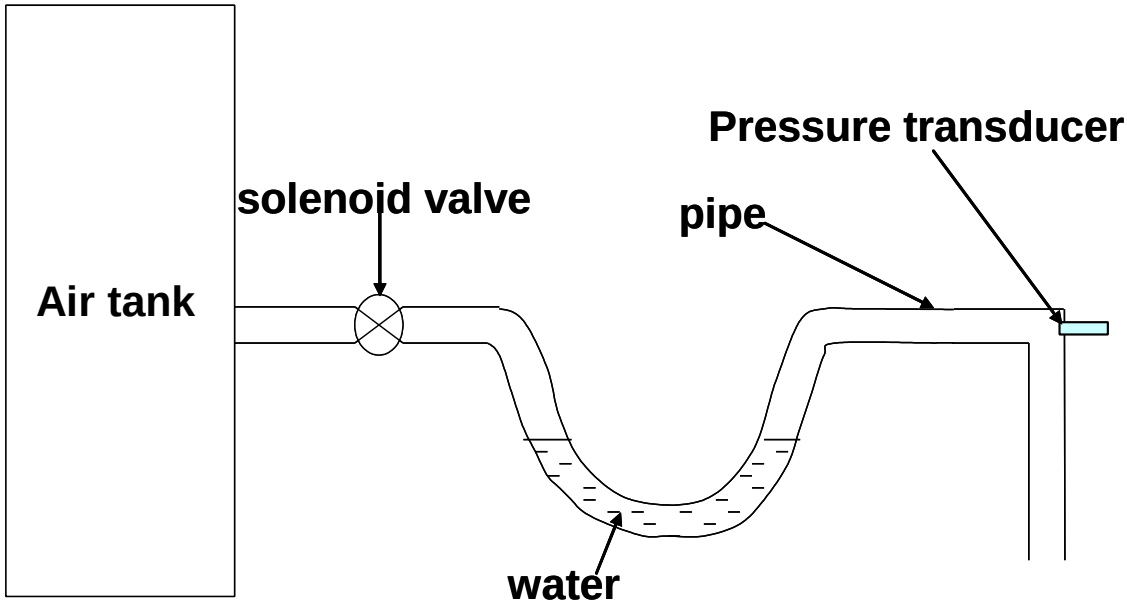
2.672 Project Laboratory
Spring 2009

4. Pipe Clearing Fluid Transients

Your firm has been hired by an apple orchard in rural Massachusetts to design its new cider pasteurization equipment. This orchard only makes cider during a short period in the fall; the equipment is stored in an unheated barn during the rest of the year. For sanitary reasons, the equipment is to be flushed with water at the end of the season. To prevent freezing damage during the winter, and to keep the equipment clean for the remainder of the year, it has been proposed that the pipes in the pasteurizer be blown dry with filtered shop air before storage.

The project lead is concerned that this air purge procedure may result in damage to the pasteurizer as slugs of residual water are forced around the numerous tubing bends[2]. You have been tasked with modeling the forces exerted by these water slugs as they are cleared by high-pressure air. Your model will be used by the design team to choose orifices that will restrict the purge flow, and thus transient pipe forces, to safe levels.

A member of the design team has made a bench-level experimental model of the pasteurizer, consisting of a section of plastic pipe in which a measurable amount of water can be trapped. This water is driven out of the pipe by an air flow metered by a choked flow orifice of known diameter, which is that of the throat area of the solenoid valve used to switch on the flow. The nominal orifice size is stated on the valve body. Due to the compact valve design, the valve's discharge coefficient is significantly lower than 1. (If you have time, you can calibrate the discharge coefficient by discharging the tank; if you do not, you can assume a discharge coefficient of 0.5.) The mass flow rate through this orifice can then be calculated using formulas that are in your fluid mechanics text books under the section of compressible flow. The pressure exerted by the slug of moving water is recorded by a pressure transducer on the pipe elbow. From this pressure, the force on the elbow may be deduced.



[2] For instance, see http://www.dairyengineering.com/juicepasteur.asp