and condensate flow in the same line, but at different velocities, such as in condensate return lines.

In biphase systems, velocity of the steam is often 10 times the velocity of the liquid. If condensate waves rise and fill a pipe, a seal is formed with the pressure of the steam behind it (Fig. 2). Since the steam cannot flow through the condensate seal, pressure drops on the downstream side. The condensate seal now becomes a "piston" accelerated downstream by this pressure differential. As it is driven downstream it picks up more liquid, which adds to the existing mass of the slug, and the velocity increases.

If this slug of condensate gains high enough momentum and is then required to change direction, for example at a tee, elbow or valve, great damage can result.

Since a biphase mixture is possible in most condensate return lines, their correct sizing becomes essential.

Condensate normally flows at the bottom of a return line. It flows because of the pitch in the pipe and also because of the higher velocity flash steam above it, dragging it along. The flash steam moves at a higher velocity because it moves by differential pressure.

Flash steam occurring in return lines, due to the discharge of steam traps, creates a pressure in the return line. This pressure pushes the flash steam at relatively high velocities toward the condensate receiver, where it is vented. Condensing of some of the flash steam, due to heat loss, contributes to this pressure difference and amplifies the velocity. Because the flash steam moves faster than the condensate, it makes waves. As long as these waves are not high enough to touch the top of the pipe and so do not close off the flash steam's passageway, all is well.

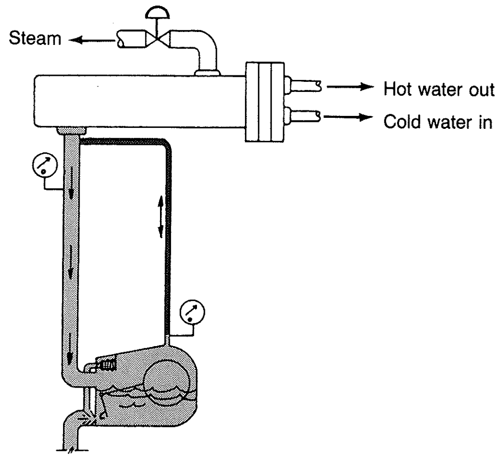

Fig. 3—Back-venting a trap on elevated heat exchangers.

In our glass pipe demonstrator, cold water is used to simulate condensate and air pressure is applied to simulate the flash steam in the top portion of the pipe (Fig.2).

Damaging water hammer similar to that just described is experienced also when elevated heat exchange equipment is drained with a long vertical drop to a trap.

Condensing of steam downstream of the slug produces a drop in pressure and, therefore, a pressure differential across the slug. This pressure differential, together with gravity, accelerates the slug downward. It does not take much of this strong force to collapse a ball float in a trap. Back-venting the trap to the top of the vertical drop can correct this problem (Fig. 3).

Since condensation is what produces the acceleration, uninsulated pipes and their appurtenances would be expected to suffer greater damage than those with insulation.

To control differential shock, the condensate seal must be prevented from forming in a biphase system. Steam mains must be properly pitched, condensate lines must be sized and pitched correctly, and long vertical drops to traps must be back-vented. The length of lines to traps should be minimized, and pipes may have to be insulated to prevent water hammer.

About the author

JOHN KREMERS *is the manager, applications engineering, at Armstrong Machine Works, a division of Armstrong International. In this position he is responsible for providing customer assistance in diagnosing steam system problems, analyzing steam system applications, and specifying steam traps and other Armstrong products. Mr. Kremers, a registered professional engineer in Wisconsin and Michigan, received his degree in mechanical engineering at the University of Wisconsin. He is a member of ASHRAE, and during his 20 years with Armstrong, Mr. Kremers has worked in the engineering department, research and development and in the applications engineering department.*

F/5M/292

Printed in United States