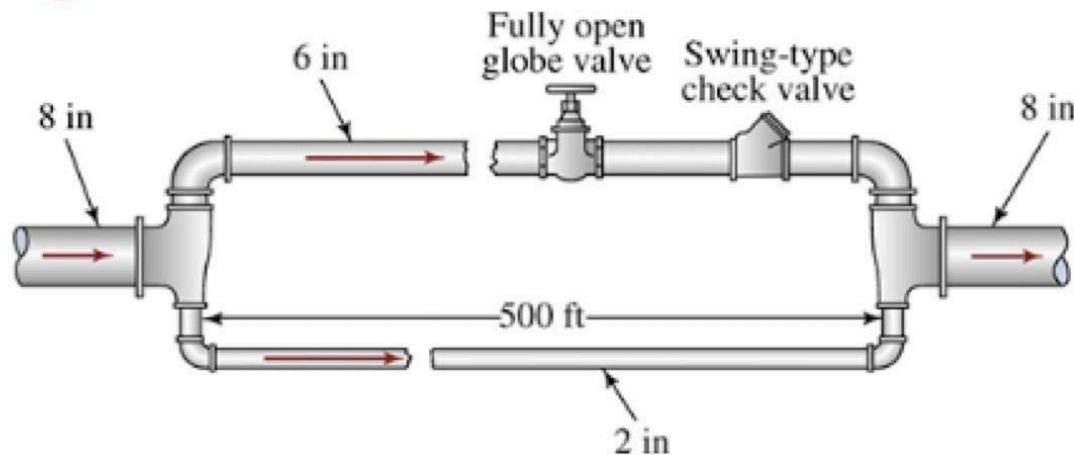


12.7 1350 gal/min $sg=0.87$ of benzene

at 140F is flowing in the 8-in pipe. Calculate the volume flow rate in the 6-in and the 2-in pipes. All pipes are standard Schedule 40 steel pipes. Solve using the Cross technique.

Figure P12.4



A short horizontal 8-inches pipe branches into two pipes, a 6-inches pipe and a 2-inches pipe. From an unequal joint at the end of 8-inches pipe, an elbow connects upward to a horizontal pipe of 6-inches that has a fully open globe valve, and a swing-type check valve in it. An opening at the bottom side of the unequal joint connects to a horizontal 2-inches pipe at the bottom through an elbow. The lengths of the branches of pipes are 500 feet. The branches of pipe again join to another unequal joint that again connects to a horizontal 8-inches pipe on the right side. Arrows point to the right inside each pipe.

$$Q_{\text{total}} = 1350 \text{ gal/min} \times \frac{1 \text{ ft}^3/\text{s}}{948.83 \text{ gal/min}} = 3.008 \text{ ft}^3/\text{s}$$

140 ft Benzene

$$S_g: 0.87$$

$$V: 6.0 \times 10^{-8} \text{ ft}^2/\text{s}$$

$$\epsilon: 1.5 \times 10^{-4} \text{ ft}$$

6 in Pipe

$$- D_1: 0.5054 \text{ ft}$$

$$- \text{Flow Area } (A_1): 0.2006 \text{ ft}^2$$

$$- \text{Relative Roughness: } \frac{\epsilon}{D_1} = \frac{1.5 \times 10^{-4}}{0.5054} = 0.000297$$

$$- f_{T,1} = 0.015$$

2 in Pipe

$$- D_2: 0.1723 \text{ ft}$$

$$- A_2: 0.02333 \text{ ft}^2$$

$$- \frac{\epsilon}{D_2} = \frac{1.5 \times 10^{-4}}{0.1723} = 0.000871$$

$$- f_{T,2} = 0.017$$

S2 Branch 1 (6 in Upper Pipe)

$$\cdot 2 \times \text{standard 90 elbows } 2 \times 30 = 60$$

$$\cdot 1 \text{ fully open valve: } 340$$

$$\cdot 1 \text{ swing type check valve } 130$$

$$\sum \left(\frac{L_e}{D} \right)_1 = 60 + 340 + 130 = 530$$

Branch 2 (2 in lower Pipe)

$$- 2 \text{ standard 90 elbows } 2 \times 30 = 60$$

$$\sum \left(\frac{L_e}{D} \right)_2 = 60$$

Step 3

$$Q_1 + Q_2 = Q_{\text{total}} = 3.008 \text{ ft}^3/\text{s}$$

$$h_{L,1} = h_{L,2} \Rightarrow h_{L,1} - h_{L,2} = 0$$

$$h_L = \left(f \frac{L}{D} + f_T \sum \frac{L_e}{D} \right) \frac{v^2}{2g}$$

$$v = \frac{Q}{A}$$

$$h_L = \left[\left(f \frac{L}{D} + f_T \sum \frac{L_e}{D} \right) \frac{1}{2gA^2} \right] Q^2 = K Q^2$$

$$\Delta Q = \frac{-\sum h_L}{2 \sum \left| \frac{h_L}{Q} \right|} = \frac{-(h_{L,1} - h_{L,2})}{2 \left(\frac{h_{L,1}}{Q_1} + \frac{h_{L,2}}{Q_2} \right)}$$

Step 4

Branch 1 (6-in Pipe)

$$V_1 = \frac{Q_1}{A_1} = \frac{2.805 \text{ ft}^3/\text{s}}{0.2006 \text{ ft}^2} = 13.983 \text{ ft/s}$$

$$NR_1 = \frac{V_1 D_1}{\nu} = \frac{13.983 \times 0.5054}{6.0 \times 10^{-6}} = 1.178 \times 10^5$$

$$f_1 = \frac{0.25}{\left[\log_{10} \left(\frac{0.000297}{3.7} + \frac{5.74}{(1.178 \times 10^5)^{0.9}} \right) \right]^2} = 0.0163$$

$$h_{L1} = \left(0.0163 \frac{500}{0.5054} + 0.015(500) \right) \frac{(13.983)^2}{2(32.2)} = 73.10 \text{ ft}$$

$$\frac{h_{L1}}{Q_1} = \frac{73.10}{2.805} = 26.06 \text{ ft}/\left(\frac{\text{ft}^3}{\text{s}}\right)$$

Branch 2 (2-in Pipe)

$$V_2 = \frac{Q_2}{A_2} = \frac{0.203 \text{ ft}^3/\text{s}}{0.0233 \text{ ft}^2} = 8.701 \text{ ft/s}$$

$$NR_2 = \frac{V_2 D_2}{\nu} = \frac{8.701 \times 0.1723}{6.0 \times 10^{-6}} = 2.499 \times 10^5$$

$$f_2 = \frac{0.25}{\left[\log_{10} \left(\frac{0.000871}{3.7} + \frac{5.74}{(2.499 \times 10^5)^{0.9}} \right) \right]^2} = 0.0202$$

$$h_{L2} = \left(0.0202 \frac{500}{0.1723} + 0.019(500) \right) \frac{(8.701)^2}{2(32.2)} = 70.28 \text{ ft}$$

$$\frac{h_{L2}}{Q_2} = \frac{70.28}{0.203} = 346.21 \text{ ft}/\left(\frac{\text{ft}^3}{\text{s}}\right)$$

iteration

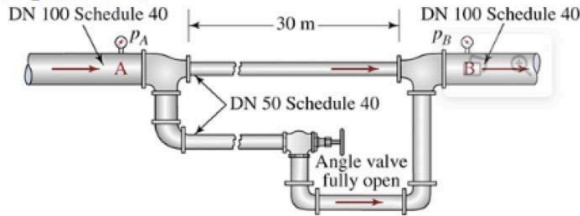
$$\Delta Q = \frac{-(73.10 - 70.28)}{2 \times \left[26.06 + 346.21 \right]} = \frac{-2.82}{744.54} = -0.0038 \text{ ft}^3/\text{s}$$

$$Q_{1 \text{ final}} = 2.805 - 0.0038 = 2.801 \text{ ft}^3/\text{s}$$

$$Q_{2 \text{ final}} = 0.203 - (-0.0038) = 0.207 \text{ ft}^3/\text{s}$$

12.8) In the branched pipe system shown in Fig. P12.3, 850 L/min of water at 10°C is flowing in a DN 100 Schedule 40 pipe at A. The flow splits into two DN 50 Schedule 40 pipes as shown and then rejoins at B. Calculate (a) the flow rate in each of the branches and (b) the pressure difference PA-PB. Include the effect of the minor losses in the lower branch of the system. The total length of pipe in the lower branch is 60 m. The elbows are standard. using the Cross technique.

Figure P12.3



A horizontal pipe A of DN 100 Schedule 40 has a pressure gauge p_A attached close to the right end. The pipe connects to the left side of an unequal T joint. The right side of the unequal T joint connects to a 30-meters-long horizontal DN 50 Schedule 40 pipe that on the right end connects to another unequal T. The right end of the second unequal T further connects to a horizontal pipe B of DN 100 Schedule 40. An arrow in each flows to the right in the horizontal DN 100 Schedule 40 pipes. A pressure gauge p_B is fit beyond the right end of the second unequal T. The bottom end of the first unequal T connects downward to a short vertical pipe that connects to a horizontal DN 50 Schedule 40 pipe through an unequal elbow. The right end of the pipe of reduced size connects to an angle valve fully open. The angle valve connects downward to a short vertical pipe, and then to a horizontal pipe through an elbow. The horizontal pipe again connects upward to a vertical pipe through another elbow. The vertical pipe connects to the bottom end of the second unequal T close to the pipe B.

$$Q_{\text{total}} = 850 \text{ L/min} \times \frac{1 \text{ m}^3/\text{s}}{60,000 \text{ L/min}} = 0.01417 \text{ m}^3/\text{s}$$

10°C of water

$$V: 1.30 \times 10^{-5} \text{ m}^2/\text{s}$$

$$\rho: 1000 \text{ kg/m}^3$$

$$E: 4.6 \times 10^{-5} \text{ m}$$

Main line DN 100

$$D_{100}: 102.3 \text{ mm} = 0.1023 \text{ m}$$

$$A_{100}: 8.213 \times 10^{-3} \text{ m}^2$$

Branch 1

$$L_1: 30 \text{ m}$$

Branch line DN 50

$$D_{50}: 52.5 \text{ mm} = 0.0525 \text{ m}$$

$$A_{50}: 2.168 \times 10^{-3} \text{ m}^2$$

$$\frac{E}{D_{50}} = \frac{4.6 \times 10^{-5} \text{ m}}{0.0525 \text{ m}} = 0.000876$$

$$f_f: 0.019$$

Branch 2

$$L_2: 60$$

$$4 \times 90^\circ \text{ elbows} \rightarrow \frac{L_e}{D} = 30 \text{ each}$$

$$1 \times \text{open valve} \frac{L_e}{D} = 150$$

$$\sum \left(\frac{L_e}{D} \right)_2 = 4(30) + 150 = 270$$

iteration 1 - Branch 1

$$V_1 = \frac{0.010}{2.168 \times 10^{-3}} = 4.613 \text{ m/s}$$

$$N_{R1} = \frac{V_1 D_{50}}{\nu} = \frac{4.613 \times 0.0525}{1.3 \times 10^{-6}} = 1.86 \times 10^5$$

$$f_1 = f_i = 0.0211$$

$$h_{L1} = \left(f_1 \frac{L_1}{D_{50}} \right) \frac{V_1^2}{2g} = \left(0.0211 \frac{60}{0.0525} \right) \frac{4.613^2}{2(9.81)} = 13.06 \text{ m}$$

$$\frac{h_{L1}}{Q_1} = \frac{13.06}{0.01} = 1306 \text{ s/m}^2$$

branch 2

$$V_2 = \frac{0.00417}{2.168 \times 10^{-3}} = 1.923 \text{ m/s}$$

$$N_{R2} = \frac{V_2 D_{50}}{\nu} = \frac{1.923 \times 0.0525}{1.3 \times 10^{-6}} = 7.77 \times 10^4$$

$$f_2 = 0.0233$$

$$h_{L2} = \left(f_2 \frac{L_2}{D_{50}} + f_r \sum \frac{L_e}{D} \right) \frac{V_2^2}{2g}$$

$$= 0.0233 \frac{60}{0.0525} + 0.019(270) \frac{1.923^2}{2(9.81)} = 5.97 \text{ m}$$

$$\frac{h_{L2}}{Q_2} = \frac{5.97}{0.00417} = 1436 \text{ s/m}^2$$

$$\Delta Q = \frac{-(h_{L1} - h_{L2})}{2 \left(\frac{h_{L1}}{Q_1} + \frac{h_{L2}}{Q_2} \right)} = \frac{-(13.06 - 5.97)}{2(1306 + 1436)} = -0.00129 \text{ m}^3/\text{s}$$

Iteration 2

$$Q_1 = 0.01000 - 0.00129 = 0.00871 \text{ m}^3/\text{s} \quad (522.6 \text{ L/min})$$

$$Q_2 = 0.00417 - (-0.00129) = 0.00546 \text{ m}^3/\text{s} \quad (327.6 \text{ L/min})$$

$$V_A = \frac{Q_{\text{total}}}{A_{\text{AO}}} = \frac{0.01417 \text{ m}^3/\text{s}}{8.213 \times 10^{-3} \text{ m}^2} = 1.725 \text{ m/s}$$

$$V_1 = \frac{0.00871 \text{ m}^3/\text{s}}{2.168 \times 10^{-3} \text{ m}^2} = 4.018 \text{ m/s}$$

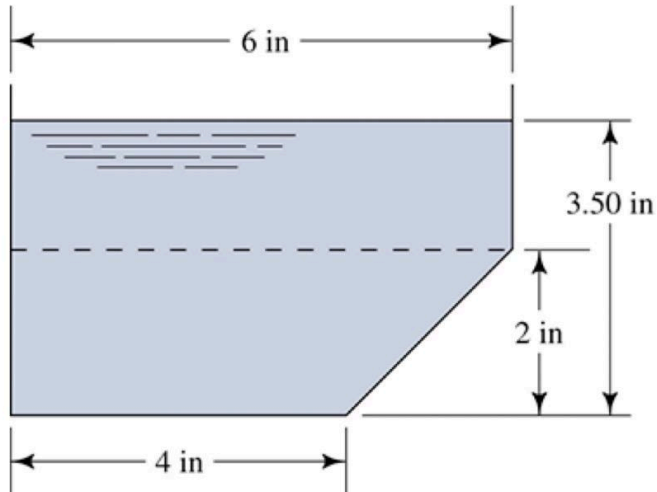
$$P_A - P_B = \gamma \left[h_{L1} + \left(\frac{V_1^2 - V_A^2}{2g} \right) \right]$$

$$= 9.81 \text{ kN/m}^3 \left[10 \text{ m} + \frac{(4.018)^2 - (1.725)^2}{2(9.81)} \right]$$

$$= 105.7 \text{ kPa}$$

14.6 Compute the hydraulic radius for the section shown in Fig. P14.6 if water flows at a depth of 2.0 in. The section is that of a rain gutter for a house.

Figure P14.6



$$A = \left(\frac{a+B}{2} \right) y = \frac{4+6}{2} \cdot 2 = 10 \text{ in}^2$$

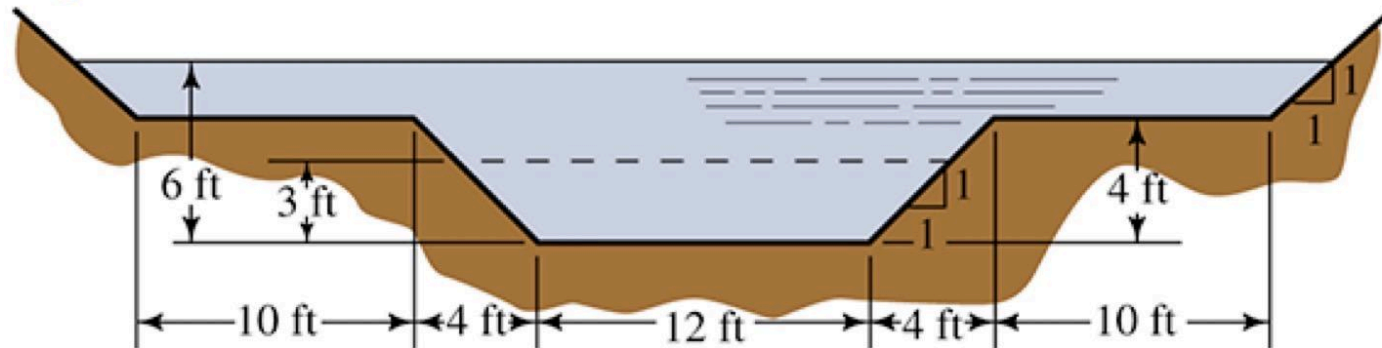
$$L_{\text{slope}} = \sqrt{(\text{rise})^2 + (\text{run})^2} = \sqrt{2.0^2 + 2.0^2} = 2.828 \text{ in}$$

$$WP = 2.0 + 4 + 2.828 = 8.828 \text{ in}$$

$$R = \frac{A}{WP} = \frac{10.0}{8.828 \text{ in}} = 1.133 \text{ in}$$

14.15 Figure P14.15 represents the approximate shape of a natural stream channel with levees built on either side. The channel is earth with grass cover. Use $n=0.04$. If the average slope is 0.000 15, determine the normal discharge for depths of 3 and 6 ft.

Figure P14.15



Stream with levees for **Problem 14.15** .

The natural stream shows a trapezoidal section at the bottom with bottom width of 12 feet, slope of 1 foot by 1 foot, and horizontal length of the inclined slope as 4 feet. The depth of the trapezoidal section is 4 feet. Then the stream extends horizontally on both the sides for a length of 10 feet on either sides, and then rises with a slope to either sides with a slope of 1 foot by 1 foot. The depth of water from the bottom of the channel is 6 feet.

. The

$$Q = \frac{1.486}{n} A R^{2/3} S^{1/2}$$

$$n = 0.04$$

$$S = 0.0015 \rightarrow S^{1/2} = \sqrt{0.0015} = 0.01225$$

$$B = 12 \text{ ft} + 2(1 \times 3 \text{ ft}) = 18 \text{ ft}$$

$$A = \left(\frac{b+B}{2} \right) z = \left(\frac{12+18}{2} \right) \times 3 = 45.0 \text{ ft}^2$$

$$\text{Side length} = \sqrt{3^2 + 3^2} = 4.243 \text{ ft}$$

$$WP = 12 + 2(4.243) = 20.486 \text{ ft}$$

$$R = \frac{A}{WP} = \frac{45.0}{20.486} = 2.197 \text{ ft}$$

$$R^{2/3} = (2.197)^{2/3} = 1.671$$

$$Q = \frac{1.486}{0.04} \times 45 \times 1.671 \times \sqrt{0.0015} = 34.7 \text{ ft}^3/\text{s}$$

b)

$$A_{\text{lower}} = \frac{12+20}{2} \times 4 = 64 \text{ ft}^2$$

$$A_{\text{upper}} = \left(\frac{40+44}{2} \right) 2 = 84 \text{ ft}^2$$

$$A_{\text{total}} = 64.0 + 84.0 = 148.0 \text{ ft}^2$$

$$WP = 12 + 11.314 + 20 + 5.657 = 49.971 \text{ ft}$$

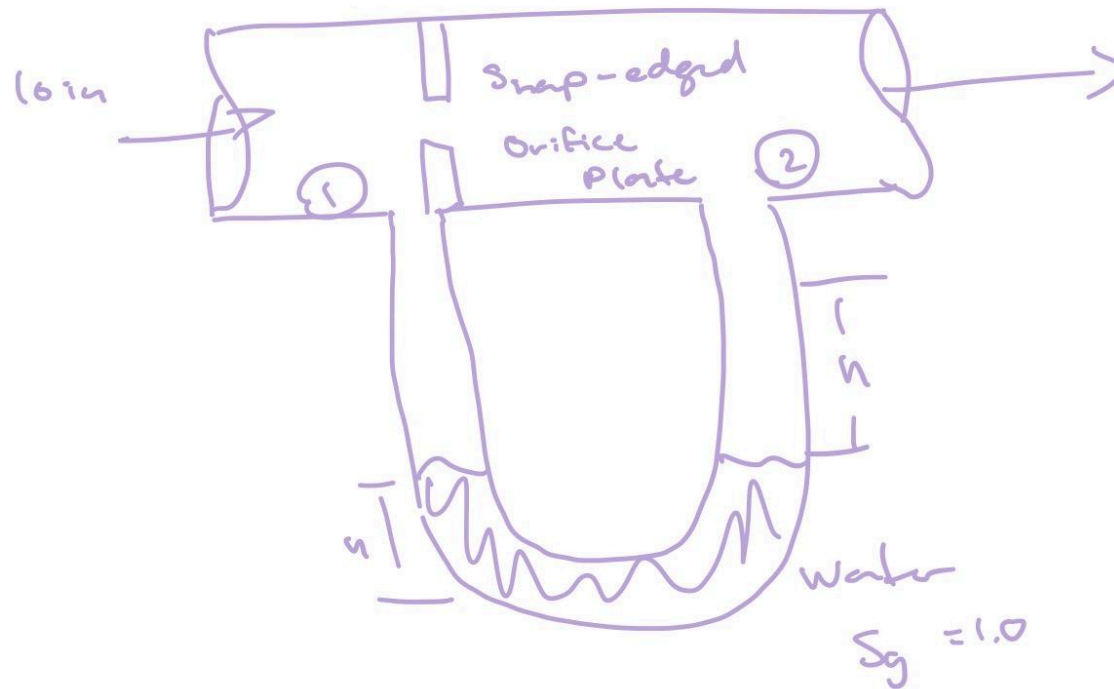
$$R = \frac{A}{WP} = \frac{148}{49.971} = 3.022 \text{ ft}$$

$$R^{2/3} = (3.022)^{2/3} = 2.092$$

$$Q = \frac{1.486}{0.04} \times 148 \times 2.092 \times \sqrt{0.0015} = 141.1 \text{ ft}^3/\text{s}$$

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15.4 A sharp-edged orifice is placed in a 10-in-diameter pipe carrying ammonia. If the volume flow rate is 25 gal/min, calculate the deflection of a water manometer (a) if the orifice diameter is 1.0 in and (b) if the orifice diameter is 7.0 in. The ammonia has a specific gravity of 0.83 and a dynamic viscosity of 2.5×10^{-6} lbs/ft²



$$D_{in} = 0.833 \text{ ft}$$

$$Q = 25 \text{ gal/min} = \frac{25}{448.83} = 0.0557 \text{ ft}^3/\text{s}$$

$$s_{gf} = 0.83$$

$$P: 0.83 \times 1.94 \text{ slug/ft}^3 = 1.61 \text{ slug/ft}^3$$

$$\mu: 2.5 \times 10^{-6} \text{ lb-s/ft}^2$$

$$s_{gm} = 1.00$$

$$A_{pipe} = \frac{\pi D^2}{4} = \frac{\pi (0.833)^2}{4} = 0.5454 \text{ ft}^2$$

$$v = \frac{Q}{A_{pipe}} = \frac{0.0557 \text{ ft}^3/\text{s}}{0.5454 \text{ ft}^2} = 0.1021 \text{ ft/s}$$

$$N_R = \frac{v D P}{\mu} = \frac{0.1021 \cdot 0.833 \cdot 1.61}{2.5 \times 10^{-6}} \approx 54770$$

$$Q = C A_o \sqrt{\frac{2g \cdot h'}{1 - \beta^4}}$$

$$h' = h \left(\frac{s_{gm}}{s_{gf}} - 1 \right) = h \left(\frac{1.00}{0.83} - 1 \right) = 0.2048 h$$

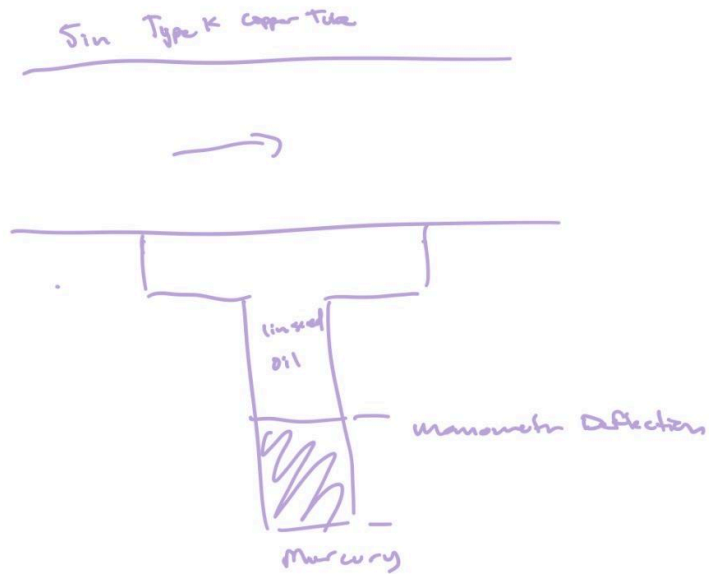
$$h = \frac{1}{0.2048 \cdot 2g} \left[\frac{Q (1 - \beta^4)^{1/2}}{C A_o} \right]^2 =$$

$$a) \quad h = \frac{1}{0.2048 \cdot 2(32.2)} \left[\frac{0.0557 \sqrt{1 - 0}}{(0.598)(0.005454)} \right]^2 = 22.11 \text{ ft}$$

$$b) \quad h = \frac{1}{0.2048 \cdot 2(32.2)} \left[\frac{0.0557 \sqrt{1 - 0.2401}}{(0.612)(0.2673)} \right]^2 = 0.00668 \text{ ft}$$

15.9 A flow nozzle is to be installed in a 5-in Type K copper tube carrying linseed oil at 77F

A mercury manometer is to be used to measure the pressure difference across the nozzle when the expected range of the flow rate is from 700 to 1000 gal/min. The manometer scale ranges from 0 to 8.0 in of mercury. Determine an appropriate diameter of the nozzle.



Pipe 5 in

$$D : 4.805 \text{ in} = 0.400 \text{ ft}$$

$$A_i : 0.1257 \text{ ft}^2$$

oil

$$S_{gf} : 0.930$$

$$V : 3.56 \times 10^{-5} \text{ m}^3/\text{s}$$

$$V : 3.56 \times 10^{-5} \text{ m}^3/\text{s} \times 10.7639 \text{ ft}^3/\text{m}^3 = 3.832 \times 10^{-4} \text{ ft}^3/\text{s}$$

$$\text{Manometer Fluid (mercury)} S_{gm} : 13.54$$

$$h : 8.0 \text{ in} = 0.6667 \text{ ft}$$

$$Q : 1000 \text{ gal/min} = \frac{1000}{448.83} = 2.228 \text{ ft}^3/\text{s}$$

$$h' = h \left(\frac{S_{gm}}{S_{gf}} - 1 \right)$$

$$= 0.6667 \left(\frac{13.54}{0.930} - 1 \right) = 9.039 \text{ ft oil}$$

$$V_1 = \frac{Q}{A_1} = \frac{2.228 \text{ ft}^3/\text{s}}{0.1259 \text{ ft}^2} = 17.697 \text{ ft/s}$$

$$N_R = \frac{V_1 D}{\nu} = \frac{17.697 \times 0.4004}{3.832 \times 10^{-4}} = 18451 = 1.85 \times 10^4$$

$$Q = K A_1 \sqrt{2g \cdot h'}$$

$$K\beta^2 = \frac{Q}{A_1 \sqrt{2g \cdot h'}}$$

$$= \frac{2.228}{0.1259 \times \sqrt{2(32.2)(9.039)}} = 0.7335$$

$$\beta = 0.775$$

$$d = \beta \times D = 0.775 \times 4.805 \text{ in} = 3.724 \text{ in}$$