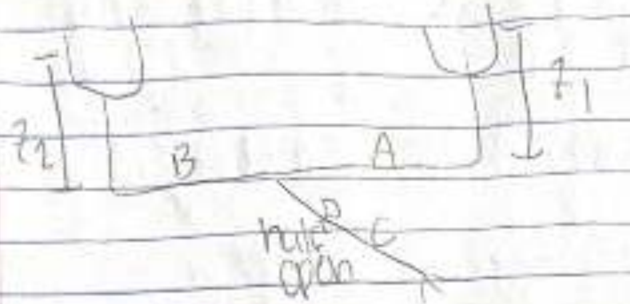
Micah Ferguson Test 2

1) Purpose

Find the flow rate of each branch in the system with the valve only half open



design
incompressible
isothermal
steady state

Data

$L_A = 15m$
$L_B = 9m$
$L_C = 10m$
$z_1 = 4m$
$z_2 = 3m$
$d_{inner} = .75in = .019m$
$\gamma = 9.81 kN/m^3$
$g = 9.81$
$\varepsilon = 4.6x10^{-5}m$
$\nu = 1.75e^{-6} m^2/s$

$K_{elbow} = 30$
$K_{ent} = .5$
$K_{tee} = 60$
$K_{valve} = 150$
$f = 0.025$

A to C

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

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

$$h_L = f\left(\frac{L_A + L_C + 2L_{elbow} + L_{valve} + L_{tee}}{D}\right)\frac{1}{2g}\frac{16Q_2^2}{\pi^2 D^4}$$

$$z_1 = \frac{V_2^2}{2g} + f\frac{L_A}{D}\frac{V^2}{2g} + f\frac{L_C}{D}\frac{V^2}{2g} + K_{ent}\frac{V^2}{2g} + K_{elbow}\frac{V^2}{2g} + K_{tee}\frac{V^2}{2g}$$

$$+ K_{valve}\frac{V^2}{2g}$$

$$z_1 = \frac{8}{g\pi^2 D^4} + \frac{8K_{valve}}{g\pi^2 D^4} + \frac{8fL}{g\pi^2 D}Q^2 + \frac{8}{g\pi^2 d^4}\left(K_{ent} + K_{elbow} + K_{tee} + \frac{8fL}{g\pi^2 D}\right)Q^2$$

$$4 = \frac{8}{9.81\pi^2(.019)} + \frac{8(1.6)}{9.81\pi^2(.019)^4} + \frac{8(.025)(10)}{9.81\pi^2(.019)}Q_c^2 + \frac{8}{9.81\pi^2(.019)^4}\left(.5 + 2(.3) + 1.6 + \frac{8(.025)}{9.81\pi^2(.019)}\right)$$

$$4 = 0.238Q_c^2 + .0281Q_A^2$$

$$Q_A = \sqrt{\frac{4 - .238Q_c^2}{.0281}}$$

B to C

$$z_2 = \frac{V^2}{2g} + f\frac{L_B}{D}\frac{V^2}{2g} + f\frac{L_C}{D}\frac{V_2^2}{2g} + K_{ent}\frac{V^2}{2g} + K_{valve}\frac{V^2}{2g} + K_{elbow}\frac{V^2}{2g} + K_{tee}\frac{V^2}{2g}$$

$$z_2 = \frac{8Q_c}{g\pi^2 D^4} + \left(K_{ent} + 2K_{elbow} + f\frac{L}{D}\right)\frac{8Q_B}{\pi^2 g D^4} + \left(K_{valve} + K_{tee} + f\frac{L}{D}\right)\frac{8Q_c}{\pi^2 g D^4}$$

$$3 = \frac{8}{\pi^2 9.81(.019)^4} + \left(.5 + 2(.3) + .025\left(\frac{9}{.019}\right)\right)\left(\frac{8Q_B^2}{\pi^2 9.81(.025)^4}\right)$$
$$+ \left(.25 + 1.6 + 15 + (.025)(0.23)\left(\frac{10}{.019}\right)\right)\frac{8Q_c^2}{\pi^2 9.81(.019)^4}$$

$$3 = 0.0062Q_B^2 + 4.74Q_c^2$$

$$Q_B = \sqrt{\frac{3 - 4.74Q_c^2}{.0062}}$$

process
guess Q_C

obtain Q_A and Q_B
guess f
calculate
compare Re

Completed in excel

$Q_A = 1.35\ m^3/s$
$Q_B = 1.65\ m^3/s$
$Q_C = Q_A + Q_B = 3\ m^3/s$

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\gamma} + \frac{V^2}{2g} + z_2 - h_L$$

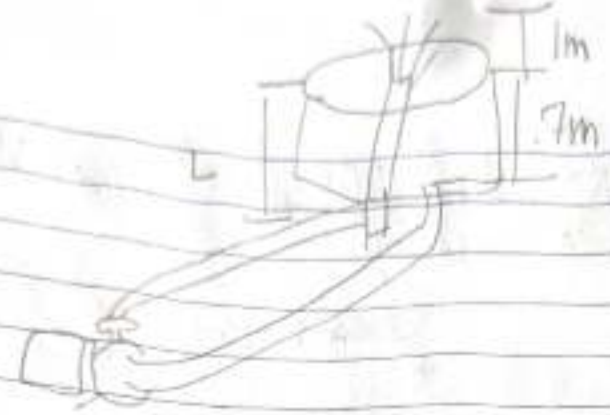
$$P_3 = \gamma\left(z - \frac{V^2}{2g} - h_L\right)$$

$$P = 9.81\left(4 - \frac{4.45^2}{2(9.81)} - .0002\right)$$

$$P = 29.42\ kPa$$

Summary
I was able to use Bernoulli's equation to get Q_A and Q_B equations with Q_C as a variable. I the used that equation in excel to guess Q_C and f which gave me Re and the correct f with percentage differences. I was finally able to get all Q values then lastly calculate the pressure with another use of Bernoulli's equation

2)



reference

design
isothermal
incompressible
PVC pipe
negligible exit

data

L = 18m	92 L
L = 20m	h_1 = 1m
K = 2	h_2 = .7m
Lp = 1.8m	z_1 =
D_o = 10cm	z_2 = 1.7
D_i = 7cm	z_3 = .7

$$\cancel{\frac{P_2}{\gamma}} + \cancel{\frac{V_2^2}{2g}} + z_2 = \frac{P_3}{\gamma} + \frac{V_3^2}{2g} + z_3 + \cancel{h_L}$$

$$z_2 = z_3 + \frac{V_2^2}{2g} \qquad V = \sqrt{2g(z_2 - z_3)} = \sqrt{2(9.81)(1.7-.7)}$$
$$= 4.43\ m/s$$

$$R = \frac{A}{wp} \qquad A = \frac{\pi}{4}(D_o^2 - D_i^2) = \frac{\pi}{4}(.1^2 - .07^2) = .00401$$

$$W = \pi(D_o + D_i) = \pi(.1 + .07) = .534$$

$$R = \frac{.00401}{.534} = .0075m$$

$$Q = AV = \frac{\pi(D_o^2 - D_i^2)V}{4} = \frac{\pi(.1^2 - .07^2)4.43}{4} = .05\ m^3/s$$

$$Q = 4.43(.05) = 0.229\ m^3/s$$

$$h = \frac{V^2}{2g} + (z_2 - z_1)^0 + K_{ent} + f\frac{L_{suction}}{D}\frac{V^2}{2g} + f\frac{L_{dis}}{D}\frac{V^2}{2g}$$

$$+ K_{expansion}$$

$$= \frac{4.43}{2(9.81)} + .5 \quad + f\left(\frac{20}{.125}\right)\frac{4.43^2}{2(9.81)} + f\frac{18}{.125}\frac{4.43^2}{2(9.81)}$$

guess $f = .01$ did not work

$= .001$

$= .002$

$h = 80.76$

$P = h\gamma Q = 80.76(9.81)(0.229)$

$= 181.42\,W = \boxed{.181\,kW}$

$\frac{P}{\eta_{th}} = \frac{181.42}{.92} = \boxed{.197\,kW}$

Pledge for Honor Code

[signature]

Summary

I was able to use Bernoulli's equation to solve this problem. First I calculated the losses and Q. The hydraulic radius equation was used to determine all losses needed. Once the equation was determined, f was guessed to get the correct value. From there the Power formula was used and it could also be determined the power with 92% efficiency.

specific weight	9.8	kn/m2
viscosity	1.40E-06	m2/s
Z1	4	
Z2	3	
LA	10	m
LB	9	m
Lc	10	m
Di	0.019	m

Le/Dvalve	150
Le/d elbow	30
Le/d entrance	0.5
Le/d tee	60
g	9.81
roughness	4.60E-05

For QA

iteration	f	QC	Q	V	Re	f	%diff
1	0.01	0.0005	2.00	0.00	0.78	3.41E-01	-3410.61
2	1.05	0.0015	1.96	0.00	0.76	0.335147	-30.8737
3	2.30	0.0115	1.69	0.00	0.66	0.293475	-10.4429
4	5.31	0.0215	1.35	0.00	0.53	0.245814	0.673431
5	14.83	0.0315	0.91	0.00	0.35	0.184495	13.58455

For QB

iteration	f	QC	Q	V	Re	f	%diff
1	0.01	0.0005	1.73034	4.97083E-05	6.75E-01	3.00E-01	-3000.69
2	1.05	0.0015	1.716588	4.93132E-05	6.69E-01	2.98E-01	-27.3383
3	2.30	0.0025	1.68875	4.85135E-05	6.58E-01	2.94E-01	-10.462
4	5.31	0.0035	1.646109	4.72885E-05	6.42E-01	2.88E-01	-0.11492
5	14.83	0.0045	1.587474	4.56041E-05	6.19E-01	2.79E-01	12.94661
6	72.85	0.0055	1.510985	4.34068E-05	5.89E-01	2.68E-01	72.48282