**Water Hammer**

**Water Hammer** is a pressure surge or wave caused when a fluid, a liquid or a gas in motion is forced to stop or change direction suddenly (momentum change). A water hammer commonly occurs when a valve closes suddenly at an end of a pipeline system, and a pressure wave propagates in the pipe. It is also called *hydraulic shock*.

This pressure wave can cause major problems, from noise and vibration to pipe collapse. It is possible to reduce the effects of the water hammer pulses with accumulators, expansion tanks, surge tanks, and other features.

Rough calculations can be made using Joukowsky equation

**Cause and effect**

When a pipe is suddenly closed at the outlet (downstream), the mass of water before the closure is still moving, thereby building up high pressure and a resulting shock wave. In domestic plumbing this is experienced as a loud banging, resembling a hammering noise. Water hammer can cause pipelines to break if the pressure is high enough. Air Valves are sometimes added as dampers to water systems to absorb the potentially damaging forces caused by the moving water.

In hydroelectric generating stations, the water travelling along pipeline may be prevented from entering a turbine by closing a valve. However, if, for example, there is 14 km of tunnel of 7.7 m diameter, full of water travelling at 3.75 m/s, that represents approximately 8000 megajoules of kinetic energy that must be arrested.

When an upstream valve in a pipe closes, water downstream of the valve attempts to continue flowing, creating a vacuum that may cause the pipe to collapse or implode. This problem can be particularly acute if the pipe is on a downhill slope. To prevent this, air and vacuum relief valves, or air vents, are installed just downstream of the valve to allow air to enter the line for preventing this vacuum from occurring.
Water Hammer

Major causes of water hammer are pump failure, and check valve slam due to sudden deceleration, a check valve may slam shut slowly the dynamic characteristic of the check valve and the mass of the water between a check valve and pipeline or tank

Steam distribution systems may also be vulnerable to a situation similar to water hammer, known as steam hammer. In a steam system, water hammer most often occurs when some of the steam condenses into water in a horizontal section of the steam piping. Subsequently, steam picks up the water, forms a "slug" and hurls it at high velocity into a pipe fitting, creating a loud hammering noise and greatly stressing the pipe. This condition is usually caused by a poor condensate drainage strategy.

Where air filled traps are used, these eventually become depleted of their trapped air over a long period of time through absorption into the water. This can be cured by shutting off the supply, opening taps at the highest and lowest locations to drain the system restoring air to the traps, and then closing the taps and re-opening the supply.

Mitigating measures

Water hammer has caused accidents and fatalities, but usually damage is limited to breakage of pipes or appendages. An engineer should always assess the risk of a pipeline burst. A pipeline must be carefully designed and maintained because the water hammer can cause water pipes to fail catastrophically.

The following characteristics may reduce or eliminate water hammer:

- Install correctly sized Non Slam Check Valve (Nozzle Checks)
- Reduce the pressure of the water supply using a Pressure Regulating Valve.
- Lower fluid velocities. To keep water hammer low, pipe-sizing charts for some applications recommend flow velocity at or below 1.5 m/s (4.9 ft/s)
- Fit slowly closing valves.
- Higher the pipeline pressure rating
- Good pipeline control (start-up and shut-down procedures).
- Air vessels. They typically have an air cushion above the fluid level in the vessel, which may be regulated or separated by a bladder. Sizes of air vessels may be up to hundreds of cubic meters on large pipelines. They come in many shapes, sizes and configurations. Such vessels often are called accumulators or expansion tanks.
- Pumping station bypass.
Typical pressure wave caused by closing a valve in a pipeline

Column separation

Column separation is a phenomenon that can occur during a water-hammer event. If the pressure in a pipeline drops below the vapor pressure of the liquid, cavitation will occur (some of the liquid vaporizes, forming a bubble in the pipeline, keeping the pressure close to the vapor pressure). This is most likely to occur at specific locations such as closed ends, high points or changes in pipe slope. When the pressure later increases above the vapor pressure of the liquid, the vapor in the bubble returns to a liquid state, which leaves a vacuum in the space formerly occupied by the vapor. The liquid either side of the vacuum is then accelerated into this space by the pressure difference. The collision of the two columns of liquid (or of one liquid column if at a closed end) causes a large and nearly instantaneous rise in pressure. This pressure rise can damage hydraulic machinery, individual pipes and supporting structures. Many repetitions of cavity formation and collapse may occur in a single water-hammer event.