From: Max Flowe

Subject: Project 315-Lab 4: Water Hammer

To: XYZ Consulting Inc

We had a bit of a mess at the hospital out in Seeville, BC - a water main blew out and flooded the entire basement - a lot of equipment damaged. Nearcreek was doing some unrelated work in the basement but nearby the mains. The hospital admin is, of course, trying to stick us with the bill.

It looks like the accident might have been caused by a water hammer hit and we'd like you do to a bit of work to show that the blow-out could have been independent of what Nearcreek was doing. For good measure, if you could recommend to the hospital some prevention mechanisms, it would be great.

Data that's needed, (plots as necessary):

- Water hammer measured for a number of flows.
- The pressure rise predicted by frictionless water hammer theory for each of the cases examined. Comparison with measured.
- Effect on pressure of distance away from the valve closure.
- Comparison of the pressure rise and wave travel time for the high flow rate for your data collected manually and automatically.
- Comment on the effect of the surge tank on the magnitude of the pressure rise.

If you need to filter, use a moving average.

We're pretty sure that that that Seeville Hospital admin. won't pay us for this work, but we feel like we have to recommend prevention mechanisms for something that could shut down a critical regional hospital, even though we'll take a loss on this.

We need this soon, so please submit a pdf of your report via the Canvas system within two weeks. I'll have accounting put together a PO and send it your way.

Regards,

Max Flowe

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Background

When a valve at the end of a pipeline is closed suddenly, very high pressures are generated which can cause pipes to fail. This is called water hammer. When designing pipe systems, it is very important to compute these pressures and to design to limit the pressures to reasonable values.

The high-pressure wave is transmitted upstream at velocity close to the speed of sound in water. If there is an open reservoir at the other end of the pipe, the wave is reflected as a negative wave, causing the pressure to drop. If there were no friction, the negative wave would have the same magnitude as the positive wave and the wave would continue indefinitely being reflected back and forth from one end of the pipe to the other.

However because of friction the pressure wave gradually diminishes in magnitude and the waveform becomes "rounded" instead of its theoretical rectangular form (see textbook for appropriate figures).

An interesting point to note is that as long as the valve is fully closed before the negative wave returns, the pressure rise at the valve is the same as it would be if the valve were closed instantaneously.

The pressure head rise due to sudden valve closure is

$$\Delta h = \frac{va}{g} \qquad \text{or} \qquad \Delta p = \rho v a$$

where Δp is the pressure rise, Δh is the head rise, v is the velocity of water in the pipe (before valve closure), a is the celerity of the water hammer wave (see next equation) and ρ is the density of water.

$$a = \sqrt{\frac{B/\rho}{1 + c\dfrac{D}{e}\dfrac{B}{E}}}$$

where: B = fluid bulk modulus of elasticity (B = 2100 MPa for water), ρ = the fluid density, D = pipe diameter, e = pipe wall thickness, E = modulus of elasticity for the pipe material (110,000 MPa for copper) and c = 0.9 (depends on how the pipe is restrained and Poisson's ratio).

Apparatus

Familiarize yourself with the apparatus by studying the schematic below. The level of water in the constant head tank determines the absolute pressures that can be generated in the system. From the constant head tank the water flows through a 300 foot long pipe which is coiled to conserve space. Three pressure ports are located at various distances along the pipe (each port has both an analog gauge and a pressure transducer hooked up to the computer). At the end of the pipe, there is a surge tube and a computer controlled solenoid valve C which is used to cause the water hammer. The flow rate through the pipe is varied by adjusting Valve E. After flowing through valve E, the water goes into a measuring tank (volume measurement) which can be used with a timer to determine the flow rate (the drain valve F has to be closed when making a flow rate measurement).

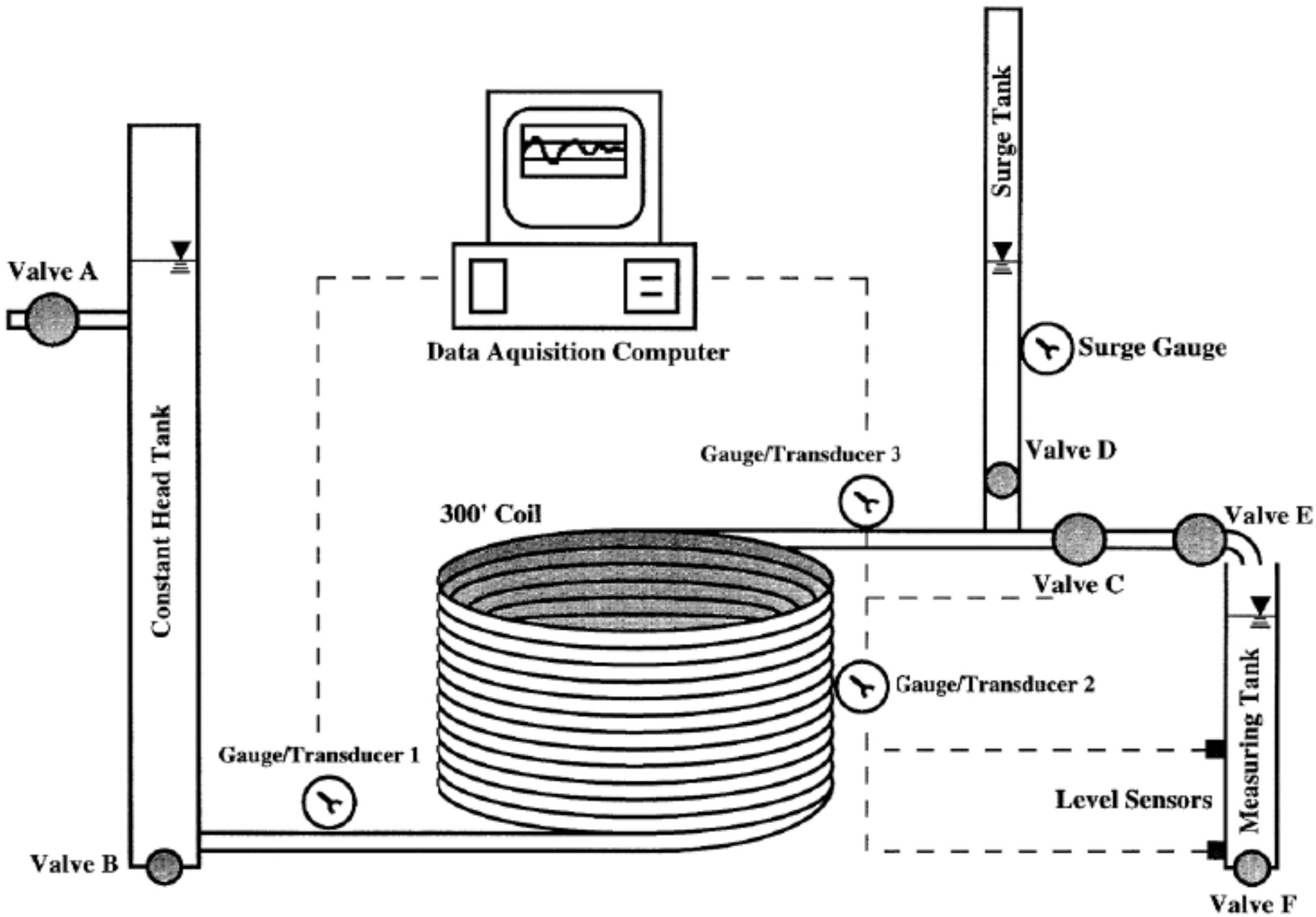

FIGURE - SCHEMATIC OF WATERHAMMER APPARATUS

J. VINE 8/9/95

Cautions

1) Do not start the experiment until you understand the equipment and have discussed the experiment with your TA.
2) Switching the pressure ports from analog gauges (manual operation) to pressure transducers (computer operation) can be tricky and you are asked to get the assistance of the TA to operate (or confirm) the small valves at each of the three pressure ports, at least until you thoroughly understand the experiment.

Procedure

During the experiment, the solenoid valve C creates a water hammer condition in which a pressure pulse travels down the pipe. This pulse is measured at the three pressure ports along the pipe. This is repeated using different flow rates and with or without the surge tank (by opening or closing Valve D).

The experiment is first done by making the measurements manually (pressures with the analog pressure gauges and flow rate by manually timing the volume change) then repeated using the computer to automatically measure the pressures and determine the flows.