

# Fluid Hammer Effect

Water hammer, a shock wave which is produced by the sudden stoppage or reduction of a fluid flow, can cause sudden rises in pressure which can damage instrumentation. In tank level measurement applications, surprisingly 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  $\Delta P = -\rho c \Delta V$  where  $\rho$  is the density of the fluid,  $c$  is the sonic velocity of the fluid,  $\Delta V$  is the change in velocity. For example, 25°C distilled water ( $\rho=1.937$ ,  $c=4911$ ) flowing in a pipe at 10ft/s can generate a hammer pressure of 661 psi if a valve is closed "suddenly". 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 return. That time constant  $T_c=2L/c$  where  $L$  is the length of the pipe and  $c$  is the sonic velocity of the fluid. In this example, if the pipe were 200 feet long, the time constant would be .082 seconds.

The above example describes the pressure change that can occur within the pipe. 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...

$$\Delta P_{\text{Tank}} \approx (\Delta P_{\text{Pipe}}) \frac{A_{\text{Pipe}}}{A_{\text{Tank}}}$$

...the ratio of the pipe area to tank area:

Water hammer can also be affected 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 water hammer effect.

A table of densities and sonic velocities of a variety of fluids (from CRC Handbook of Chemistry and Physics, 62nd Edition, 1981-1982) is provided below:

Fluids	Density (lbm/ft <sup>3</sup> )	Sonic velocity at 25°C (ft/sec)
Acetone	1.533	3852
Benzene	1.689	4249
Carbon disulfide	2.446	3770
Carbon tetrachloride	3.096	3038
Castor oil	1.881	4846
Chloroform	2.892	3238
Ethanol amide	1.976	5656
Ethyl ether	1.384	3232

Ethylene glycol	2.160	5440
Glycerol	2.446	6247
Kerosene	1.572	4344
Mercury	26.203	4757
Methanol	1.535	3619
Nitrobenzene	2.329	4800
Turpentine	1.708	4118
Water (distilled)	1.937	4911
Water (sea)	1.990	5023
Xylene hexafluoride	2.659	2884