Fluid Hammer Effect

Fluid hammer, a shock wave produced by the sudden stoppage or reduction of a fluid flow, can cause sudden rises in pressure and damage instrumentation. In tank level measurement applications, high pressures can be generated by the sudden closure of a valve on an outlet line.

Ignoring friction and pipe elasticity, the equation for the pressure change in a pipe due to a sudden valve closure is:

$$P=-pc\,V$$

P = change in pressure from sudden valve closure
p = density of the fluid (See Table 1)
c = sonic velocity of the fluid (See Table 1)
V = change in pressure

If distilled water at 25°C (p=1.937, c=4,911) is flowing in a pipe at rate of 10ft/s, a hammer pressure of 661 PSI is generated if a valve is suddenly closed. A valve is considered to be closed suddenly if the time of closure is less than the time it takes a pressure wave to travel the length of a pipe and back.

Pressure change occurring within the pipe can be determined by using the formula:

$$Tc=2L/c$$

L = length of the pipe
c = sonic velocity of the fluid

In this example, if the pipe were 200 feet long, the time constant would be 0.082 seconds. If that pipe were an outlet pipe for a tank, the tank itself would not see the same pressure change as the pipe.

A rough estimate of the pressure of the pressure rise seen in the tank relative to the pressure rise in the pipe would be the ratio of the pipe area to the tank area:

$$\Delta P_{Tank} = \left(\Delta P_{Pipe}\right) \frac{A_{Pipe}}{A_{Tank}}$$

Fluid hammer effect can also be magnified by the installation of the valve. A valve closing against the direction of flow closes more slowly than a valve closing with the direction of flow, minimizing the fluid hammer effect. Table 1 shows the densities and sonic velocities of a variety of fluids (from CRC Handbook of Chemistry and Physics, 62nd Edition, 1981-1982).

TABLE 1: DENSITIES AND SONIC VELOCITIES OF FLUIDS

Fluid	Density (lbm/ft$^{3)}$	Sonic Velocity at 25°C (ft/sec)
Acetone	1.533	3,852
Benzene	1.689	4,249
Carbon disulfide	2.446	3,770
Carbon tetrachloride	3.096	3,038
Castor oil	1.881	4,846
Chloroform	2.892	3,238
Ethanol amide	1.976	5,656
Ethyl ether	1.384	3,232
Ethylene glycol	2.160	5,440
Glycerol	2.446	6,247
Kerosene	1.572	4,344
Mercury	26.203	4,757
Methanol	1.535	3,619
Nitrobenzene	2.329	4,800
Turpentine	1.708	4,118
Water (distilled)	1.937	4,911
Water (sea)	1.990	5,023
Xylene hexaflouride	2.659	2,884