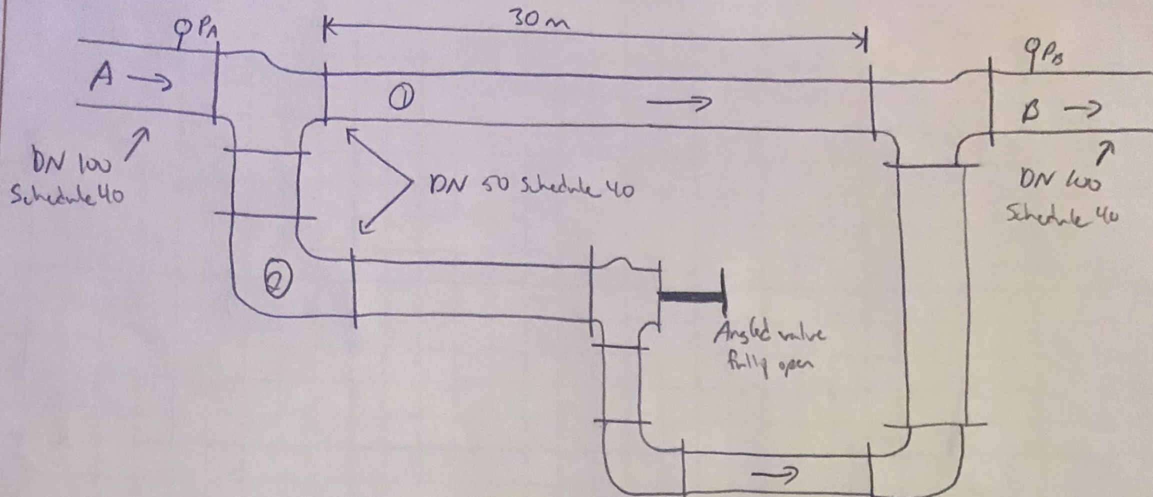
Jacob Schwartz	MET330	Test 3	4-13-20

Purpose: Calculate the total flow rate through the pipe system.

Drawings & Diagrams:



Sources: Holt, R. Untener. J.A., "Applied Fluid Mechanics", 7th Edition, Pearson Education Inc (2015)

Design Considerations: Flow rate same at beginning as the end.
60 m lower branch total pipe length

Data & variables: DN 100 Schedule 40 pipe $\qquad \varepsilon = (4.6\times10^{-5})\,m$
DN 50 Schedule 40 pipe
Angle Valve coefficient = 150
Elbow coefficient = 30 $\quad$ Table 10.4
$Q_1 = 136.84\,gpm = 0.00863\,m^3/s$

DN 50	DN 100
$D_o = 60.3\,mm$	$d_o = 114.3\,mm$
$T_W = 3.91\,mm$	$T_W = 6.02\,mm$
$d_i = 52.5\,mm$	$d_i = 102.3\,mm$
$FA = 2.168\times10^{-3}\,m^2$	$FA = 8.213\times10^{-3}\,m^2$

$S_g = 9.807\,kN/m^3$

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

$$R_1 = \frac{D}{\varepsilon} = \frac{0.0525}{4.6\times10^{-5}} = 1.141\times10^3$$

$f = 0.019$

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Procedure & Calculations: The flow rate of the top branch is 136.84 gpm at 10°C. Now we will find the losses in the second branch to help us find the flow rate, and the first branch energy loss.

$$(h_L)_2 = h_{fric} + h_{valve} + 3h_{elbow}$$

$$\frac{\Delta P}{\gamma} = f_2\left(\frac{L}{D}\right)\left(\frac{V_2^2}{2g}\right) + f_{bt}\left(\frac{L_e}{D}\right)\left(\frac{V_2^2}{2g}\right) + 3f_{bt}\left(\frac{L_e}{D}\right)\left(\frac{V_2^2}{2g}\right)$$

$$(h_L)_1 = h_{fric}$$

$$= f\left(\frac{L}{D}\right)\left(\frac{V_1^2}{2g}\right)$$

$$= f\left(\frac{30m}{0.0525}\right)\left(\frac{V_1^2}{2g}\right)$$

$$\underline{(h_L)_1 = f(571)\frac{V_1^2}{2g}}$$

$$(h_L)_2 = f\left(\frac{60}{0.0525}\right)\left(\frac{V_2^2}{2g}\right) + 0.019(150)\left(\frac{V_2^2}{2g}\right) + 3(0.019)(30)\left(\frac{V_2^2}{2g}\right)$$

$$\underline{(h_L)_2 = (1142f + 4.56)\frac{V_2^2}{2g}}$$

$$(h_L)_1 = (h_L)_2$$

Assume f_1 & $f_2 = 0.02$

$$f_1(571)\left(\frac{V_1^2}{2g}\right) = (1142f_2 + 4.56)\left(\frac{V_2^2}{2g}\right)$$

$$(0.02)(571)\left(\frac{V_1^2}{2g}\right) = ((1142)(0.02) + 4.56)\left(\frac{V_2^2}{2g}\right)$$

$$11.42(V_1^2) = 27.4(V_2^2)$$

$$\underline{V_1 = 1.548\,V_2}$$

$$Q = V_1 A_1$$

$$0.00863\,m^3/s = V_1(2.168 \times 10^{-3}\,m/s)$$

$$\underline{V_1 = 3.98\,m/s}$$

$$V_1 = 1.548\,v_2$$

$$V_2 = 2.571\,m/s$$

$$Q_2 = V_2 A_2$$

$$= 2.571(2.168 \times 10^{-3})$$

$$\underline{Q_2 = 0.00557\,m^3/s = 88.29\text{ gpm}}$$

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Procedure & calculations

$Q_{total} = Q_1 + Q_2$

$= 136.84\ gpm + 88.29\ gpm$

$\boxed{Q_{total} = 225.13\ gpm}$

$(h_L)_2 = (1142f + 4.56)\frac{v_2^2}{2g}$

$= (1142(0.02) + 4.56)\left(\frac{2.57^2}{2(9.81)}\right)$

$(h_L)_2 = 9.23m$

$\Delta P = \gamma (h_L)_2$

$= (9.807\ kN/m^3)(9.23m)$

$\Delta P = 90.52\ kN/m^2$

Excel Equations

$$Q_2 = \sqrt{\frac{\frac{\Delta P}{\gamma}}{f_2\left(\frac{L_2}{D_2} + 3\left(\frac{L_e}{D}\right)_{elbow} + \left(\frac{L_e}{D}\right)_{valve}\right)\frac{8}{g\pi^2 D_2^4}}}$$

$$\% = \frac{f^{old} - f^{new}}{f^{old}}(100)$$

$$f = \frac{0.25}{\left(\log\left(\frac{1}{3.7(D/\varepsilon)} + \frac{5.74}{R_e^{0.9}}\right)\right)^2}$$

$$R_e = \frac{vD}{\nu}$$

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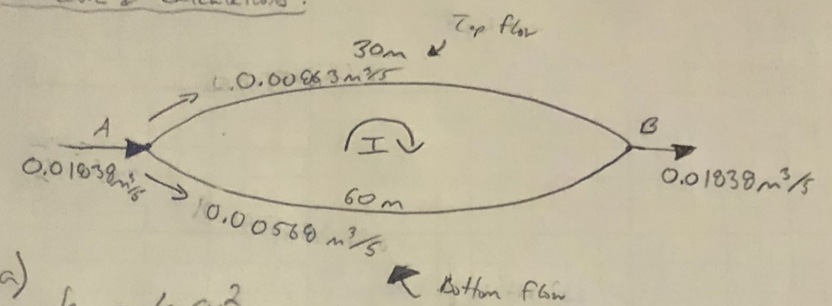
Procedure & Calculations:



a) $h_L = k_i Q_i^2$

$\frac{\Delta P}{\gamma} = k_i Q_i^2$

$\Delta P = k_i Q_i^2 (\gamma)$

Excel Sheets Attached

b) Increase the valve coefficient by a factor of 100, and find the iteration where the friction factors are the same, and take the new flow rate of the bottom and find the other new flow rate. The find the pressure drop using $k_i Q_i^2$ & γ

Excel Sheet attached with work provided.

c) Using the same information from part b & the pressure drop from part a, I adjusted the flow rates to get the same pressure drop as part a. I changed the top and bottom branches to achieve this.

Excel sheet attached with work provided.

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Summary: 1) The total flow rate in the system is 226.87 gpm or 0.01451352258 m^3/s

2a) The pressure drop is 11,528 kN/m^2 in the system.

2b) The new flow rates are

$$Q_1 = 136.84\ gpm = 0.008632\ m^3/s$$

$$Q_2 = 26.27\ gpm = 0.0016579\ m^3/s$$

and the new pressure drop is

$$\Delta P = 79.96\ kN/m^2$$

2c) The new total flow rate is 90.98 gpm or 0.00574 m^3/s to achieve the same pressure drop as 2a.

$$Q_1 = 0.004\ m^3/s$$
$$Q_2 = 0.00174\ m^3/s$$

Analysis: The key to understanding the flow rate in the system was to understand that the upper branch should be larger than the lower branch. This was supposed to be the case, and makes sense as the lower branch has more energy loses.

Problem 1

Input Data

Specific Weight	9.807	kN/m^3
Kinematic Viscosity	1.31E-06	m^2/s
Pressure Delta	90.52	kN/m^2
Pipe Length 1	30	m
Pipe Length 2	60	m
D1 (DN 100)	0.1023	m
D2 (DN 50)	0.0525	m
Wall Roughness	4.60E-05	m
Le/D Valve	150	
Le/D Elbow	30	
D/e	1.14E+03	
f	0.019	
g	9.81	m/s^2
Gamma	9.807	kN/m^3
AREA	2.17E-03	m^2

For Q2

					NEW	
Iteration	f2	Q2(m^3/s)	V2 (m/s)	Re2	f2	%diff
1	0.01	0.00783382	3.62	1.45E+05	0.019020000	-90.20%
2	0.02	0.00553935	2.56	1.03E+05	0.019020498	4.90%
3	0.019	0.00568325	2.63	1.05E+05	0.019020455	-0.11%
4	0.0191	0.00566835	2.62	1.05E+05	0.019020460	0.42%
5	0.01905	0.00567579	2.62	1.05E+05	0.019020457	0.16%
6	0.01902	0.00568026	2.62	1.05E+05	0.019020456	0.00%

f2 = 0.01902

Q2 = 0.00568026 m^3/s or 90.03 gpm

Q Total = 0.0143135225 m^3/s or 226.87 gpm

Q2 Equation Parts

Delta P/Gamma	9.230141735
L/D Section	1382.857143
8/ (g)PI^2(D2^4)	10876.37118

V2 Equation V2 = Q2(A2)

Re Equation V(D)/v

f Equation Parts

1/3.7(D/e)

5.74/Re^0.9

Problem 2

a) **Circuit 1**

Branch	L	D (m)	e (m)	D/e	L (m)	Le (m)	Q (m^3/s)	V = 4Q/(PI)D^2	Re = VD/v	f	ki	kiQi	kiQi^2	2*k*Q		% diff
a	30	0.0525	4.60E-05	1.14E+03	30	0	0.00863	3.986596742	1.60E+05	1.90E-02	118209.91	1020.151541	8.803907796	2040.303081		2.88%
b	60	0.0525	4.60E-05	1.14E+03	60	0	-0.00568	2.623975204	1.05E+05	1.90E-02	236426.90	1342.966288	-7.62839769	2685.932577	Delta Q	-4.38%
											SUMS ->	2363.117829	1.175510108	4726.235658	0.000249	

Delta P = (kiQi^2)(Gamma)

Delta P = 11.52822763 kN/m^2

b)

For Q2 Valve Increase

Iteration	f2	Q2(m^3/s)	V2 (m/s)	Re2	NEW f2	%diff
1	0.01	0.00228647	1.05622442	4.24E+04	1.90E-02	-90.20%
2	0.02	0.00161678	0.74686345	3.00E+04	1.90E-02	4.90%
3	0.019	0.00165878	0.76626573	3.08E+04	1.90E-02	-0.11%
4	0.0191	0.00165443	0.76425717	3.82E-01	2.49E-03	0.42%
5	0.01905	0.0016566	0.76525947	3.08E+04	1.90E-02	0.16%
6	0.01902	0.0016579	0.76586275	3.08E+04	1.90E-02	0.00%

f2 = 0.01902

Q1 = 0.00863274 m^3/s or 136.84 gpm
Q2 = 0.0016579 m^3/s or 26.27 gpm

Q Total = 0.01029064 m^3/s or 163.11 gpm

Q2 Equation Parts

Delta P/Gamma	9.230141735
L/D Section	16232.85714
8/ (g)PI^2(D2^4)	10876.37118

V2 Equation V2 = Q2(A2)

Re Equation V(D)/v

f Equation Parts

1/3.7(D/e)

5.74/Re^0.9

Circuit 1 (Coefficient Increase)

Branch	L	D (m)	e (m)	D/e	L (m)	Le (m)	Q (m^3/s)	V = 4Q/(PI)D^2	Re = VD/v	f	ki	kiQi	kiQi^2	2*k*Q		% diff
a	30	0.0525	4.60E-05	1.14E+03	30	0	0.00863	3.986596742	1.60E+05	1.90E-02	118209.91	1020.151541	8.803907796	2040.303081		33.45%
b	60	0.0525	4.60E-05	1.14E+03	60	0	-0.001658	0.765906999	3.08E+04	1.90E-02	236472.71	392.0717543	-0.65005497	784.1435087	Delta Q	-174.12%
											SUMS ->	1412.223295	8.153852828	2824.44659	0.002887	

Delta P = (kiQi^2)(Gamma)

Delta P = 79.96483468 kN/m^2

c)

For Q2 Valve Increase Original

Iteration	f2	Q2(m^3/s)	V2 (m/s)	Re2	NEW f2	%diff
1	0.01	0.00228647	1.05622442	4.24E+04	1.90E-02	-90.20%
2	0.02	0.00161678	0.74686345	3.00E+04	1.90E-02	4.90%
3	0.019	0.00165878	0.76626573	3.08E+04	1.90E-02	-0.11%
4	0.0191	0.00165443	0.76425717	3.07E+04	1.90E-02	0.42%
5	0.01905	0.0016566	0.76525947	3.08E+04	1.90E-02	0.16%
6	0.01902	0.0016579	0.76586275	3.08E+04	1.90E-02	0.00%

f2 = 0.01902

Q1 = 0.00863274 m^3/s or 136.84 gpm
Q2 = 0.0016579 m^3/s or 26.27 gpm

Q Total = 0.01029064 m^3/s or 163.11 gpm

Q2 Equation Parts

Delta P/Gamma	9.230141735
L/D Section	16232.85714
8/ (g)PI^2(D2^4)	10876.37118

V2 Equation V2 = Q2(A2)

Re Equation V(D)/v

f Equation Parts

1/3.7(D/e)

5.74/Re^0.9

Circuit 1 (Coefficient Increase Original)

Branch	L	D (m)	e (m)	D/e	L (m)	Le (m)	Q (m^3/s)	V = 4Q/(PI)D^2	Re = VD/v	f	ki	kiQi	kiQi^2	2*k*Q		% diff
a	30	0.0525	4.60E-05	1.14E+03	30	0	0.00863	3.986596742	1.60E+05	1.90E-02	118209.91	1020.151541	8.803907796	2040.303081		33.45%
b	60	0.0525	4.60E-05	1.14E+03	60	0	-0.001658	0.765906999	3.08E+04	1.90E-02	236472.71	392.0717543	-0.65005497	784.1435087	Delta Q	-174.12%
											SUMS ->	1412.223295	8.153852828	2824.44659	0.002887	

Delta P = (kiQi^2)(Gamma)
Delta P = 79.96483468 kN/m^2

Circuit 1 (Coefficient Increase - Flow Rate modification to have same Pressure Drop)

Branch	L	D (m)	e (m)	D/e	L (m)	Le (m)	Q (m^3/s)	V = 4Q/(PI)D^2	Re = VD/v	f	ki	kiQi	kiQi^2	2*k*Q		% diff
a	30	0.0525	4.60E-05	1.14E+03	30	0	0.004	1.84778528	7.43E+04	1.90E-02	118217.64	472.8705635	1.891482254	945.741127		16.62%
b	60	0.0525	4.60E-05	1.14E+03	60	0	-0.00174	0.803786597	3.23E+04	1.90E-02	236469.80	411.4574573	-0.71593598	822.9149145	Delta Q	-38.20%
											SUMS ->	884.3280207	1.175546278	1768.656041	0.000665	

Delta P = (kiQi^2)(Gamma)
Delta P = 11.52858235 kN/m^2