



Dealing with Water Pressure Surge and Water Hammer in Fire Protection Systems



Fire Protection

The Source of Pressure Surge and Water Hammer in Fire Protection Systems

Water surge or water hammer is a pressure wave in a piping system caused when a fluid in motion is forced to stop or change velocity or direction suddenly. Such changes in velocity can typically occur when a valve closes or opens too quickly, or a pump starts or shuts down suddenly and creates a pressure wave in the pipeline. This momentum change can create a significant pressure rise.

The pressure rise of a surge wave can often be quite extreme, frequently above the maximum system design pressure, and can potentially cause damage to piping and instrumentation. The pictures opposite show examples of catastrophic damage to piping and accessories as a result of an excessive pressure rise from water surge/hammer.



1. A valve casing cracked by surge pressure



2. Piping breached by water hammer

The Potential Energy of Flowing Water

To illustrate the energy in a surge pressure wave, imagine a 10" pipe that is 100 meters long. This will hold about 5 metric tons of water.

At an average flow velocity of 5 meters per second, 5 metric tons of water will be moving at 18 kilometers an hour (11 mph). Bringing a 5 ton mass to a standstill or accelerating or decelerating it too quickly will result in a rapid release of large amounts of kinetic energy.

This energy will take the transitory form of a momentary rise or fall in water pressure within the piping, creating a pressure wave or surge that will travel along the pipe.



2. Piping breached by water hammer

Calculating the Potential Pressure Rise or Surge

There are many surge analysis computer programs and formulae for a highly accurate prediction of surge or water hammer in complex piping systems. When we do not have access to these calculating tools, we can at least simply and fairly accurately calculate the maximum potential pressure rise from changing the dynamics of water moving in a pipeline by using the Zhukovsky equation (see opposite).

In our case (using the parameters of the aforementioned example and with metric units):

$$\Delta H = (1000 \text{ ms} \times 5 \text{ ms}) / 9.81 \text{ m/s}^2 = 509.7 \text{ mh} \text{ (51 bar or 740 psi)}$$

Where:

ΔH = Pressure increase or surge

mh – Pressure in meter head

Δv = Change in velocity

ms – Velocity in meters per second

C = Celerity / Wave velocity

m/s² - gravitational acceleration

G = Gravitational acceleration

Zhukovsky Equation

$$\Delta H = \frac{c \times \Delta v}{g}$$

For an even simpler and only slightly less accurate approach when using metric units, and if our medium is water, we can just multiply the water velocity in meters per second by 10 to get the potential pressure rise from surge in bars. For example:

5 ms x 10 = 50 bar (730 psi)* maximum potential surge pressure

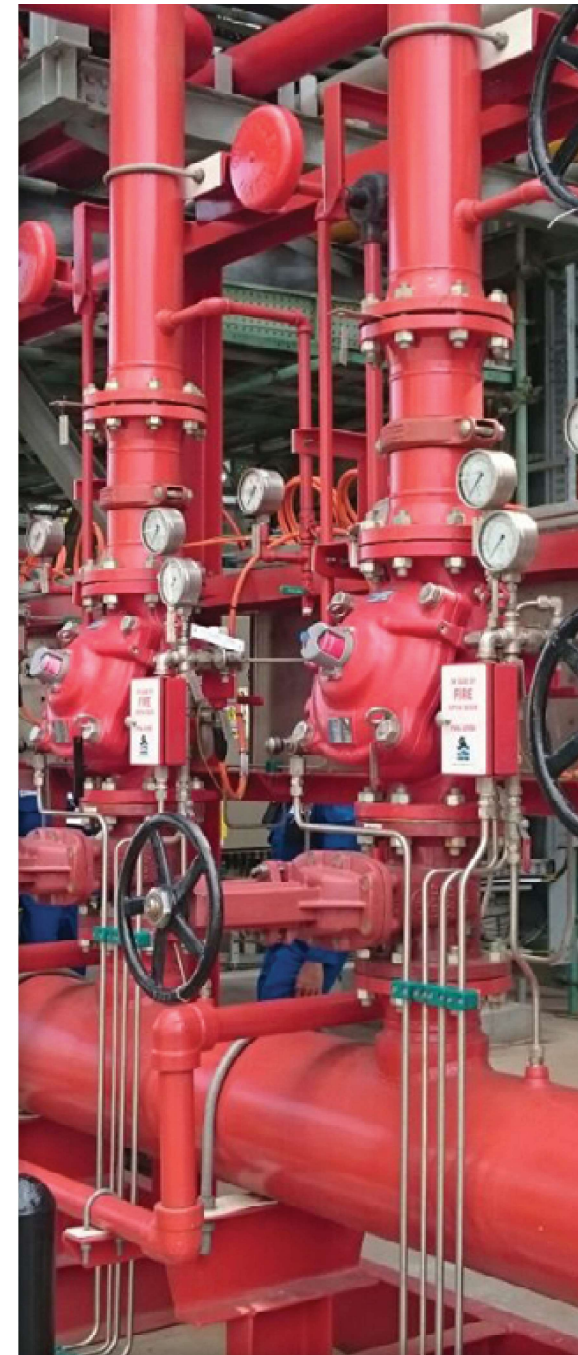
** Note that there are other factors not in the scope of this article that influence the pressure wave such as piping material, topography, and so on.*

Preventing Pressure Surge and Water Hammer Damage

Most fire protection systems are designed to operate at a working pressure of 12 barg (175 psi). Therefore, a pressure wave of 51 barg (740 psi), as calculated in the example, would be destructive in a typical fire protection system.

If after specific system hydraulic calculations, a threat of damaging surge is probable, there are several ways or methods to avoid or contain the damaging effects. The suitability of each method is dependent on the source of the problem.

The following hopes to present a suitable solution for most water surge/hammer scenarios.



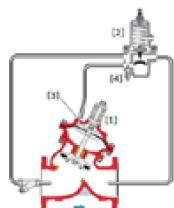
Anti-Surge Pump Control Valve

An effective way to prevent surge or water hammer deriving from Vertical Shaft Turbine Pump start-up is to use a normally open pre-emptive adjustable relief valve such as the [BERMAD model FP-730-48-BL](#) to prevent the surge wave at pump start-up at the source.

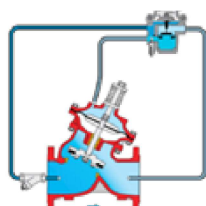
Being a normally open valve, it will relieve any air or surge potential on pump start-up. As soon as pump pressure at below the set maximum arrives at the valve inlet, the valve will close in a controlled manner and continue duty as a relief valve, relieving pressure spikes when needed to keep system pressure within the set level.



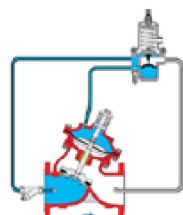
Anti-surge pump control valve sequence of operation



Standby: The [BERMAD model 730-48](#) is a normally open valve with an external lifting spring. [1] This spring keeps the valve in a fully open position when the system piping is depressurized, as it might be before a pump start-up. When the pump starts, the initial pressure surge will be nullified and excess air will be expelled from the system through the valve.



Relief/Modulating: After the surge threat has passed, air has been exhausted, and the system piping reaches normal pressure, the BERMAD 730-48 will close and continue duty as a pressure relief / sustaining valve . When the system pressure rises above the set pressure, the valve will open and relieve system over-pressure.



Closed: When the system pressure falls to below the set pressure, the valve will close. The valve will remain closed and will open only when either the piping system pressure exceeds the required set pressure, or when there is no pressure in the piping system on the upstream or inlet side of the valve.

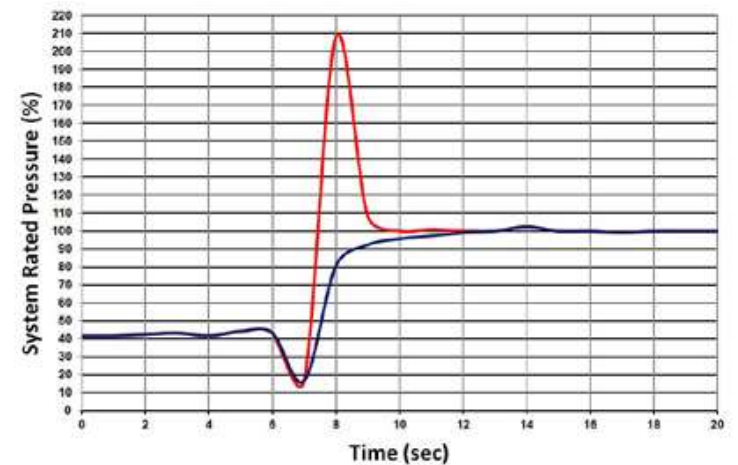


Fire Pump Control Valve

When pump start-up momentarily creates an intolerable surge level, a Fire Pump Control valve suitable for most pump configurations presents an efficient all-round solution.

Typically installed downstream of the pump outlet isolating valve, when the fire pump is dormant, this valve will be held closed using the system maintenance or jockey pump pressure. When the pump starts, the initial surge will be prevented by the closed valve that will continue to open releasing water into the system in a controlled manner to quell any potential surge or water hammer (see the graph opposite).

This controlled feed of water to the system has the added advantage of arresting excessive flow at pump start up and helping to maintain Net Positive Suction Head Required (NPSHR) whilst inhibiting pump cavitation damage.



In the above graph, the red line shows the pressure spike in the system piping at pump start up.

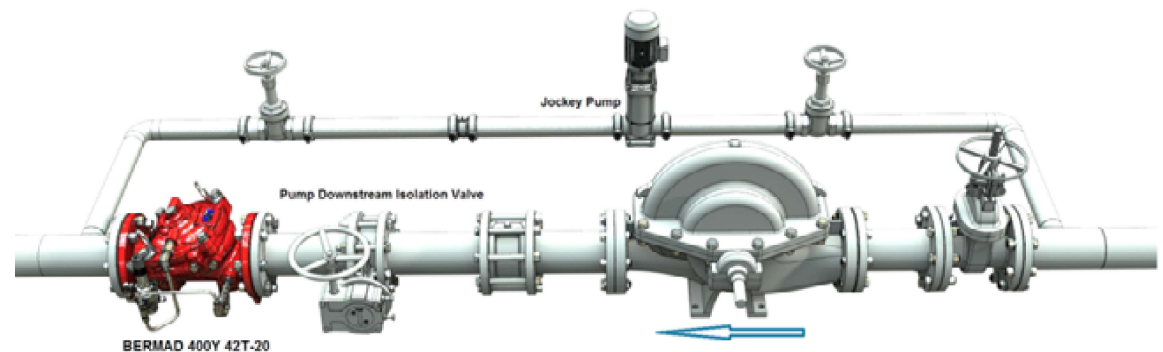
The blue line shows the controlled system pressure after "fire pump control valve" installation.

Fire Pump Control Valve installed downstream of a centrifugal fire pump

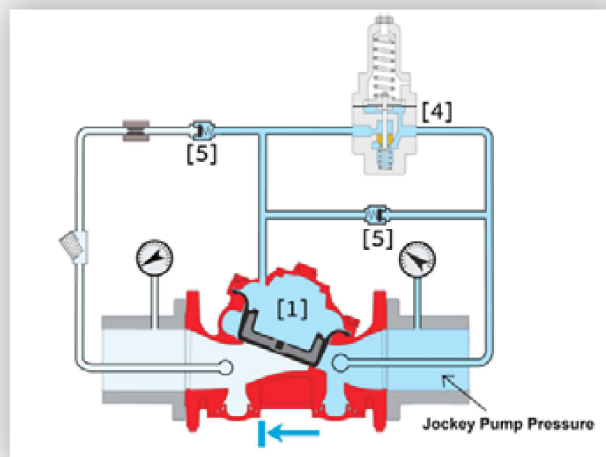
A good example of such a valve is the listed [BERMAD 42T-20](#). It features the high reliability inherent in elastomeric valves as this type of valve does not have bearings or shafts that might stick if the valve is dormant for long periods.

When fully open and not modulating, the exceptionally low friction loss or flow resistance and straight-through, unobstructed flow path of this valve allows the pump to continue to function efficiently, with minimal hindrance to delivering firewater to the extinguishing devices.

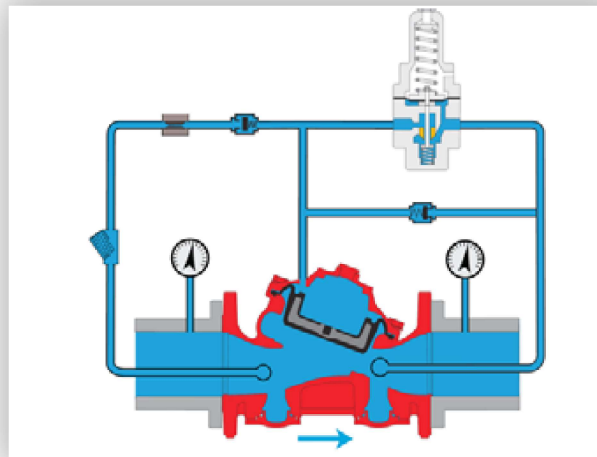
Fire Pump Control Valve installed downstream of a centrifugal fire pump



BERMAD 42T-20 Fire Pump Control Valve - sequence of operation



Before Pump Start



After Pump Start

Before Pump Start

Check valves [5] in the control trim hold jockey pump pressure in the valve control chamber [1] keeping the valve closed. Using the same principle, the valve acts as a non-return valve.

After Pump Start

After arresting the pump surge the valve fully opens. If required, the pilot can be adjusted to control the outlet pressure, keeping the downstream pressure stable at a chosen set point regardless of the upstream pressure or flow rate.

This valve also includes an inherent non-return check valve characteristic, which will prevent the backflow of system water to the pump.

In addition, the integral pilot can be adjusted to control the outlet/system pressure. Both these functions are inbuilt as standard together with preventing surge or water hammer damage at pump start up.

Valve Reaction Speed Control

Water hammer or surge can be caused by the overly fast reaction of fire protection valves.

The level of these pressure changes and the damage potential of the resulting surge will largely depend on the speed at which the valve has opened or closed.

When a valve opens too quickly, the high pressure surge will be felt downstream of the valve, with a fall of pressure upstream (Fig. 1). When a valve closes too quickly, a rise in pressure will be felt upstream of the deluge valve with a fall of pressure downstream (fig. 2).

After fast closing, there will be momentary fall in pressure downstream. Sometimes this even creating vacuum pressure as momentum carries the remaining water forward in the piping. Such a fall in pressure can cause damage to instrumentation and in some cases can cause older piping to collapse.

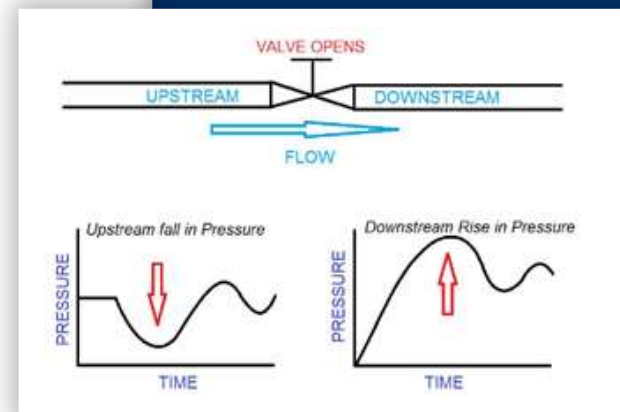


Fig. 1

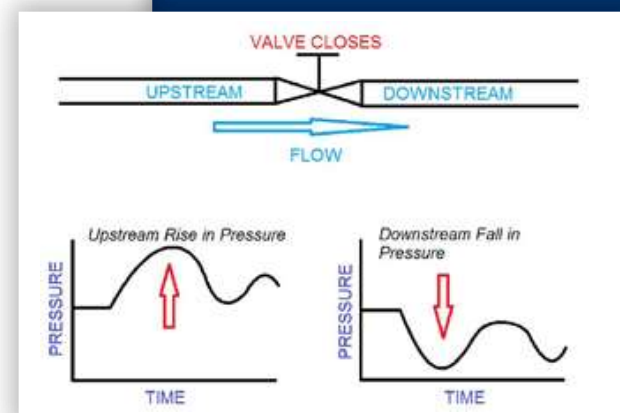


Fig. 2

The Influence of Valve Reaction Speed to Surge and Water Hammer

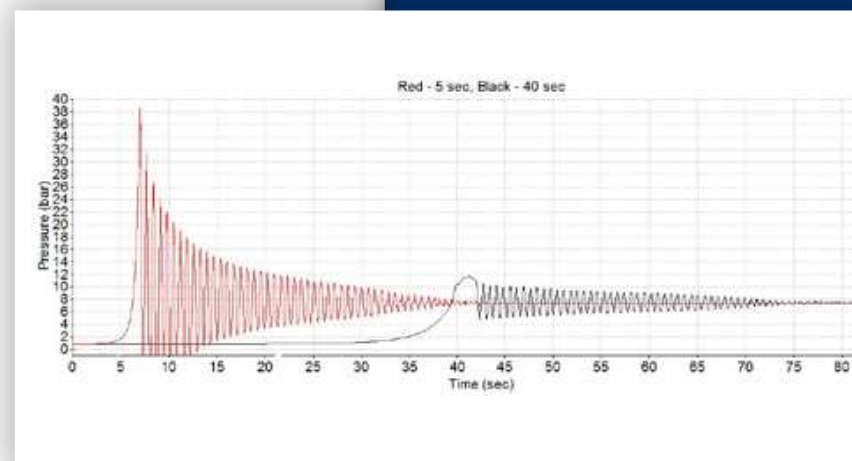
The graph opposite uses a computer program to compare the expected upstream pressure surge created by closing a fully open 6" deluge valve with 200 meters of steel piping upstream and a water flow rate of 6 meters per second. The graph shows the difference in water surge/water hammer effect created by the valve closing at two different speeds.

The red line shows the expected surge when the valve is closed quickly within 5 seconds: the upstream pressure rises to 38 barg. When the same valve with the same flow conditions closes within 40 seconds, the upstream pressure rises to a more manageable 11 barg. Also note that there will be a sudden potentially damaging fall in pressure each time the pressure wave starts to return to the valve, as shown in the graph.

This fall in pressure increases the pressure span on the surge to bring the differential change in the pressure wave to 39 bar.

In their design, most fire protection systems take into consideration the aggressive nature of fire protection water flow, designed to get the extinguishing media to the application devices in the shortest time possible. Despite this, there is occasionally a need for valve reaction control when the level of surge pressure is intolerable and piping and instruments must be protected.

Graph: upstream pressure rise as a function of valve closing speed



Red - 5 sec, Black 40 sec

fire protection deluge valve with reaction speed controls

As can be seen in the illustration opposite (fig.3), certain valves can be equipped with a reaction speed device to control the rate of opening and/or closing and avoid damaging surge. By using an adjustable flow restricting device on the control trim/loop of the valve, we can control the opening and closing speed as required, and as shown in the graph we can soften the surge effect to a bearable level.

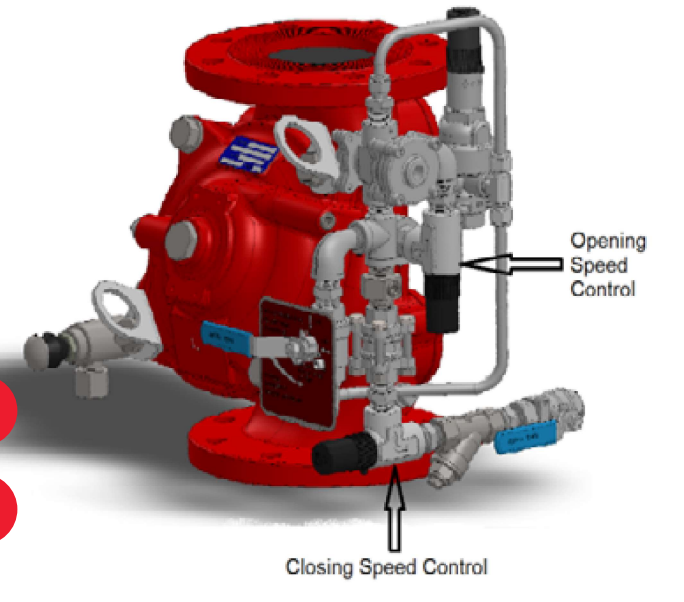
When adjusting the opening speed, care should be taken to remain within the time boundaries stated in the NFPA 13. In certain cases, this limits the time in which water is to be delivered to the extinguishing devices.

BERMAD's hydraulically operated deluge valves can be fitted with control loop flow devices to enable adjustment of the valve reaction in [closing](#) and/or [opening](#), controlling the valve reaction speed and therefore the development of surge within the piping system.

Fig. 3

CLOSING

OPENING



Jockey Pump Pressure

Despite the NFPA recommendation that the pressure maintenance or jockey pump pressure should be set (stop point) at the fire pump churn pressure, and the start point at 10 psi below, the reality is that because of system leakage and other factors, operators frequently set to a pressure lower than this. In this way, preserving the piping and reducing leakage.

As a result when the fire pump starts in a pressurized fire protection system, it frequently has to considerably raise the pressure held in the system by the jockey pump up to system operating pressure. This always creates a degree of surge. The force of this surge will depend, among other factors, on the amount of pressure that has to be made up between the system maintenance pressure and the fire pump operational pressure. Sometimes in such cases the surge level can be damaging.

By reducing the difference between the jockey pump holding pressure and the main pump operational pressure, we can reduce the surge to a manageable level. For example, as shown in (fig.4), when the operating pressure is 12 barg and the system maintenance or jockey pump pressure is set to maintain 6 barg, the main pump will quickly raise the pressure by 6 bar plus the 15 psi (1 bar) required fall in maintenance pressure to start the fire pump. In all, this equals a 7 bar sudden rise in system pressure and will result in a degree of surge.

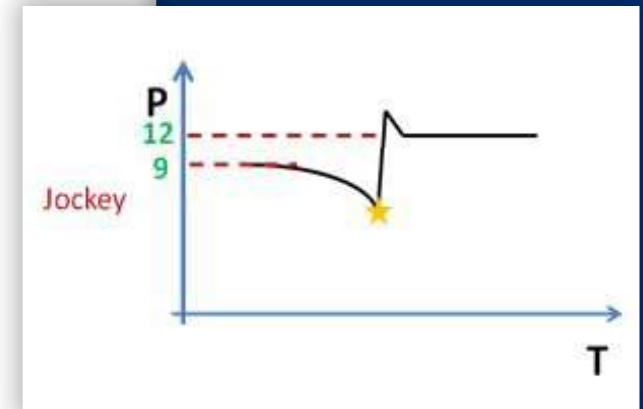
Whereas if we can set the jockey pump pressure to 9 barg (fig.5), the main pump will need to raise the pressure by only 3 bar + 1 bar = 4 bar - the resultant surge will be considerably less.



Fig. 4 - Lower jockey pressure setting



Fig. 5 - Higher jockey pump setting



Anti-Surge Bladder tanks

An effective answer to existing surge or hammer is a [surge preventing bladder tank](#) (fig. 5) that can be installed on the pipeline. The steel tank contains a flexible bladder which is fixed to the tank's connection with the main pipe of the water system. The bladder shape is similar to the tank's shape (fig. 6), so it can expand to the full capacity of the tank.

Compressed air is confined between the bladder and the external tank's housing at a pressure level compatible with the system requirements. The bladder's internal and external pressures are always equal, enabling inbound and outbound flows of water as needed.

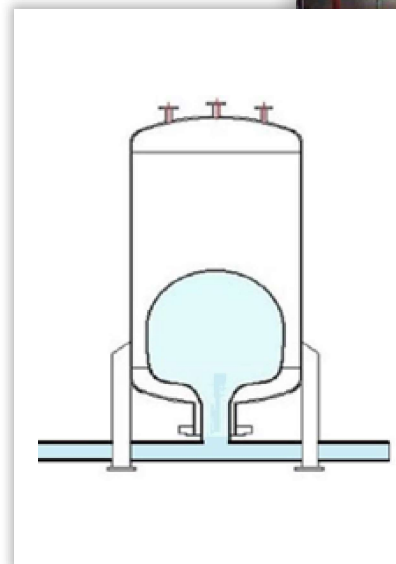
On arrival of a pressure wave to the bladder tank, the tank will displace the bladder and in effect increase the volume of the system piping to which the surge is delivered. Flow to the expanded area thereby absorbs and suppresses the surge wave.



Fig.5



Fig.6



About BERMAD

BERMAD is a leading, privately-owned global company that designs, develops and manufactures tailor-made water & flow management solutions that include state-of-the-art hydraulic control valves, air valves and advanced metering solutions.

BERMAD offers assistance to fire protection system designers. Contact your BERMAD representative to learn more, or visit bermad.com to connect with a BERMAD fire protection representative in your region.

Contact Us