Chemical Engineering 3110  
Spring Semester, 2003  
**Homework Assignment #1**  
For hand-in at the beginning of class on January 20

1. Hydrogen is flowing at the rate of 160 lb per hour at 20 psia and 212°F in a 6" Schedule 40 steel pipe. Determine the velocity pressure head and the stagnation pressure head. Express your answers in ft-lbf/lb.

2. In cases where open liquid manometer columns would be unusually high or when the liquid under pressure cannot be exposed to the atmosphere, the inverted U-tube manometer illustrated below is sometimes used. Develop a general expression for the pressure difference between points 1 and 2 in terms of $R$, $a$, $b$ and the fluid densities $\rho_a$ and $\rho_b$.

![Diagram of inverted U-tube manometer]

3. We want to construct a U-tube manometer for our laboratory. We want to measure a maximum pressure of 10 psig at a precision of 0.01% full scale (FS). The level in the manometer will be measured with a meter stick with a precision of 1 mm.
   A. What should be the maximum specific gravity of the fluid to achieve this measurement objective? If this fluid is used, what will be the minimum height of the manometer?
   B. Liquid mercury has a specific gravity of 13.5. The next nearest liquid has a specific gravity of 2.95. If we use the liquid with a specific gravity of 2.95, what will be the measurement precision of this manometer, in % of FS? What will be the maximum height of the manometer?

4. Figure 2.2-6 in the textbook shows a fluid separation system for gravity separation of two immiscible fluids.

   An empirical formula to estimate the separation time is provided below. This formula assumes that the liquids are clean and do not form emulsions.

   $$ t = \frac{6.24 \mu}{\rho_a - \rho_b} $$
where \( t \) is the separation time (hour)
\( \mu \) is the viscosity of the continuous phase (centipoise = cP)
\( \rho \) is the fluid density (lb/ft\(^3\))

From an industrial standpoint, the separation would most likely be done in a horizontal, bullet shaped vessel as shown below.

In practice, the length of the vessel would normally be five times its diameter, and should never be more than 95% full.

Design a system as described to separate 1,500 bbl/day (1 bbl = 1 barrel = 42 gallons) of a liquid petroleum fraction from an equal volume of wash acid. The oil is the continuous phase and at the operating temperature has a viscosity of 1.1 cP and a density of 54 lb/ft\(^3\). The density of the acid is 72 lb/ft\(^3\). Determine

a. The separation time for this process.
b. The diameter and length of the vessel. Use the table on page 10-139 of Perry’s (7th edition) to account for partial filling of the bullet vessel, and use the volume equation in Table 10-65 to account for the volume of the rounded ends or heads of the vessel. Assume that the heads are ASME heads with a 6% knuckle radius.
c. The height of the acid overflow above the vessel bottom.