Water Hammer PREVENTION

Using Check Valves to Protect Against Harmful Process Conditions in Pipeline Applications
Why Water Hammer Occurs in SAGD Process Pipelines

Steam Assisted Gravity Drainage (SAGD) plants produce steam to inject into formations to reduce the viscosity of bitumen and increase the flow beneath thousands of meters.

When an SAGD plant installs the traditional swing check valves, the function of closing this valve is for disc-to-travel distance to closure, and during high volume, process flow becomes greater, causing surge (water hammer or slam).

Water hammer generated in steam and condensate recovery systems is usually classified into two main categories:
- Caused by high-speed condensate slamming into piping, etc.
- Caused by the sudden condensation of steam, which produces walls of condensate that crash into each other.

After injecting steam during the recovery of oil, SAGD plants produce oil, water (condensate) and sand, silt, as well as some recycled drilling/production chemicals. This is called recovery of oil. In an oil pipeline, water hammer (pressure surges) occurs from sudden events, such as a valve closure or a pump trip, often triggered by an emergency shutdown (ESD). The moving fluid in the pipeline acts much like a train when it hits an obstacle; that is, each car slamming into the one ahead causing multiple water hammers.

A Few Events Typically Induce Water Hammer:
- **Pump startup**: Startup can cause a rapid collapse of the void space downstream from a starting pump. This generates high pressures.
- **Pump power failure**: This can cause a pressure upsurge on the suction side and a pressure down-surge on the discharge side. The down-surge is usually the major problem. The pressure on the discharge side reaches vapor pressure, resulting in vapor column separation.
- **Valve opening and closing**: Closing a valve at the downstream end of a pipeline creates a pressure wave that moves back toward the reservoir. Closing a valve in less time than it takes for the water hammer to travel to the end of the pipeline and back is called “Sudden Valve Closure.” Sudden valve closure changes the velocity quickly and results in a pressure surge. The pressure surge resulting from a sudden valve opening is usually not as excessive.
Improper operation or incorrect design of surge protection devices: Oversizing the non-slam check valve or attempting to incorporate some means of preventing water hammer when it may not be a problem can do more harm than good.

What Are the Causes of Varying Velocity in an SAGD Plant?

Daily operation of a plant demands a few checklist action items for production and performance optimization such as:

- Closing a valve
- Opening a valve
- Rhythmic valve operation
- Starting a pump
- Stopping a pump
- Movement of air pockets
- Sudden release of pressure from piping systems
- Sudden halt in flow when pressure has been reduced/lowering production due to operation safety requirements
- Recombination after fluid pressure-column separation
- Restarting a portion of the plant after a turn-around

Why Is This a Problem?
The resulting water hammer can be up to 10 times the normal pipeline pressure; and this can cause a pipeline rupture, blown valve or pump seals, spillage, and many other problems.

SAGD plant systems are 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.

When to Do a Water Hammer Analysis?
Consideration should be given to performing a water hammer analysis when any of the following conditions exists:

- The maximum change of flow velocity in a pipeline exceeds 4’ per second.
- The length of pipeline is over 200 meters.
- There are fast opening and closing valves in the system, especially in the case of SAGD plants.
- The production is pumped out of the ground (i.e., SAGD production starts off with pumps in offsites on the recovery side).

![Effects of water hammer](image)

**Choices of Valves?**
Industry has invented various preventing measures on water hammer as follows:

- Accumulators
- Expansion tanks
- Non-slam check valves
- Pressure-relief valves
- Surge-relief valve
- Control valves

**Selection Criteria for Check Valves in SAGD in Alberta**
Traditional check valves backflow to shut; they are emergency backflow preventers typically used around critical equipment. These rely on flow to open. How much the valve opens is dependent on the flow condition.

Normally a swing check valve is commonly used in industry, but problems can arise with this type of valve, such as leakage through its seat due to the following reasons:

- The valve was installed in an unsuitable application. For example, most swing check valves cannot be installed vertically, with the flow passing from above the valve.
- The swing check valve was installed less than 10-pipe diameters away from an upstream pipe fitting or pump. This results in turbulent flow, disc chatter, and ultimately damage to the sealing surface.
- The swing check valve is not closing fast enough, allowing water hammer to slam the disc into the seat. Continued slamming damages the sealing surface, preventing the valve from sealing fully.

As traditional swing check valves are known for sticking, when previously installed check valves have internals that are worn or damaged at the hinges, bushings or seating surface, nozzle check valves are the best alternative, as they require no spare parts.

The signs of excessive “swing check slamming” include grout cracking beneath pump and motor pads and base, damage to electrical cable connecting the motor, and increased vibration caused by induced pump and motor misalignment. Pressure gauges and switches become abnormally out of calibration, valve seat surfaces crack, there is excessive piping header displacement, and heat exchanger tube failures caused by pump cycling activations.

**Why the Nozzle Check Valve Is the Best Valve to Prevent Water Hammer?**
Nozzle check valves are clean service valves with high reliability, low maintenance requirements, and relatively low pressure losses. Two factors that determine non-slam check valve (surge) valve sizing are:

1. Location and
2. Set point pressure.

These application-sensitive valves are known to eliminate water hammer and potentially destructive surge pressures, the latter of which is usually associated with conventional check valves used with centrifugal compressors when surging.

Essentially, nozzle check valves are

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check valves that prevent reverse flow. These have an axial disc movement with short stroke and a Venturi-style nozzle, which maximizes flow impact on the disc and minimizes pressure loss. The valves have better dynamic response, high reliability, and, most significantly, non-slam operational characteristics.

The function of a non-slam check valve is to close quickly. Non-slam check valves close as fast as 30m/sec; this is achieved with its aerodynamic design built on the principals of a jet aircraft.

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Why Is it Critical to Ensure the Valve Is Specified and Installed Correctly?
One should take into consideration when check valves are located downstream of pump elbows or other sources of turbulence, and when check valves are located downstream of the pump or compressor. Nozzle check valves should be in a system where pressure surges during flow transients and valve closure produces pressure spikes approaching the system design pressure.

Essentially, when previously installed check valves have internals that are worn or damaged at the hinges, bushings or seating surface, nozzle check valves are the best alternative; also in positions where check valves are known for sticking.

The Benefits of Using Nozzle Check Valves
When properly specified and installed via non-slam check valves, the water hammer in piping systems can prevent accidents, damage, and increase equipment life.

Water hammer protection via non-slam check valves often is one of the last lines of protection for SAGD plant pipelines, saving the day when all else fails, but only if specified and installed correctly.

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