Water Circuit Lab

When a fluid flows in a conduit, there is friction between the flowing fluid and the pipe walls. The result of this friction is a net loss of energy in the flowing fluid. The fluid pressure is the source of the energy loss. Thus, whenever a fluid flows through a pipe, the pressure of the fluid will decrease in the direction of the flow in the absence of other effects, such as a gravitational field, or mechanical devices, such as pumps.

Fluid flow can be laminar or turbulent in nature. Turbulent flow is characterized by intense mixing phenomena often observed as eddies within the flow field. Laminar flow is characterized by a very smooth appearance and is devoid of intense missing phenomena. The third regime of fluid flow is transitional. As the name implies, it occurs when the fluid flow is in transition from laminar to turbulent flow or from turbulent to laminar flow. In general, the flow is considered to be laminar below Re=2000 and turbulent above Re=3000.

The pressure drop along a straight pipe segment can be calculated using the following set of equations:

1. From your textbook, use Table A.8 to find the density and dynamic viscosity of water:

   $\rho = 998\ kg/m^3$ → Density of water at room temperature (20°C)

   $\mu = 1.01x10^{-3}\ Ns/m^2$ →Dynamic viscosity of water at room temperature (20°C)

2. Calculate the inside diameter of the pipe using the measured outside diameter as follows:

   $D_i = D_o - 2t$ →where D_i is the inside diameter, D_o is the outside diameter, and t is the wall thickness of the pipe

   $D_i(in\ meters) = 0.0254 \times D_i(in\ inches)$

3. Calculate the average velocity in the pipe:

   $A = \frac{\pi}{4} D_i^2$ →Inside cross-sectional area of the pipe

   $\bar{V} = \frac{Q}{A}$ →Average velocity in the pipe

   $Q\left(\frac{gal}{min}\right) \times \frac{3.7854x10^{-3}\ m^3}{1\ gal} \times \frac{1\ min}{60\ sec} = Q\left(\frac{m^3}{s}\right)$ →Volumetric flow rate

4. Calculate the Reynolds number (Re):

- If Re<2300 then the flow in the pipe is *laminar*
- If Re>2300 then the flow in the pipe is *turbulent*

$$Re = \frac{\rho \bar{V} D_i}{\mu} = \frac{998 \frac{kg}{m^3} \times \bar{V}\left(\frac{m}{s}\right) \times D_i(m)}{1.01 \times 10^{-3} \frac{Ns}{m^2}}$$

5. Find the friction factor (f) using the Moody diagram (Fig 8.12 in your textbook):

   f = 0.0222 →Assuming a *smooth* pipe

6. Calculate the pressure drop in a 24 inch and 48 inch straight pipe segment:

   $L = 24\ in\ \times \frac{0.0254\ m}{1\ in} = 0.6096\ m$ $L = 48\ in\ \times \frac{0.0254\ in}{1\ in} = 1.2192\ m$

   For a straight pipe segment, the pressure drop between two points which are at the same elevation is given by:

   $\Delta P = P_1 - P_2 = \rho \times h_l = \rho\left(f \frac{L}{D_i} \frac{\bar{V}^2}{2}\right)$ →Note that there are no minor losses or pressure drop due to elevation difference

   where

   $h_l = f \frac{L}{D_i} \frac{\bar{V}^2}{2}$ →This equation gives the major head loss in a pipe

   $1\ Pa = 4.0149 \times 10^{-3} inH_2O = 1.45038 \times 10^{-4} psi = 2.953 \times 10^{-4} inHg$

A piping system includes many appurtenances such as bends, contractions, expansions, tees, couplings, etc. that result in a net loss of energy in the flow fluid. As noted previously, the fluid pressure is the source of the energy loss. This energy loss is mainly caused by flow separation and additional turbulence that is present, usually observed as swirling.

The head loss due to pipe fittings can be estimated from empirical data on the subject. Due to the nature of commercially available pipe fittings, the empirical data should be used as estimates only.

7. Calculate the minor losses in pipe fittings using the following equations, tables, and figures from your textbook:
   a. $h_{lm} = f \frac{L_e}{D_i} \frac{\bar{V}^2}{2}\ or\ K \frac{\bar{V}^2}{2}$
   b. Fig 8.14 →Use this figure to find the loss coefficient (K) for flow through sudden area changes

    c. Table 8.4 → Use this table to get the equivalent lengths (Le/D) for valves and fittings

8. The total pressure drop in a water circuit is given by:

$$\Delta P = P_1 - P_2 = \rho \times [g(z_2 - z_1) + h_l + h_{lm}]$$

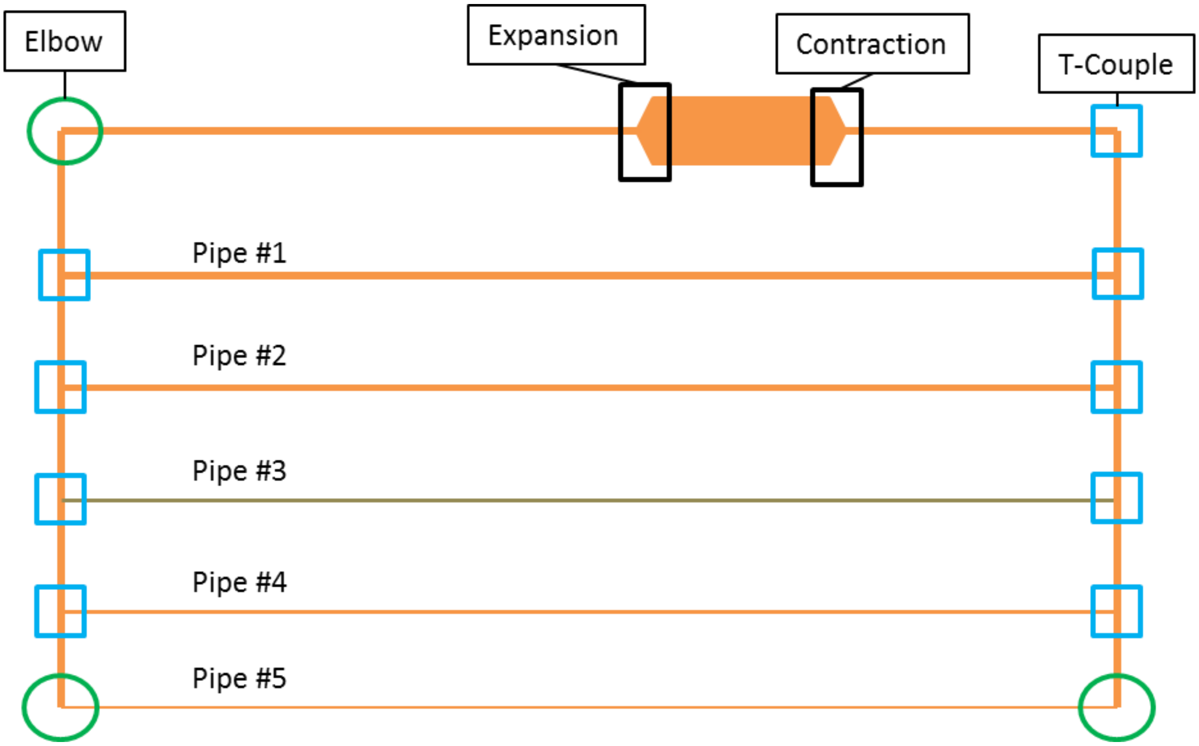
9. The efficiency of the pump can be calculated by using the following equation:

$$\eta = \frac{\dot{W}_{pump}}{\dot{W}_{in}}$$

Experimental Setup

1. Fill the water reservoir and turn on the water circuit system.
2. Open the appropriate valves to allow flow through the desired pipe.
3. Using the tubes attached to the differential pressure transducer, measure the pressure change in 24 in of pipe and 48 in of pipe. Be sure to also record down volumetric flow rate, current, and voltage.
4. Using the tubes attached to the differential pressure transducer, measure the pressure change in the minor components of the circuit found in the data tables.
5. Using the aforementioned equations, calculate the pressure drop in the straight pipe segments (24” & 48”) by means of head loss and compare to the experimental pressure drop.
6. Calculate the minor head losses.
7. Determine the total head loss in Figure 1. You can assume dimensions for Pipe #1 for any unlabeled piping. The height difference between each pipe is 8”. The number of elbows and t-couples are shown. There are 12 globe valves in this circuit.
8. Calculate the efficiency of the pump.

Figure 1: Water circuit layout



Major Losses

Pipe Type (Copper/ Stainless Steel)	O.D. (in)	Wall Thickness (in)	L = 24 in			L = 48 in			Voltage (V_{AC})
			ΔP (in H_2O)	Volume Flow Rate (GPM)	Current (A_{AC})	ΔP (in H_2O)	Volume Flow Rate (GPM)	Current (A_{AC})	
#1 Copper	1.134	0.065							
#2 Copper	0.886	0.045							
#3 St. Steel	0.845	0.055							
#4 Copper	0.621	0.045							
#5 Copper	0.468	0.045							

Minor Losses

Type	I.D. (in)	ΔP (in H_2O)	Volume Flow Rate (GPM)	Current (A_{AC})	Voltage (V_{AC})
Elbow					
T-Couple					
Valve					
Expansion					
Contraction					

Pump Efficiency

Pump Type	ΔP (in H_2O)	Volume Flow Rate (GPM)	Current (A_{AC})	Voltage (V_{AC})
Electric Motor				