Homework 3.1

This week the topic of pipe networks was discussed. We focused primarily on a two-branch parallel pipe system. To solve this kind of problem, we must use Bernoulli's equation for each branch of pipe. This kind of problem is more complicated as there are more elbow losses involved. The relative roughness of the pipes also has a greater relevance and is used to calculate the head loss for the system. The kind of problems that involve multiple branch pipe systems often have a variable that has to be guessed. This allows for iterations of values and relies on excel to do efficiently. Excel can be used to find the percent error and once the error is below 1%, it is deemed acceptable.

Homework Problems

11.5


Problem 11.5

Oil specific weight = 8.8 kN/m³
Oil kinematic viscosity = 2.12 x10⁻⁵ m²/s
length of DN 150 pipe = 180 m D = 146.3 mm
length of DN 50 pipe = 8 M D = 49.3 mm
Elbows are long-radius type
Pressure at B = 12.5 MPa
Calculate pressure at A
Q = 0.015 m³/s

$\frac{P_A}{\gamma} + \frac{V_A^2}{2g} + z_A = \frac{P_B}{\gamma} + \frac{V_B^2}{2g} + z_B + h_{LA-B}$

$\frac{P_A}{\gamma} = \frac{P_B}{\gamma} + \frac{V_B^2}{2g} + z_B + h_{LA-B} - \frac{V_A^2}{2g}$

$Q = 0.015\ m^3/s$, $A_A = 1.682\times10^{-2}\ m^2$, $A_B = 1.905\times10^{-3}\ m^2$

$V_A = 0.8918\ m/s$, $V_B = 7.874\ m/s$

$h_{LAB} = h_{L\,pipe(DN150)} + h_{L\,contraction} + h_{L\,pipe(DN50)} + 2h_{L\,elbow}$

$= f_1\frac{L_1}{D_1}\frac{V_A^2}{2g} + K_{co}\frac{V_B^2}{2g} + f_2\frac{L_2}{D_2}\frac{V_B^2}{2g} + 2K_{elbow}\frac{V_B^2}{2g}$

For DN150: $N_R = \frac{VD}{\nu} = 6.15\times10^3$, $\varepsilon = 4.6\times10^{-5}$ m, $D/\varepsilon = 318.04$ → $f_1 = 0.042$

For DN50: $N_R = \frac{VD}{\nu} = 1.83\times10^4$, $\varepsilon = 4.6\times10^{-5}$ m, $D/\varepsilon = 1071.7$ → $f_2 = 0.0255$

For the sudden contraction $D_1/D_2 = 146.3\,mm / 49.3\,mm \cong 3$, $V_2 = 7.87$ m/s → $K = 0.36$

$h_{LA-B} = 2.05\ m + 83.64\ m = 85.69\ m$

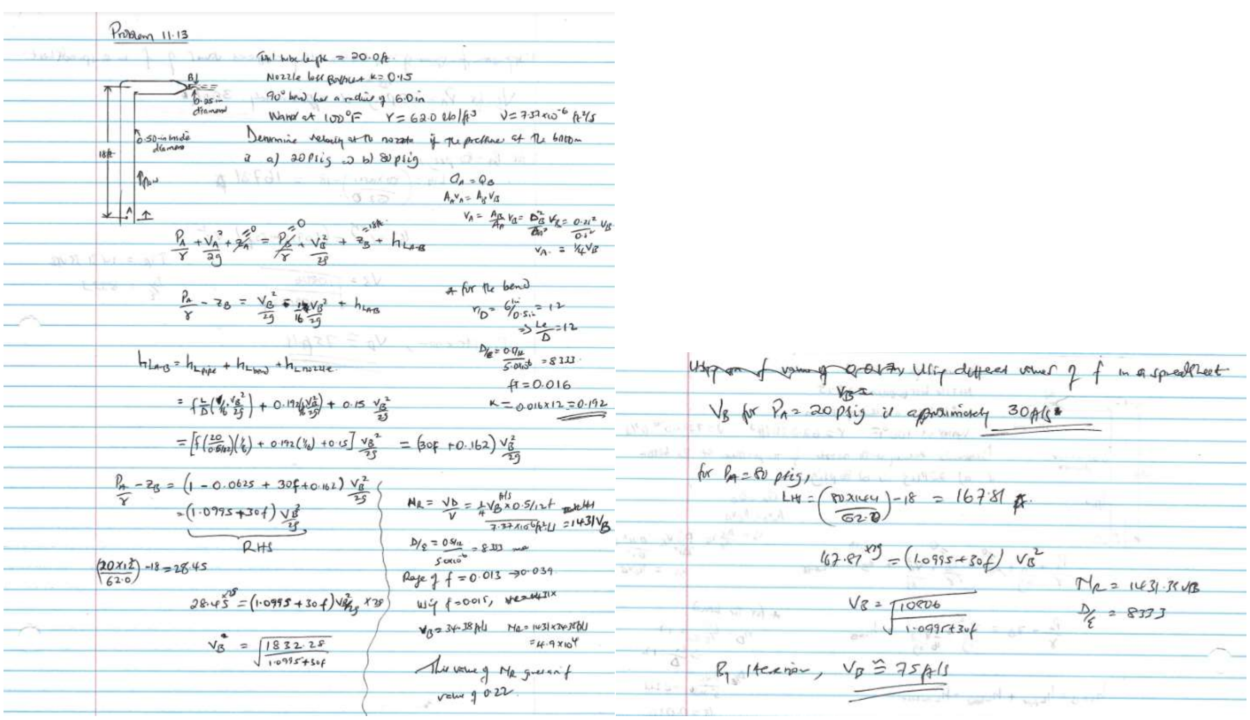
$\frac{P_A - P_B}{\gamma} = 0.04\ m + 4.5\ m + 85.69\ m - 3.16\ m = 87.13\ m$

$P_A - P_B = 87.13\ m \times 8800\ N/m^3 = 766744\ N/m^3 = 0.77\ MPa$

$P_A = P_B + 0.77\ MPa = 12.5\ MPa + 0.77$

$P_A = 13.25\ MPa$

11.13


Problem 11.13

Total tube length = 20.0 ft
Nozzle loss coefficient K = 0.15
90° bend has a radius of 6.0 in
Water at 100°F, $\gamma = 62.0\ lb/ft^3$, $\nu = 7.37\times10^{-6}\ ft^2/s$
Determine velocity at the nozzle if the pressure at the bottom is a) 20 psig and b) 80 psig

$Q_A = Q_B$, $A_A V_A = A_B V_B$, $V_A = \frac{1}{16}V_B$

$h_{LAB} = h_{L\,pipe} + h_{L\,bend} + h_{L\,nozzle}$

$= (30f + 0.162)\frac{V_B^2}{2g}$

$\frac{P_A}{\gamma} - z_B = (1.0995 + 30f)\frac{V_B^2}{2g}$

$V_B = \sqrt{\frac{1832.28}{1.0995 + 30f}}$

Using different values of f in a spreadsheet, V_B for P_A = 20 psig is approximately 30 ft/s

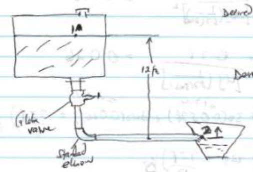
For P_A = 80 psig, LH = 167.81 ft

$V_B = \sqrt{\frac{10806}{1.0995 + 30f}}$

By iteration, $V_B \cong 75$ ft/s

11.20

Problem 11.20



Schedule 40 steel pipe $L = 75$ ft.
Desired $Q = 400$ gal/min $= 0.891$ ft³/s
Water @ 80°F

Determine the size of the pipe

$$\frac{p_1}{\gamma} + \frac{v_1^2}{2g} + z_1 = \frac{p_2}{\gamma} + \frac{v_2^2}{2g} + z_2 + h_L$$

$$z_1 = \frac{V_2^2}{2g} + h_{L_{1-2}}$$

$$V = \frac{4Q}{\pi D^2} \qquad V^2 = \frac{16Q^2}{\pi^2 D^4}$$

$$h_{L_{1-2}} = h_{L_{entrance}} + h_{L_{valve}} + h_{L_{elbow}} + h_{L_{pipe}}$$

$$= K_{en}\frac{V_2^2}{2g} + K_{elbow}\frac{V_2^2}{2g} + K_{valve}\frac{V_2^2}{2g} + f\frac{L}{D}\frac{V_2^2}{2g}$$

$$= \left(0.5 + 30 f_T + 340 f_T + f\frac{L}{D}\right)\frac{8Q^2}{\pi^2 D^4 g}$$

$$z_1 = \frac{8Q^2}{\pi^2 D^4 g} + \left(0.5 + 30f_T + 340 f_T + f\frac{75}{D}\right)\frac{8Q^2}{\pi^2 D^4 g}$$

$$12 = \left(1 + 0.5 + 30f_{T\,elbow} + 340 f_{T\,valve} + \frac{75f}{D}\right)\frac{8(0.891\ \text{ft}^3/\text{s})^2}{\pi^2 D^4 g} \quad \times \frac{\pi^2 \times 32.2}{8(0.891\ \text{ft}^3/\text{s})^2}$$

$$600.47 = \left(1.5 + 30 f_{T\,elb} + 340 f_{T\,valve} + \frac{75f}{D}\right)\frac{1}{D^4}$$

for the elbow $f_T = \dfrac{0.25}{\left[\log\left(\frac{1}{3.7(30)}\right)\right]^2} = 0.0598$

for the valve $f_T = \dfrac{0.25}{\left[\log\left(\frac{1}{3.7(3\ldots)}\right)\right]^2} = 0.026$

$$600.47 = \left(1.5 + 30(0.0598) + 340(0.026) + \frac{75f}{D}\right)\frac{1}{D^4}$$

($30(0.0598) = 1.794$, $340(0.026) = 8.84$)

$$600.47 = \left(12.134 + \frac{75f}{D}\right)\frac{1}{D^4}$$

$$600.47\,D^4 = 12.134 + \frac{75f}{D}$$

$\varepsilon = 4.6 \times 10^{-5}$
$\nu = 9.15 \times 10^{-6}$ ft²/s
$V = \dfrac{4Q}{\pi D^2}$

Using iteration on spreadsheet.

Compute N_R and D/ε for any given value of D

$N_R = \dfrac{VD}{\nu}$

Iteration gives a pipe size of 0.40 ft

pi	3.1425	
e	1.50E-04	ft
vis	9.15E-06	ft2/s
Q	0.891	ft3/s

d (ft)	v(ft/s)	d/e	nr	den1	den2	den3	f		LHS	RHS		% diff
0.1000	113.4128	6.67E+02	1.24E+06	4.05E-04	1.88E-05	1.14E+01	2.20E-02		0.060047	2.86E+01		-4.76E+04
0.2000	28.35322	1.33E+03	6.20E+05	2.03E-04	3.51E-05	1.31E+01	1.90E-02		0.960752	1.93E+01		-1.91E+03
0.3000	12.60143	2.00E+03	4.13E+05	1.35E-04	5.06E-05	1.39E+01	1.80E-02		4.863807	1.66E+01		-2.42E+02
0.4000	7.088305	2.67E+03	3.10E+05	1.01E-04	6.56E-05	1.43E+01	1.75E-02		15.37203	1.54E+01		-3.06E-01
0.4050	6.914365	2.70E+03	3.06E+05	1.00E-04	6.63E-05	1.43E+01	1.75E-02		16.15516	1.54E+01		4.82E+00
0.4100	6.746751	2.73E+03	3.02E+05	9.89E-05	6.71E-05	1.43E+01	1.75E-02		16.96784	1.53E+01		9.63E+00
0.5000	4.536515	3.33E+03	2.48E+05	8.11E-05	8.02E-05	1.44E+01	1.74E-02		37.52937	1.47E+01		6.07E+01