WATERHAMMER LAB

PURPOSE: The main purpose is to give you some experience with water hammer in a simple pipe network. You will measure the pressure changes generated by a sudden valve closure and compare these changes with theoretical pressure changes. The theoretical changes need the wave speed for the pipe. This will be calculated from the pipe period.

SETUP: The setup consists of a pump which draws water through one long pipe from a tank and sends it back to the same tank through another long pipe. A high speed manual valve is installed just upstream of the pump inlet and another is installed just downstream of the pump outlet. A high speed pressure sensor is installed in each of the valves. It is used to measure the pressure transients that are generated by a sudden valve closure. The sensor is connected to an oscilloscope. For some tests a short dead end pipe is attached to the inlet pipe.

PROCEDURE: Use a sudden valve closure to determine the pipe period of each pipe. Use the period to calculate the wave speed of each pipe. Calculate the pressure changes generated by the sudden closure. Measure the pressure changes generated by a sudden closure. Install the dead end pipe and perform a sudden valve closure.

OBSERVATIONS: For the basic system compare the theoretical pressure changes with the measured pressure changes. Explain why the pressure traces for the inlet pipe are different from the outlet pipe. Explain the pressure trace generated for the dead end pipe case.

SUDDEN VALVE CLOSURE

Consider a pipe with a valve at its downstream end and a reservoir at its upstream end. When the valve is suddenly closed, a high pressure wave propagates up the pipe. As it does so it, it brings the fluid to rest. When the wave reaches the reservoir, there is a pressure imbalance. This causes a back flow which propagates as a wave down the pipe. As this wave moves down the pipe, the pressure is restored to its original level. When the wave reaches the valve, there is flow imbalance. This causes a low pressure wave to propagate up the pipe. As it does so, it brings the fluid to rest. When the wave reaches the reservoir, there is a pressure imbalance. This causes an inflow which propagates as a wave down the pipe. As the wave moves down the pipe, the pressure is restored to its original level. When the wave reaches the valve, conditions in the pipe are the same as they were at the instant the valve was closed. So, one cycle of vibration requires 4 transits of the pipe by pressure waves. This means that the natural period of the pipe is 4 times the length of the pipe divided by the wave speed. So the wave speed 4 times the length of the pipe divided by the natural period.

WAVE SPEED

The pressure change ΔP in a pipe generated by a flow speed change ΔS caused by a sudden valve closure is

$$\Delta P = \rho \, a \, \Delta S$$

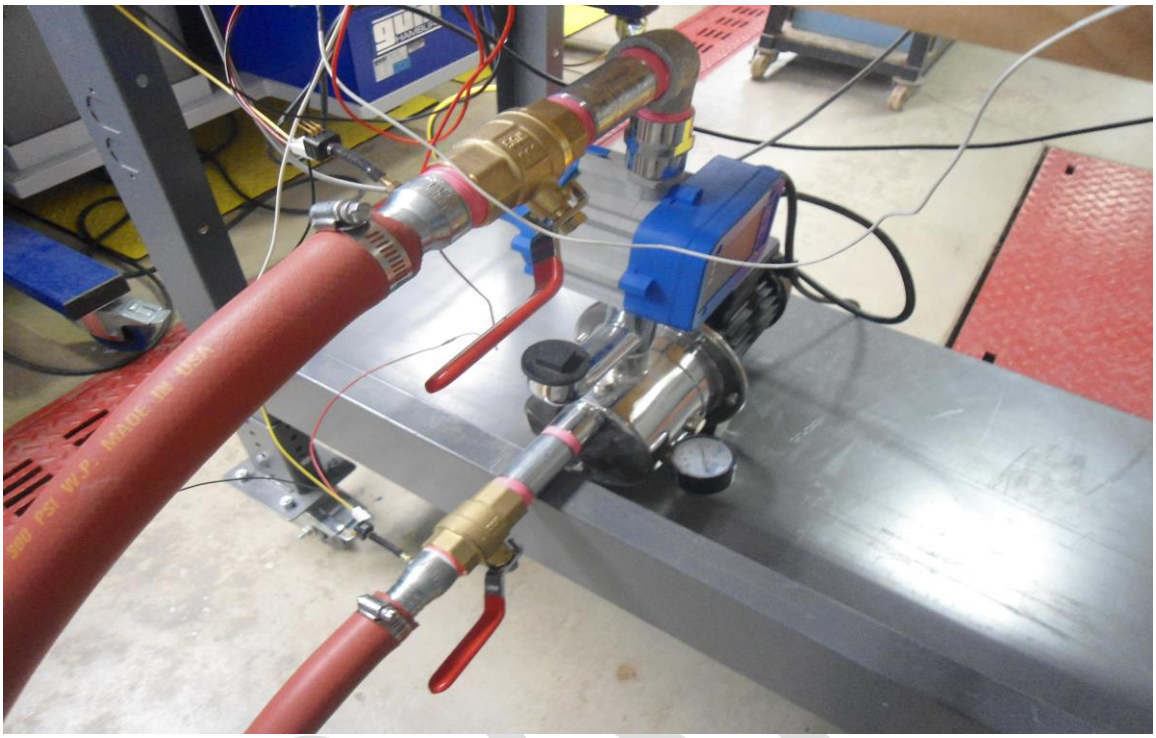
where ρ is the density of water, a is the wave speed for the pipe and ΔS is the flow speed change. A surge pressure is generated when flow is towards the valve. A suction pressure is generated when flow is away from the valve. The wave speed a for a pipe is

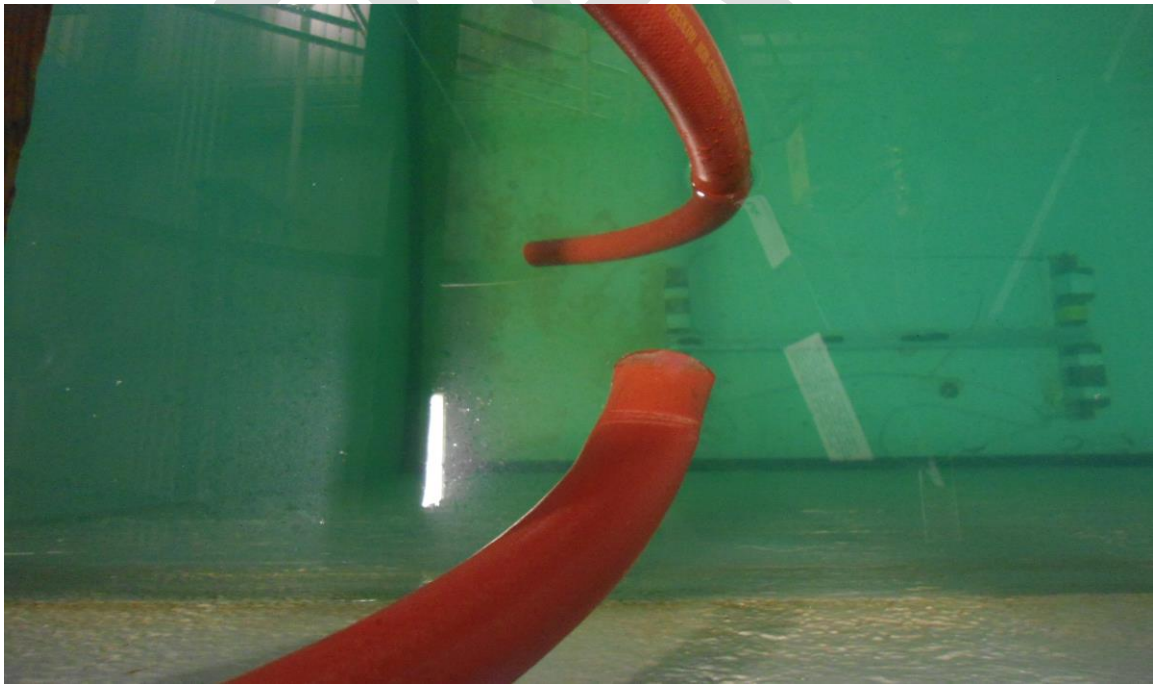
$$a = 4L/T$$

where L is the length of the pipe and T is the wave period of the pipe. The flow speed in a pipe is

$$S = Q/A$$

where Q is the volumetric flow rate in the pipe and A is the internal cross sectional area of the pipe. Q can be measured and A can be calculated.





SETUP DATA

For the basic system with long inlet and outlet pipes the length of each pipe is approximately L=21m and the nominal inside diameter of each pipe ID=2.54cm. For the dead end pipe system the dead end pipe which is 5m long is attached to the inlet pipe 5m from the pump. The overall length of the inlet and outlet pipes is still approximately 21m. The diameter of the hose is 32mm and the wall thickness is 6mm. The Elastic Modulus of Rubber Hose is 50 MPa.

The PX40 pressure sensor used to measure pressure reads 0.5VDC when pressure is zero relative to atmosphere and 4.5 VDC when the pressure is 100psi. So the sensitivity of the sensor is 100/4 or 25psi per volt.