TEST 3

HOMEWORK ASSIGNMENTS

3.1
3.2
3.3
3.4

MET 330
HW. 3.1
PROBLEMS 20, 37,
39, 43, 46, & 48

WORK DONE IN A GROUP BY:
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Oladuwa A. Oduntan HW 3.1

10.20 Given

DN 125 schedule 80 steel pipe : ID = 122.3mm , A = $1.173 \times 10^{-2} m^2$

DN 50 Schedule 80 steel pipe : ID = 49.3mm , A = $1.905 \times 10^{-3} m^2$

Q = 500 L/min

Required

Energy loss for a sudden contraction

Solution

D_1 = 122.3mm , A_1 = $1.173 \times 10^{-2} m^2$ } Table F.2

D_2 = 49.3mm , A_2 = $1.905 \times 10^{-3} m^2$ } Appendix F

$$Q = 500 L/min \times \frac{1 m^3/s}{60{,}000 L/min} = 0.0083 m^3/s$$

$$V_2 = \frac{Q}{A_2} \Rightarrow \frac{0.0083 m^3/s}{1.905 \times 10^{-3} m^2} = 4.357 m/s$$

$$\frac{D_1}{D_2} = \frac{122.3mm}{49.3mm} = 2.48 \cong 2.5$$

$$h_L = K \frac{V_2^2}{2g} \quad \text{where } K = 0.326 \text{ (By interpolation)}$$

$$\Downarrow$$

$$\frac{4.357 - 4.0}{5.0 - 4.0} = \frac{K - 0.39}{0.38 - 0.39} \Rightarrow K = 0.38643$$

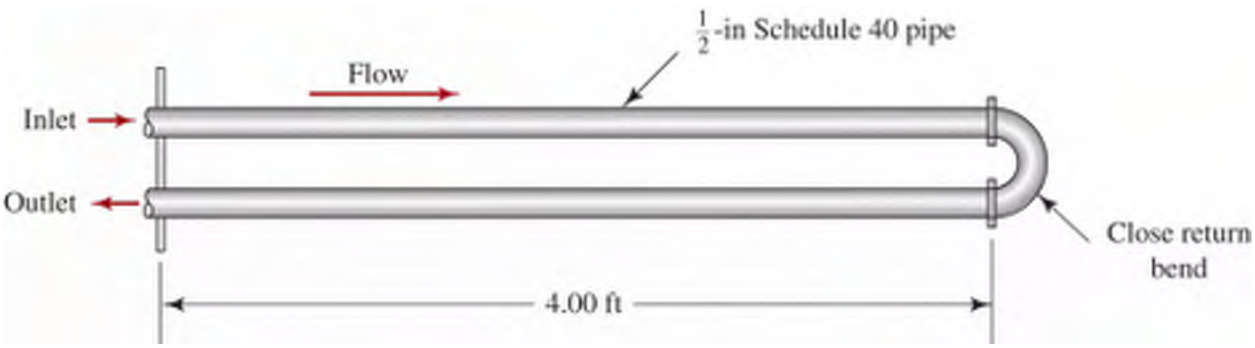
$$h_L = \frac{0.326 (4.357 m/s)^2}{2 (9.81 m/s^2)} = 0.373477$$

$$\boxed{\therefore h_L = 0.37m}$$

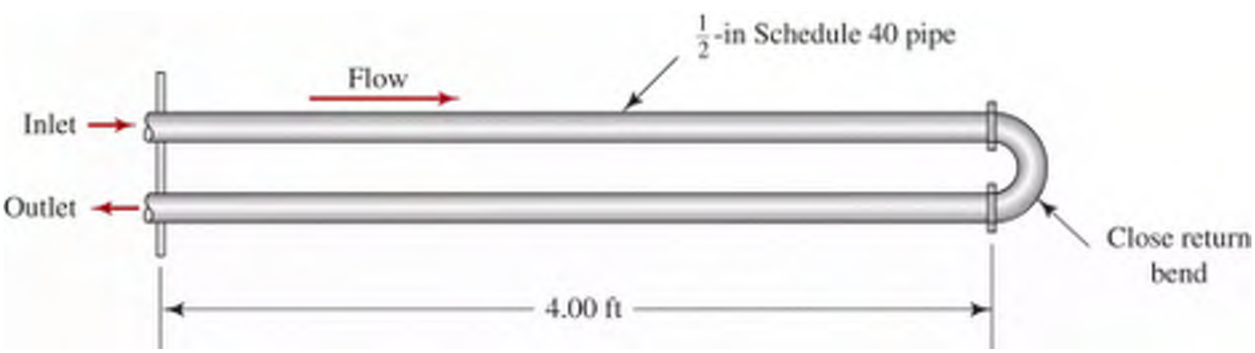
Homework 3.1

10.37

Problem: A simple heat exchanger is made by installing a close return bend on two ½-in Schedule 40 steel pipes as shown. Compute the pressure difference between the inlet and the outlet for a flow rate of 12.5 gal/min of ethylene glycol at 77°F.



Solution: Since fluid is moving, we will use Bernoulli's equation and assign points where information is known.



Our equation: $h_A + \frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + h_R + h_L$. There is no pump or turbine, and given the flow rate and constant pipe size, the inlet/outlet velocity is the same. Also, the vertical height between points 1 and 2 is negligible. Therefore: $P_1 - P_2 = h_L * \gamma$

where $h_L = h_{pipe} + h_{bend}$, $\quad h_{pipe} = f * \frac{L}{D} * \frac{v^2}{2g}$, $\quad and \quad h_{bend} = K\frac{v^2}{2g}$.

From figure 10.23 (f, close return bend), $K = 50f_t$

Table B.2: $\rho_{EG@77°F} = 2.13\frac{slugs}{ft^3}$, $\eta_{EG} = 3.38 * 10^{-4} lb - \frac{s}{ft^2}$, $\gamma = 68.47\frac{lb}{ft^3}$

Table F.1: $\frac{1}{2}$ $SCH40\ steel\ pipe$: $A = 0.00211\ ft^2$, $D = 0.0518ft$

Now $v = \frac{Q}{A} \rightarrow \frac{12.5\frac{gal}{min.} * \frac{\frac{ft^3}{s}}{449\frac{gal}{min.}}}{0.00211ft^2} = 13.19\frac{ft}{s}$.

Reynolds number: $Re = \frac{2.13\frac{slugs}{ft^3} * 13.19\frac{ft}{s} * 0.0518\ ft}{3.38 * 10^{-4} lb - \frac{s}{ft^2}} = 4{,}307$, this is >4,000 which is turbulent.

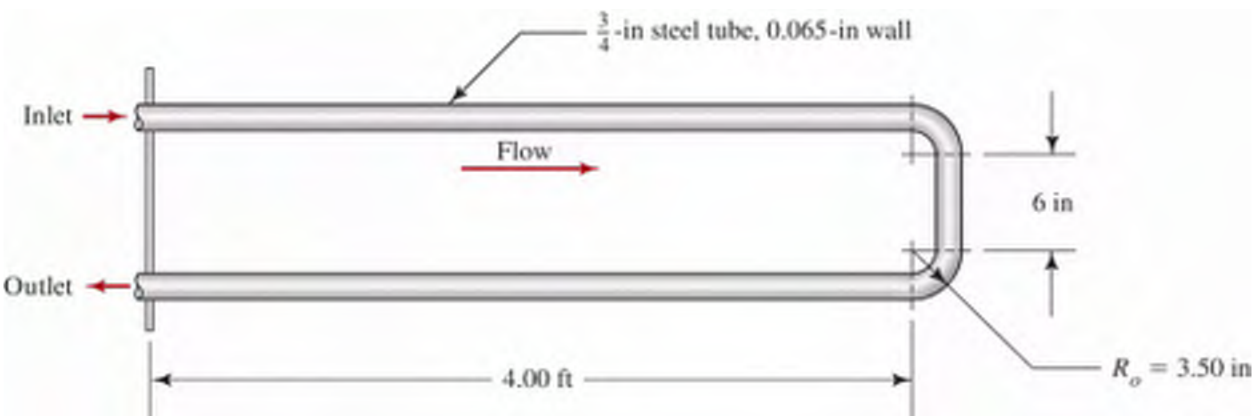
From table 10.5: $f_t = 0.026 \rightarrow K = 50 * 0.026 = 1.3 \rightarrow h_{bend} = 1.3 * \frac{\left(13.19\frac{ft}{s}\right)^2}{2 * 32.2\frac{ft}{s^2}} = 3.51ft$

Calculating in Excel: $f = 0.043 \rightarrow h_{pipe} = 0.043 * \frac{2 * 4ft}{0.0518ft} * \frac{\left(13.19\frac{ft}{s}\right)^2}{2 * 32.2\frac{ft}{s^2}} = 17.94ft$

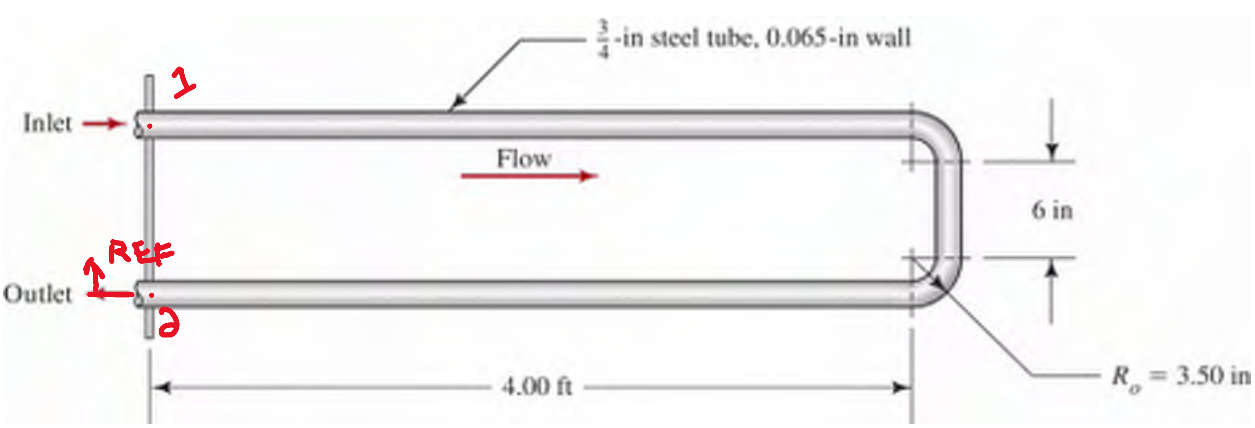
Finally: $\Delta P = (17.94ft + 3.51ft) * 68.47\frac{lb}{ft^3} * \left(\frac{1ft}{12in}\right)^2 = \mathbf{10.2psi}$

10.38

Problem: A proposed alternate form for the heat exchanger described in Problem 10.37 is shown. The entire flow conduit is a ¾-in steel tube with a wall thickness of 0.065 in. Note that the ID for this tube is 0.620 in, slightly smaller than that of the ½-in Schedule 40 pipe (D=0.622in). The return bend is formed by two 90° bends with a short length of straight tube between them. Compute the pressure difference between the inlet and the outlet of this design and compare it with the system from Problem 10.37.



Solution: Since fluid is moving, Bernoulli's equation will be use, and reference points given:



Our equation is now: $P_1 - P_2 = \frac{(h_L * \gamma)}{z_1}$. From problem 10.37:

$$h_L = h_{pipe} + h_{bend}, \quad h_{pipe} = f * \frac{L}{D} * \frac{v^2}{2g}, \quad and \quad h_{bend} = K\frac{v^2}{2g},$$

$$\rho_{EG@77°F} = 2.13\frac{slugs}{ft^3}, \ \ \eta_{EG} = 3.38 * 10^{-4} lb - \frac{s}{ft^2}, \quad \gamma = 68.47\frac{lb}{ft^3}$$

From figure 10.23, $K = 20f_T$

$$D = 0.620in * \frac{1ft}{12in} = 0.05167ft, \quad A = \pi * \frac{0.05167^2}{4} = 0.00209ft^2$$

Re-calculating V, Re: $v = \frac{Q}{A} \rightarrow \frac{12.5\frac{gal}{min.} * \frac{\frac{ft^3}{s}}{449\frac{gal}{min.}}}{0.00209ft^2} = 13.279\frac{ft}{s}$

$$Re = \frac{2.13\frac{slugs}{ft^3} * 13.19\frac{ft}{s} * 0.05167\ ft}{3.38 * 10^{-4} lb - \frac{s}{ft^2}} = 4{,}323$$

Table 10.5:

$$f_t = 0.026 \rightarrow K = 20 * 0.026 = 0.52 \rightarrow h_{bend} = 2 * \left(0.52 * \frac{\left(13.279\frac{ft}{s}\right)^2}{2*32.2\frac{ft}{s^2}}\right) = 2.847ft$$

Calculating in Excel: $f = 0.0428 \rightarrow h_{pipe} = 0.0428 * \frac{(2*4ft)+\frac{6in}{12}}{0.05167ft} * \frac{\left(13.279\frac{ft}{s}\right)^2}{2*32.2\frac{ft}{s^2}} = 18.181ft$

$$\Delta P = \left(17.94ft + 3.51ft + \frac{6in + (2 * 3.5in) - 0.75in}{12in}\right) * 68.47\frac{lb}{ft^3} * \left(\frac{1ft}{12in}\right)^2 = \boldsymbol{9.513psi}$$

Pressure difference:

$$\frac{10.190psi - 9.513psi}{9.513psi} * 100 = \boldsymbol{7.1\%\ less\ pressure\ drop\ in\ this\ configuration}$$

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10.39) Given: $T_w = 50°F$ $\quad Q = 0.40 ft^3/s$

$\gamma_w @ 50°F = 62.4\ lb/ft^3$ $\quad \rho = 1.94\ slugs/ft^3$

$\mu = 2.72 \times 10^{-5}$ $\quad \nu = 1.40 \times 10^{-5}$

3in sch. 40 pipe: $D_I = 3.068\ in$ or $0.2557 ft$

Flow Area $= 0.05132 ft^2$

3in sch. 40 pipe

Find energy loss as $0.40 ft^3/s$ of H_2O @ 50F

$K = 20 f_T$ straight run through of a tee

$h_L = K \frac{V_1^2}{2g}$ $\quad V = \frac{Q}{A}$ $\quad V = \frac{0.40 ft^3/s}{0.05132 ft^2}$

$V = 7.79 ft/s$

$h_L = 20 f_T \frac{(7.79 ft/s)^2}{2 \times 32.2 ft^2/s}$

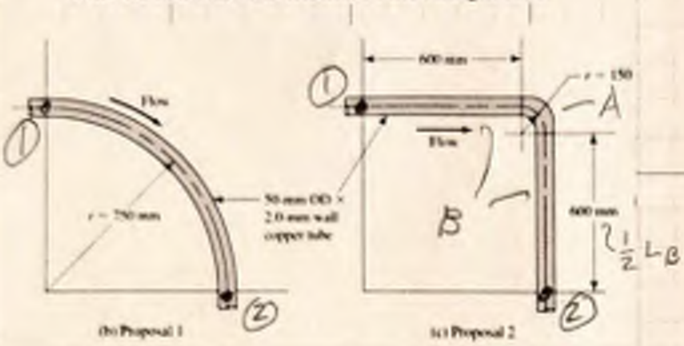
$f_T = 0.017 in$ from table 10.5

$h_L = 20 \times 0.017 \times \left(\frac{(7.79 ft/s)^2}{2 \times 32.2 ft^2/s}\right)$

$h_L = 0.32 ft$

NICK DUNHAM

10.43 The inlet and the outlet shown in Fig. P10.43(a) are to be connected with a 50 mm OD × 2.0 mm wall copper tube to carry 750 L/min of propyl alcohol at 25°C. Evaluate the two schemes shown in parts (b) and (c) of the figure with regard to the energy loss. Include the losses due to both the bend and the friction in the straight tube.



(b) Proposal 1

(c) Proposal 2

$D = 46\,mm = 0.046\,m$

$\varepsilon = 1.5\times10^{-6}\,m$ – Table 8.2

$\gamma = 7.87\,kN/m^3$, $\nu = 2.39\times10^{-6}\,m^2/s$ } Table B.1

$A = \frac{\pi}{4}D^2 = \frac{\pi}{4}(0.046m)^2 = 0.001662\,m^2$

$Q = \frac{750\,L}{min}\cdot\frac{1m^3/s}{60000\,L/min} = 0.0125\,m^3/s$

$v = \frac{Q}{A} = \frac{0.0125\,m^3/s}{0.001662\,m^2} = 7.5215\,m/s$

$R = \frac{vD}{\nu} = \frac{7.52m/s\cdot0.046m}{2.39\times10^{-6}m^2/s} = 1.45\times10^5$

$f = 0.0168$ (by Swamee-Jain)

use $h_L = f\cdot\frac{\Sigma L_e}{D}\cdot\frac{v^2}{2g}$ with

$\frac{L_e}{D}$ from Fig. 10.28 based on R/D

Proposal 1. - no straights

$\frac{R}{D} = \frac{750\,mm}{46\,mm} = 16.3$

$\frac{L_e}{D} \approx 43$ (Fig. 10.28)

$h_L = f\frac{L_e}{D}\,v^2/2g = 0.0168\cdot43\cdot\frac{(7.52m/s)^2}{2\cdot9.81m/s^2} = \underline{2.08\,m}$

Proposal 2 - 2× 0.6m straight

$\frac{R}{D} = \frac{150mm}{46mm} = 3.26$

$\frac{L_{eA}}{D} \simeq 12.5$ (Fig. 10.28) $\Rightarrow L_e = 12.5\cdot0.046m = 0.575m$

Using summed lengths

$\frac{L_B}{D}\ \frac{2\cdot0.6m}{0.046m} = 26.09$

$\Sigma L_e = L_e + L_B = 0.575m + 2\cdot0.6m = 1.775m$

$\frac{\Sigma L_e}{D} = \frac{L_{eA}}{D} + \frac{L_B}{D} = 12.5 + 26.09 = 38.59$

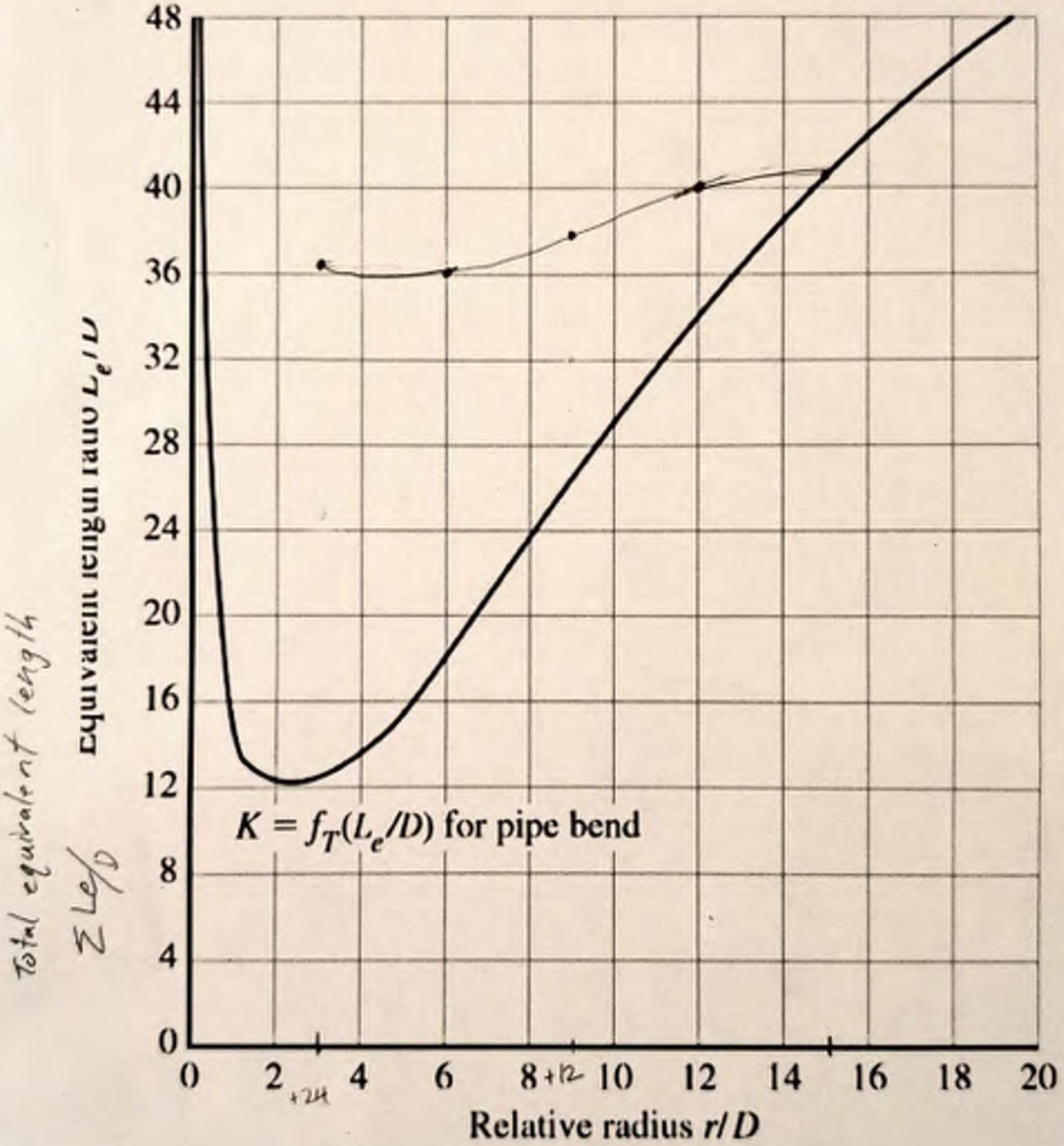
$\frac{\Sigma L_e}{D} = \frac{1.775m}{0.046m} = 38.59m$

$h_L = f\cdot\frac{\Sigma L_e}{D}\cdot\frac{v^2}{2g} = 0.0168\cdot38.59\cdot\frac{7.52^2}{2\cdot9.81}m/s^2 = \underline{1.87m}$

Note: Total equivalent length greater for proposal 1.

$\Sigma L_e = 2 \cdot L_i + L_e = 2(15D - R) + L_e$

(considering OD rather than ID for simplicity)



$\frac{r}{D} + \frac{L}{D} = 15$

$\Sigma \frac{L}{D} = \frac{r}{D} + \frac{2L}{D} = \frac{r}{D} + 2 \cdot \left(15 - \frac{r}{D}\right) \Rightarrow = 30 - \frac{r}{D}$

10.46) $T_w = 50°C$ $\quad Q = 6.0 \times 10^{-3} m^3/s$

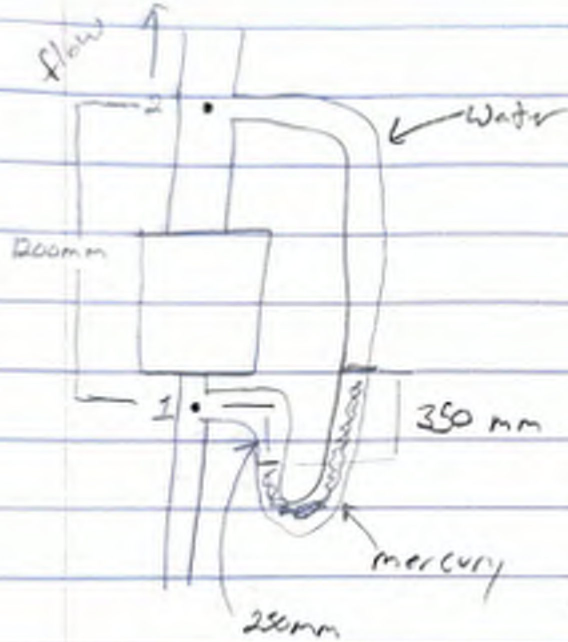
$D_{o_2} = 100mm$ $\quad D_{o_1} = 50mm$ $\quad wt_2 = 3.5mm$

$wt_1 = 2mm$ $\quad D_{I_2} = 100mm - 2 \times 3.5mm = 93mm$

$D_{I_1} = 50mm - 2 \times 2mm = 46mm$

$\gamma_w = 9.69\ kN/m^3$ $\quad \rho_w = 988\ kg/m^3$ $\quad \gamma_m = 132.8\ kN/m^3$

$\rho_m = 13540\ kg/m^3$



$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + Z_1 - h_L = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + Z_2 + h_L$$

$$\frac{P_1 - P_2}{\gamma} + \frac{V_1^2 - V_2^2}{2g} + Z_1 - Z_2 = h_L$$

$$\frac{P_1 - P_2}{\gamma_w} = \frac{\gamma_m(0.35m)}{\gamma_w} + \frac{\cancel{\gamma_w}(1.1m - 10.25m)}{\cancel{\gamma_w}}$$

$$\frac{P_1 - P_2}{\gamma_w} = \frac{132.8\ kN/m^3\ (0.35m)}{9.69\ kN/m^3} + 0.85m$$

$$\frac{P_1 - P_2}{\gamma_w} = 5.65m$$

$$h_L = \frac{P_1 - P_2}{\gamma_w} + \frac{V_1^2 - V_2^2}{2g} + Z_1 - Z_2$$

$$= 5.65m + \frac{(3.61m/s)^2 - (0.88m/s)^2}{2 \times 9.81 m/s^2} + 120m$$

$$h_L = 5.075m$$

$Q = AV$ $\quad V_1 = \frac{Q}{A_1}$

$$V_1 = \frac{6.0 \times 10^{-3} m^3/s}{\frac{\pi}{4} \times 0.046m^2}$$

$$V_1 = 3.61 m/s$$

$$V_2 = \frac{Q}{A_2}$$

$$V_2 = \frac{6. \times 10^{-3} m^3/s}{\frac{\pi}{4} \times 0.093m^2}$$

$$V_2 = 0.88 m/s$$

Eq for minor loss resistent coeff.

$$h_L = K\frac{V^2}{2g}$$

$$5.075 = K \frac{3.61^2}{2 \times 9.81}$$

$$5.075 = K \times 0.686 \qquad K = \frac{5.075}{0.686} \qquad K = 7.398$$

NICK DUNHAM

10.48 Compute the energy loss in a 90° bend in a steel tube used for a fluid power system. The tube has a 1¼-in OD and a wall thickness of 0.083 in. The mean bend radius is 3.25 in. The flow rate of hydraulic oil is 27.5 gal/min.

$Q = 27.5 \frac{gal}{min} \cdot \frac{1 ft^3/s}{449 gal/min} = 0.06125 ft^3/s$

$D = \frac{1.25 in - 2 \cdot 0.083 in}{12 in/ft} = 0.0903 ft$

$A = \frac{\pi}{4} D^2 = \frac{\pi}{4}(0.0903 ft)^2 = 0.00641 ft^2$

$v = \frac{Q}{A} = \frac{0.06125 ft^3/s}{0.00641 ft^2} = 9.557 ft/s$

Assume medium hyd. oil @ 104°F:

$\nu = 7.21 \times 10^{-4} ft^2/s$ (Appendix C)

$R = \frac{vD}{\nu} = \frac{9.557 ft/s \cdot 0.0903 ft}{7.21 \times 10^{-4} ft^2/s} = 1.20 \times 10^3$ Laminar

$f = \frac{64}{R_e} = \frac{64}{1200} = 0.0535$ (Eq. 8-5)

$\varepsilon = 5.0 \times 10^{-6} ft$ (Table 8.2)

$\frac{D}{\varepsilon} = \frac{0.903 ft}{5.0 \times 10^{-6} ft} = 18100$

$f_T \approx 0.011$ (Fig. 8.7)

Laminar value of f is worse scenario

$R/D = \frac{3.25 in}{0.0903 ft \cdot 12 in/ft} = 3.0 \Rightarrow L_e/D \approx 12.5$ (fig 10.28)

$h_L = f \frac{L_e}{D} \frac{v^2}{2g} = 0.0535 \cdot 12.5 \cdot \frac{(9.557 ft/s)^2}{2 \cdot 32.2 ft/s^2} = \boxed{0.95 ft}$

MET 330

HW. 3.2

PROBLEMS 5, 13, 15, 22, 23

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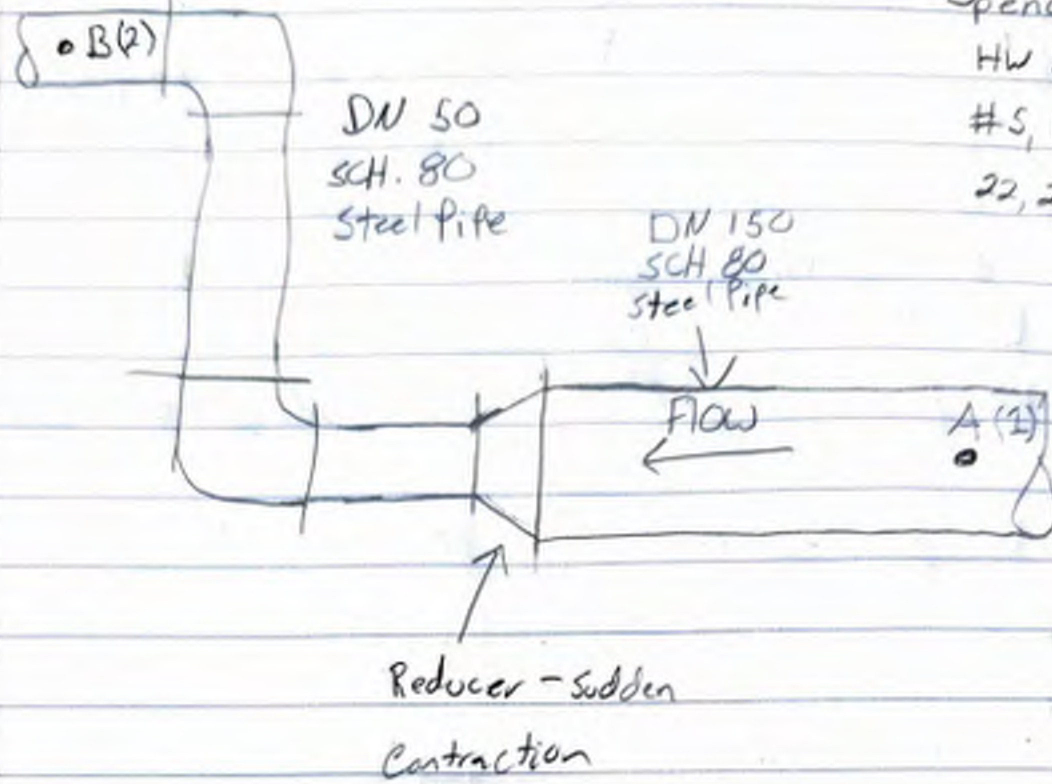
HW 3.2
#5, 13, 15,
22, 23

11. 5)



Consider pipe friction + minor losses.
Calculate pressure at A

Given: $\gamma_{oil} = 8.80 kN/m^3$ $\quad v = 2.12 \times 10^{-5} m^2/s$ $\quad Q = 0.015 m^3/s$

$L_{DN50} = 80m$ $\quad L_{DN150} = 180m$ $\quad$ Elbows = long radius

$P_B = 12.5 Mpa \times \frac{1000 KPa}{1 Mpa} = 12{,}500 Kpa \times \frac{1000 Pa}{1 Kpa} = 12{,}500{,}000 pa$

$12{,}500{,}000 pa \times \frac{1 Pa}{1 N/m^2} = 12{,}500{,}000 N/m^2 \times \frac{1 kN/m^2}{1000 N/m^2} = 12{,}500 kN/m^2$

Eq. for long radius elbows $\quad f_T = \dfrac{0.25}{\left[\log\left(\frac{1}{D/\epsilon}\right)\right]^2}$

$K = 20 f_T$

$R_e = \frac{VD}{v}$ $\quad R_r = D/\epsilon$ $\quad$ Major losses $= h_L = f \frac{L}{D} \frac{V^2}{2g}$

minor losses $= h_L = K \frac{V^2}{2g}$

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + \cancel{Z_1}^{0} = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + Z_2 + h_{L_{1-2}}$$

DN 50 (2)

$D_{in} = 49.3\,mm$ or $0.0493\,m$

Flow Area $= 1.905 \times 10^{-3}\,m^2$

DN 150 (1)

$D_{in} = 146.3\,mm$ or $0.146\,m$

Flow Area $= 1.682 \times 10^{-2}\,m^2$

$$V_1 = \frac{Q_1}{A_1} \Rightarrow \frac{0.015\,m^3/s}{0.01682\,m^2} \Rightarrow V_1 = 0.892\,m/s$$

$P_2 = 12{,}500\,kN/m^2$

$$V_2 = \frac{Q_2}{A_2} \Rightarrow \frac{0.015\,m^3/s}{0.001905\,m^2} \Rightarrow V_2 = 7.874\,m/s$$

$Z_2 = 4.5\,m$

$$h_{L_{1-2}} \Rightarrow f\frac{L}{D}\frac{V^2}{2g} + 2 \times K\frac{V^2}{2g}$$

$$\frac{P_1}{\gamma} = \frac{P_2}{\gamma} + \frac{V_2^2 - V_1^2}{2g} + Z_2 + h_{L_{1-2}}$$

$$P_1 = \gamma \times \left(\frac{P_2}{\gamma} + \frac{V_2^2 - V_1^2}{2g} + Z_2 + h_{L_{1-2}}\right)$$

$$P_1 = \gamma\left(\frac{P_2}{\gamma} + \frac{V_2^2 - V_1^2}{2g} + Z_2 + h_{L_{1-4}}\right)$$

$$P_1 = 8.80 kN/m^3 \times \left(\left(\frac{12500 kN/m^3}{8.80 kN/m^3}\right) + \left(\frac{(7.874 m/s^2 - 0.892 m/s^2)}{2 \times 9.81 m/s}\right) + 4.5m + h_{L_{1-2}}\right)$$

$$h_{L_{1-2}} \Rightarrow \underbrace{f_1 \frac{L}{D}\frac{V^2}{2g}}_{\text{(Section 1)}} + \underbrace{\left(2 \times K \frac{V^2}{2g}\right)}_{\text{(Elbows)}} + \underbrace{f_2 \frac{L}{D}\frac{V^2}{2g}}_{\text{(Section 2)}} + \underbrace{K \frac{V^2}{2g}}_{\text{(Sudden contraction)}}$$

Section 1 $f = \dfrac{0.25}{\left[\log\left(\frac{1}{3.7 \times (D/\varepsilon)} + \frac{5.74}{Re^{0.9}}\right)\right]^2}$ $\qquad Re = \dfrac{VD}{\nu}$

Section 1 $= f \frac{L}{D}\frac{V^2}{2g}$ $\qquad Re = \dfrac{0.892 m/s \times 0.146 m}{0.000021 m^3/s}$

$= 6201$

$D/\varepsilon = \dfrac{0.146}{4.6 \times 10^{-5}} = 3173.91$

$$f = \frac{0.25}{\left[\log\left(\frac{1}{3.7 \times 3173} + \frac{5.74}{6201.^{0.9}}\right)\right]^2} = 0.035847$$

$$h_{L_1} = 0.035847 \times \left(\frac{180m}{0.146m} \times \frac{0.892^2 m/s}{2 \times 9.81 m/s^2}\right) = 1.79m$$

$h_{L_1} = 1.79m$

Section 2) $D/\varepsilon = \frac{0.0493m}{4.6\times10^{-5}} = 1071.74$

$Re = \frac{7.874 m/s \times 0.0493m}{0.000021 m^2/s} = 18,372$

$f = \frac{0.25}{\left[\log\left(\frac{1}{3.7\times1071} + \frac{5.7}{18,372^{0.9}}\right)\right]^2} = 0.0284$

$h_{L_2} = 0.0284 \times \left(\frac{80m}{0.0493m} \times \frac{7.874 m/s^2}{2\times9.81 m/s^2}\right) = 145.63m$

Elbows) $2 \times K\frac{v^2}{2g}$ $K = 20 f_T$ $f_T = \frac{0.25}{\log\left(\frac{1}{3.7\times D/\varepsilon}\right)^2}$

$D/\varepsilon = 1071$

$f_T = \frac{0.25}{\log\left(\frac{1}{3.7\times1071}\right)^2} = 0.0193$ $K = 20\times0.0193$
$= 0.386$

$h_{L_3} = 2\times\left(0.386 \times \frac{7.874 m/s^2}{2\times9.81 m/s^2}\right) = 2.44m$

Contraction) $h_{L_4} = K\frac{v^2}{2g}$ $D_1/D_2 \Rightarrow \frac{0.146}{0.0493} = 2.96$

$h_{L_4} = 0.386 \times \frac{0.892^2}{2\times9.81} = 0.0156m$

$$P_1 = 8.80\,kN/m^3 \times \left(\frac{12{,}300\,kN/m^3}{8.80\,kN/m^3} + \frac{7.874\,m/s - 0.892\,m/s}{2 \times 9.81\,m/s^2} + 4.5\,m \right.$$

$$\left. + (1.79\,m + 145.63\,m + 2.44\,m + 0.0156\,m) \right)$$

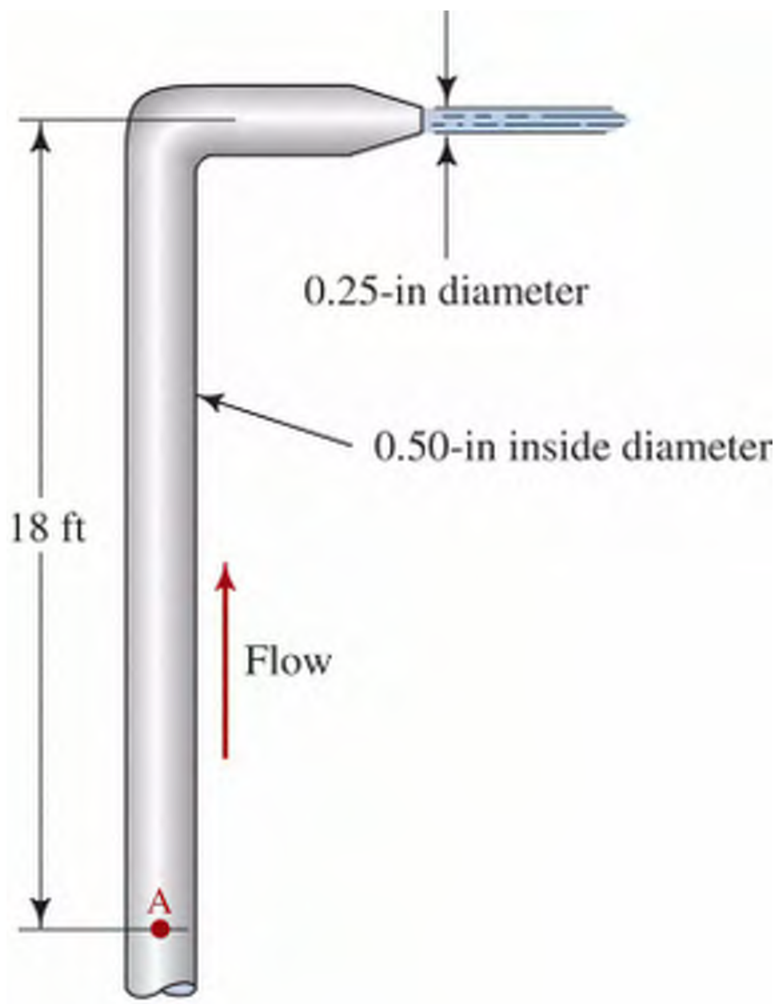
$$P_1 = 8.80\,kN/m^3 \times \left(\frac{12{,}500\,kN/m^3}{8.80\,kN/m^3} + \frac{7.874\,m/s - 0.892\,m/s}{2 \times 9.81\,m/s^2} + 4.5\,m + 149.87\,m \right)$$

$$P_1 = 13{,}861.58\,kN/m^3 = 13.861\,MPa$$

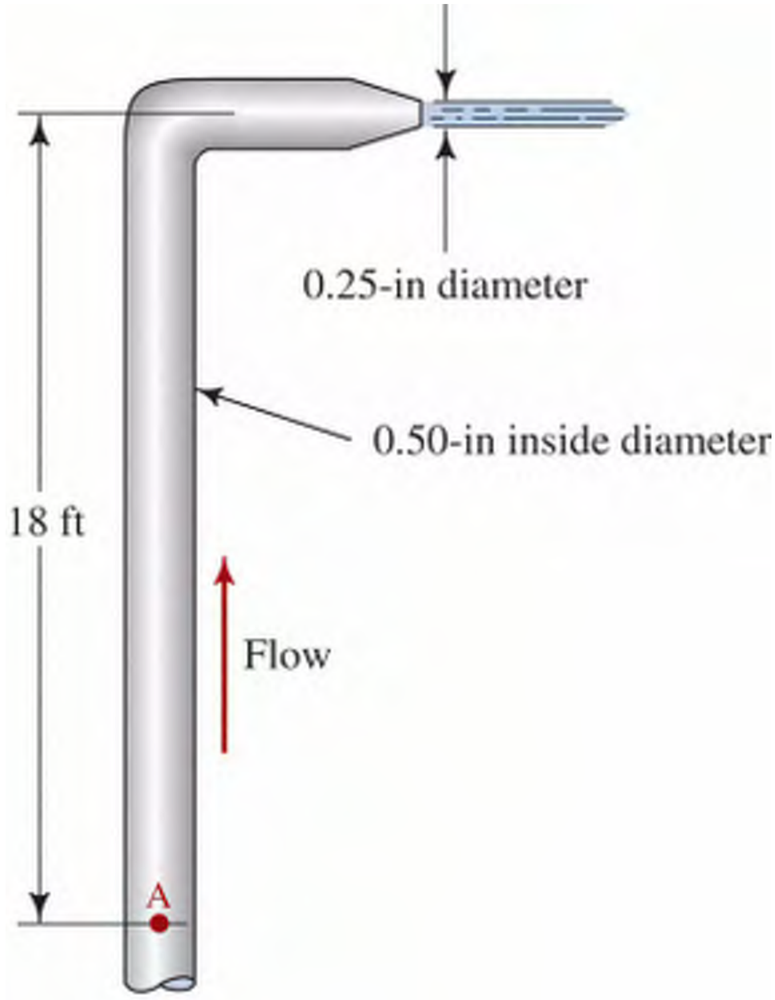
Homework 3.1

11.13

Problem: A device designed to allow cleaning of walls and windows on the second floor of homes is similar to the system shown. Determine the velocity of flow from the nozzle if the pressure at the bottom is (a) 20 psig and (b) 80 psig. The nozzle has a loss coefficient *K* of 0.15 based on the outlet velocity head. The tube is smooth drawn aluminum and has an ID of 0.50 in. The 90° bend has a radius of 6.0 in. The total length of straight tube is 20.0 ft. The fluid is water at 100°F.



Solution: Since fluid is moving, Bernoulli's equation will be used and a reference line drawn and points labeled:



From Bernoulli's equation, there is no pump or turbine, Z1 is at the level of the reference, and P2 is zero (vented to the atmosphere), therefore:

$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} = \frac{V_2^2}{2g} + z_2 + h_L$. Re-arranging for known values: $\frac{P_1}{\gamma} - z_2 = \frac{V_2^2 - V_1^2}{2g} + h_L$ (1).

Because there is a nozzle, the velocity increases in the system. The energy losses are made up of: $h_{pipe} = f * \frac{l}{D} * \frac{v_1^2}{2g}$, $\quad h_{bend} = f * \frac{Le}{D} * \frac{v_1^2}{2g}$, $\quad h_{nozzel} = k * \frac{v_1^2}{2g}$ (2). Velocity is a function of flow rate, therefore: $V = \frac{Q}{A}, \quad A = \pi * \frac{D^2}{4} \rightarrow V_1 = \frac{Q_1}{\pi * \frac{0.5^2}{4}}, V_2 = \frac{Q_2}{\pi * \frac{0.25^2}{4}}$. It can now be said: $V_2 = 4V_1$ (3)

Integrating all equations:

$$\frac{L_e}{D} = \frac{r}{D}(chart) \rightarrow \frac{6in}{0.5in} = 12, from\ figure\ 10.28: \frac{L_e}{D} = 34$$

$$\frac{P_1}{\gamma} - z_2 = \frac{V_2^2 - (0.25v_2)^2}{2g} + \left(f * \frac{20ft}{\frac{0.5in}{12}} * \frac{(0.25v_2)^2}{2g}\right) + \left(f * 34 * \frac{(0.25v_2)^2}{2g}\right) + 0.5\left(\frac{v_2^2}{2g}\right)$$

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

Given:

$l = 20ft, \quad D = 0.5in, \quad K_{nozzel} = 0.5, \quad z_2 = 18ft, \quad T = 100°\text{F}$

From the book:

$\gamma_{water@100} = \frac{62lb}{ft^3}, \quad \rho = \frac{1.93slugs}{ft^3}, \quad \mu = 1.42 * 10^{-5}lb - \frac{s}{ft^2} \quad (table\ A.2)$

$\varepsilon = 5.0 * 10^{-6}ft \quad (table\ 8.2)$

Calculating in Excel:

Pressure	V2 (ft/s)	LHS	RHS	% diff
20PSI	32.5	28.452	28.905	1.60%
80PSI	81.0	167.806	168.853	0.62%

NICK DUNHAM

11.15 Water at 40°C is flowing from A to B through the system shown in Fig. P11.15. Determine the volume flow rate of water if the vertical distance between the surfaces of the two reservoirs is 10 m. The elbows are standard.

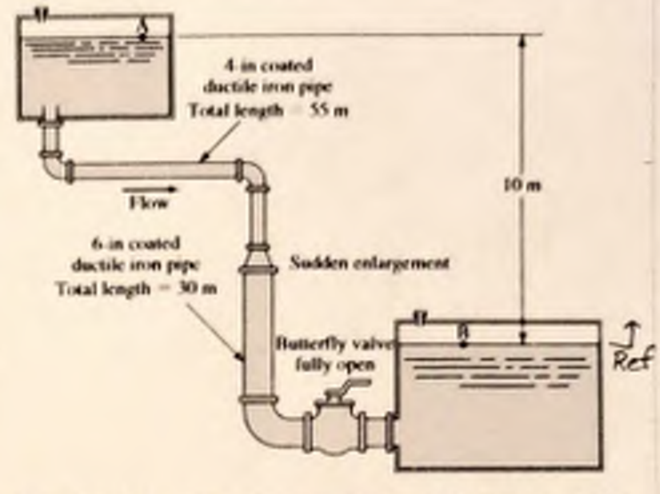


FIGURE P11.15 Water flow from reservoir for Problem 11.15.

$\varepsilon = 1.2\times10^{-4}\,m$ - Table 8.2

$\gamma = 9.73\ kN/m^3$

$\nu = 6.56\times10^{-7}\ m^2/s$

$$\frac{p_A}{\gamma} + \frac{v_A^2}{2g} + z_A = \frac{p_B}{\gamma} + \frac{v_B^2}{2g} + z_B + h_L$$

$$z_A = h_{L_{A\text{-}B}} = 10m$$

$$h_{L_{A\text{-}B}} = h_{L_{pipe\,4in}} + h_{L_{pipe\,6in}} + 2\cdot h_{L_{elbow\,4in}} + h_{L_{enlarg\,4\text{-}6}} + h_{L_{elbow\,6in}} + h_{L_{Valve}} + h_{L_{Entrance}} + h_{L_{Exit}}$$

$$h_{L_{pipe\,4in}} = f_{4in}\frac{L_{4in}\,v_4^2}{D_{4in}\,2g}$$

$D_{4in} = 0.1059\ m$
$A_{4in} = 0.00881\ m^2$
$D_{6in} = 0.1593m$
$A_{6in} = 0.01993m^2$
} Table I.1

$$h_{L_{elbow\,4in}} = K_{elbow_{4in}}\cdot v_4^2/2g = 30\cdot f_{T_{4in}}\cdot v_4^2/2g$$

$$h_{L_{elbow\,6in}} = K_{elbow_{6in}}\cdot\frac{v_6^2}{2g} = 30\cdot f_{T_{4in}}\cdot\frac{v_6^2}{2g}$$

$$h_{L_{enlarg}} = K_{enlarg}\cdot\frac{v_4^2}{2g}$$ K_{enlarg} depends on v_4 & $\frac{D_6}{D_4}$; $D_6/D_4 = \frac{0.1593}{0.1059}$

$2.6 < K_{enlarg} < 3.2$ - Fig 10.3 or $K_{enlarg} \approx \left(1 - A_{4in}/A_{6in}\right)^2 = 0.3114$

$$h_{L_{valve}} = K_{valve}\cdot\frac{v_6^2}{2g} = 45\,f_{T_{6in}}\frac{v_6^2}{2g}$$

$$h_{L_{entry}} = K_{entry}\cdot\frac{v_4^2}{2g} = 0.78\frac{v_4^2}{2g}$$

$$h_{L_{exit}} = K_{exit}\frac{v_6^2}{2g} = 1.0\frac{v_6^2}{2g}$$

$$h_{L_{pipe\,6in}} = f_{4in}\cdot\frac{L_{6in}}{D_{6in}}\cdot\frac{v_6^2}{2g}$$

$$10m = h_{L_{A\text{-}B}} = \frac{v_4^2}{2g}\left(f_{4in}\frac{L_{4in}}{D_{4in}} + 2\cdot30f_T + K_{enlarg} + K_{entry}\right) + \frac{v_6^2}{2g}\left(f_{6in}\frac{L_{6in}}{D_{6in}} + f_{T_{6in}}(30+45) + 1.0\right)$$

calculate v_4 & v_6 from Q guesses, calculate h_L based on v, f → iterate

$\underline{Q = 0.0327\ m^3/s}$: $h_L = 10.04m$

NICK DUNHAM

11.22 The tank shown in Fig. P11.22 is to be drained to a sewer. Determine the size of new Schedule 40 steel pipe that will carry at least 400 gal/min of water at through the system shown. The total length of pipe is 75 ft.

$Q = 400 \frac{gal}{min} \cdot \frac{1\ ft^3/s}{449\ gal/min} = 0.891\ ft^3/s$

$\varepsilon = 1.50\times10^{-4}\ ft$ (Table 8.2)

Assume 60°F

$\left.\begin{array}{l}\gamma = 62.4\ lb/ft^3 \\ \nu = 1.21\times10^{-5}\ ft^2/s\end{array}\right\}$ Table A.2

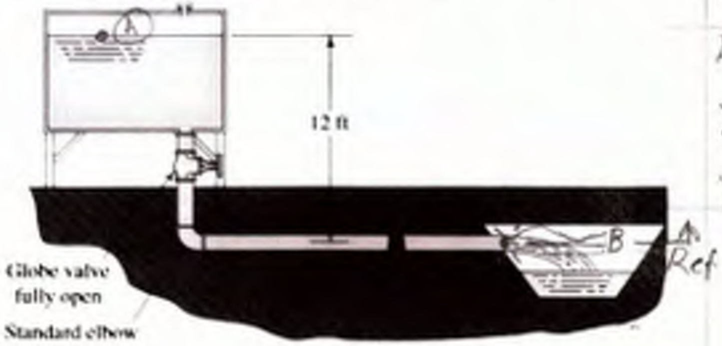


FIGURE P11.22 Sewer drain for Problem 11.22.

$K_{valve} = 340 f_T$ – Fig. 10.15

$K_{elbow} = 30 f_T$ – Fig. 10.23

$K_{entry} = 0.5$ – Fig 10.14 (square-edge)

$K_{exit} = 1.0$ – Fig. 10-4

$$\cancel{\frac{p_A}{\gamma}}^{0} + \cancel{\frac{v_A^2}{2g}}^{0} + z_A = \cancel{\frac{p_B}{\gamma}}^{0} + \cancel{\frac{v_B^2}{2g}}^{0} + \cancel{z_B}^{0} + h_L \Rightarrow z_A = h_L = 12\ ft$$

Losses
Globe valve
Elbow
Pipe
< Entry
Exit

$$h_{L\,A\text{-}B} = h_{L\,pipe} + h_{L\,valve} + h_{L\,elbow} = \left(f\frac{L}{D} + K_{valve} + K_{elbow}\right)\frac{v^2}{2g}$$

$h_{L\,pipe} = f\frac{L}{D}\frac{v^2}{2g}$

$h_{L\,valve} = K_{valve}\frac{v^2}{2g}$

$h_{L\,elbow} = K_{elbow}\frac{v^2}{2g}$

Entry $= K_{entry}\frac{v^2}{2g}$

Exit $= K_{exit}\ v^2/2g$

$$\underbrace{h_{L\,A\text{-}B} = 12\,ft}_{LHS} = \underbrace{\left[f\frac{L}{D} + f_T(340+30) + 0.5 + 1.0\right]\frac{v^2}{2g}}_{RHS}$$

1. List pipe diameters for standard sizes
2. calculate v, D/ε, Re, f, f_T for each size
3. calculate $h_{L\,A\text{-}B}$ for each size.
4. select appropriate size: <u>5" NPS</u> : $h_L = 6.66$ ft; 4" NPS is too small w/ $h_L = 18.25$ ft

Oladuwa A. Oduntan HW 3.2 Pg 1

11.23 Given

Fluid ⇒ gasoline

$sg = 0.68$

$T = 25°C$

$Q = 1500 L/min \quad \left(\frac{1500 L/min}{60{,}000 L/min} \times 1 m^3/s \right) = 0.025\ m^3/s$

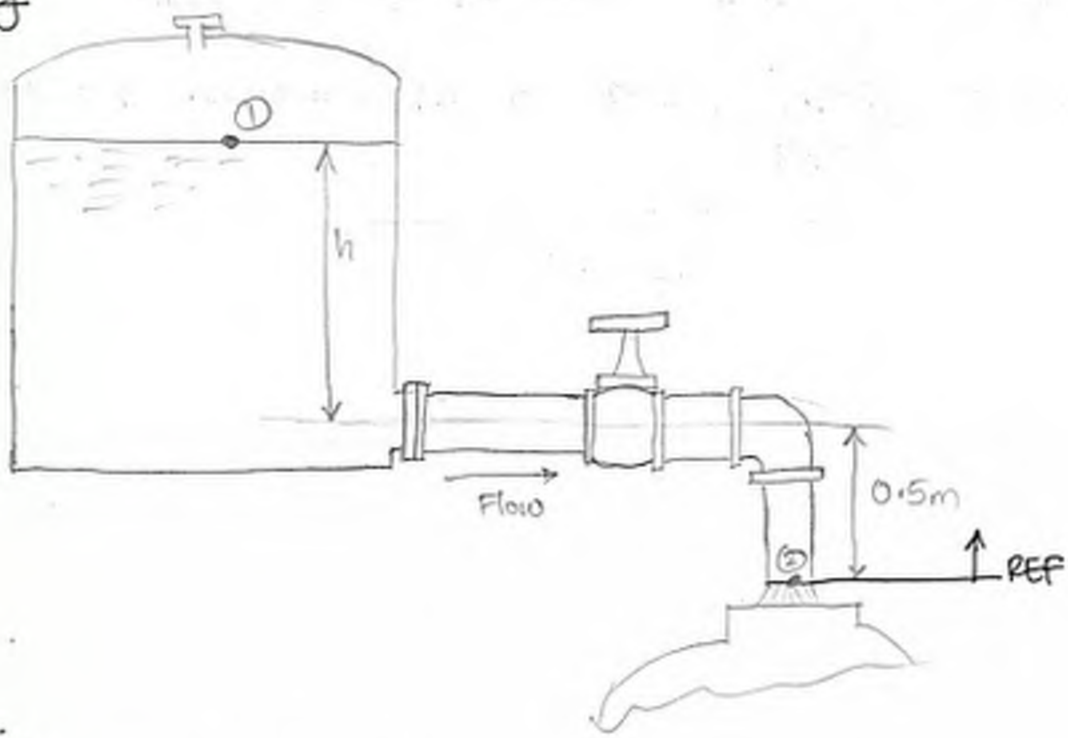
Pipe ⇒ DN 90 schedule 40 steel pipe with $A = 6.381 \times 10^{-3}\ m^2$

Gate valve ½ open.

Required

Find heigh in the tank. Neglect the energy losses due to pipe friction, but consider minor losses.

Drawing



Calculation

Using the Bernoulli's equation,

$$\cancel{\frac{P_1}{\gamma}} + Z_1 + \cancel{\frac{V_1^2}{2g}} = \cancel{\frac{P_2}{\gamma}} + Z_2 + \frac{V_2^2}{2g} + h_{L_{1-2}}$$ where $P_1 = 0$, $P_2 = 0$, and $V_1 = 0$.

$$Z_1 - Z_2 = \frac{V_2^2}{2g} + h_{L_{1-2}} \quad \text{——— (1)}$$

$$V = \frac{Q}{A} \Rightarrow \frac{0.025\ m^3/s}{6.381 \times 10^{-3}\ m^2} \Rightarrow V = 3.91788\ m/s \simeq 3.92\ m/s$$

$$h_{L1-2} = h_{ent.} + h_{val} + h_{elb} \Rightarrow K_{ent}\frac{V^2}{2g} + K_{val}\frac{V^2}{2g} + K_{elb}\frac{V^2}{2g} \Rightarrow \frac{V^2}{2g}\left(K_{ent.} + K_{val} + K_{elb}\right).$$

$K_{ent.} = 0.5$ (entrance resistance coefficient).

$K_{val} = 160 f_T$ where $f_T = 0.017$

$K_{val} = 160(0.017) \Rightarrow K_{valve} = 2.72$

$K_{elb} = 30 f_T$

$= 30(0.017) \Rightarrow K_{elbow} = 0.51$

$$h_{L1-2} = \frac{(3.92)^2}{2 \times 9.81}\left(0.5 + 2.72 + 0.51\right) = 2.92\,m.$$

Substituting h_{L1-2} into eqn (1),

$$Z_1 - Z_2 = \frac{V^2}{2g} + 2.92 \qquad \text{where } Z_1 - Z_2 = (h + 0.5)\,m.$$

$$h + 0.5 = \frac{(3.92)^2}{2 \times 9.81} + 2.92 \Rightarrow h + 0.5 = 3.7032 \Rightarrow 3.7032 - 0.5$$

$h = 3.2032$

$$\boxed{\therefore h = 3.20\,m}$$

MET 330
HW. 3.3
PROBLEMS 17, 19, 22, 23,
25 & 34

WORK DONE IN A GROUP BY:
Spencer Reed
Joel Thomas
Nick Dunham
Olaoluwa Oduntan

13.17 Required

If the speed of rotation of the impeller is cut in half, how does the total head capability change?

Solution

For a centrifugal pump,

$$\frac{ha_1}{ha_2} = \left(\frac{N_1}{N_2}\right)^2$$

Let $(ha_1/ha_2) = x$ and $(N_1/N_2)^2 = y$. We have,

$$x = (y)^2$$

If y is cut in half,

$$x = \left(\frac{y}{2}\right)^2 \Rightarrow x = \frac{y^2}{4}$$ (x is directly proportional to y^2).

∴ If the speed of rotation of the impeller is cut in half, the total head capacity is cut by a factor of 4.

13.19 Required

If the diameter of the impeller is reduced by 25 percent, how much does the capacity change?

Solution

For a centrifugal pump casing,

$$\frac{Q_1}{Q_2} = \frac{D_1}{D_2}$$

Let $(Q_1/Q_2) = x$ and $(D_1/D_2) = y$. We have,

$$x = y$$

If y is cut by 25%,

$$x = \frac{y}{0.25} = \frac{y}{4}$$ (x is directly proportional to y).

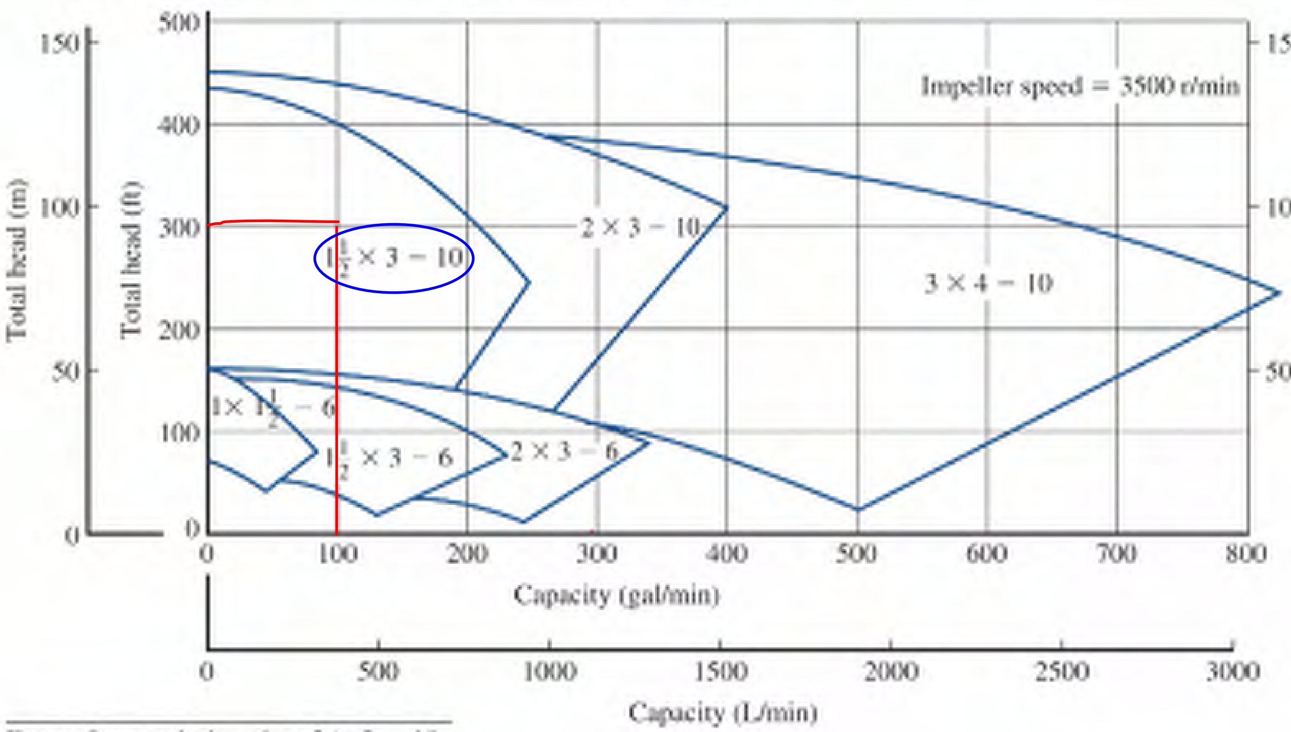
∴ If the diameter of the impeller is reduced by 25%, the capacity changes by 25%.

13.22 1½×3−6: Describes a pump with a 1½-in discharge connection, a 3-in suction connection, and a casing that can accommodate an impeller with a diameter of 6 in or smaller.

13.23) Needs to deliver 100 gal/min H_2O Spencer Reed
Total Head of 300 ft. HW 3.4
Ch. 13
#17, 19,
$1\frac{1}{2} \times 3 - 10$ based on figure 13.22 22, 23, 25
34

Figure 13.22

Composite rating chart for a line of centrifugal pumps.



Form of pump designation: 2 × 3 − 10

- Casing class—Nominal size (in inches) of largest impeller
- Suction connection size (nominal inch)
- Discharge connection size (nominal inch)

13.25) Given: 8 in impeller   Head = 200 ft

Need: capacity, power, efficiency + NPSH

Capacity = 230 gal/min

Power = 22 HP

$$\text{Efficiency} = \frac{P_{out}}{P_{in}} = \frac{11.62}{22}$$

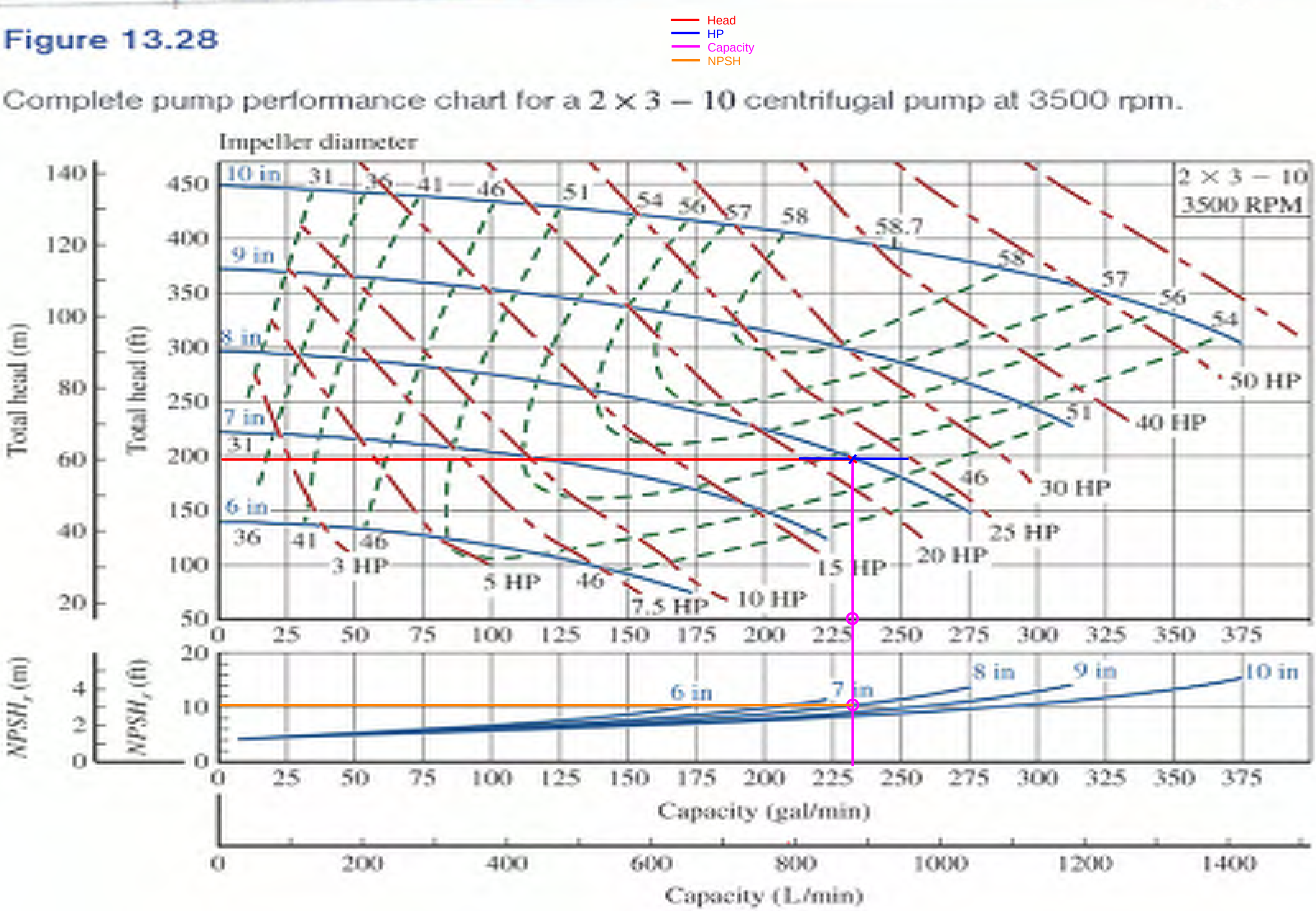
$$P_{out} = \gamma Q h \Rightarrow 62.4 \times 0.512 \times 200 = 6{,}389.76 \text{ lbft/s} \times \frac{1 \text{ HP}}{550 \text{ lbft/s}} = 11.62 \text{ HP}$$

$$\eta = 0.53$$

53%

NPSH = 10 ft

Figure 13.28



Complete pump performance chart for a 2 × 3 − 10 centrifugal pump at 3500 rpm.

NICK DUNHAM

13.34 For each of the following sets of operating conditions, list at least one appropriate type of pump. See Fig. 13.52.

a. 500 gal/min of water at 80 ft of total head
b. 500 gal/min of water at 800 ft of head
c. 500 gal/min of a viscous adhesive at 80 ft of head
d. 80 gal/min of water at 8000 ft of head
e. 80 gal/min of water at 800 ft of head
f. 8000 gal/min of water at 200 ft of head
g. 8000 gal/min of water at 60 ft of head
h. 8000 gal/min of water at 12 ft of head

a. centrifugal, 3500 RPM
b. Rotary
h. Axial flow or mixed flow

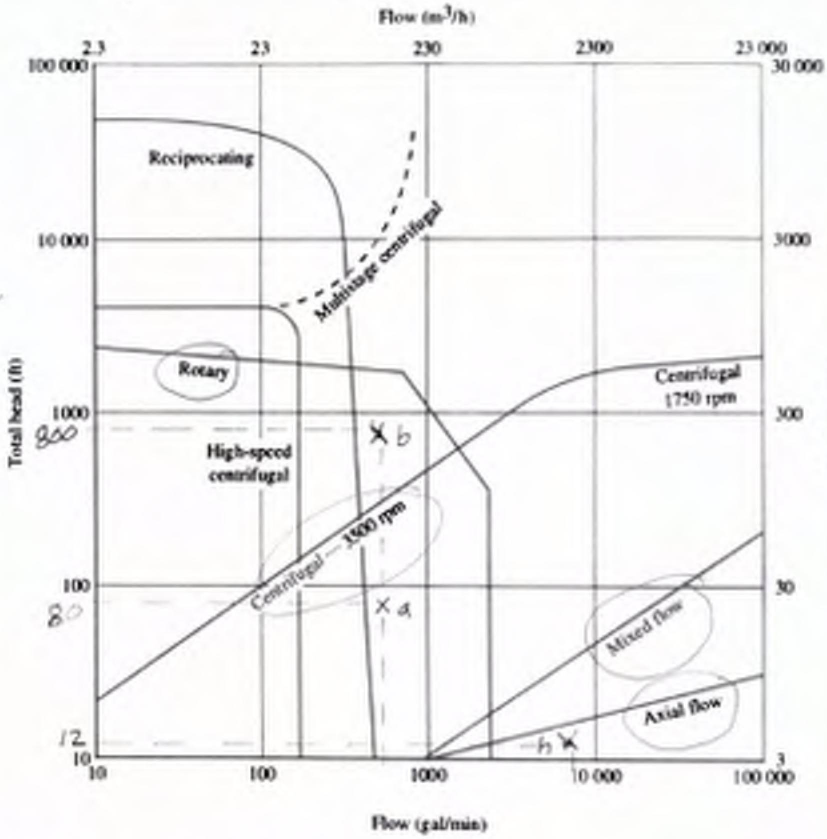


FIGURE 13.52 Pump selection chart.

Homework 3.4

13.39

Problem: Compute the specific speed for a pump operating at 1750 rpm delivering 12,000 gal/min of water at a total head of 300 ft.

Solution: Specific speed is given by the equation $N_{ss} = \frac{N\sqrt{Q}}{H^{\frac{3}{4}}}$, therefore,

$$N_{SS} = \frac{1{,}750rpm * \sqrt{12{,}000\frac{gal}{min}}}{300ft} = \mathbf{2,659\ RPM}$$

13.59

Problem: Determine the *NPSH* available when a pump draws gasoline at 110°F (sg=0.65) from an outside storage tank whose level is 4.8 ft above the pump inlet. The energy losses in the suction line total 0.87 ft and the atmospheric pressure is 14.28 psia.

Solution: Since the pump is below the storage tank, $NPSH_a = h_{sp} + h_s - h_f - h_{vp}$

Where: $h_{sp} = \frac{P_{sp}}{\gamma} \rightarrow \frac{14.28\frac{lb}{in^2}*\left(\frac{12in}{1ft}\right)^2}{0.65*\frac{62.4lb}{ft^3}} = 50.698ft,\quad h_s = 4.8ft,\quad h_f = 0.87ft\ and$

$h_{vp} \cong 52ft\ (gasoline\ @110°\text{F}, table\ 13.37)$. Therefore: $NPSH_a = 50.698ft + 4.8ft - 0.87ft - 52ft = \mathbf{2.628ft}$

13.61

Problem: Repeat Problem 13.59 if the pump is 27 in above the fluid surface.

Solution: Since the pump is above the fluid surface, the only difference is that h_s becomes $h_s = -27in$. Thus: $NPSH_a = 50.698ft - \left(\frac{27in}{12in}\right) - 0.87ft - 52ft = \mathbf{-4.422ft}$.

Since this value is negative. This pump is extremely susceptible to cavitation.

MET 330
HW. 3.3
PROBLEMS 17, 19, 22, 23,
25 & 34

WORK DONE IN A GROUP BY:
Spencer Reed
Joel Thomas
Nick Dunham
Olaoluwa Oduntan

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Spencer Reed
HW 3.4
Ch. 13
17, 19, 22, 23, 25, 34

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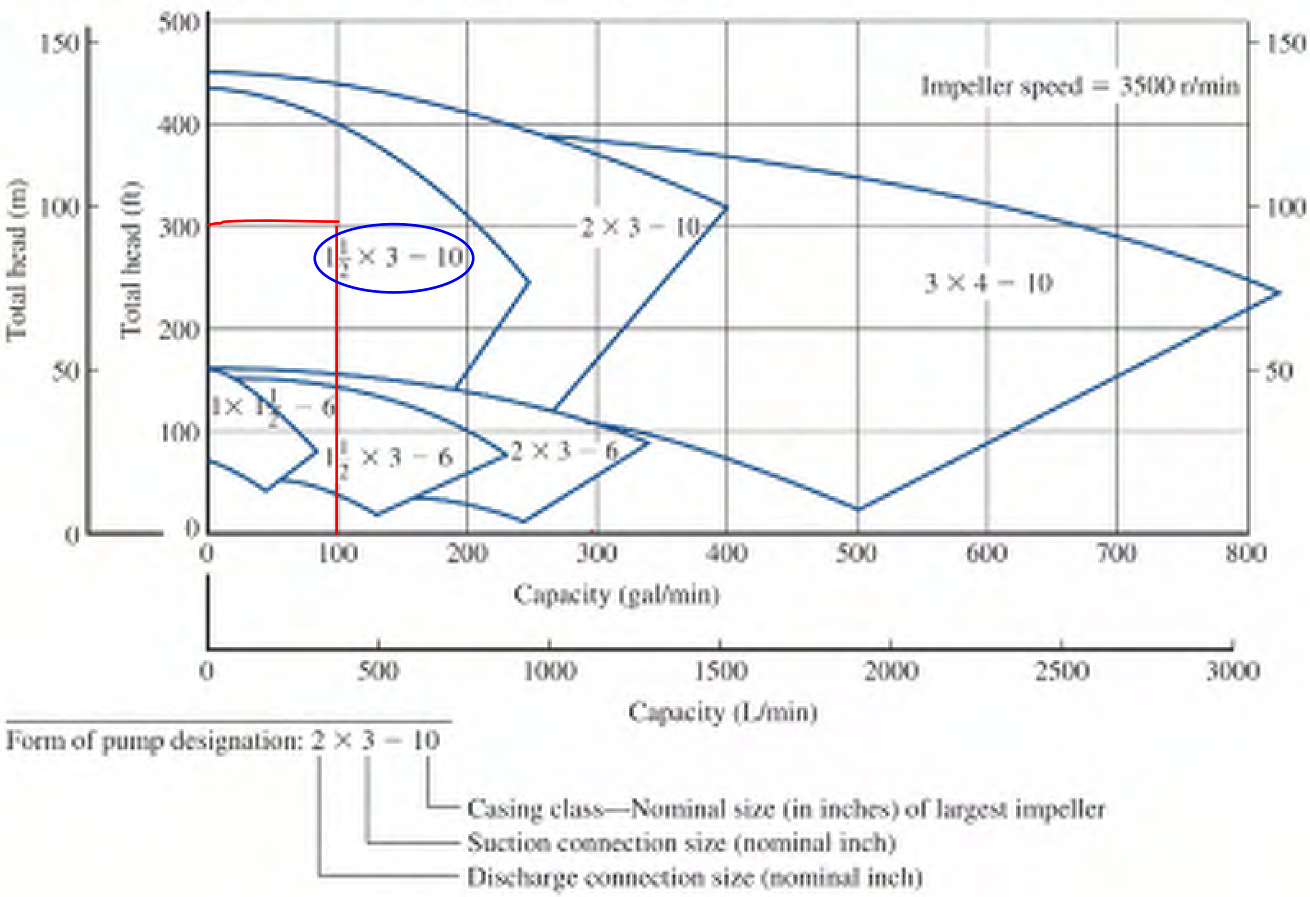

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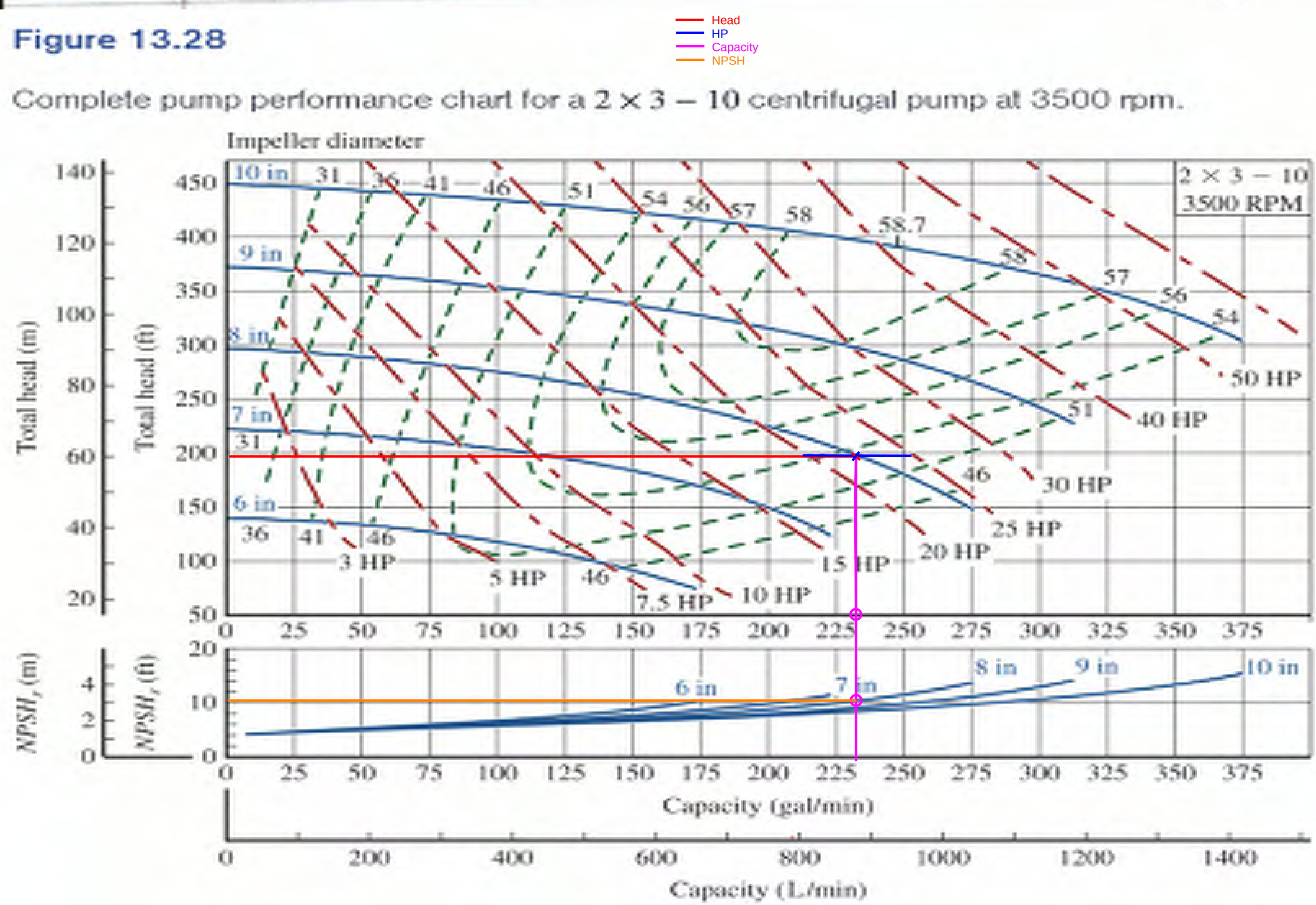

NICK DUNHAM

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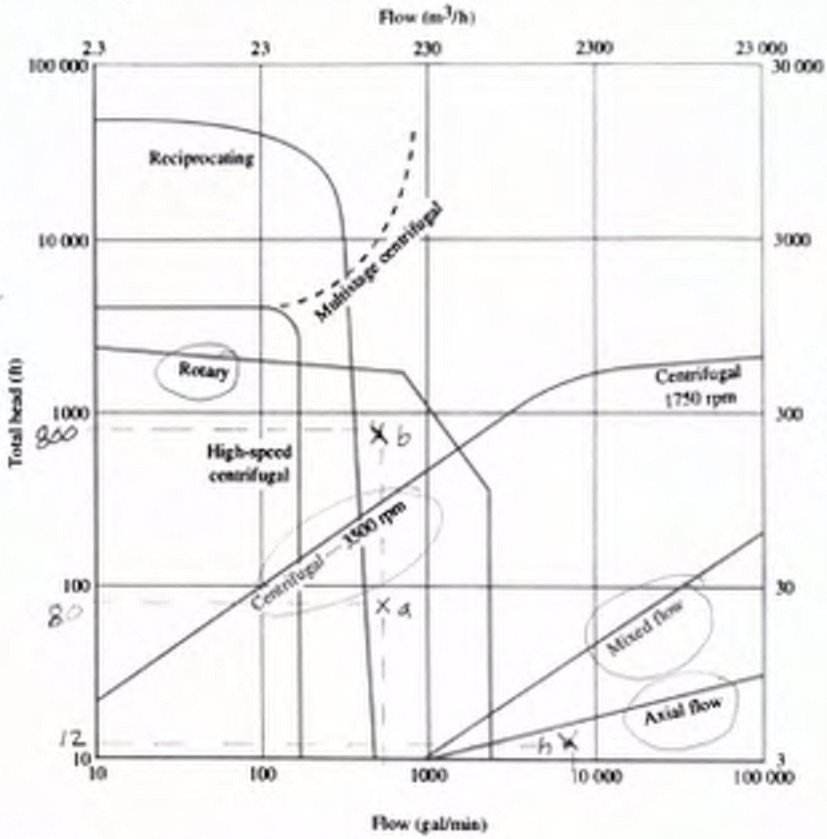
h. 8000 gal/min of water at 12 ft of head

a. centrifugal, 3500 RPM

b. Rotary

h. Axial flow or mixed flow



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