
Steam System Best Practices

Document No. 11

The Number One Problem in a Steam System - Water Hammer

There is only one “time” to correct water hammer – IMMEDIATELY

Water Hammer Is Never Normal; It Is Abnormal

Water hammer is not only a system issue; it is primarily a safety issue. Understanding the nature and severity of water hammer in a steam and condensate system, will allow facilities to avoid its destructive forces. This greater understanding should also help with introduction of preventative measures into system designs, steam system startups, maintenance and installations, which help provide maximum safety for personnel, reduce maintenance cost, and reduced system downtime.

Water hammer; in its most severe form, can injure or even cause fatalities to plant personnel.

Unfortunately, 82% of the steam systems in North America are experiencing some type of water hammer. Many mistakenly believe that water hammer is unavoidable and a natural part of steam and condensate systems. This is entirely false. If the system is properly designed and correctly operated water hammer in any form will not occur. There are high pressure steam systems operating without water hammer and having long operational life from the steam components.

* Red circles show improper connection to the condensate header.



Where Does Water Hammer Occur?

Water hammer can occur in any steam or condensate line. Its effects can be even more pronounced in heterogeneous or condensate bi-phase systems. Condensate bi-phase systems contain two states, the liquid (condensate) and a vapor (flash or generated steam). The bi-phase condition exists in a steam system where condensate coexists with generated or flash steam. Typically examples include heat exchangers, tracer lines, steam mains, condensate return lines and sometimes, pump discharge lines.

A common example is water hammer occurring during the start-up or energizing of a steam main. If the steam line is energized too quickly and the condensate created during the startup is not being properly removed; water hammer will be the result.

Effects of Water Hammer

The effect of water hammer cannot be underestimated as its forces have been documented to result in many of the following:

- Collapse the float elements in steam traps
- Overstress pressure gauges
- Bend internal system mechanisms
- Crack steam trap bodies
- Rupture pipe fittings
- Cause valve failures
- Cause heat exchanger equipment tube failures
- Break pipe welds and even rupture piping systems
- Failure of pipe supports.

When water hammer is severe, it can result in not only damage to equipment, but significant injury to plant personnel.

Water hammer is not only audible but can also be occurring and yet silent to personnel. This means water hammer is not always accompanied by audible noise. For example, a steam bubble may be small in size and the collapsing bubble creates a “thermal shock” that is not heard by the human ear. However, the damage to steam and condensate components is still occurring.

The continuing banging or audible sound accompanying water hammer should be interpreted as the way the steam system is trying to communicate with plant personnel. This audible banging should be an alarm meaning fix the problem or damage will occur. This sound means something in the system is wrong and needs to be corrected.

Evidence gathered while conducting root cause analysis on steam component failure suggested water hammer causes 67% of the premature component failures.

Conditions Causing Water Hammer

Four conditions have been identified as causes of violent reactions known as water hammer. These conditions are:

Hydraulic shock

Thermal shock

Flow shock

Differential shock

Following is a description of each of these causes.

Hydraulic Shock

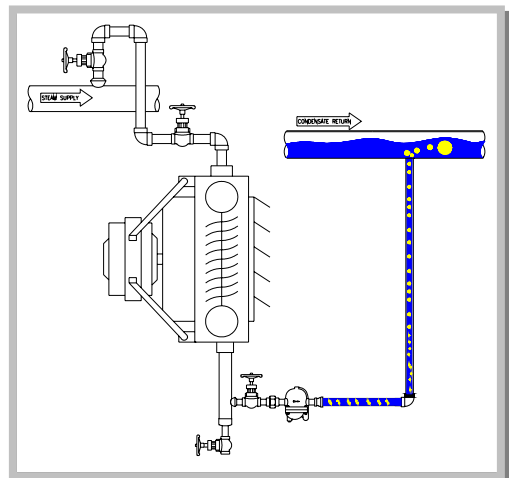
A small percentage of the water hammer problems found in a steam system are caused by hydraulic shock. This type can be easily described by using the example of a home faucet. When the faucet in a home opens, a solid shaft of water is moving through the pipes from the point where it enters the house to the outlet of the faucet. This could be 200 pounds of water moving at 10 feet per second or about seven miles per hour.

When the faucet is suddenly shut, it could be compared to a 91-kg hammer coming to a stop. There is a noticeable “bang” heard in the system when the faucet is closed. This shockwave sound is similar to a hammer hitting a piece of steel. The shock pressure wave of about 20.7-bar is reflected back and forth from end to end until the energy is dissipated in the piping system.

This is the same action that can take place in the suction or discharge piping in a steam and condensate system. Pumps are often installed with check valves. As the pump starts and stops, hydraulic shock can occur as the flow rapidly stops and the check valves restrict the flow in one direction. Slow closure of the valve, just like slowly closing a faucet, is the solution to this problem. When a column of water is slowed before it is stopped, its momentum is reduced gradually and, therefore, damaging water hammer will not be produced.

Thermal Shock

One pound of steam at -1 bar occupies 1,600 times the volume of a pound of water at atmospheric conditions. This ratio drops proportionately as the condensate line pressure increases. When the steam collapses, water is accelerated into the resulting vacuum from all directions.

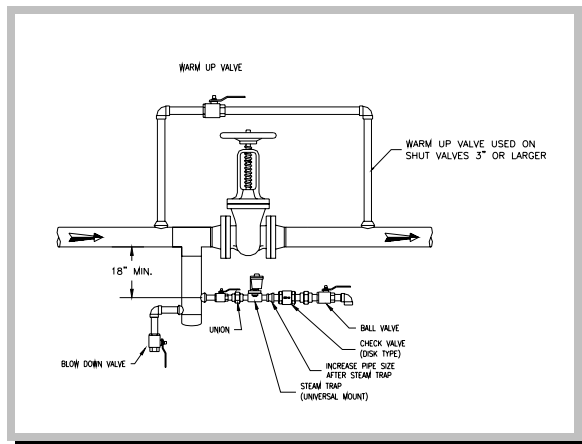


In bi-phase condensate systems, steam bubbles may be introduced below the level of condensate in a steam line. (Branch line from a steam trap is piped to the bottom of a condensate main header). The pressure in the condensate line (lower pressure = lower temperature) is lower than the flash steam temperature. The condensate cools the flash steam bubble and the steam bubble collapses immediately. While collapsing, a void is created in the volume of the pipe and condensate rushes to fill this void, thus causing an audible pinging sound.

Flow Shock

Flow shock is most commonly caused due to lack of proper drainage ahead of a steam line isolation valve or steam control valve. For example, consider a steam line isolation valve (typically used with pipe of 3" or larger) opened without the use of a warm up. When the large valve is opened, steam rushes down a cold pipe producing a large quantity of condensate at high velocity. This condensate will continue to build in mass as it travels along the pipe and a large wave of condensate is created. The wave will travel at a high velocity until there is a sudden change in direction, possibly an elbow or valve in the line. When the condensate changes direction, the sudden stop will generate water hammer.

When a steam control valve opens, a slug of condensate enters the equipment at a high velocity. Water hammer is produced when the condensate impinges on the heat exchanger tubes or walls. Additionally, water hammer from thermal shock will result from the mixing of steam and condensate that follows the relatively cooler condensate.

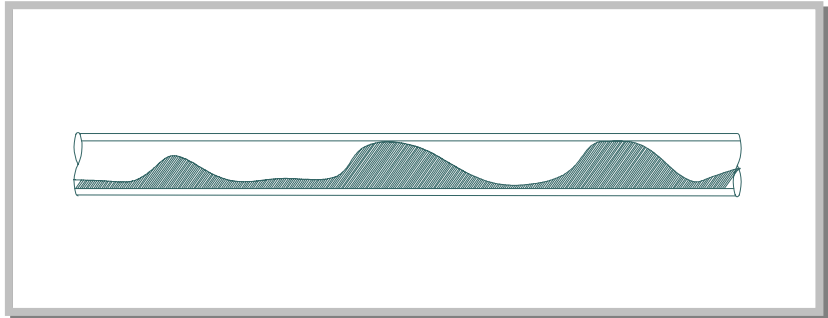


* The above AutoCAD print is the standard installation of a isolation valve in a steam system. Two main points are the warm-up valve and the drip leg pocket with a steam trap ahead of the isolation valve. The installation will prevent waterhammer during startup, but it will also promote long valve life.

Differential Shock

Differential shock, like flow shock, occurs in bi-phase systems. It occurs whenever steam and condensate flow in the same line, but at different velocities. This is commonly seen in condensate return lines.

In bi-phase 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 temporarily between the upstream and downstream side of the condensate wave. Since the steam cannot flow through the condensate seal, pressure drops on the downstream side. The pressure differential now drives the condensate seal at a high velocity downstream accelerating it like a “piston”. As it is driven downstream it picks up more liquid, which adds to the existing mass of the slug, and the velocity increases.



Just as in the example above, the slug of condensate gains high momentum and will be forced to change direction due to a tee, elbow or valve in the line. The result is usually great damage when the condensate slug pounds into the wall of a valve or fitting while changing direction.

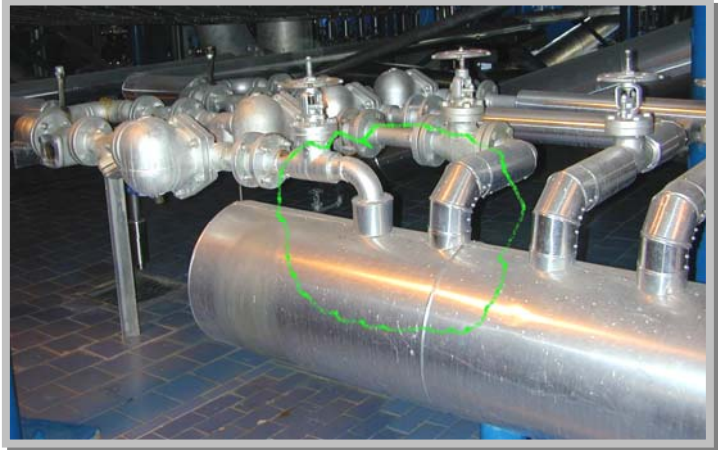
Since having a bi-phase mixture is possible in most condensate return lines, correctly sizing condensate return lines becomes essential.

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

Flash steam occurs in return lines when condensate discharges into these lines that are operating at a lower pressure. The lower pressure causes a percentage of the condensate to flash back to steam at the given saturation pressure. If the lines are also undersized, additional pressure is created in the line. This pressure pushes the flash steam at relatively high velocities toward the condensate receiver, where it is vented to atmosphere. Heat loss of the flash steam while moving in the line causes some of the flash steam to condense which 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 do not close off the flash steam's passageway, there is not a problem. This is why larger sized condensate return lines are preferred.

To control differential shock, the condensate seal must be prevented from forming in a bi-phase system. Steam mains must be properly trapped and condensate lines must be properly sized. The length of horizontal lines to the trap's inlet should be minimized.

Steam main drainage is one of the most common applications for steam traps. It is important that water is removed from steam mains as quickly as possible, for reasons of safety and to permit greater plant efficiency. A build-up of water can lead to water hammer, and as we have already discussed, the water hammer can have any number of adverse effects on the steam and condensate components of a system.



* Picture indicates the proper connections to the main condensate header.

Preventing or Resolving Water Hammer

There are a variety of design or system changes that can be implemented to prevent or eliminate water hammer:

1. Proper training for plant personnel.
2. Ensure correct steam and condensate design
3. Have documented SOP's (standard operation procedures) for steam system startups and shut downs.
4. Have installation standards for steam components.
5. Properly place steam line drip steam traps on the steam system.
6. Correct condensate connections of branch lines to the main condensate line (enter only on the top).
7. Use steam traps that are properly sized and appropriate for the application.
8. Use warm up valves on steam line isolation valves larger than 2 inch. Do not "crack open" large steam isolation valves with the hope of avoiding condensation-induced water hammer. This will not guarantee safe operation.
9. Check or repair the pipe insulation. It saves energy and reduces accumulation of condensate in the piping system.
10. Condensate line sizing is crucial to insure proper operation of the steam system. Under-sizing the condensate lines is one of the largest contributors to water hammer.
11. System that has a modulating control valve should have a drip leg trap upstream of the valve to remove condensate during a closed condition for the valve.
12. Always gravity drain away from the process applications with a modulating control valve.

13. Condensate can be drained into a pressurized condensate return line, if proper differential is maintained.
14. Proper labeling of steam and condensate lines.
15. Abandoned steam and condensate lines, remove from the system.
16. Pro-active maintenance program.

* AutoCAD drawing of a standard drip leg installation.

* Below is AutoCAD drawing of a standard unit heater installation. Steam branch line off the top and condensate branch line return to the top of the condensate header.

