WATER HAMMER

CONTROL VALVES CAN HELP SOLVE THE PROBLEM

Water hammer occurs when kinetic energy is converted into elastic energy. Rapid changes in velocity will produce this effect, e.g. by a valve or a pump suddenly stopping due to power failure. The reason why high pressure surges are damaging is because the wave velocity is close to the speed of sound. A wave of increased pressure is transmitted back through the pipe with constant intensity and velocity when sudden closure of a valve occurs.

The phenomenon called water hammer can cause serious incidents such as pipe rupture and damage of pipe connections or valves, and if a power failure occurs in a pumping station, the water wave inertia can cause the fluid flow on the downstream side of the pump to collapse into separate columns with vapour.

When the pressure falls and separation of liquid occurs (macro cavitation), incidents such as bending of plastic or thin wall steel pipes, dirty water being drawn into pipes through gland packings, flanges or small leaks or even damages to the valve may happen. As the separate liquid column subsequently move back and recombine, a hammer impact is formed and high pressure waves develop with the same effects as of a suddenly closing valve.

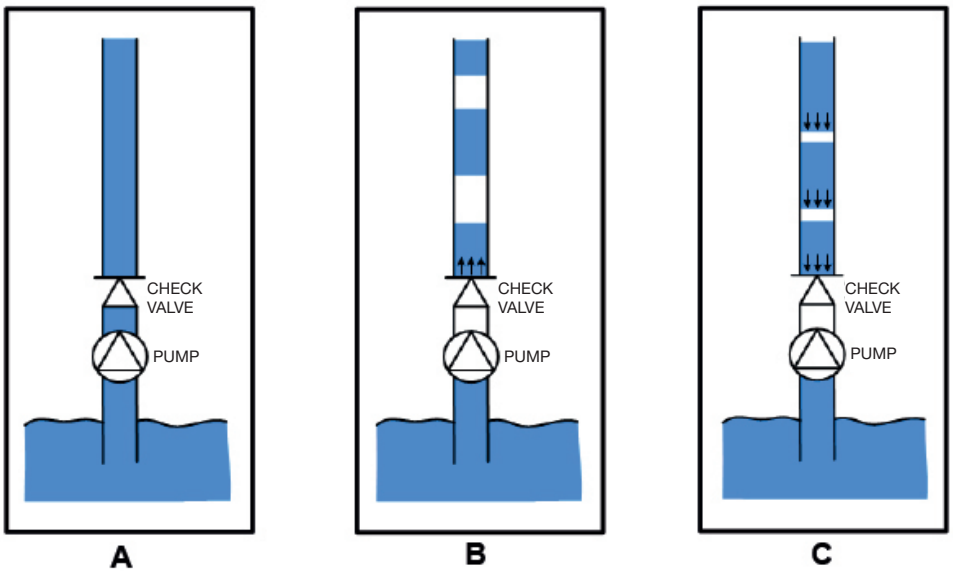

Fig. 1

A - Pump running
B - Pump power failure - Macro cavitation - Column separation
C - Column recombination - High pressure waves

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Sudden closure of a valve causes the mass inertia of the water column to produce a pulse of high pressure in the shut-off element.

Example:

Pipe: DN400	$M = \frac{0.4^2 \pi}{4}$
Length: 1500 m	M = 188496 kg
Velocity: 4 m/s	4 m/s = 14 km/h

This is the approximate weight of a small ship, and if such a ship crashes into the dock at a speed of 14 km/h, you can imagine the damages it will cause.

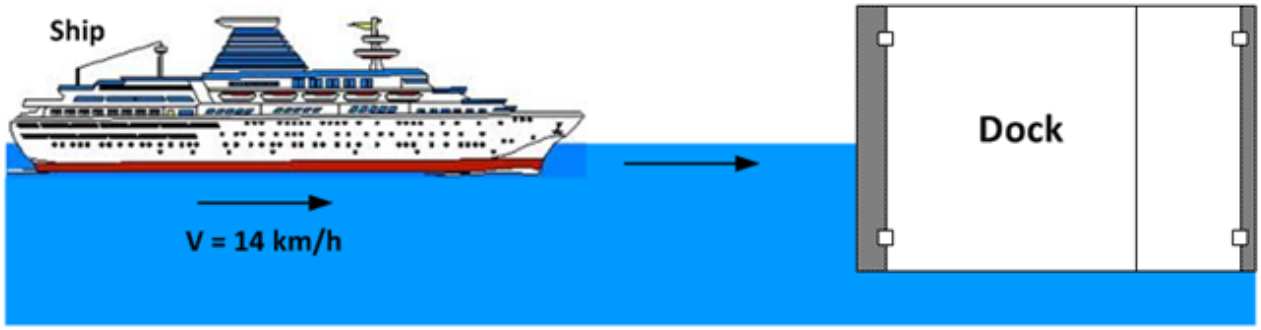
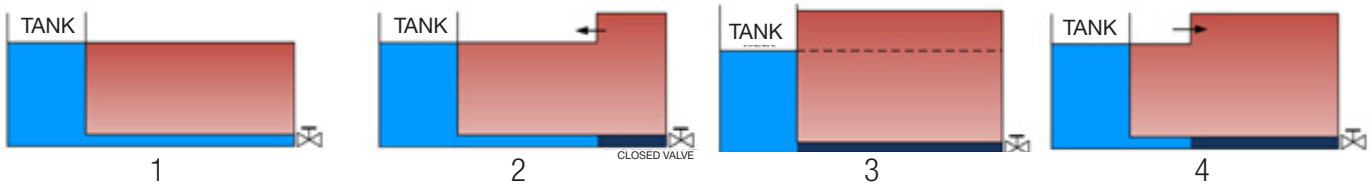


Fig. 2

In our pipeline, the sequence of these events results in high pressure and strong forces acting on the valve and on the pipes. Of course, this example is hypothetical and the ship and the dock are rigid. In our pipeline we have the elasticity of the water and the pipe walls acting as a spring sliding inside the pipe. A spring suffers from elastic deformation when it is suddenly stopped and there is a similar effect for water.

Sudden closure of a stop valve



The elasticity of the water and the pipe reverses the flow when the stop valve is suddenly closed.
When a pressure wave travels upstream in the direction of the tank, pressure increases (2, 3) and decreases (4).

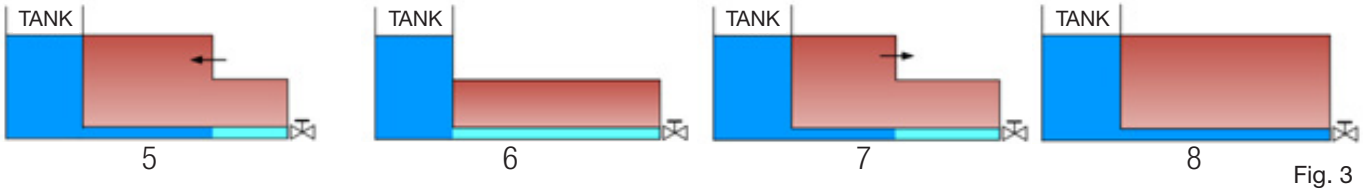


Fig. 3

When the normal pressure wave reaches the valve, the reversed flow of the column (5, 6) tends to create a vacuum near the valve resulting in a subnormal pressure up till the tank.
The reverse flow creates the initial conditions starting another cycle (6, 7, 8, 2).

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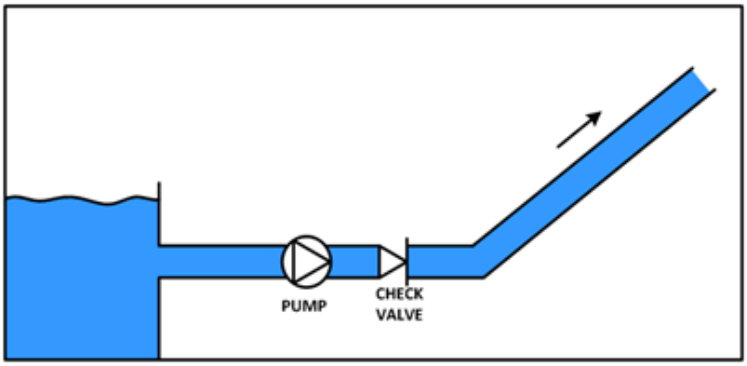
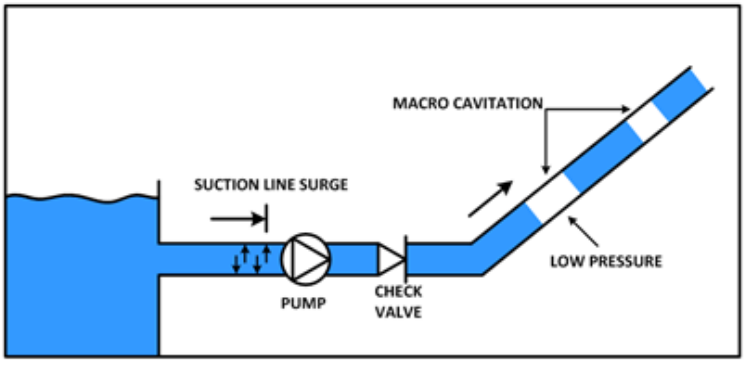
SURGE CONTROL IN PUMP STATIONS

When a power failure causes a pump stop it can cause pressure waves at the inlet of the pump when the supply line to the pump is long and velocity is high. The main problem, however, is when the high pressure surge wave at the pump discharge meets the check valve or the pump control valve (which also includes a non-return function). Then serious damages can be seen.

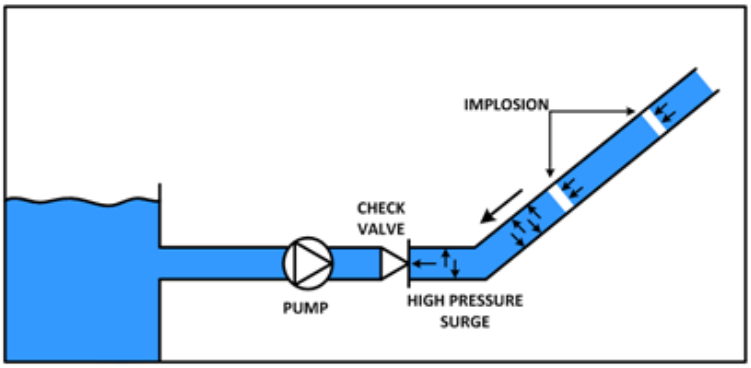
The damages are increased if the pumps are oversized and the pipelines are undersized as this will cause high velocity in the pipes.



Pump running without surge control devices. Fig. 4



Pump stop due to power failure.
High pressure at pump inlet.
Macro cavitation formation at pump discharge. Fig. 5



High and damaging pressure wave (water hammer) at the check valve and in the pipe. Fig. 6

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PREVENTION OF SURGES

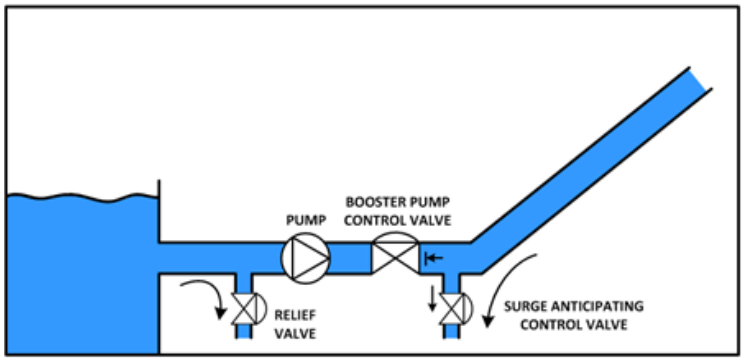

Fig. 7

Inlet surge can be prevented with a fast opening/slow closing relief valve.
Discharge line high pressure surges generated by the return flow column can be eliminated with a surge anticipating valve.
The valve will start opening when in low pressure discharge (power failure) and is open for return flow and then closes slowly to dissipate gradually the high pressure surge.

Air vessels or accumulators can also be used to dissipate energy located at pump discharge or at the inlet of the pump.

If the pump fails, the upstream accumulator will absorbe energy and the discharge accumulator will dissipate energy.

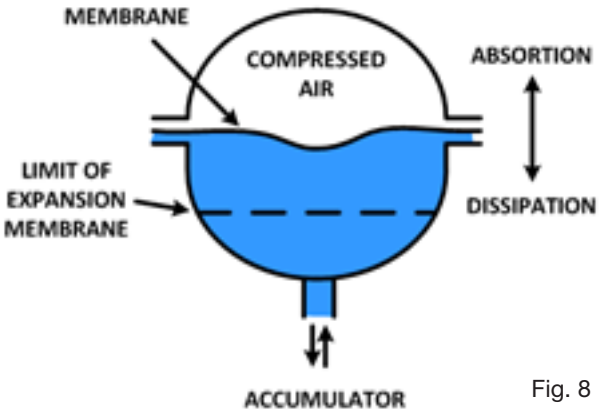

Fig. 8

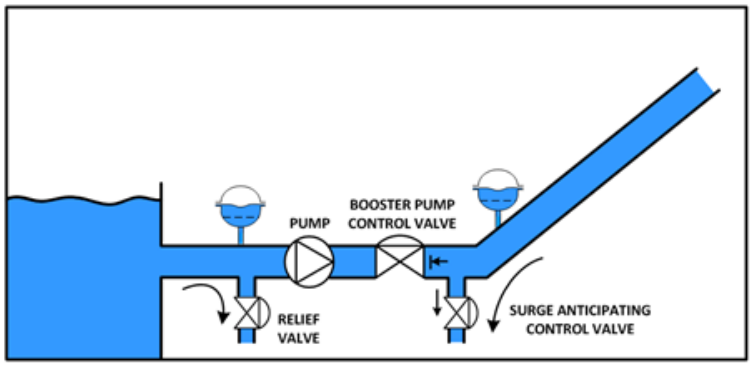

Fig. 9

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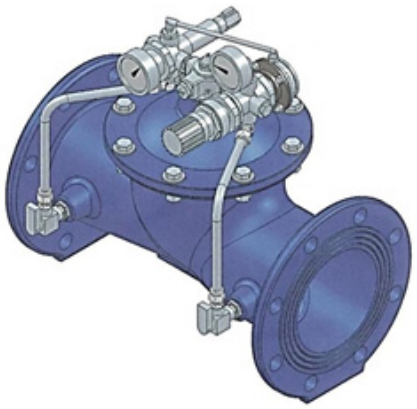
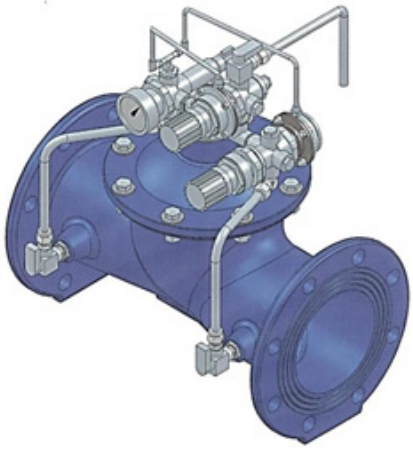
PRESSURE SUSTAINING/RELIEF VALVE



This valve automatically maintains a minimum preset inlet pressure by relieving excess pressure, regardless of changes in flow rate.

Operation
The pressure sustaining pilot reacts to small changes in the inlet pressure, controlling the valve position. If the inlet pressure falls below the set point, the main valve closes or modulates to ensure a minimum inlet pressure. The sustaining valve holds a minimum back pressure on the inlet and normally allows flow. The relief valve normally remains closed and only opens when pressure exceeds a pre-determined set-point.

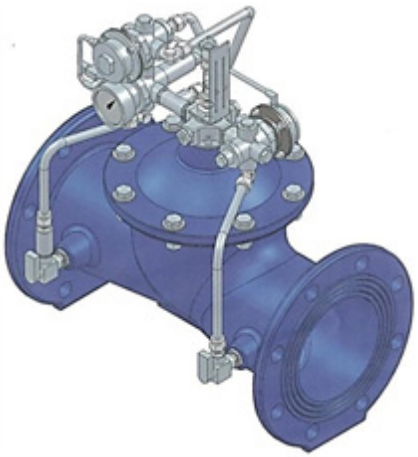
SURGE ANTICIPATING VALVE



This valve automatically opens to relieve overpressure.
It protects the pipe system against pressure surges, mainly happening at pump start up or failures.

Operation
When the pump starts and stops gradually, surges do not occur. Both pilots of the control valve (negative and positive pressure) are closed.
At power failure, the abrupt stopping of the pump results in a down surge in pressure. The negative pressure pilot senses the low pressure wave and opens the main valve. The valve anticipates the returning of a high pressure wave. If pressure increases until the preset value of the positive pressure relief pilot, the valve opens to dissipate energy. It closes slowly to prevent surges.

BOOSTER PUMP CONTROL VALVE



This valve is installed in-line, downstream of the pump discharge to prevent surges at pump starts and stops.

Operation
The valve is normally closed. On pump startup two solenoid pilots are energized. The three-way pilot discharges the water from the control chamber governed by the opening speed control valve for slow opening. The second solenoid pilot closes to stop downstream pressure on the control chamber. When the valve should close, the three-way pilot is de-energized to slowly close the main valve. The pump is kept running. When the main valve is fully closed, the limit switch de-energizes the two-way pilot and stops the pump. In case of power failure, the system closes the main valve.

Remember: Damages caused by surges and water hammer by far exceeds the costs of prevention devices!