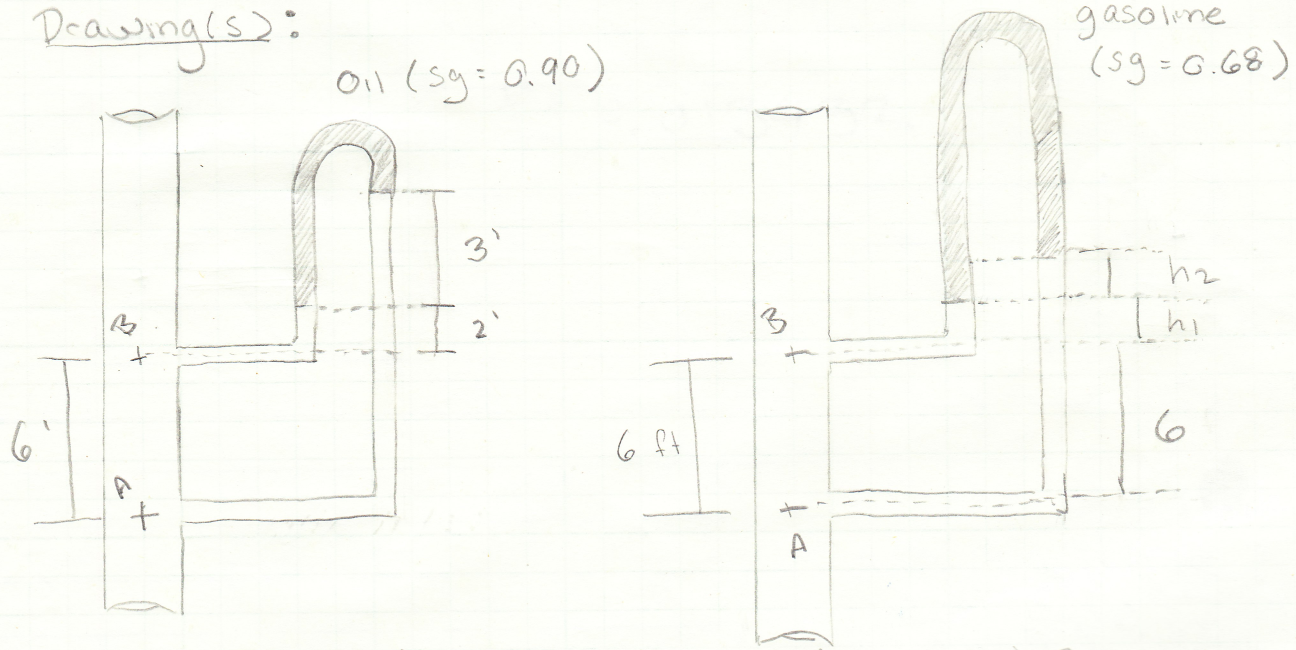
MET 330 | Test 1

Problem 1

Purpose:
- Find deflection of manometer if oil were replaced with gasoline
- Find min. height of manometer so gasoline doesn't enter system
- Find deflection using mercury in excel

Drawing(s):



Sources: Applied Fluid mechanics (7th ed.) R. Mott & J. Untener, Ch 3 powerpoints (prob. 3.69)

Design Considerations: - Fluids assumed incompressible + isothermic

Data:
- Distances using oil given
- Oil sg = 0.90 ; γ_{oil} = 56.16 lb/ft^3
- gasoline sg = 0.68 ; γ_g = 42.40 lb/ft^3
- Δp using oil = 2.7177 psi
- γ_{water} = 62.4 lb/ft^3

Procedure: The missing heights can be solved by applying the equation for pressure: $\Delta p = \gamma h$. In this case, we are given pressure, so the equation can easily be manipulated

Calculations:

First convert pressure to lb/ft^2 to be similar units of specific weight

$$2.7177 \frac{lb}{in^2} \times \frac{144\ in^2}{1\ ft^2} = 391.349 \frac{lb}{ft^2}$$

Then we will apply $\Delta p = \gamma h$ using the given data. then solve for unknown heights

$$P_A = P_B - \cancel{\gamma_w h_1} - \gamma_g h_2 + \gamma_w h_2 + \cancel{\gamma_w h_1} + \gamma_w 6\ ft$$

$$P_A = P_B \underbrace{- \gamma_g h_2 + \gamma_w h_2 + \gamma_w 6\ ft}$$

$$P_A = P_B + 391.349 \frac{lb}{ft^2} \quad \text{so,}$$

$$391.349 \frac{lb}{ft^2} = \gamma_w h_2 + \gamma_w 6ft - \gamma_g h_2$$

Plug in known data

$$391.349 \frac{lb}{ft^2} = 62.4 h_2 \frac{lb}{ft^2} + 374.4 \frac{lb}{ft^2} - 42.4 h_2 \frac{lb}{ft^2}$$

$$\frac{16.949 \frac{lb}{ft^2}}{20} = \frac{20 h_2 \frac{lb}{ft^2}}{20}$$

$$\boxed{h_2 \text{ (deflection)} = 0.847 ft}$$

For min heigh of manometer:

$\gamma_{oil} = 56.16 \frac{lb}{ft^3}$ $\qquad \frac{56.16}{42.40} \approx 1.32$

$\gamma_{gasoline} = 42.40 \frac{lb}{ft^3}$

Specific weight of gasoline is 1.32 times less than that of the oil given ∴ longer manometer would be needed.

left vertical leg of manometer with oil ≥ 3 ft

right vertical leg " " ≥ 9 ft

left leg with gasoline $\geq 3 \times 1.32 = \underline{3.96 \text{ ft}}$

right leg with gasolin $\geq 9 \times 1.32 = \underline{11.88 \text{ ft}}$

Summary: Deflection using gasoline as the manometer fluid will result in a 0.85 ft deflection. The left and right legs of the manometer must at least be 3.96 ft and 11.88 ft respectively.

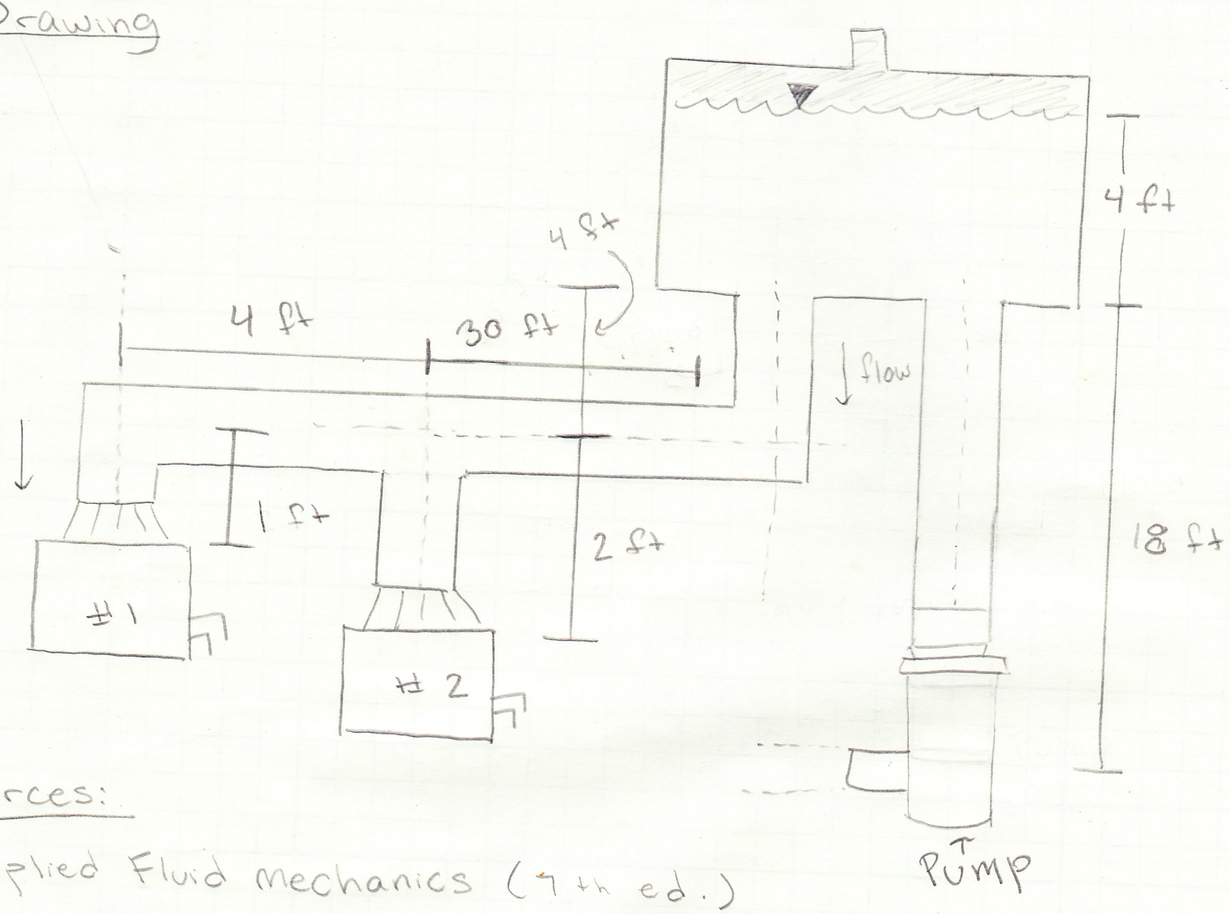
Analysis: Fluids with a lower specific weight will generally require more length of the manometer to avoid entering the system. Likewise, they will occypy more of the manometer tubing resulting in less vertical deflection (h_2).

Materials: Water, Oil, gasoline, mercury

Problem 2

Purpose: redesign pumped system by choosing best pipe size

Drawing



Sources:

Applied Fluid Mechanics (7th ed.)

R Mott & J. Untener

Design Considerations:

- Coolant assumed incompressible
- Isothermal process

Data:

- 30 gpm for machines #1 & #2
- Coolant sg = 0.92
- Dynamic Viscosity 3.6×10^{-5} lb-s/ft^2 (?)
- Filter resistance coeff (k) = 1.85
- Flow velocity ≈ 3 m/s

<u>Procedure:</u> To choose a Schedule 40 pipe, we will need to calculate its approximate flow area using the equation for flow rate: $Q = vA$. Q and v are given.

<u>Calculations:</u>

$$Q = 30 \text{ gpm} \times \frac{0.0038 \text{ m}^3}{1 \text{ gal}} \times \frac{1 \text{ min}}{60 \text{ sec}}$$

$$30 \frac{\text{gal}}{\text{min}} = 0.00189 \frac{\text{m}^3}{\text{s}}$$

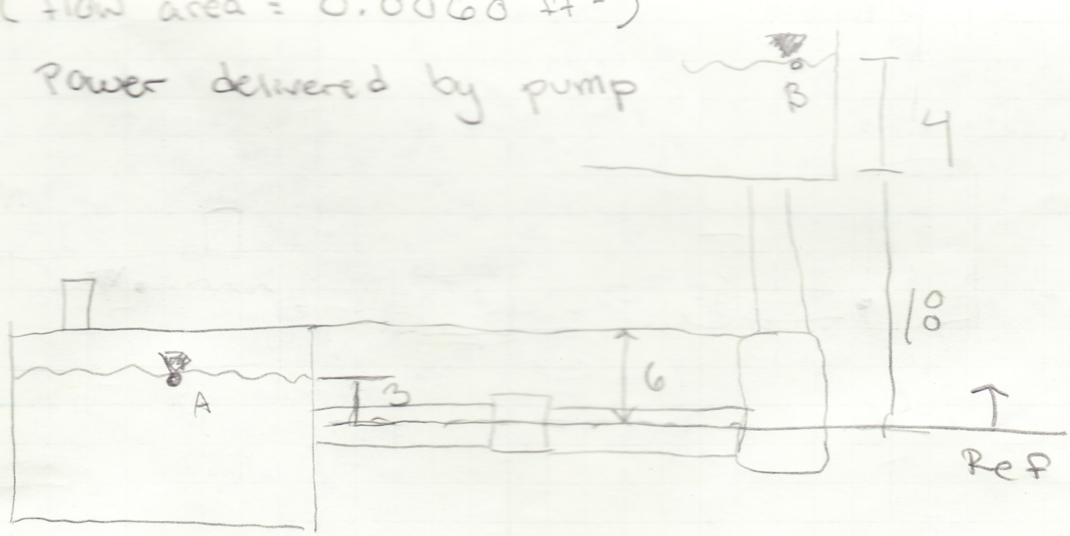
$$v = 3 \text{ m/s}$$

$$A = \frac{Q}{v} = \frac{0.00189 \frac{\text{m}^3}{\text{s}}}{3 \frac{\text{m}}{\text{s}}} = 0.000631 \text{ m}^2$$

$$= \underline{0.00679 \text{ ft}^2}$$

- This is closest to the area of NPS 1 in pipe (flow area = 0.0060 ft²)

Power delivered by pump



$$h_A = \frac{\cancel{P_B - P_A}}{\gamma} + (z_B - z_A) + \frac{\cancel{V_B^2 - V_A^2}}{2g} + h_L$$

0 gage

0 velocity (tank)

$$h_A = (22 - 3) + \underbrace{K_{filter} + f\frac{L}{D}}_{h_L}$$

Finding f as part of calculating energy loss

$$Re = \frac{\rho v D}{\eta}$$

$$sg = 0.92 = \frac{\rho_c}{1.94 \text{ slugs}} = 1.784$$

$$Re = \frac{(1.784)(9.84 \text{ ft/s})(0.0874)}{3.6 \times 10^{-5} \text{ (given)}}$$

~3 m/s ↑ Pipe Dia.

$$Re = 42618.6$$

$$f = \frac{0.25}{\log\left(\frac{1}{3.7\left(\frac{0.0874}{4.6\times10^{-5}}\right)} + \frac{5.74}{42618.6^{0.9}}\right)^2}$$

↑ ε from chart 8.2; ↑ Re

$$f = 0.0169$$

Insert "f" back into Bernoulli's

$$h_A = 19 + 1.85 + (0.0169)\left(\frac{10}{0.0874}\right)$$

$$h_A = 22.78 \text{ ft}$$

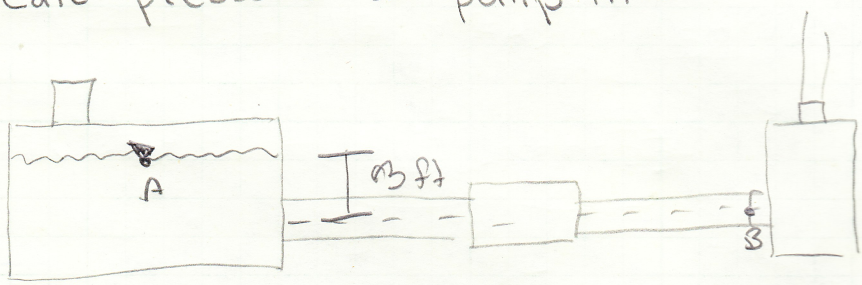
0.92 × 62.4

$$\text{Power} = h_A \gamma Q = 22.78(57.408)(0.0668)$$

$Q = 30$ gpm $= 0.0668 \frac{ft^3}{s}$

Pump power = 87.36 Hp

Calc pressure at pump inlet



$$P_B = 0 + 3\,ft\left(57.408\ \frac{lb}{ft^3}\right)$$

$$= 172.22\ \frac{lb}{ft^2}$$

Summary: 1 in. Nominal pipe determined closest to 3 m/s velocity. Pressure at pump inlet calculated as 172.22 lb/ft^2, power delivered by pump equal to 87.36 hp.

Materials: coolant, commercial steel schedule 40 pipe

Analysis: velocity slows as the cross-sectional area of the pipe increases. The larger pipes are more expensive to install, but are among the cheapest in terms of maintenance. Overall, choosing a larger pipe such as the 3 in or 2 1/2 in. would require less power and be cheaper over a two year period. In general, costs tended to be in the high hundreds of millions, though whether that is a normal range could depend on the type of plant it is (such as nuclear).