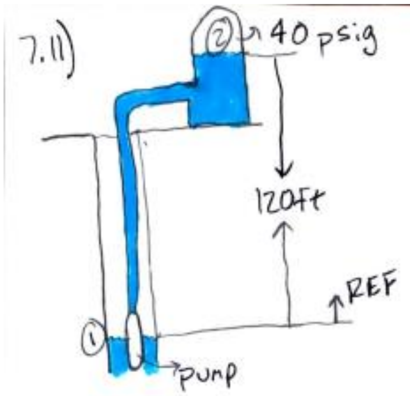
7.11)

7.11)



Given

$\varnothing_{pipe} = 1.049$ in

$\therefore A_{pipe} = \frac{\pi D^2}{4} = \frac{\pi\ 1.049^2}{4} = .864 \text{ in}^2 = .006 \text{ ft}^2$

$P_2 = 40$ psig

$P_1 = 0$ psig

$\gamma = 62.4\ \text{lbft}/\text{ft}^3$

$h_L = 10.5\ \text{lb-ft}/\text{lb}$

$z_1 = 0$

$z_2 = 120$ ft

$Q = 745\ \text{gal/hr} = .028\ \text{ft}^3/\text{s}$

$v_1 = \frac{Q}{A} = \frac{.028}{.006} = 4.667\ \text{ft/s}$

$v_2 = 0$

Robert Knupp
MET 330
HW 1.4
Group 2

Bernoulli's:

$$\cancel{\frac{P_1}{\gamma}} + \cancel{z_1} + \frac{v_1^2}{2g} + h_A = \frac{P_2}{\gamma} + z_2 + \cancel{\frac{v_2^2}{2g}} + h_L$$

$$\therefore h_A = \frac{P_2}{\gamma} + z_2 + h_L - \frac{v_1^2}{2g} = \frac{40}{62.4} + 120 + 10.5 - \frac{4.667^2}{2(32.2)} = .641 + 120 + 10.5 - .338$$

$\Rightarrow h_A = 130.803$ ft

a) Power Delivered by Pump to Water

$P_A = h_A \gamma Q$

$\therefore P_A = 130.803\ \text{ft}\,(62.4\ \text{lbft}/\text{ft}^3)(.028\ \text{ft}^3/\text{s})$

$\Rightarrow P_A = 228.539\ \text{ftlb/s}$ or 0.415 hp

b) Pump Efficiency drawing 1hp

$e_M = \frac{P_A}{P_I}$

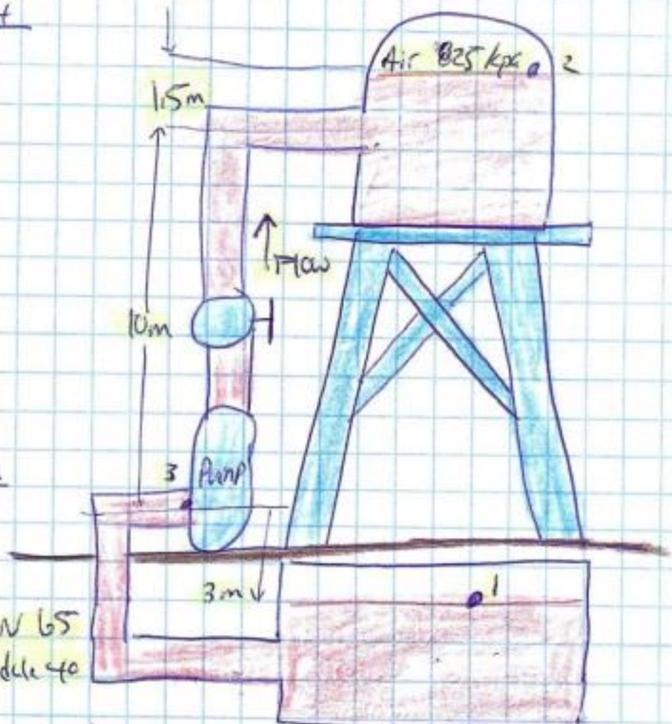
$\therefore e_M = \frac{.415\text{hp}}{1\text{ hp}} = .415 \Rightarrow 41.5\%$ efficiency

7.16)

John Vasquez HW 1.4

#7.16 module 5, slide 20

- pump delivering = $840 \frac{L}{min} = Q$
- Oil $Sg = .85$
- $h_L = 4.2 \frac{Nm}{N}$
- Find power delivered by pump?
- Calculate pressure if $h_L = 1.4 \frac{Nm}{N}$ at pump inlet



*power of pump = $P = \gamma Q h_A$

Find h_A

$$h_A + \frac{p_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{p_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + h_{L_{1-2}}$$

(1) point 1 → 2

$$h_A = \frac{p_2 - p_1}{\gamma} + \frac{V_2^2 - V_1^2}{2g} + z_2 - z_1 + h_{L_{1\to 2}}$$

$p_1 = 0$ = gage

$p_2 = 825$ kPa → 825000 Pa

$V_2 = 0$ not moving

$V_1 = 0$ not moving

$z_2 = 3m + 10m + 1.5m = 14.5$ m

$z_1 = 0m$

$h_{L_{1-2}} = 4.2$ Nm/N *given of system

$h_L = 1.4$ m suction

$Sg = .85$

$\gamma = (.85)(9810) = 8338.5 \frac{N}{m^3}$

power = kW

(2)

$$h_A = \frac{825\text{kPa} - 0}{8338.5 \frac{N}{m^3}} + \frac{0-0}{2g} + 14.5m + 0m + 4.2m$$

$h_A = 98.93 + 14.5 + 4.2 = 117.64$ m

(3) power of pump = $P = \gamma Q h_A$

$P = (8338.5) Q (117.64m)$

*need volume flow rate $Q = 840 \frac{L}{min} = \frac{840}{60000} = .014 \frac{m^3}{s}$

1

7.16 continued)

power of pump $= P = \gamma Q h_A \Rightarrow \left(8838.5 \frac{N}{m^3}\right)\left(.014 \frac{m^3}{s}\right)(117.64m)$

$$\boxed{= 13733.18 \text{ Watts} \text{ or } 13.733 \text{ kW}}$$

Point 1→3

(4) $\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + Z_1 = \frac{P_3}{\gamma} + \frac{V_3^2}{2g} + Z_3 + h_{L_{1\to3}}$

P_1: 0 gage
V_1: 0 not moving
Z_1: 0 m
P_3: ? we need
V_3: ? we need
$h_{L_{1\to3}} = 1.4$ m *given
$Z_3 = 3$ m *given

$= \frac{P_3}{\gamma} = -\frac{V_3^2}{2g} - Z_3 - h_{L_{1\to3}}$

$= P_3 = \gamma\left(-\frac{V_3^2}{2g} - Z_3 - h_{L_{1\to3}}\right)$

$V_3^2 = \frac{Q}{A_3} = \frac{.014 \, m^3/s}{3.09 \times 10^{-3}}$

A_3: DN 65 Schedule 40 pg 500

$$\boxed{V_3^2 = 4.53 \, m/s}$$

$= P_3 = \left(8338.5 \frac{N}{m^3}\right)\left(-\frac{4.53^2}{(2)(9.81)} - 3m - 1.4m\right)$

$= P_3 = (8338.5)(-1.05 - 3 - 1.4)$

$$\boxed{P_3 = -45444.83 \text{ Pa} \quad -45.44 \text{ KPa}}$$

7.22)

Homework 1.4 Met 330 Carroll, Shaunmark 1/6

7.22) Figure 7.26 shows the arrangement of a circuit for a hydraulic system. The pump draws oil with a specific gravity of 0.90 from a reservoir and delivers it to the hydraulic cylinder. The cylinder has an inside diameter of 5.0 in, and in 15 sec the piston must travel 20 in while exerting a force of 11,000 lb. It is estimated that there are energy losses of 11.5 lb-ft/lb in the suction pipe and 35.0 lb-ft/lb in the discharge pipe. Both pipes are 3/8-in Schedule 80 steel pipes. Calculate:

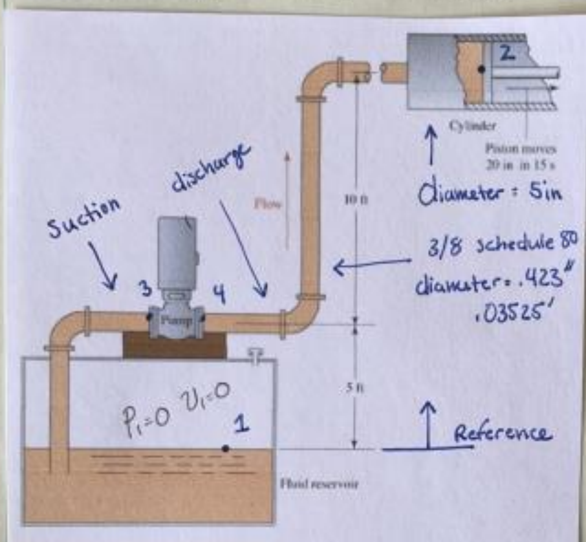


Figure 7.26

a) volume flow rate through pump
b) pressure at cylinder
c) The pressure at the outlet of the pump
d) The pressure at the inlet of the pump
e) power delivered to the oil by the pump

$Sg_{oil} = 0.90 = \frac{\gamma_{oil}}{\gamma_{water}}$, $\gamma_{oil} = .90(62.4 \text{ lb/ft}^3)$, $\gamma_{oil} = 56.16 \text{ lb/ft}^3$

3/8 Schedule 80 → 0.423" inside diameter

F = 11,000 lb

$h_{L\,suction} = 11.5$ lb ft/lb

$h_{L\,discharge} = 35.0$ lb ft/lb

$A_{cylinder} = \frac{\pi}{4}(5/12)^2 \rightarrow .13635 \text{ ft}^2$

$v_2 = d/t \rightarrow (20/12)/15 \text{ sec} \rightarrow .111 \text{ ft/sec}$

a) $Q_2 = v_2 A_{cylinder} \rightarrow .111(.13635) \rightarrow .01515 \text{ ft}^3/\text{sec}$

$Q_{pump} = Q_2 \rightarrow Q_{pump} = .01515 \text{ ft}^3/\text{sec}$

b) $P_{cylinder} = F/A \rightarrow 11{,}000 \text{ lb} / \frac{\pi}{4}(5/12)^2 \rightarrow P_{cylinder} = 80{,}672.5 \text{ lb/ft} = P_2$

c) $v_4 = \frac{Q}{A_{4\,pipe}} \rightarrow v_4 = .01515 / \frac{\pi}{4}(.03525)^2 \rightarrow v_4 = 15.52 \text{ ft/sec}$

$$\overset{0}{\cancel{h_A}} + \frac{P_4}{\gamma_{oil}} + \frac{v_4^2}{2g} + z_4 = \frac{P_2}{\gamma_{oil}} + \frac{v_2^2}{2g} + z_2 + h_{L\,discharge}$$

$$P_4 = \left(\frac{P_2}{\gamma_{oil}} + \frac{v_2^2}{2g} + z_2 + h_{L\,disch} - \frac{v_4^2}{2g} - z_4\right)\gamma_{oil}$$

$$P_4 = \left(\frac{80{,}672.5}{56.16} + \frac{.111^2}{2(32.1)} + 15 + 35 - \frac{15.52^2}{2(32.1)} - 5\right)56.16 \rightarrow P_4 = 82989.0 \text{ lb/ft}^2$$

7.22 Continued)

Homework 1.4 | Met 330 | Carroll, Shaunmark | 2/6

7.22 Continue)

D) $v_3 = v_4 = 15.52$ ft/sec

$$h_a + \cancel{\frac{P_1}{\gamma_{oil}}}^{0} + \cancel{\frac{v_1^2}{2g}}^{0} + \cancel{z_1}^{0} = \frac{P_3}{\gamma_{oil}} + \frac{v_3^2}{2g} + z_3 + h_{L\,suction}$$

$$\left(-\frac{v_3^2}{2g} - z_3 - h_{L_{suction}}\right)\gamma_{oil} = P_3$$

$$P_3 = \left(-\frac{(15.52)^2}{2(32.1)} - 5 - 11.5\right) \rightarrow \boxed{P_3 = 1,137.35\ lb/ft^3}$$

e) $$h_a + \cancel{\frac{P_1}{\gamma_{oil}}}^{0} + \cancel{\frac{v_1^2}{2g}}^{0} + \cancel{z_1}^{0} = \frac{P_2}{\gamma_{oil}} + \frac{v_2^2}{2g} + z_2 + h_L$$

$$h_a = \frac{80,672.5}{56.16} + \frac{.111^2}{2(32.1)} + 15 + (11.5 + 35)$$

$$h_a = 1497.97\ lb/ft^3$$

$$P = \gamma_{oil} Q h_a \rightarrow 56.16(.01515)(1497.97) \rightarrow 1274.51\ lb\frac{ft}{s}$$

$$1274.51\ lb\frac{ft}{s}\left(\frac{1hp}{550\ lb\frac{ft}{s}}\right) \rightarrow \boxed{P = 2.32\ hp}$$

7.30)

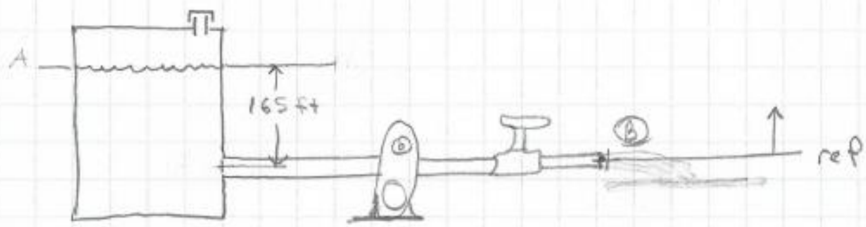
Kevin Smith
MET 330
HW 1.3
7.30, 8.38, 8.62, 10.43

(1)

7.30) <u>Given:</u> H_2O @ 60°F
Volume = 1000 gal/min
Fluid motor removes 37 hp from water
Pipe = 8" sch. 40 steel

<u>Find:</u> Energy losses in system

<u>Assume:</u> No energy losses except those given above (Text pg 167)



From table A.2

H_2O @ 60°F $\gamma = 62.4$ lb/ft³
$\rho = 1.94$ slugs/ft³
$\nu = 2.35 \times 10^{-5}$

Convert: 1000 gal/min → ft³/s

$\frac{1000 \text{ gal}}{\text{min}} \cdot \frac{\text{min}}{60 s} \cdot \frac{0.13368 \text{ ft}^3}{\text{gal}}$

1000 gal/min = 2.23 ft³/s = Q

Pipe ID = 0.6651 ft
Pipe flow area = 0.3472 ft²

37 HP → ft/lb/s

$37 \text{ HP} \cdot \frac{550 \text{ ft·lb/s}}{\text{HP}} = 20{,}350$ ft·lb/s

Q = 2.23 ft³/s

$V = \frac{2.23 \text{ ft}^3}{s} \cdot 0.3472$

$$\cancel{h_A} + \cancel{\frac{P_1}{\gamma}} + \cancel{\frac{V_1^2}{2g}} + z_1 = \cancel{\frac{P_2}{\gamma}} + \frac{V_2^2}{2g} + \cancel{z_2} + h_R + h_L$$

$$z_1 = \frac{V_2^2}{2g} + h_R + h_L$$

$v = \frac{Q}{A} \Rightarrow \frac{2.23 \text{ ft}^3/s}{0.3472 \text{ ft}^2}$

v = 6.42 ft/s

7.30 Continued)

HW 1.3 cont. (2)

$$z_1 = \frac{V_2^2}{2g} + h_R + h_L$$

Find H_R: $P_{HP} = \frac{\gamma Q h_R}{550 \text{ lb ft/s}} \rightarrow 37 \text{ Hp} =$ 62.4 lb/ft³·

$$37 \text{ HP} = \frac{62.4 \text{ lb/ft}^3 \cdot 2.23 \text{ ft}^3\text{/s} \cdot h_R}{550 \text{ lb ft/s}}$$

$$550 \text{ lb ft/s} \cdot 37 \text{ HP} = 139.15 \text{ lb/s} \cdot h$$

$$\frac{20350 \text{ lb ft/s}}{139.15 \text{ lb/s}} = h_R$$

$$146.25 \text{ ft} = h_R$$

$$165 \text{ ft} = \frac{(6.42 \text{ ft/s})^2}{2 \cdot 32.2 \text{ ft/s}^2} + 146.25 + h_L$$

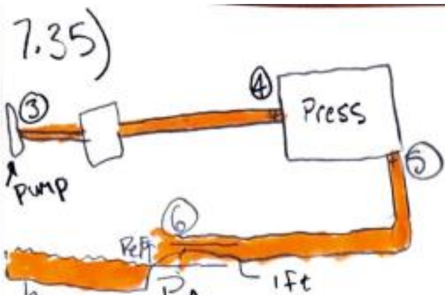
$$165 \text{ ft} = 0.64 \text{ ft} + 146.25 \text{ ft} + h_L$$

$$165 \text{ ft} = 146.89 \text{ ft} + h_L$$

$$\boxed{18 \text{ ft} = h_L = \text{Energy lost in system}}$$

7.35)

7.35)



$h_{A_{pump}} = \frac{P_A}{\gamma Q}$

$h_{A_{PUMP}} = \frac{12{,}496}{56.16(.390)} = 570.531 \ lbft/lb$

Bernoulli's

$\frac{\cancel{P_1}}{\cancel{\gamma}} + \cancel{z_1} + \cancel{\frac{v_1^2}{2g}} + h_A = \frac{\cancel{P_6}}{\cancel{\gamma}} + z_6 + \frac{v_6^2}{2g} + h_{R_{4\text{-}5}} + h_{L_{1\text{-}6}}$

$\therefore h_A = z_6 + \frac{v_6^2}{2g} + h_{R_{4\text{-}5}} + h_{L_{1\text{-}6}}$

$h_{R_{4\text{-}5}} = h_A - z_6 - \frac{v_6^2}{2g} - h_{L_{1\text{-}6}}$

$\therefore h_{R_{4\text{-}5}} = 570.531 - 1 - \frac{11.818^2}{2(32.2)} - 34.8$

$= 570.531 - 1 - 2.169 - 34.8$

$\Rightarrow h_{R_{4\text{-}5}} = 532.562 \ lbft/lb$

Given

$Sg_{oil} = 0.90$

$Q = 175 \ gal/m = .390 \ ft^3/s$

$P_{pump} = 28.4 \ hp$

$e_{pump} = 80\%$

$h_{L_{3\text{-}4}} = 28.50 \ lbft/lb$

$\gamma_{oil} = (.90)(62.4 \ lbft/ft^3) = 56.16 \ lbft/ft$

$P_A = e_{pump}(P_{pump}) = .8(28.4) = 22.72 \ hp = 12{,}496 \ ftlb/s$

$\varnothing_{pipe} = 2.469 \ in = .206 \ ft$

$A_{pipe} = \frac{\pi D^2}{4} = \frac{\pi \, .206^2}{4} = .033 \ ft^2$

$h_{L_{1\text{-}6}} = 2.80 + 28.50 + 3.50 = 34.8 \ lbft/lb$

$P_1 = P_6 = 0$

$v_6 = \frac{Q}{A} = \frac{.390}{.033} = 11.818 \ ft/s$

$v_1 = 0 \ ft/s$

$z_1 = 0 \ ft$

$z_6 = 1 \ ft$

$P_{R_{4\text{-}5}}$

Robert Knapp
MET 330
HW 1.4
Group 2

$P_R = h_r \gamma Q$

$P_R = 532.562(56.16)(.390)$

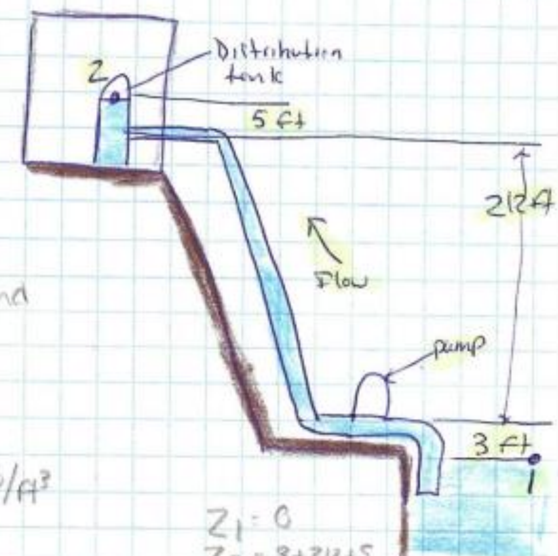
$\Rightarrow P_{R_{4\text{-}5}} = 11{,}664.386 \ ftlb/s$ or $21.208 \ hp$

7.42)

#7.42

- Distribution of Tank = P = 30 psig
- Volume Flow rate = Q = 40 gal/min
  Pump delivering
- $h_L = 15.5 \frac{lb\,ft}{lb}$
- Efficiency pump = .72
- Find hp of Pump = $P_m = \frac{P_A}{\eta_A} = \frac{\gamma Q h_A}{\eta A}$

* Need to Find



$Z_1 = 0$
$Z_2 = 3 + 212 + 5 = 220\,ft$
$V_1 \,\&\, V_2 = 0$

① Point 1→2 Solve for h_A + $\gamma_{water} = 62.4\ lb/ft^3$

$$h_A + \frac{P_1}{\gamma_{water}} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\gamma_{water}} + \frac{V_2^2}{2g} + Z_2 + h_{L_{1\to 2}}$$

$$h_A = \frac{P_2 - P_1}{\gamma_{water}} + \frac{V_2^2 - V_1^2}{2g} + Z_2 - Z_1 + h_{L_{1\to 2}}$$

$$h_A = \frac{30\,lb/in^2 - 0}{62.4\,lb/ft^3} + \frac{0-0}{2g} + 220 - 0 + 15.5\,\frac{lb\,ft}{lb}$$

$$h_A = \frac{30(144)}{62.4} + 220 + 15.5 = \boxed{h_A = 304.73\,ft}$$

② hydralic power required

$P_A = \gamma Q h_A$

$Q = 40\frac{gal}{min} = \frac{40}{449} = \boxed{.089\ ft^3/s}$

$1\,hp = 550\,ft\,lb/s$

$$P_A = 62.4\frac{lb}{ft^3}\left(.089\frac{ft^3}{s}\right)(304.73\,ft) = 1692.35\,\frac{ft\,lb}{s}$$

$$\frac{1692.35\ \frac{ft\,lb}{s}}{550\ \frac{ft\,lb}{s}}$$

$\boxed{P_A = 3.077\,hp}$

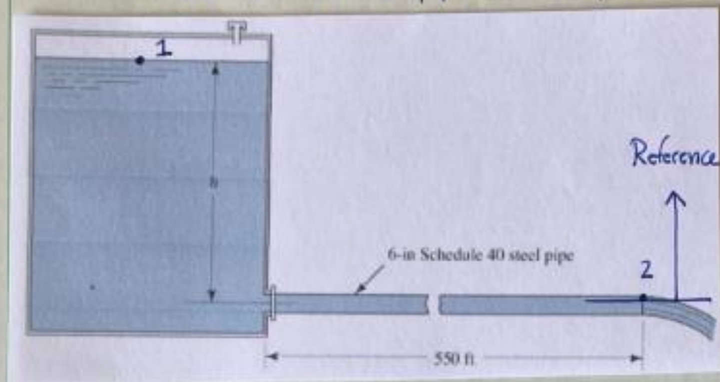
③ $P_m = \frac{P_A}{\eta_A} = \frac{3.077\,hp}{.72} = \boxed{P_m = 4.274\,HP}$

3

8.33)

Homework 1.4 | Met 330 | Carroll, Shaunmark | 3/6

8.33) Water at 80°F flows from a storage tank through 550 ft of 6 in Schedule 40 Steel pipe, as shown in figure 8.11. Taking the energy losses due to friction into account, calculate the required head h above the pipe inlet to produce a volume flow rate 2.50 ft³/s.



γ_{water} @ 80°F = 62.2 lb/ft³

pipe dimensions
inside diameter = .5054 ft
Flow Area = .2006 ft²

$Q = 2.50\ ft^3/s$

$\rho_{water} = 1.93\ slugs/ft^3$
$\eta = 1.77 \times 10^{-5}\ lb\text{-}s/ft^3$

$Q = v_2 A_{pipe} \rightarrow v_2 = Q/A_{pipe} \rightarrow 2.50/.2006 \rightarrow v_2 = 12.46\ ft/s$

$N_R = \frac{vD\rho}{\eta} \rightarrow \frac{12.46(.5054)1.93}{1.77\times10^{-5}} \rightarrow N_R = 686653.0 \rightarrow 6.87\times10^5$

$N_R > 4{,}000 \rightarrow$ Turbulent

table 8.2 for steel $\rightarrow \varepsilon = 1.5\times10^{-4}$ (roughness)

$D/\varepsilon \rightarrow .5054/1.5\times10^{-4} \rightarrow 3369.33$ (relative roughness)

$$f = .25/\left[\log\left(\frac{1}{3.7(D/\varepsilon)} + \frac{5.74}{N_R^{.9}}\right)\right]^2$$

$$f = .25/\left[\log\left(\frac{1}{3.7(3369.33)} + \frac{5.74}{(6.87\times10^5)^{.9}}\right)\right]^2 \rightarrow f = .016$$

$$h_L = f \times L/D \times \frac{v_2^2}{2g} \rightarrow h_L = .016\left(\frac{550}{.5054}\right)\left(\frac{12.46^2}{2(32.1)}\right) \rightarrow 42.1\ lb/ft^3$$

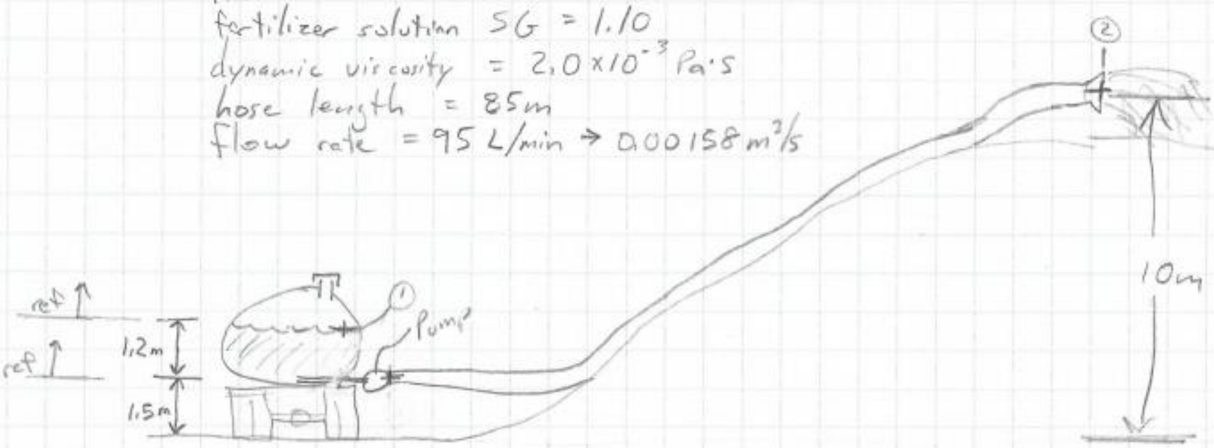
$$\frac{\cancel{P_1}^{0}}{\gamma_{water}} + \frac{\cancel{v_1^2}^{0}}{2g} + h = \frac{\cancel{P_2}^{0}}{\gamma_{water}} + \frac{v_2^2}{2g} + \cancel{h_2}^{0} + h_L$$

$$h = \frac{v_2^2}{2g} + h_L \rightarrow \frac{(12.46)^2}{2(32.1)} + 42.1 \rightarrow h = 44.5\ ft$$

8.38)

8.38) Given:

nozzle pressure is 140 kPa minimum
hose is smooth plastic
Hose ID = 25 mm = 0.025 m
fertilizer solution SG = 1.10
dynamic viscosity = 2.0×10^{-3} Pa·s
hose length = 85 m
flow rate = 95 L/min → 0.00158 m^3/s



Find: a) power delivered by pump to the solution = 5.9×10^{-9} kW
b) pressure at the outlet of the pump = 78.8 kN/m^2

$$h_A + \cancel{\frac{P_1}{\gamma}} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + Z_2 + \cancel{h_R} + h_L$$

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

$Q = \frac{95\,L}{min} \cdot \frac{m^3}{1000\,L} \cdot \frac{min}{60\,s} = 0.00158\ m^3/s$

$V = \frac{0.00158\,m^3/s}{0.0004909\,m^2}$

$A = 4.909 \times 10^{-4}\ m^2$

$V = 3.23\ m/s$

$z_1 = 1.2\ m$

$Z_2 = 10m - 1.2m - 1.5m = 7.3m$

$h_L = 15m$ (from HW pg 4)

8.38 Continued)

8.38 cont.) (4)

Find Reynolds Number:

$$Re = \frac{\rho v D}{\eta} = \frac{1100 \cdot 3.23\ m/s \cdot 0.025\ m}{2.0\times10^{-3}\ Pa \cdot s} = \frac{0.08825}{2.0\times10^{-3}} = 44{,}413$$

$$sg = \frac{\gamma_s}{\gamma_w @ 4°C} \rightarrow \text{find } \gamma_s \rightarrow 1.10 = \frac{\gamma_s}{9.81}$$

$$10.79 = \gamma_s$$

$$\gamma = \rho g \rightarrow \text{find } \rho \rightarrow \frac{\gamma}{g} = \rho \rightarrow \frac{10.79}{9.81} = \rho = 1.10 = SG$$

For turbulent flow:

$$f = \frac{0.25}{\left[\log\left(\frac{1}{3.7(D/\epsilon)} + \frac{5.74}{N_R^{0.9}}\right)\right]^2}$$

$$f = \frac{0.25}{\left[\log\left(\frac{1}{3.7\left(\frac{0.025}{3.0\times10^{-7}}\right)} + \frac{5.74}{44413^{0.9}}\right)\right]^2}$$

$$f = \frac{0.25}{\left[\log\left(\frac{1}{3.7(83{,}333} + 2.191\right)\right]^2}$$

$$f = \frac{0.25}{\left[\log(3.24\times10^{-6})\right]^2}$$

$$f = \frac{0.25}{30.13} = 0.0083$$

Now, find energy loss:

$$h_L = f \times \frac{L}{D} \times \frac{v^2}{2g}$$

$$h_L = 0.0083 \times \frac{85\ m}{0.025\ m} \times \frac{3.23\ m/s^2}{2 \cdot 9.81} = h_L = 15\ m$$

8.38 Continued)

8.38 cont.) (5)

$$h_A + z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + h_L$$

$$h_A + 1.2\,m = \frac{140\ kPa}{10.79} + \frac{3.23\ m/s}{2 \cdot 9.81\ m/s^2} + 7.3\,m + 15\,m$$

$$h_A = 34.2\,m$$

$$P = \frac{Q \cdot h \cdot (SG)}{3.6 \times 10^6}$$

$$P = \frac{0.00158 \cdot 34.2 \cdot 1.10}{3.6 \times 10^6} \cdot \frac{3600\,s}{hr}$$

$$P = \frac{5.68 \cdot 34.2 \cdot 1.1}{3.6 \times 10^6}$$

$$\boxed{P_P = 5.9 \times 10^{-5}\ kW} \rightarrow 8.38\ pg\ 3$$

Pressure at pump exit

$$P_{pump\ exit} = \gamma \cdot z_2 = 1.10 \cdot 7.3\,m \cdot 9.81\,m/s^2$$

$$\boxed{P_{pump\ exit} = 78.8\ kN/m^2} \rightarrow 8.38\ pg\ 3$$

8.44)

8.44)

Given

$P_2 = 25.0$ psig

$P_1 = -3.50$ psig

$Q = 0.50\ ft^3/s$

$\eta = 4.0 \times 10^{-5}\ lbs/ft^2$

$Sg = 1.026$

$\gamma_{fluid} = 1.026(62.4\ lbft/ft^3) = 64.022\ lbft/ft^3$

$\varnothing_A = 3.548\ in = 0.296\ ft$

$\varnothing_B = 2.469\ in = 0.206\ ft$

$A_A = \frac{\pi(0.296)^2}{4} = .069\ ft^2$

$A_B = \frac{\pi(0.206)^2}{4} = .033\ ft^2$

$V_2 = \frac{Q}{A} = \frac{.50\ ft^3/s}{.033\ ft^2} = 15.152\ ft/s$

$\rho_{fluid} = 1.026(1.94\ slugs/ft^3) = 1.990\ slugs/ft^3$

$V_1 = \frac{Q}{A} = \frac{.50\ ft^3/s}{.069\ ft^2} = 7.246\ ft/s$

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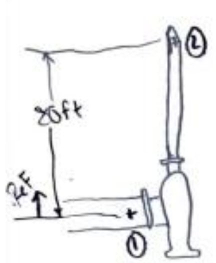


$N_R = \frac{vD\rho}{\eta} = \frac{15.152(0.206ft)(1.990)}{4.0 \times 10^{-5}}$

$N_R = 1.55 \times 10^5$ ← Turbulent

$\therefore f = \frac{0.25}{\left[\log\left(\frac{1}{3.7(D/\epsilon)} + \frac{5.74}{N_R^{.9}}\right)\right]^2}$

$= \frac{0.25}{\left[\log\left(\frac{1}{3.7\left(\frac{.206}{1.5 \times 10^{-4}}\right)} + \frac{5.74}{1.55 \times 10^5}\right)\right]^2}$

$= \frac{.25}{13.185}$

$f = .019$

Darcy's Equation

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

$= .019\left(\frac{80}{.206}\right)\left(\frac{15.152^2}{2(32.2)}\right)$

$= .019\ (388.350)(3.565)$

$\therefore h_{Lf} = 26.30\ ft$

$\therefore P_A = h_A \gamma Q$

$= 173.153(64.022)(.5)$

$P_A = 5542.801\ ft\,lb/s$

or

$10.078\ hp$

Bernoulli's

$\frac{P_1}{\gamma} + \cancel{z_1} + \frac{v_1^2}{2g} + h_A = \frac{P_2}{\gamma} + z_2 + \frac{v_2^2}{2g} + h_L$

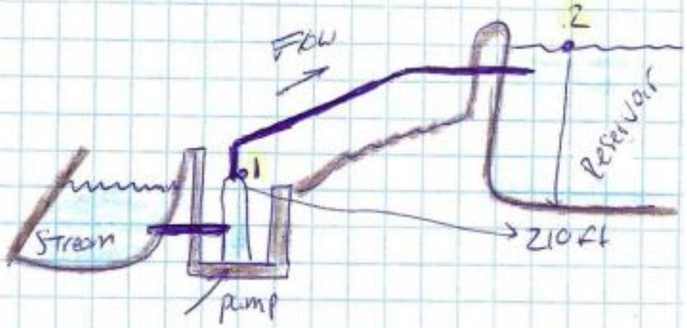
$\therefore h_A = \frac{P_2 - P_1}{\gamma} + z_2 + \frac{v_2^2 - v_1^2}{2g} + h_L$

$= \frac{25.0 + 3.5(144)}{64.022} + 80 + \frac{15.152^2 - 7.246^2}{2(32.2)} + 26.3 = 173.153 = h_A$

8.46)

8.46

- Water temp = 60°f
- pipe from pump = 8 in Schedule 40 Steel
- Pipe length = 2500 ft long
- Volume flow Rate = Q = 4 ft³/s



*Find p at pump outlet
* Consider friction loss

$V_2 + V_1 = 0$ Not moving
$Z_1 = 0$
$Z_2 = 210$
$h_A = 0$? Nothing Added
$h_{L\,1\to2}$?
$\gamma_{water} = 62.4\ lb/ft^3$

① Point 1 → 2

$$h_A + \frac{P_1}{\gamma} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} - Z_2 + h_{L\,1\to2}$$

$$P1 = \gamma\left(\frac{V_2^2 - V_1^2}{2g} - Z_2 - Z_1\right) + h_{L\,1\to2} - h_{A\,1\to2}$$

$$P1 = \gamma\left(\frac{0-0}{2g}\right) - 210 - 0 + h_L - 0$$

$$P1 = \gamma(210 - 0) + h_L$$ ← Need h_L

②

$$h_L = f\frac{L}{d}\times\frac{V^2}{2g}$$ ← Need Velocity →

③ Velocity

$$V = \frac{Q}{A} = \frac{4\ ft^3/s}{.3472} = \boxed{11.52\ ft/s}$$

Pg 500 Appendix f 8 in pipe Flow Area

L = 2500 ft
d = 8 in pipe pg 500 = .6651 ft
g = 32.2 ft/s
f = ?
V = 11.52 ft/s

④ a Roughness of pipe + Reynolds Number

$$N_R = \frac{VD}{\text{Viscosity}}$$

4

8.46 Continued)

4b Reynolds Number & Roughness of Water at 60°F

$N_R = \frac{VD}{\text{viscosity}} = \frac{11.52 ft/s\,(.6651 ft)}{.121 \times 10^{-5}} = \boxed{633219.18 = N_R}$

Velocity = 11.52 ft/s
D = .6651
V = Kinematic Viscosity
pg 489 @ 14.7psia
Table A.2
$= 1.21 \times 10^{-5}$

5 Roughness $= R = \frac{D}{\varepsilon} = \frac{.6651}{1.5 \times 10^{-4}} = \boxed{4434}$

D = .6651
ε = pg 185
Table 8.2
pipe Roughness
$= 1.5 \times 10^{-4}$

Roughness $= 1.5 \times 10^{-4}$ or .00015 ft
Given

6 Friction Factor pg 185 *Moody diagram*

N_R = 633219.18
R = 4434
D = .6651

$\boxed{f = .0155}$

7 Energy Loss (h_L)

$h_L = f \times \frac{L}{D} \times \frac{V^2}{2g} \Rightarrow .0155 \left(\frac{2500}{.6651}\right) \times \left(\frac{11.52^2}{2(32.2)}\right)$

$= .0155\,(3758.9)(2.06)$

$\boxed{= 120.02 ft}$

V = 11.52 ft/s
D = .6651
f = .0155
g = 32.2 ft/s
L = 2500 ft

5

8.46 Continued)

(B) Pressure at pump outlet

$P_1 = \gamma(210-0) + h_L \Rightarrow 62.4(210-0+120.02)$

$\gamma = 62.4$

$h_L = 120.02$

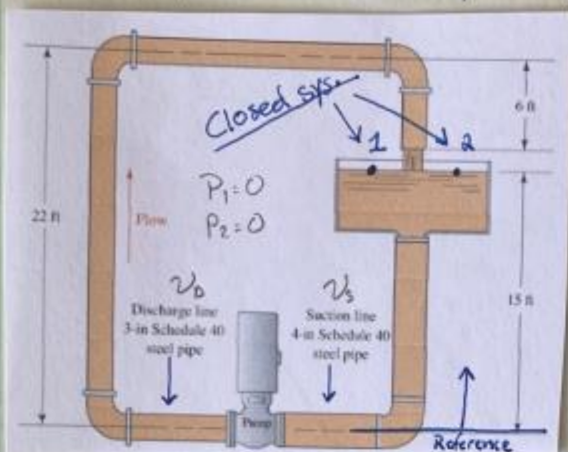
$P1 = 20593.2 \, ft^2$ Need psi

$$\boxed{P1 = \frac{20593.2}{144} = 142.9 \text{ PSI}}$$

8.49)

Homework 1.4 | Met 330 | Carroll, Shaunmark | 4/6

8.49) Figure 8.20 Shows a pump recirculating 300 gal/min of heavy machine tool lubricating oil at 104°F to test the oil's Stability. The total length of the 4 in pipe is 25.0 ft and the total length of 3 in pipe is 75.0 ft. Compute the power delivered by the pump to the oil.



Q: 300 gal/min $1\ \frac{gal}{min} = .0022\ \frac{ft^3}{sec}$

$S_g = 0.890$

ν = Kinematic Viscosity = 2.15×10^{-3}

3in Schedule 40 pipe
diameter = 0.2557 ft
area = 0.05132 ft²

4in schedule 40 pipe
diameter = 0.3355 ft
area = 0.08840 ft²

$S_{g\,oil} = \gamma_{oil}/\gamma_{water} \rightarrow \gamma_{oil} = S_g \gamma_{water} \rightarrow \gamma_{oil} = 0.890(62.4) \rightarrow \gamma_{oil} = 55.54\ lb/ft^3$

$$Q = v_D A \rightarrow v_D = Q/A \rightarrow v_D = \frac{\left(300\ \frac{gal}{min}\left(\frac{0.133681\ ft^3}{1\ gal}\right)\left(\frac{min}{60}\right)\right)}{.05132} \rightarrow v_D = 13.02\ \frac{ft}{sec}$$

$$Q = v_s A \rightarrow v_s = Q/A \rightarrow v_s = \frac{\left(300\ gal/min\left(\frac{0.133681\ ft^3}{1\ gal}\right)\left(\frac{min}{60 sec}\right)\right)}{.08840} \rightarrow v_s = 7.56\ ft/sec$$

$$h_a + \cancel{\frac{P_1}{\gamma_{oil}}} + \cancel{\frac{v_1^2}{2g}} + z_1 \rightarrow \cancel{\frac{P_2}{\gamma_{oil}}} + \cancel{\frac{v_2^2}{2g}} + z_2 + h_L \rightarrow h_a + 15 = 15 + h_L \rightarrow h_a = h_L$$

$h_a = (h_{L\,suction} + h_{L\,Discharge})$

Suction

$$N_R = \frac{v_s D}{\nu} \rightarrow N_R = \frac{7.56(0.3355)}{2.15 \times 10^{-3}} \rightarrow N_R = 1179.89 \quad N_R < 2000 = \text{laminar}$$

$$f_s = 64/N_R \rightarrow f_s = 64/1179.89 \rightarrow f_s = .0542$$

$$h_{L\,suction} = f_s\, L/D\, v_s^2/2g \rightarrow .0542\left(\frac{25}{.3355}\right)\left(\frac{7.56^2}{2(32.2)}\right) \rightarrow h_{L\,suction} = 3.59\ ft$$

8.49 Continued)

Homework 1.49 Met 330 Carroll, Shaunmark 5/6

8.49 Continued) $Q = 300 \frac{gal}{min}\left(\frac{0.133681\ ft^3}{gal}\right)\left(\frac{1\ min}{60\ sec}\right) \rightarrow Q = .6684 \frac{ft^3}{sec}$

Discharge

$N_R = \frac{v_D D}{V} \rightarrow N_R = \frac{13.02(.2557)}{(2.15\times10^{-3})} \rightarrow N_R = 1548.47$

$N_R < 2000$ = laminar

$f_D = 64/N_R \rightarrow f_D = 64/1548.47 \rightarrow f_D = .0413$

$h_{L\,Discharge} = f_D\ L/D\ v_D^2/2g \rightarrow .0413\left(\frac{75}{.2557}\right)\left(\frac{13.02^2}{2(32.2)}\right) \rightarrow h_{L_D} = 31.91 ft$

$h_a = (h_{L_S} + h_{L_D}) \rightarrow h_a = (3.59 ft + 31.91 ft) \rightarrow h_a = 35.5 ft$

$Power = \frac{\gamma Q h_a}{100\%\ eff} \rightarrow \frac{55.54\ lb/ft^3\ (.6684\ ft^3/sec)(35.5\ ft)}{1} \rightarrow 1317.87$

$Power = 1317.87\ lb\cdot\frac{ft}{s}\left(\frac{1 hp}{550\ lb\cdot\frac{ft}{s}}\right) \rightarrow$ Power = 2.40 hp

8.62)

8.62)

Find friction factor for:

Heavy fuel oil @77°F
6in Sch. 40 steel pipe → $\varepsilon = 1.5 \times 10^{-4}$ (Table 8.2), $D = 0.5054$ ft (Appx F)
12 ft/s flow rate

From Appendix B table B.1:

Fuel Oil, Heavy
$SG = 0.906$
$\gamma = 56.53 \ \text{lb/ft}^3$
$\rho = 1.76 \ \text{slugs/ft}^3$
$\nu = 1.27 \times 10^{-3} \ \text{ft}^2/\text{s}$
$\eta = 2.24 \times 10^{-3} \ \text{lb}\cdot\text{s/ft}^2$

Find Reynolds number:

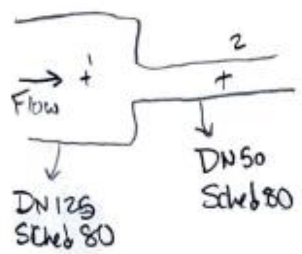
$$Re = \frac{\rho v D}{\eta} = \frac{1.76 \cdot 12 \cdot 0.5054}{2.24 \times 10^{-3}} = 4765 \ \therefore \text{turbulent}$$

$$f = \frac{0.25}{\left[\log\left(\frac{1}{3.7(.5054/1.5 \times 10^{-4})} + \frac{5.74}{4765^{0.9}}\right)\right]^2}$$

$$\boxed{f = 0.388}$$

10.20)

10.20)



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MET 330
HW 1.4
Group 2

Given

$\varnothing_1 = 122.3\,\text{mm} = .1223\,\text{m}$

$\varnothing_2 = 49.3\,\text{mm} = .0493\,\text{m}$

$Q = 500\,\text{L/min} = .0083\,\text{m}^3/\text{s}$

$\frac{\varnothing_1}{\varnothing_2} = \frac{.1223}{.0493} = 2.481$

$A_1 = \frac{\pi(.1223)^2}{4} = .0117\,\text{m}^2$

$A_2 = \frac{\pi(.0493)^2}{4} = .0019\,\text{m}^2$

$V_2 = \frac{Q}{A} = \frac{.0083}{.0019} = 4.368\,\text{m/s}$

$K = .39$ (from table 10.3A)

$h_L = K\left(\frac{V_2^2}{2g}\right)$

$= .39\left(\frac{4.368^2}{2(9.81)}\right)$

$h_L = 0.379\,\text{m}$

10.37)

#10.37

- Close bend return 1/2 inch Schedule 40 Steel pipe
- $12.5 \frac{gal}{min}$
- ethylene @ 77°F
- Find pressure difference between inlet & outlet

$* h_{L_{bend}} = f_T \frac{Le}{D} \frac{v^2}{2g} \Rightarrow * K = f_T \frac{Le}{D}$

K = Roughness

$* h_{L_{pipe}} = f_T \frac{L}{D} \frac{v^2}{2g} \Rightarrow * K = \frac{D}{\varepsilon} + N_R = f_T$

$\boxed{* h_L = K \frac{v^2}{2g}}$ Pg 247

$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + h_{L_{Pipe}} + h_{L_{Bend}}$

$\frac{P_1}{\gamma} = \frac{P_2}{\gamma} + h_{L_P} + h_{L_B} \Rightarrow P_1 - P_2 = \gamma (h_{L_P} + h_{L_B})$ *Find $h_{L_{pipe}}$ $h_{L_{Bend}}$

① $h_{L_{Bend}} = f_T \frac{Le}{D} \frac{v^2}{2g}$

g = 32.2
V = ? = 13.17 ft/s
Le/D = ? 50
f_T = ? .026
A = .00211 ft²
D = .0518 ft

② Velocity
$Q = VA = V = \frac{Q}{A} = \quad V = \frac{.0278}{.00211} = \boxed{13.17\ ft/s}$

$Q = \frac{12.5\ gal/min}{449\ gal/min} = \boxed{.0278\ ft^3/s}$

③ Area + Diameter
Pg 500 Appendix F
Schedule 40 Steel pipe
1/2 inch NPS

$\boxed{D = .0518\ ft}$ inner
$\boxed{A = .00211\ ft^2}$

④ Friction Factor = 1/2" Schedule Steel pipe $= \boxed{f_T = .026}$
Pg 242 Table 10.5

⑤ $\frac{Le}{D} = ?$ page 242 Table 10.4 = 90° Street Elbow ?

$\boxed{\frac{Le}{D} = 50}$

Pg 241 Image (d)

⑥ $h_{L_{Bend}} = f_T \frac{Le}{D} \frac{v^2}{2g}$

$= (.026)(50)\frac{(13.17)^2}{2(32.2)}$

$= \boxed{h_{L_{Bend}} = 3.61\ ft}$

7

10.37 Continued)

(7) $h_{L_{pipe}} = f \frac{L}{D} \frac{v^2}{2g}$

$K = ?$ Roughness
$L = 2(4ft) = 8ft$
$V = 13.17 ft/s$
$g = 32.2 ft/s$
$D = .0518$
$f = ?$
$\varepsilon = ? =$ Table 8.2 pg 185 Steel pipe

$\varepsilon = 1.5 \times 10^{-4}$

$K = \frac{D}{\varepsilon} = \frac{.0518}{1.5 \times 10^{-4}} = \boxed{K = 345.3}$

$\frac{\varepsilon}{D} = \frac{1.5 \times 10^{-4}}{.0518} = .00289$

f_T = Moody Diagram pg 185

Need $N_R = 4300$
Need K/R = Roughness $= 345.3$
relative roughness $= .00289 = K$
To Find f_T on Chart

$\boxed{= f = .041}$

pg 491
Ethylene glycol
At 77°f
Table In Book
was it marked as Celcius

(8) $N_R = \frac{V D \rho}{\mu} = \frac{(13.17ft)(.0518ft)(2.13)}{3.38 \times 10^{-4}}$

$V = 13.17 ft$
$D = .0518 ft$
density $= \rho = 2.13$
viscosity $\mu = 3.38 \times 10^{-4}$

$N_R = 4300 = 4.3 \times 10^3$

(9) $h_{L_{pipe}} = f \frac{L}{D} \frac{v^2}{2g} = (.041)\left[\frac{8}{.0518}\right]\left[\frac{13.17^2}{2(32.2)}\right] =$

$f = .041$
$L = 8ft$
$V = 13.17$
$g = 32.2$
$D = .0518$

$= (.041)(154.4)(2.69)$

$\boxed{h_{L_{pipe}} = 17.05 ft}$

(10) Pressure Difference

$P1 - P2 = \gamma(h_{L_{pipe}} + h_{L_{bend}})$ ⟹ $P1 - P2 = 68.47(17.05 + 3.61)$

$\gamma = 68.47$
page 491
Specific weight

$P1 - P2 = 1414.6\ ft$ Need psi

$P1 - P2 = \frac{1414.6}{144} = 9.82\ PSI$

$h_{L_{pipe}} = 17.05 ft$ $h_{L_{bend}} = 3.61 ft$

$\boxed{P1 - P2 = 9.82\ PSI}$

8

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10.39) A piping system for a pump contains a tee, as shown in fig 10.34 to permit the pressure at the outlet of the pump to be measured. However, there is no flow into the line leading to the gauge. Compute the energy loss, as $0.40\ ft^3/s$ of water at 50°F flows through the tee.

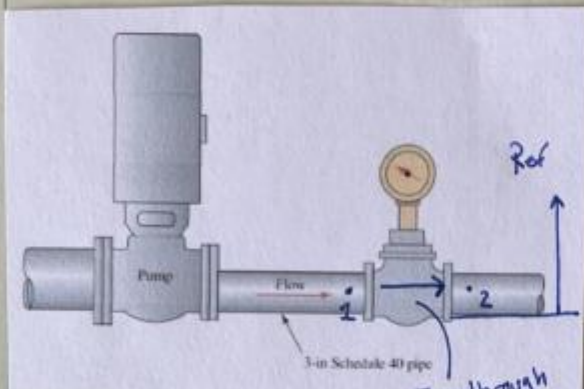


Figure 10.34

$Q = 0.40\ ft^3/s$

3 in Pipe Schedule 40
diameter $= 0.2557\ ft$
Area $= 0.05132\ ft^2$

Water at 50° F
$\gamma = 62.4\ lb/ft^3$
$\eta = 2.72 \times 10^{-5}\ lb \cdot s/ft^2$ → dynamic
$\nu = 1.40 \times 10^{-5}\ ft^2/s$ → kinematic

table 10.4 → Standard tee → with flow through run → $L_e/D = 20$

table 8.2 → Roughness Steel → $\epsilon = 1.5 \times 10^{-4}$

$Q = vA \rightarrow v = Q/A \rightarrow 0.40/.05132 \rightarrow v = 7.79\ ft/s$

$N_R = \frac{vD}{\nu} \rightarrow \frac{7.79(.2557)}{1.40 \times 10^{-5}} \rightarrow N_R = 142356.08 \rightarrow N_R = 1.4 \times 10^5$

$D/\epsilon \rightarrow .2557/1.5 \times 10^{-4} \rightarrow D/\epsilon = 1704$

moody chart → $f_t = .0195$

$K = f_T(L_e/D) \rightarrow K = .0195(20) \rightarrow K = .39$

Minor Energy loss → $h_L = K\frac{v^2}{2g} \rightarrow .39\left(\frac{7.79^2}{2(32.2)}\right) \rightarrow h_L = .37\ ft$

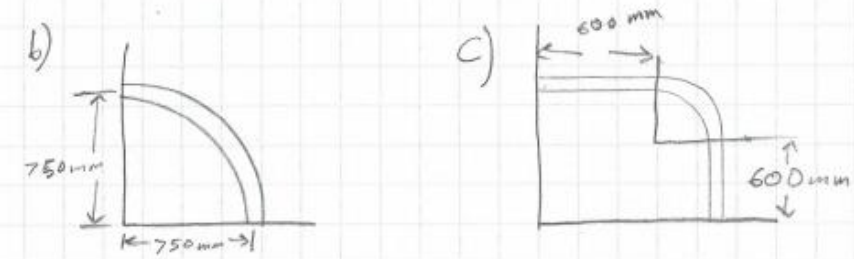
table 10.5 → Friction factor 3in Schedule 40 steel pipe → $f_t = 0.017$

$K = .017(20) \rightarrow 0.34$

$h_L = K\frac{v^2}{2g} \rightarrow 0.34\left(\frac{7.79^2}{2(32.2)}\right) \rightarrow h_L = 0.32\ ft$

10.43)

10.43) (7)



Given: copper tube 50 mm OD × 2.0 mm wall
propyl alcohol flow rate 750 L/min @ 25°C

$$Q = 0.750 \frac{m^3}{min} \cdot \frac{min}{60s} = 0.0125\ m^3/s$$

Find: Find energy loss in both scenarios b) and c).

Tube ID = 46 mm = 0.046m
tube flow area = $1.662 \times 10^{-3}\ m^2 = A$
$\mathcal{E} = 1.5 \times 10^{-6}$ m

Propyl Alcohol: (appendix B)
$SG = 0.802$
$\gamma = 7.87\ kN/m^3$
$\rho = 802\ kg/m^3$
$\eta = 1.92 \times 10^{-3}\ Pa \cdot s$
$\nu = 2.39 \times 10^{-6}\ m^2/s$
$v = \frac{Q}{A} = \frac{0.0125}{1.662 \times 10^{-3}} = 7.5\ m/s$

Find the Reynolds Number

$$R_e = \frac{\rho v D}{\eta} = \frac{802\ kg/m^3 \cdot 0.0125\ m^3/s \cdot 0.046\ m}{1.92 \times 10^{-3}\ Pa \cdot s}$$

$$= \frac{0.46}{1.92 \times 10^{-3}\ Pa \cdot s}$$

$R_e = 240.2$ ∴ Laminar flow

$$f = \frac{64}{N_R} = \frac{64}{240.2} = 0.266$$

$$h_L = f \times \frac{L}{D} \times \frac{V^2}{D}$$

$r/D = 0.75/0.046m = 16.30$ → from table 10.28 $L_e/D = 43$

$D/\mathcal{E} = 0.046/1.5 \times 10^{-6} = 30{,}667\ m$

10.43 Continued)

10.43 cont.) (8)

from the Moody diagram

$30{,}667 \rightarrow 0.0095\ f$

$K = f_T\left(\frac{L_e}{D}\right) = 0.0095(43) = 0.409$

$h_L = K\frac{V^2}{2g} = 0.409 \cdot \frac{7.5^2}{2 \cdot 9.81} = 1.17\ Nm/N$ proposal 1

for proposal 2

$r/D = \frac{0.150\ m}{0.046\ m} = 3.26 \rightarrow$ from figure 10.28 $\rightarrow L_e/D \approx 13$

$V = 7.5\ m/s$

$D/\varepsilon = 30{,}667$

$f_T \approx 0.0095$

$K = f_T\left(\frac{L_e}{D}\right) = 0.0095(13) = 1.24$

$h_L = K\frac{V^2}{2g} = 1.24\left(\frac{7.5^2}{19.62}\right) = 3.56\ Nm/N + 2\cdot\left(f \cdot \frac{L}{D} \times \frac{7.5^2}{19.62}\right)$

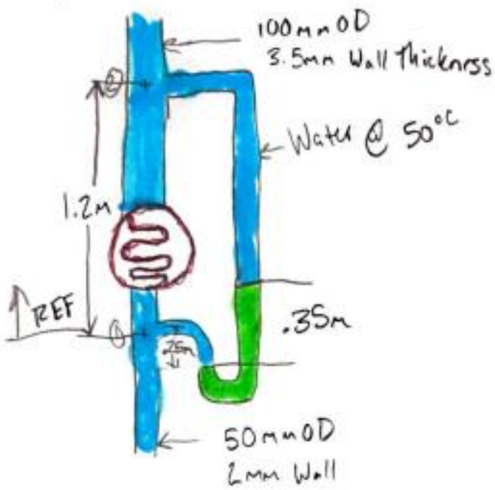
$h_L = 3.56 + 0.266 \cdot (0.60/0.046) \cdot \frac{7.5^2}{19.62})$

$h_L = 13.51\ Nm/N$ proposal 2

$$\boxed{\begin{array}{l}\text{Proposal 1 has total } h_L = 1.17\ m \\ \text{Proposal 2 has total } h_L = 13.51\ m\end{array}}$$

10.46)

10.46)



Given

$\varnothing_1 = 50-(2\times2) = 46\,mm = .046\,m$

$\varnothing_2 = 100-(3.5\times2) = 93\,mm = .093\,m$

$Q = 6.0\times10^{-3}\ m^3/s$

$\eta = 5.41\times10^{-4}\ Pa\cdot s$

$\rho = 988\ kN/m^3$

$\gamma_w = 9.69\ kN/m^3$

$A_1 = \frac{\pi(.046)^2}{4} = .0017\,m^2$

$A_2 = \frac{\pi(.093)^2}{4} = .0068\,m^2$

$v_1 = \frac{Q}{A} = \frac{6.0\times10^{-3}}{.0017} = 3.529\,m/s$

$v_2 = \frac{Q}{A} = \frac{6.0\times10^{-3}}{.0068} = 0.882\,m/s$

$\gamma_m = 132.8\ kN/m^3$

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MET 330
HW 1.4
Group 2

Bernoulli's

$$\frac{P_1}{\gamma} + \cancel{z_1} + \frac{v_1^2}{2g} = \frac{P_2}{\gamma} + z_2 + \frac{v_2^2}{2g} + h_L$$

$$h_L = \frac{P_1-P_2}{\gamma} - z_2 + \frac{v_1^2 - v_2^2}{2g}$$

$$\therefore h_L = 5.647 - 1.2 + \frac{3.529^2 - 0.882^2}{2(9.81)}$$

$$h_L = 5.042\,m$$

$$\therefore h_L = K\left(\frac{v_1^2}{2g}\right)$$

$$5.042 = K\left(\frac{3.529^2}{2(9.81)}\right)$$

$$5.042 = K(0.635)$$

$$K = 7.940$$

$$P_1 + .25\,\gamma_w + .35\,\gamma_m - 1.10\,\gamma_w = P_2$$

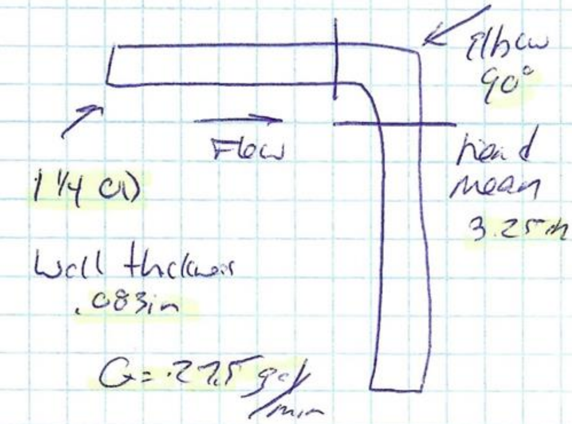
$$\frac{P_1 - P_2}{\gamma_w} = \frac{(1.10-.25)\cancel{\gamma_w}}{\cancel{\gamma_w}} + \frac{.35\,\gamma_m}{\gamma_w}$$

$$\frac{P_1-P_2}{\gamma_w} = .85 + \frac{.35(132.8)}{9.69}$$

$$\frac{P_1-P_2}{\gamma_w} = 5.647\,m$$

10.48)

10.48



- Energy Loss = h_L for 90° steel bend
- Tube = 1 1/4 OD
- Tube = .083 in Wall thickness
- bend mean Radius = 3.25"
- Flow Rate Q = 27.5 gall/min

$$h_L = k\left(\frac{v^2}{2g}\right)$$

k = ?
v = ?
g = 32.2 ft/s
$Q = \frac{27.5}{449}$ gal/min
Q = .0612 ft³/s
D = 1.084 in = .09033 ft
r = 3.25 in

① Area + Velocity

$$V = \frac{Q}{A} = \frac{.0612}{6.469\times10^{-3}} = \underbrace{9.56\ ft/s}$$

$$\frac{r}{D} = \frac{3.25}{1.084} = \underbrace{3.00}$$

$$\frac{v^2}{2g} = \frac{9.56^2}{2(32.2)} = \underbrace{1.484\ ft}$$

$\varepsilon = 1.5\times10^{-4}$

$$\frac{D}{\varepsilon} = \frac{.09033}{1.5\times10^{-4}} = \underbrace{602}$$

f_T = .023 - Turbulent
A = 6.469×10^{-3}

② Friction Factor

$$k = f_T\left(\frac{L_e}{D}\right) = .023(12.5) = \underbrace{.2875}$$

pg 246 $\frac{L_e}{D}$ = 12.5
r = 3.00

③ Energy Loss

$$h_L = k\left(\frac{v^2}{2g}\right) = .2875(1.484)$$

$$\boxed{h_L = .4267\ ft}$$?

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