Surge Analysis and Control

Overview

Understanding surges (also called water hammer or hydraulic transients) is important in determining the best way to prevent them. Surges are caused by one or more events that change the velocity of the water in the pipe. Common causes of surge events include the following conditions.

- Pump failure
- Pump startup or shutdown
- Rapid valve closure
- Column separation
- Malfunctioning check valves

When a surge is generated a wave travels down the pipeline at the speed of sound in the pipe. The surge wave velocity is the speed with which the wave travels in the pipeline. The waves travel back and forth and are reflected at each boundary. The formula to determine the wave velocity is:

$$a = \frac{4660}{\sqrt{1+\frac{K(SDR-2)}{E}}}$$ where

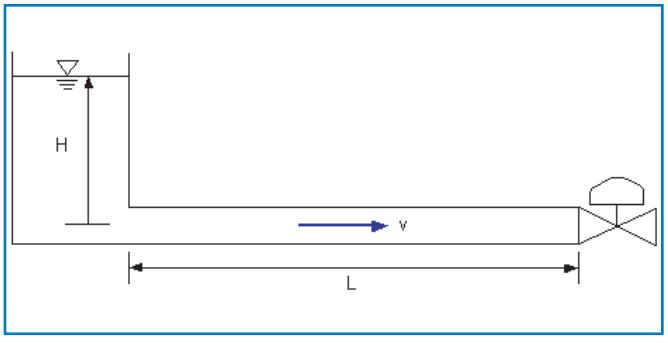
a = Surge wave velocity (ft/sec)
K = Bulk modulus of the fluid (water ~ 300,000 psi)
= density of the fluid (water ~ 62.4 lbs./cu ft)
E = Pipe material modulus of elasticity (steel ~29,000,000 psi)
SDR = Standard Dimension Ratio (pipe OD / wall thickness)

A 12-inch Schedule 40 steel pipe (OD = 12.75 in and wall thickness = 0.34 inches) has a wave velocity of about 4000 ft/sec. Entrained air in the water will reduce the velocity to a degree dependent on the content.

Maximum pressure rise due to velocity change:

$$\Delta h = \frac{a\Delta v}{g}$$ where

Δh = head rise (ft)
Δv = velocity change (ft/sec)
g = gravitational acceleration (32.2 ft/sec2)

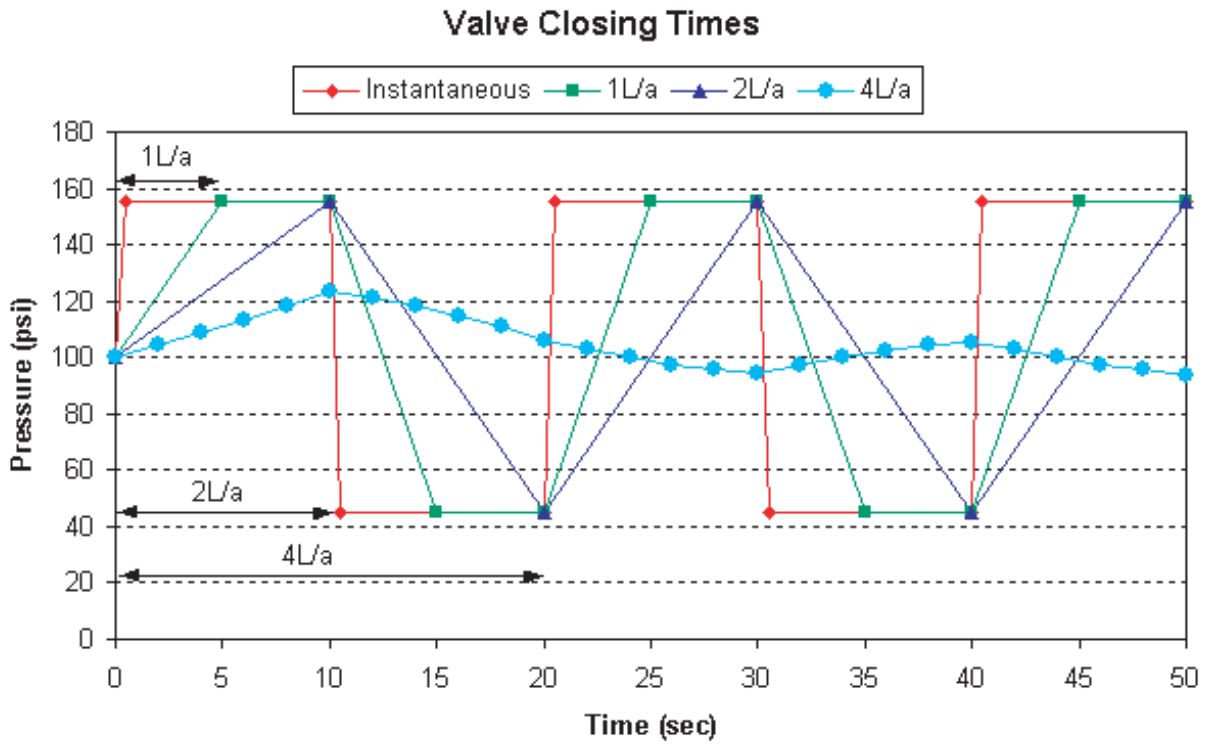


From the pipe example shown above, the pressure rise for a 1 ft/sec change in velocity v is 4000 * 1 / 32.2 = 127 ft = 55 psi.

Valve Closing Time

With this information, it is now possible to calculate valve closing time to prevent maximum surge. Using the pipe shown above with length L = 20,000 feet, the following chart illustrates the effects over time of instantaneous, 1L/a, and 2L/a, and 4L/a closing times. 1L/a closing time is 5 seconds; 2L/a is 10 seconds; and 4L/a closing time is 20 seconds for this length of pipe.

The instantaneous case exhibits a square wave with alternating high and low pressure waves. The 1L/a and 2L/a closing times have less time at the peak pressures but still reach the maximum surge pressure. Increasing closing time to 4L/a (20 seconds) reduces the peak pressure approximately by half in this simple example.

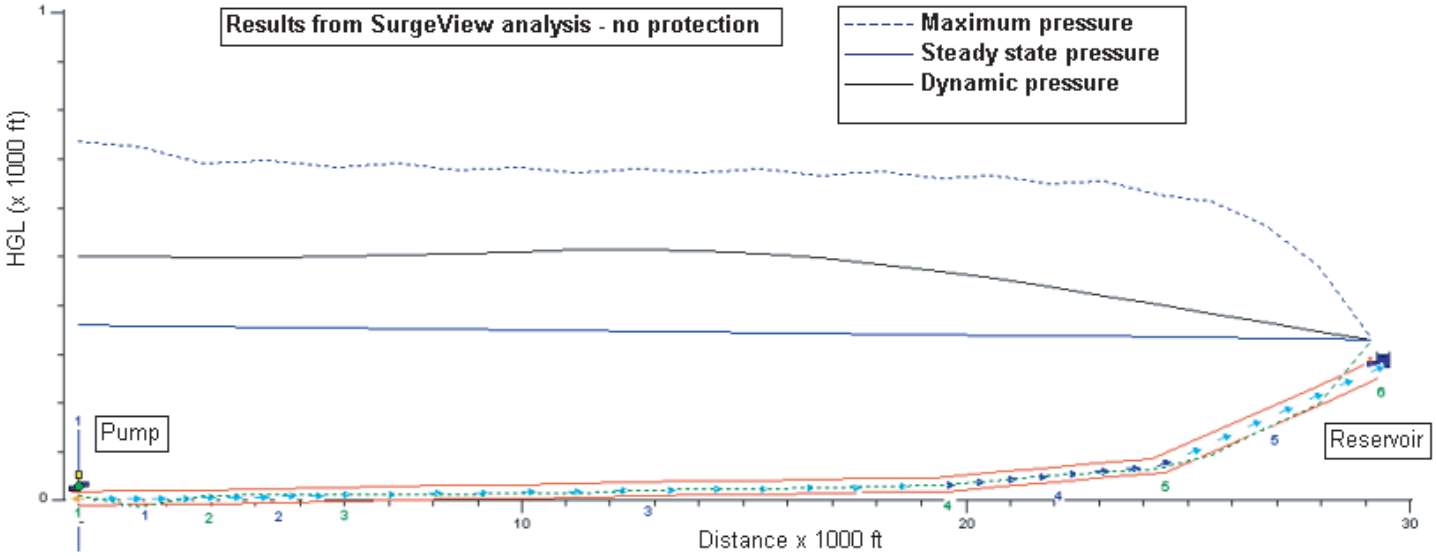


Determining the closing time to prevent a specific over-pressurization requires a computer surge analysis. Cla-Val SurgeView is a surge analysis program that examines a surge event with all system parameters and evaluates which alternatives provide a satisfactory level of protection during a surge event. It may be used for all types of surge events to evaluate various control valve alternatives to reduce peak pressures to an acceptable level.

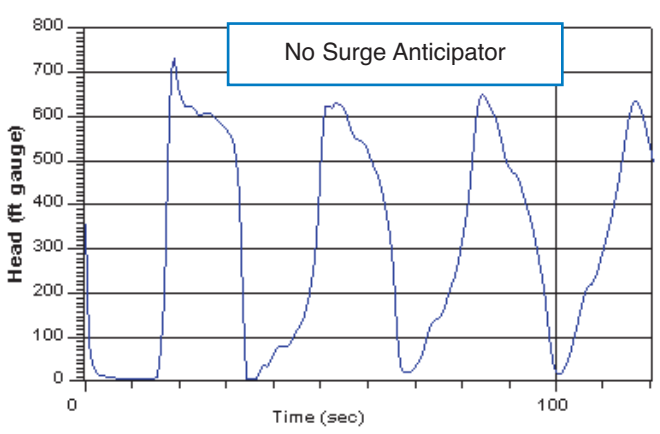
Pump Failure

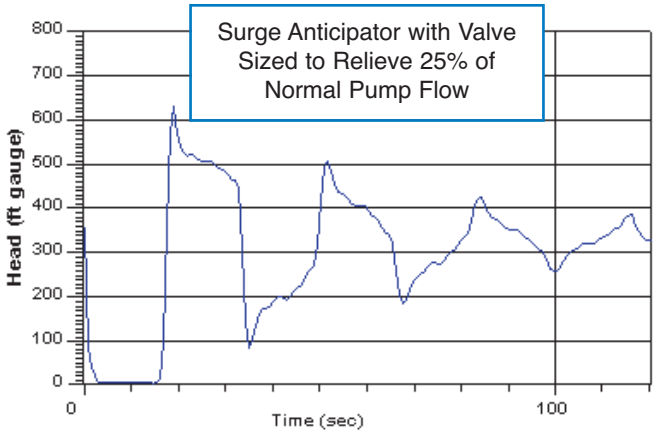
One of the most common surge events is when a pump stops due to power failure. The pump stops rotating in a short period of time, causing a downsurge wave to travel down the pipe. This low pressure wave is reflected at the pipe end boundary back to the pump with a resulting high pressure spike generated at the pump. This high pressure spike can cause damage to the piping. A standard relief valve cannot open fast enough to dissipate the excess pressure spike. The Cla-Val 52-03 Surge Anticipator Valve, however, opens on the initial downsurge pressure and stays open to dissipate the returning high pressure wave.

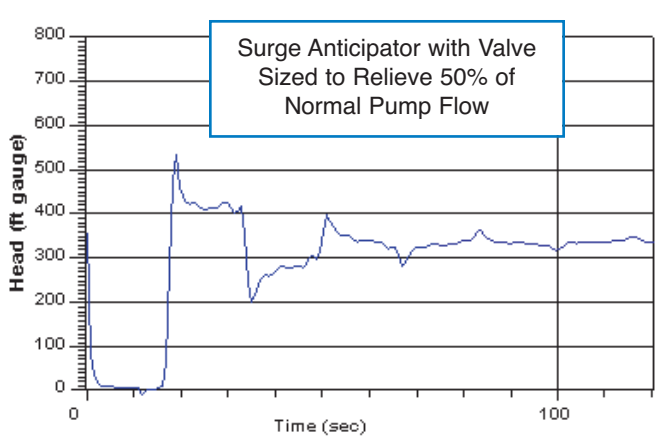
Analyzing a pump failure surge event can be relatively simple or complex, depending on the pipeline configuration and the probability of column separation or air admission into the pipe. The pipeline profile directly affects this complexity and all inputs are required for a proper SurgeView evaluation. The example shown at right shows a steel pipeline 5.5 miles long with initial velocity of 3 ft/sec. The profile is gently rising which, in turn, reduces the likelihood of column separation or air admission into the line.

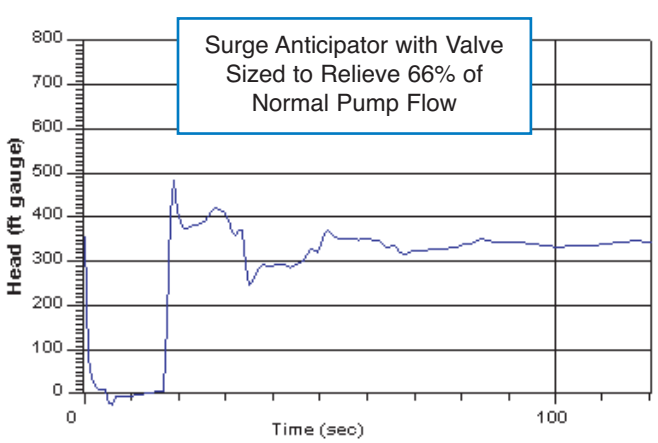


The plot of the system shown above includes the maximum head pressure along the pipeline (top dashed line) when no surge anticipator valve is used. The pressure plots below list various combinations with and without a Cla-Val Model 52-03 Surge Anticipator Valve. Each percentage refers to the flow capacity of the Model 52-03, relative to normal pump flow. The design valve sizing is based on the allowable pressure rise as specified by the customer.









Complex pipelines with undulating terrain, where either column separation or air admission into the pipe may occur, require detailed information on the pipeline profile as well as air valve size and placement. In some cases, special air valves may be needed to reduce "air valve slam" caused by rapidly rejoining water columns. Contact your Cla-Val representative for further information about SurgeView surge analysis for all your control valve applications.

Surge Control Solutions

Combination Surge Relief Valves with programmable closing time feature

A surge analysis for long pipelines often results in a recommendation to use surge relief valves as the primary surge control device. In this application, the surge relief valve would be required to open quickly to relieve a sudden rise in pressure upstream of a booster pump. To prevent a new surge, however, the valves may then be required to close over a period of several minutes (in some cases, as much as 30 minutes or more).

The Cla-Val Combination Surge Relief Valve with the programmable closing time feature are an ideal way to achieve the fast opening/"slowed" closing operation as described above. In this scenario, the surge relief valve uses a special combination of hydraulic and programmable electronic controls to achieve accelerated, hydraulically controlled opening and electronically controlled closing times. This combination produces a two-stage closing process in which the valve closes quickly during the initial stage where they have little effect on reducing flow velocity, followed by a second stage where the valves continue to close at a slower rate, limiting the subsequent pressure rise in the upstream pipe. Cla-Val's SurgeView analysis can be utilized to determine the optimal controlled closing times, as well as to accurately predict the surge conditions that will occur with and without surge relief valves.

This is an example of how simple hydraulics can be combined with electronics to solve the age-old problem of how to prevent surge in pipleine.

For more information on Cla-Val SurgeView Analysis, please contact the factory or your nearby authorized Cla-Val Manufacturer's Sales Agent.

CLA-VAL

PO Box 1325 Newport Beach CA 92659-0325

800-942-6326 • Fax: 949-548-5441 • Web Site: cla-val.com • E-mail: claval@cla-val.com

CLA-VAL CANADA
4687 Christie Drive
Beamsville, Ontario
Canada L0R 1B4
Phone: 905-563-4963
Fax: 905-563-4040
E-mail sales@cla-val.ca

CLA-VAL EUROPE
Chemin des Mésanges 1
CH-1032 Romanel/
Lausanne, Switzerland
Phone: 41-21-643-15-55
Fax: 41-21-643-15-50
E-mail: cla-val@cla-val.ch

CLA-VAL UK
Dainton House, Goods Station Road
Tunbridge Wells
Kent TN1 2 DH England
Phone: 44-1892-514-400
Fax: 44-1892-543-423
E-mail: info@cla-val.co.uk

CLA-VAL FRANCE
Porte du Grand Lyon 1
ZAC du Champ du Périer
France - 01700 Neyron
Phone: 33-4-72-25-92-93
Fax: 33-4-72-25-04-17
E-mail: cla-val@cla-val.fr