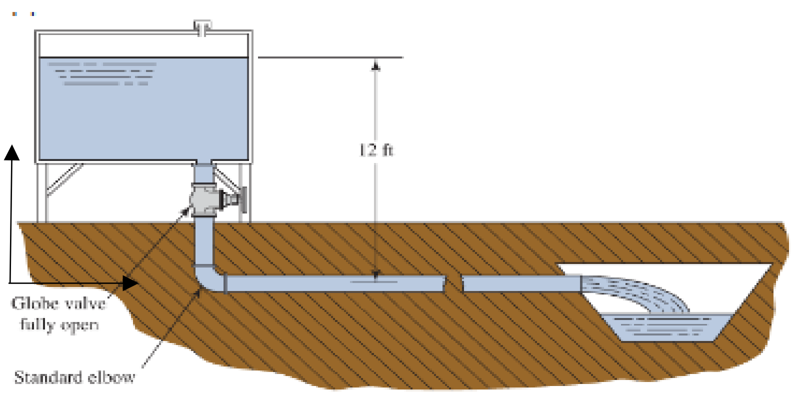
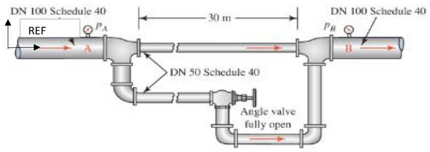
DATA

p1=	0	lb/ft2	Kvalve	240
p2=	0	lb/ft2	Kelbow	30
L=	75	ft		
Z1=	12	ft		
gamma=	64.4	lb/ft2		
nu=	9.15E-06	ft2/s		
e=	0.00015	ft		
Q=	0.891	ft3/s		

Iterations	f	assumed D (ft)	V (ft/s)	Re	D/e	D	%diff	D new	
1	3.33E-02	0.0224	2260.954	5.54E+06	149.3333	24.6543	-8374.82%	1.8984	
2	1.99E-02	1.8984	0.314797	6.531E+04	12655.74	23.7910	0.71%	1.8849	
3	1.99E-02	1.8849	0.319318	6.578E+04	12565.83	23.7893	0.00%	1.8848	approx. DN600 Pipe



Pa=		kPa
Pb=		kPa
L=	60	m
gamma=	8.8	kN/m3
nu=	1.30E-06	m2/s
e=	4.60E-05	m
D1=	0.1143	m
D2=	0.0603	m
D3=	0.0603	m
Ktee=	60	
Kelbow=	30	
Kvalve=	150	



Assume Kpa	Iteration	Q1 (m3/s)	Re1	(D/e)1	f1	fT1	NUM	Assume f2	(D/e)2	fT2	DEN2	Q2 (m3/s)	Re2	f2	%diff2	Assume f3	(D/e)3	fT3	DEN3	Q3 (m3/s)	Re3	f3	%diff3	1	3	2			% diff delta P
100	1	0.01417	1.21E+05	2484.78	0.0195	0.0159	10.18439	0.010000	1.31E+03	0.018403	62300.05	0.012786	2.08E+05	0.0201	101.47%	0.010000	1.31E+03	0.018403	89787.57	0.01065	1.73E+05	0.0204	104.21%						
		0.01417	1.21E+05	2.48E+03	0.0195	0.0159	10.18439	0.020147	1.31E+03	0.018403	125401.7	0.009012	1.46E+05	0.0207	2.76%	0.020421	1.31E+03	0.018403	151139.1	0.008209	1.33E+05	0.0209	2.23%						
		0.01417	1.21E+05	2.48E+03	0.0195	0.0159	10.18439	0.020703	1.31E+03	0.018403	128859.1	0.00889	1.44E+05	0.0207	0.12%	0.020876	1.31E+03	0.018403	153969.6	0.008133	1.32E+05	0.0209	0.09%						
		0.01417	1.21E+05	2.48E+03	0.0195	0.0159	10.18439	0.020728	1.31E+03	0.018403	129011.2	0.008885	1.44E+05	0.0207	0.01%	0.020894	1.31E+03	0.018403	154080	0.00813	1.32E+05	0.0209	0.00%						
		0.01417	1.21E+05	2.48E+03	0.0195	0.0159	10.18439	0.020729	1.31E+03	0.018403	129017.9	0.008885	1.44E+05	0.0207	0.00%	0.020894	1.31E+03	0.018403	154084.3	0.00813	1.32E+05	0.0209	0.00%	11.66426	180.41	5.087658	197.16	22.40511	-78%

Assume Kpa	Iteration	Q1 (m3/s)	Re1	(D/e)1	f1	fT1	NUM	Assume f2	(D/e)2	fT2	DEN2	Q2 (m3/s)	Re2	f2	%diff2	Assume f3	(D/e)3	fT3	DEN3	Q3 (m3/s)	Re3	f3	%diff3	1	3	2			
22.40511	1	0.01417	1.21E+05	2484.78	0.0195	0.0159	1.366793	0.010000	1.31E+03	0.018403	62300.05	0.004684	7.61E+04	0.0222	121.68%	0.010000	1.31E+03	0.018403	89787.57	0.003902	6.34E+04	0.0227	126.96%						
		0.01417	1.21E+05	2.48E+03	0.0195	0.0159	10.18439	0.022168	1.31E+03	0.018403	137967.3	0.008592	1.40E+05	0.0208	-6.22%	0.022696	1.31E+03	0.018403	165287.4	0.00785	1.27E+05	0.0210	-7.64%						
		0.01417	1.21E+05	2.48E+03	0.0195	0.0159	10.18439	0.020790	1.31E+03	0.018403	129399.6	0.008872	1.44E+05	0.0207	-0.28%	0.020963	1.31E+03	0.018403	154508.5	0.008119	1.32E+05	0.0209	-0.31%						
		0.01417	1.21E+05	2.48E+03	0.0195	0.0159	10.18439	0.020732	1.31E+03	0.018403	129034.8	0.008884	1.44E+05	0.0207	-0.01%	0.020897	1.31E+03	0.018403	154100.8	0.00813	1.32E+05	0.0209	-0.01%						
		0.01417	1.21E+05	2.48E+03	0.0195	0.0159	10.18439	0.020729	1.31E+03	0.018403	129018.9	0.008885	1.44E+05	0.0207	0.00%	0.020895	1.31E+03	0.018403	154085.1	0.00813	1.32E+05	0.0209	0.00%	11.66426	180.41	5.087658	197.16	22.40511	0%

QA=	0.02	M3/S		PB	12500000	N/M2	
G=	9,810.00	N/M3		SW	8800	N/M3	
AA=	0.02	M2					
LA=	180.00	M					
LB=	8.00	M					
DA=	0.15	M					
DB=	0.05	M					
e=	0.00	M					
VA=	0.89	M/S					
VKE=	0.00	M2/S					
AB=	0.00	M2	VB	PA	PB/SW	VA/2G	QB
LENGTH=	4.50	M	2.00	223,584.66	1,420.45	0.000045	1,049.87
			742.37	233,982.90	1,420.45	0.000045	389,695.18
			0.89	223,569.08	1,420.45	0.000045	467.19
			1.00	223,570.62	1,420.45	0.000045	524.93

VB/2G	ZB	PIPE1	REDUCER	FB	PIPE2	VB
28.09	192.50	221,943.62	0.000016	0.016928	1,100,488,671.69	742.37
10,426.32	192.50	221,943.62	0.000016	0.016928	1,100,488,671.69	204,564,400.65
12.50	192.50	221,943.62	0.000016	0.016928	1,100,488,671.69	245,244.93
14.04	192.50	221,943.62	0.000016	0.016928	1,100,488,671.69	275,556.11

% DIFF
100.00%
74136.93%
-11.00%
0.00%

Constants		
Q1=	0.0668	ft3/s
Q2=	0.0223	ft3/s
Q3=	0.0445	ft3/s
zA=	8	ft
zB=	-2	ft
zC=	-1	ft
V1=	10	ft/s
D1=	0.0922	ft
nu=	1.21E-05	ft2/s
L1=	34	ft
L2=	2	ft
L3=	1	ft
g=	32.2	ft/s2
e=	1.50E-04	ft

Re1	f1	fT elbow	fT tee	zA-zB	V1^2/2g	LHS
7.62E+04	0.05071	1.52119	3.04238	10	1.5544	374.524

Assume							
D2	A2	v2	Re2	f2	V2^2/2g	RHS	%diff
0.05	0.001963495	11.35729674	4.69E+04	6.54E-02	2.0029	7.2451	-98.06%
0.06	0.002827433	7.887011624	3.91E+04	6.04E-02	0.9659	2.9118	-99.22%
0.04	0.001256637	17.74577615	5.87E+04	7.24E-02	4.8899	22.6004	-93.96%
0.03	0.000706858	31.5480465	7.82E+04	8.33E-02	15.4546	101.2366	-72.96%
0.025	0.000490874	45.42918696	9.39E+04	9.14E-02	32.0468	266.4305	-28.86%
0.0245	0.000471435	47.30236043	9.58E+04	9.24E-02	34.7440	296.8144	-20.74%
0.023	0.000415476	53.67342504	1.02E+05	9.56E-02	44.7335	416.4572	11.19%
0.0239	0.000448627	49.70718623	9.82E+04	9.36E-02	38.3665	338.9491	-9.49%
0.0235	0.000433736	51.41374712	9.99E+04	9.45E-02	41.0462	371.0499	-0.92%
0.02344	0.000431524	51.6772943	1.00E+05	9.46E-02	41.4681	376.1738	0.44%

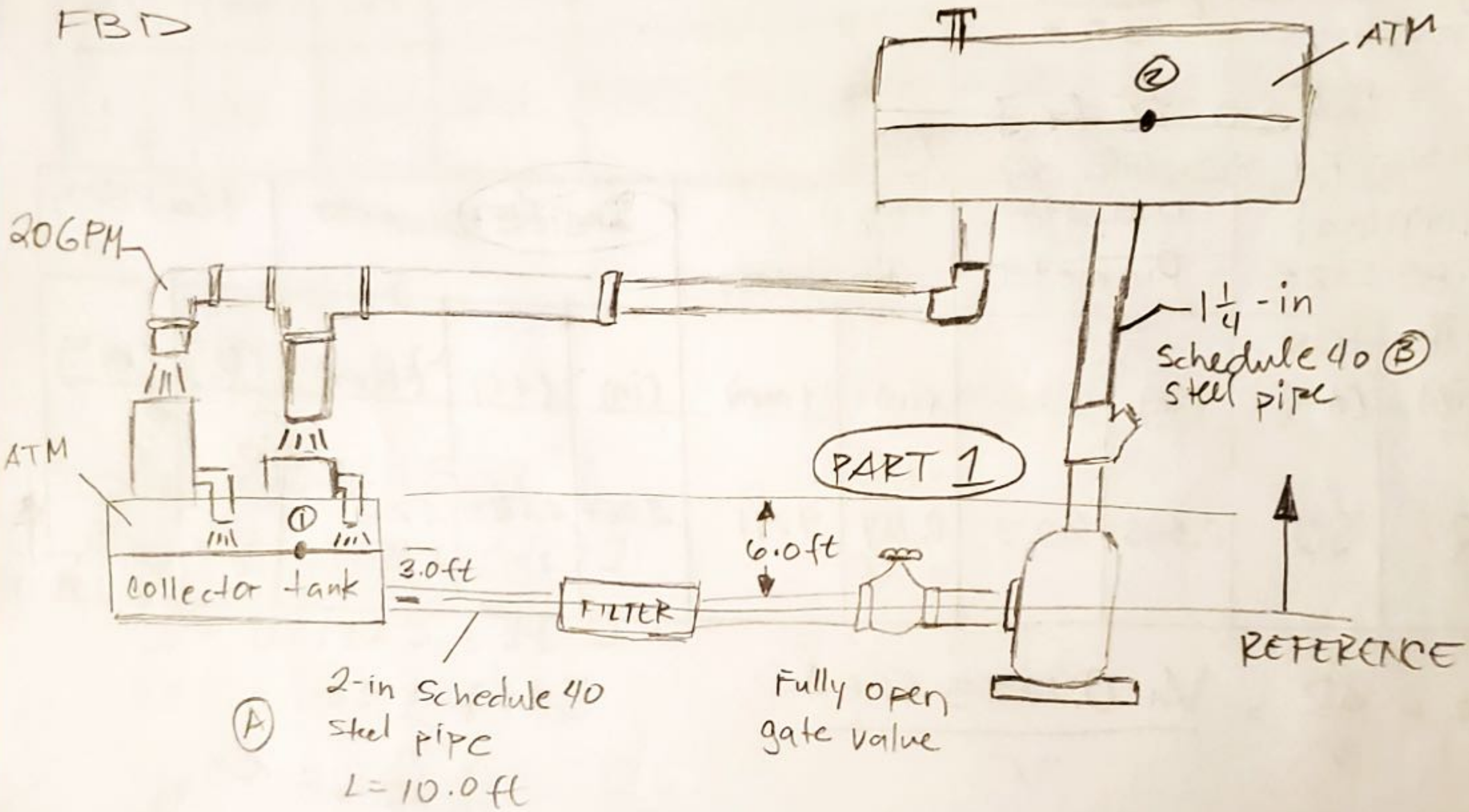
Re1	f1	fT elbow	fT tee	zA-zC	V1^2/2g	LHS
7.62E+04	0.05071	1.52119	1.01413	9	1.554402946	186.36060

Assume							
D3	A3	V3	Re3	f3	V3^2/2g	RHS	%diff
0.03	0.000706858	11.35729674	2.82E+04	8.33E-02	61.54168358	2.32E+02	12.28%
0.035	0.000962113	7.887011624	2.28E+04	7.72E-02	33.21866802	1.06E+02	-21.33%
0.031	0.000754768	17.74577615	4.55E+04	8.19E-02	53.97685998	1.97E+02	2.73%
0.0311	0.000759645	31.5480465	8.11E+04	8.18E-02	53.28596507	1.93E+02	1.88%
0.0313	0.000769447	45.42918696	1.18E+05	8.15E-02	51.93702171	1.87E+02	0.22%

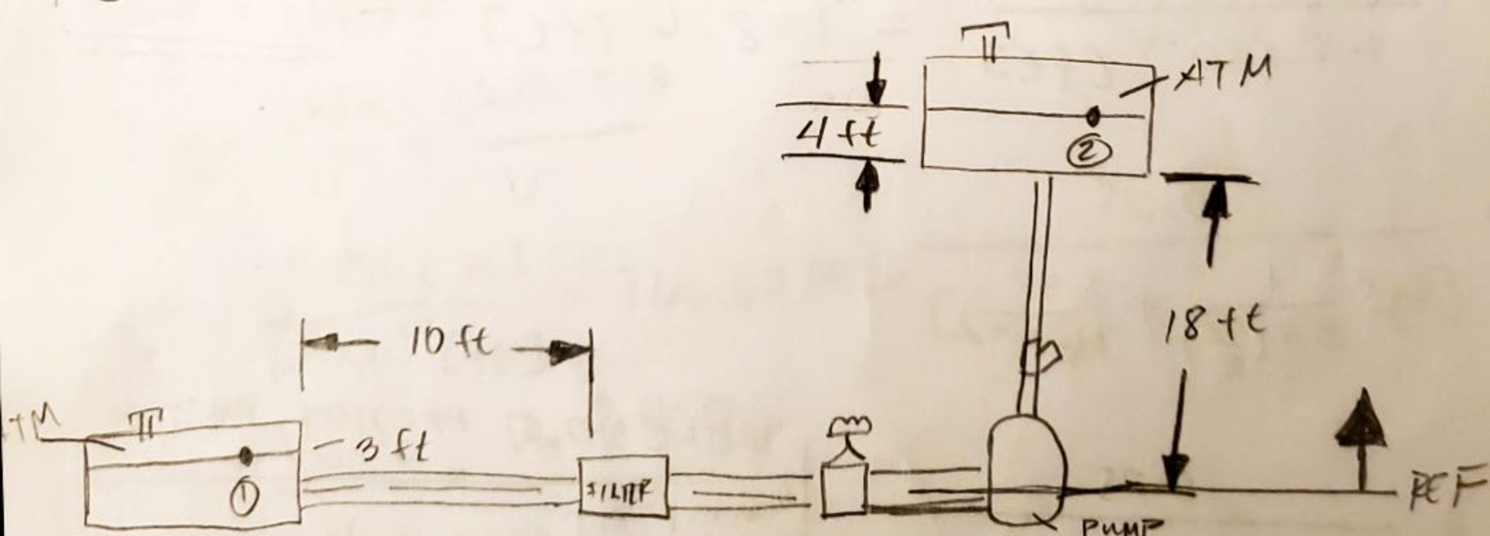
11.23

GIVEN: For the system Fig. 11.26 compute the total head on the pump and the power delivered by the pump to the coolant

FBD



FBD



$$h_{A_1} + \cancel{\frac{p_{A_1}}{\gamma_1}} + \cancel{\frac{V_{A_1}^2}{2g}} + z_A = \cancel{\frac{p_{B_1}}{\gamma}} + \cancel{\frac{V_{B_1}^2}{2g}} + z_{B_1} + h_{L_1} + \cancel{h_{R_1}}$$

②

* FLOW RATE

$Q_A = \quad [\frac{ft^3}{s}]$

* LENGTH

$L = 10\,[ft]$

* GRAVITY

$g = 32.2\,[\frac{ft}{s^2}]$

* ROUGHNESS

$\varepsilon = 1.5 \times 10^{-4}\,[ft]$

TABLE F.1 Schedule 40 Ⓐ

Nominal Pipe size		Outside Diameter		Wall Thickness		Inside Diameter			Flow Area	
NPS (in)	DN (mm)	(in)	(mm)	(in)	(mm)	(in)	(ft)	(mm)	(ft^2)	(m^2)
2	50	2.375	60.3	0.154	3.91	2.067	0.1723	52.5	0.02333	2.168×10^{-3}

$$N_R = \frac{V_A D}{\nu} = \frac{V_A\, 0.1723\,[ft]}{\nu}$$

$$\frac{D}{\varepsilon} = \frac{0.1723\,[ft]}{1.5 \times 10^{-4}\,[ft]} = 1148.6\,[ft]$$

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

$$f_T = \frac{0.25}{\left[\log\left(\frac{1}{3.7\left(\frac{D}{\varepsilon}\right)}\right)\right]^2}$$

TABLE 10.5 FRICTION FACTOR

Nominal Pipe size [in]	FRICTION FACTOR F_T
2	0.019

TABLE F.1 Schedule 40 (13) (3)

Nominal Pipe Size		Outside Diameter		Wall Thickness		Inside Diameter			Flow Area	
NPS (in)	DN (mm)	(in)	(mm)	(in)	(mm)	(in)	(ft)	(mm)	(ft^2)	(m^2)
$1\frac{1}{4}$	32	1.660	42.2	0.140	3.56	1.380	0.1150	35.01	0.01039	9.653×10^{-4}

$L_A = 10.0\ ft$

$L_B = 20.0\ ft$

$A_A = 0.02333\ [ft^2]$

$A_B = 0.01039\ [ft^2]$

$D_A = 0.1723\ [ft]$

$D_B = 0.1150\ [ft]$

$g = 32.2\ [\frac{ft}{s^2}]$

$Q_A = ?$ $V_A = ?$

K_{FILTER}

$Q_B = ?$ $V_B = ?$

$\nu = ?$

$$\frac{D_A}{\varepsilon} = 1148.6$$

$$N_{R_A} = \frac{V_A D_A}{\nu} = \frac{V_A\, 0.1723}{\nu}$$

$$\frac{D_B}{\varepsilon} = \frac{0.1150\ [ft]}{1.5 \times 10^{-4}\ [ft]} = 766.67\ [ft]$$

$$N_{R_B} = \frac{V_B D_B}{\nu} = \frac{V_B\, 0.1150}{\nu}$$

* Entrance loss (square - Edged inlet use $k = 0.5$)

$$h_{L_1} = k\left(\frac{V^2}{2g}\right)$$

* Fully open gave value $\left(\frac{L_e}{D}\right) = 8$

$$h_{L_2} = k\left(\frac{V^2}{2g}\right) = 8f_T\frac{V^2}{2g} = 8(0.019)\frac{V^2}{2g} = .152\frac{V^2}{2g}$$

* SWING CHECK VALUE

$$h_{L_3} = k\left(\frac{V^2}{2g}\right) = 100f_T\frac{V^2}{2g} = 100(0.019)\frac{V^2}{2g} = 1.9\frac{V^2}{2g}$$

* Filter $k = ?$

$$h_{L_4} = k\left(\frac{V^2}{2g}\right)$$

* Pipe # 1

$$h_{L_5} = f\frac{L_1}{D_1}\frac{V^2}{2g}$$

* Pipe # 2

$$h_{L_6} = f\frac{L_2}{D_2}\frac{V^2}{2g}$$

* Exit loss

$$h_{L_7} = (1.0)\left(\frac{V^2}{2g}\right)$$

$$h_A = -z_A - z_B + h_L$$
$$= -3\,[ft] + (18\,[ft] + 4\,[ft]) + h_L$$
$$h_A = 19\,[ft] + h_L$$

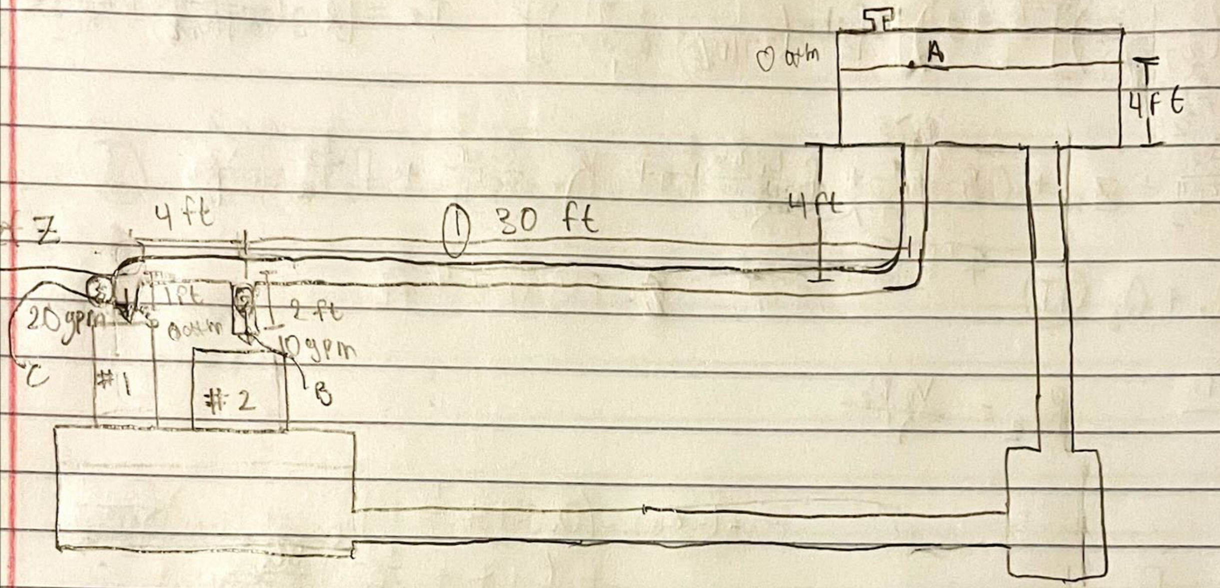
* Energy losses $= h_L = ?$

$$h_{L_{TOTAL\ PART\ 1}} = h_{L_1} + h_{L_2} + h_{L_3} + h_{L_4} + h_{L_5} + h_{L_6} + h_{L_7}$$
$$= K_{h_{L_1}}\left(\frac{V_A^2}{2g}\right) + 2\left(f\frac{L_1}{D_1}\frac{V_A^2}{2g}\right) + K_{FILTER}\left(\frac{V_A^2}{2g}\right) + K_{GATE}\frac{V_A^2}{2g} +$$
$$K_{SWING}\left(\frac{V_B^2}{2g}\right) + f\frac{L_2}{D_2}\frac{V_B^2}{2g} + (1.0)\left(\frac{V_B^2}{2g}\right)$$
$$= 0.5\left(\frac{\left(\frac{Q_A}{A_A}\right)^2}{2g}\right) + 2\left(f\frac{L_1}{D_1}\frac{\left(\frac{Q_A}{A_A}\right)^2}{2g}\right) + K_{FILTER}\left(\frac{\left(\frac{Q_A}{A_A}\right)^2}{2g}\right) + .152\left(\frac{\left(\frac{Q_A}{A_A}\right)^2}{2g}\right) + 1.9\left(\frac{\left(\frac{Q_B}{A_B}\right)^2}{2g}\right)$$
$$f\frac{L_2}{D_2}\frac{\left(\frac{Q_B}{A_B}\right)^2}{2g} + (1.0)\left(\frac{\left(\frac{Q_B}{A_B}\right)^2}{2g}\right)$$

* TOTAL HEAD ON THE PUMP h_A

$$h_A = 19\,[ft] + h_L$$

For the system, specify the size of schedule 40 steel pipe requried to return the fluid to the machines. Machine 1 requries 20 gpm + Machine 2 requries 10 gpm. The fluid leaves the pipe at 0 psig



$Q = VA \qquad V = \frac{Q}{A} \qquad A = \frac{\pi D^2}{4} \qquad V^2 = \left(\frac{Q}{\frac{\pi D^2}{4}}\right)^2 \qquad \frac{16Q^2}{\pi^2 D^4} \Rightarrow \frac{16Q^2}{\pi^2 D^4} \cdot \frac{1}{2g} = \frac{8Q^2}{g\pi^2 D^4}$

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

$Q_1 = Q_2 + Q_3 \qquad 10\text{ gpm} \Rightarrow \frac{10\text{ gpm}}{449\text{ gpm}} = 0.0223\ ft^3/s$

$20\text{ gpm} \Rightarrow \frac{20\text{ gpm}}{449\text{ gpm}} = 0.0445\ ft^3/s$

$Q_1 = 0.0223\ ft^3/s + 0.0445\ ft^3/s$

$Q_1 = 0.0668\ ft^3/s$

Assuming an ideal velocity for Pipe ① . $V_1 = 10\ ft/s$ *

$A_1 = \frac{Q}{V} = \frac{0.0668\ ft^3/s}{10.0\ ft/s} = 0.00668\ ft^2$

$D_1 = \sqrt{\frac{4A_1}{\pi}} = 0.0922\ ft$

$$h_{L\,A\text{-}B} = 0.5\frac{V_1^2}{2g} + f_1\frac{34ft}{D_1}\frac{V_1^2}{2g} + K_{Tee}\frac{V_2^2}{2g} + f_2\frac{4ft}{D_2}\frac{V_2^2}{2g}$$

$$K_{Tee} = 60f_T,\ K_{Elbow} = 30f_T \quad f_{T_{Elbow}} = \frac{0.25}{\left[\log\left(\frac{1}{3.7(D_1/\varepsilon)}\right)\right]^2}$$

$$f_{T_{tee}} = \frac{0.25}{\left[\log\left(\frac{1}{3.7(D_2/\varepsilon)}\right)\right]^2} \quad f_1 = \frac{0.25}{\left[\log\left(\frac{1}{3.7(D_1/\varepsilon)} + \frac{5.74}{Re_1^{0.9}}\right)\right]^2} \quad f_2 = \frac{0.25}{\left[\log\left(\frac{1}{3.7(D_2/\varepsilon)} + \frac{5.74}{Re_2^{0.9}}\right)\right]^2}$$

$$Z_A = \frac{8Q_2^2}{g\pi^2 D_2^4} + Z_B + 0.5\frac{8Q_1^2}{g\pi^2 D_1^4} + f_1\frac{L_1}{D_1}\frac{8Q_1^2}{g\pi^2 D_1^4} + K_{Tee}\frac{8Q_1^2}{g\pi^2 D_1^4} + f_2\frac{L_2}{D_2}\frac{8Q_2^2}{g\pi^2 D_2^4} + K_{elbow}\frac{8Q_1^2}{g\pi^2 D_1^4} \quad \text{I}$$

$$Q_1 = Q_2 + Q_3 \quad \text{II} \qquad \varepsilon = 1.5\times10^{-4}\ ft$$

$$Re_1 = \frac{V_1 D_1}{\nu} \qquad Re_2 = \frac{V_2 D_2}{\nu}$$

Process:

1) Assume D_2
2) solve for Re_2, f_2 & f_T
3) solve RHS
4) Compare to LHS

$$Z_A + (-Z_B) = \left(0.5 + f_1\frac{L_1}{D_1} + K_{Elbow} + K_{Tee}\right)\frac{8Q_1^2}{g\pi^2 D_1^4} + \left(1 + f_2\frac{L_2}{D_2}\right)\frac{8Q_2^2}{g\pi^2 D_2^4}$$

$$10ft - \left(0.5 + f_1\frac{L_1}{D_1} + K_{Elbow} + K_{Tee}\right)\frac{8Q_1^2}{g\pi^2 D_1^4} = \left(1 + f_2\frac{L_2}{D_2}\right)\frac{8Q_2^2}{g\pi^2 D_2^4}$$

$L_2 = 38ft$

$$h_{L\,A\text{-}C} = 0.5\frac{V_1^2}{2g} + f_1\frac{L_2}{D_1}\frac{V_1^2}{2g} + 2K_{Elbow}\frac{V_1^2}{2g} + K_{Tee}\frac{V_1^2}{2g} + f_3\frac{L_3}{D_3}\frac{V_3^2}{2g}$$

$$Z_A = \frac{8Q_3^2}{g\pi^2 D_3^4} + Z_3 + 0.5\frac{8Q_1^2}{g\pi^2 D_1^4} + 2K_{Elbow}\frac{8Q_1^2}{g\pi^2 D_1^4} + \underbrace{K_{Tee}}_{20f_T}\frac{8Q_1^2}{g\pi^2 D_1^4} + f_3\frac{L_3}{D_3}\frac{8Q_3^2}{g\pi^2 D_3^4}$$

11.5

Problem : oil is flowing at the rate of 0.015 $\frac{m^3}{s}$ in the system shown in Fig. 11.17

→ Considering all pipe friction and minor losses CALCULATE the pressure at A

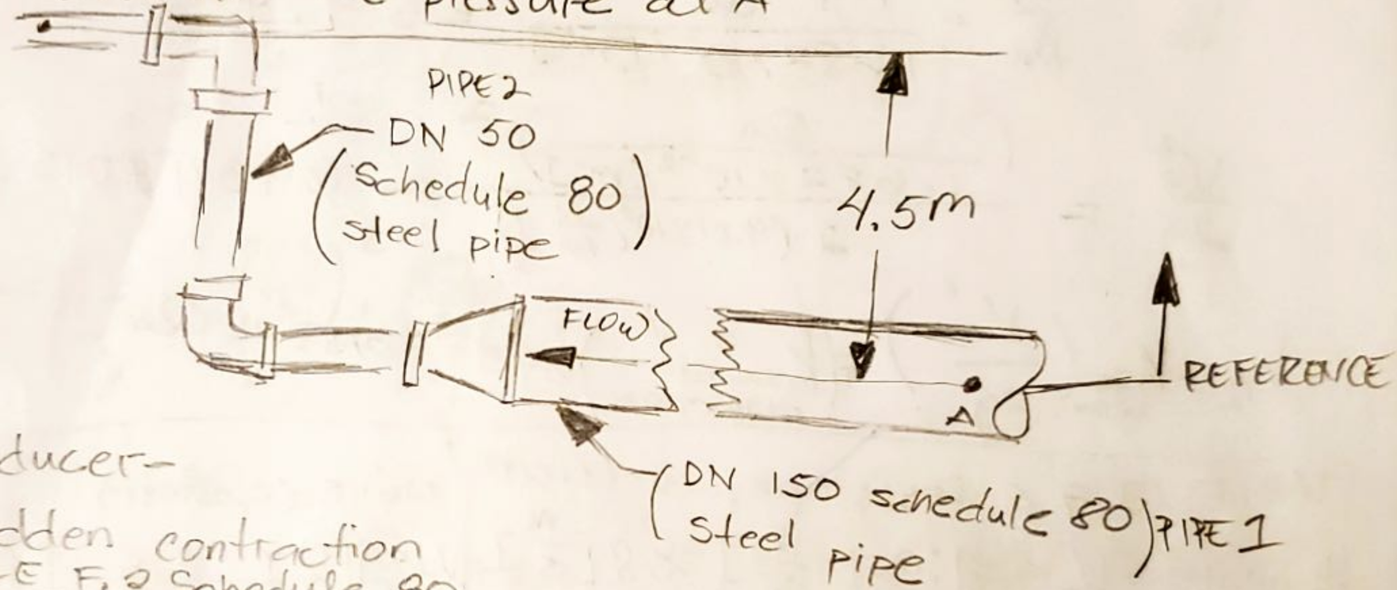


TABLE F.2 Schedule 80

Nominal Pipe size		Outside Diameter		Wall Thickness		Inside Diameter			Flow Area		
NPS (in	DN (mm)	(in)	(mm)	(in)	(mm)	(in)	(ft)	(mm)	(ft²)	(m²)	
2	50	2.375	60.3	0.218	5.54	1.939	0.1616	49.3	0.02051	1.905×10^{-3}	B
6	150	6.625	168.3	0.432	10.97	5.761	0.480	146.3	0.1810	1.682×10^{-2}	A

DATA FOR THE SYSTEM AS FOLLOWS:

* Oil specific weight = 8.80 kN/m^3 = 8800 $[\frac{N}{m^3}]$
* Oil kinematic viscosity = $2.12\times10^{-5}\ \frac{m^2}{s}$
* Length of DN 150 pipe = 180 m
* Length of DN 50 pipe = 8m
* Elbows are long radius type ($K_{ELBOW} = 20f_T$)
* Pressure at B = 12.5 MPa = 12,500,000 $[\frac{N}{m^2}]$

$g = 9.81 \times 10^3 \left[\frac{N}{m^3}\right]$

$$\frac{D_1}{D_2} = \frac{146.3\,[mm]}{49.3\,[mm]} = 2.97\,(mm) = 0.00297\,[m]$$

$$V_2 = \frac{Q_A}{A_A} = \frac{Q_A}{1.682 \times 10^{-2}\,[m^2]} = 59.45\,Q_A$$

$$\frac{V_2^2}{2g} = \frac{\left(\frac{Q_A}{1.682 \times 10^{-2}\,[m^2]}\right)^2}{2\,(9.81 \times 10^3\left[\frac{N}{m^3}\right])} = 69343015.05\,Q_A^2$$

$$h_L = K_{\substack{\text{SUDDEN}\\\text{CONTRACTION}}}\left(\frac{V_2^2}{2g}\right) = (K_{\substack{\text{SUDDEN}\\\text{CONTRACTION}}})\,69343015.05\,Q_A^2$$

TABLE 10.7 A Resistance coefficient | TABLE (CLOSEST)

Assuming: $V_2 = 7.9 \left[\frac{m}{s}\right] \approx 8 \left[\frac{m}{s}\right]$ | $V_2 = 9 \left[\frac{m}{s}\right]$

$$\frac{D_1}{D_2} = 2.97 \approx 3.0$$

Resistance coefficient $k = 0.35$

* $K_{ELBOW} = 30 f_T$

$$Q_A = 0.015 \left[\frac{m^3}{s}\right]$$

$$V = \frac{Q}{A} = \frac{0.015\left[\frac{m^3}{s}\right]}{1.905 \times 10^{-3}\,[m]^2} = 7.9\left[\frac{m}{s}\right]$$

*FLOWION:

Find $P_A = ?$

Q

$$* \frac{P_A}{\gamma} + \frac{V_A^2}{2g} + \cancel{z_A}^{0} = \frac{P_B}{\gamma} + \frac{V_B^2}{2g} + z_B + h_L + \cancel{h_R}^{0}$$

$$P_A = \left(-\frac{V_A^2}{2g} + \frac{P_B}{\gamma} + \frac{V_B^2}{2g} + z_B + h_L\right)\gamma$$

$$P_A = \left(\frac{P_B}{\gamma} - \frac{\left(\frac{Q_A}{A_A}\right)^2}{2g} + \frac{\left(\frac{Q_B}{A_B}\right)^2}{2g} + z_B + h_L\right)\gamma$$

$$P_A = \left(\left(\frac{12{,}500{,}000[\frac{N}{m^2}]}{8800[\frac{N}{m^3}]}\right) - \left(\frac{\frac{Q_A}{1.682\times10^{-2}[m^2]}}{2(9.81\times10^3[\frac{N}{m^3}])}\right) + \left(\frac{\frac{Q_B}{1.905\times10^{-3}[m^2]}}{2(9.81\times10^3[\frac{N}{m^3}])}\right) + 180[m] + 8[m]\right.$$

$$\left. + 4.5[m] + h_L\right)\left(8800[\tfrac{N}{m^3}]\right)$$

$$P_A = 1420.45 - \left(\frac{Q_A}{11160468.49}\right) + \left(\frac{Q_B}{10299212.6}\right) + 192.5[m] + h_L$$

* If we assume $Q_A = 0.015 \frac{m^3}{s}$

* $h_L = ?$ Energy losses = ?

$$h_L = f_A \frac{L_A}{D_A}\frac{V_A^2}{2g} + K_{\text{SUDDEN CONTRACTION}}\left(\frac{V_A^2}{2g}\right) + f_B \frac{L_B}{D_B}\frac{V_B^2}{2g} + 2\left(K_{ELBOW}\frac{V_B^2}{2g}\right)$$

$$= f_A \frac{L_A}{D_A}\frac{\left(\frac{Q_A}{A_A}\right)^2}{2g} + 0.35\frac{\left(\frac{Q_A}{A_A}\right)^2}{2g} + f_B \frac{L_B}{D_B}\frac{\left(\frac{Q_B}{A_B}\right)^2}{2g} + 2(30f_T)\frac{\left(\frac{Q_B}{A_B}\right)^2}{2g}$$

*Fi...

$$f_A = \frac{0.25}{\left[\log\left(\frac{1}{3.7\left(\frac{D_A}{\varepsilon}\right)} + \frac{5.74}{\left(\frac{V D_A}{\nu}\right)^{0.9}}\right)\right]^2}$$

$$f_T = \frac{0.25}{\left[\log\left(\frac{1}{3.7\left(\frac{D_B}{\varepsilon}\right)}\right)\right]^2}$$

$$f_B = \frac{0.25}{\left[\log\left(\frac{1}{3.7\left(\frac{D_B}{\varepsilon}\right)}\right) + \left(\frac{5.74}{\left(\frac{V D_B}{\nu}\right)^{0.9}}\right)\right]^2}$$

$$h_L = \frac{0.25}{\left[\log\left(\frac{1}{3.7\left(\frac{D_A}{\varepsilon}\right)} + \frac{5.74}{\left(\frac{V D_A}{\nu}\right)^{0.9}}\right)\right]^2} \frac{L_A}{D_A} \frac{\left(\frac{Q_A}{A_A}\right)^2}{2g} + 0.35 \frac{\left(\frac{Q_A}{A_A}\right)^2}{2g} + \frac{0.25}{\left[\log\left(\frac{1}{3.7\left(\frac{D_B}{\varepsilon}\right)} + \frac{5.74}{\left(\frac{V D_B}{\nu}\right)^{0.9}}\right)\right]^2} \frac{L_B}{D_B} \frac{\left(\frac{Q_B}{A_B}\right)^2}{2g}$$

$$+ 2(30)\left(\frac{0.25}{\left[\log\left(\frac{1}{3.7\left(\frac{D_B}{\varepsilon}\right)}\right)\right]^2}\right)$$

* $Q_A = 0.015 \frac{m^3}{s}$
* $g = 9.81 \times 10^3 \left[\frac{N}{m^3}\right]$
* $A_A = 1.682 \times 10^{-2} [m^2]$
* $L_A = 180 [m]$
* $L_B = 8 [m]$
* $D_A = 146.3 [mm] = 0.146 [m]$
* $D_B = 49.3 [mm] = 0.0493 [m]$
* $\varepsilon = 1.5 \times 10^{-4} [ft] = 4.572 \times 10^{-5} [m]$
* $V_A = \frac{0.015 \left[\frac{m^3}{s}\right]}{1.682 \times 10^{-2} [m^2]} = 0.89 \left[\frac{m}{s}\right]$
* $\nu_{1\varepsilon} = 2.12 \times 10^{-5} \left[\frac{m^2}{s}\right]$

$$P_A = 1420.45 - \left(\frac{0.015\ \frac{m}{s}}{1166468.5}\right) + \left(\frac{\frac{V_B}{1.905\times10^{-3}}}{10299212.6}\right) + 192.5\,[m] + \frac{0.25}{\left[\log\left(\frac{1}{3.7\left(\frac{0.146}{4.6\times10^{-5}}\right)} + \frac{5.74}{\left(\frac{0.89\times0.146}{1.5\times10^{-4}}\right)^{0.9}}\right)\right]^2}\ \frac{180\,[m]}{0.146\,[m]}\ \frac{\left(\frac{0.015}{1.682\times10^{-2}}\right)^2}{2(9.81\times10^3)}$$

$$+0.35\,\frac{\left(\frac{0.015}{1.682\times10^{-2}}\right)}{(2)(9.81)} + \frac{0.25}{\left[\log\left(\frac{1}{3.7\left(\frac{0.0493}{4.6\times10^{-5}}\right)} + \frac{5.74}{\left(\frac{V_B\,1.0493}{2.12\times10^{-5}}\right)^{0.9}}\right)\right]^2}\ \frac{8\,[m]}{1.905\times10^{-3}}\ \frac{\left(\frac{\frac{V_B}{1.905\times10^{-3}}}{1.905\times10^{-3}}\right)^2}{2(9.81)}$$

Assuming $V_B = 2$ $\quad$ %Diff = 100.00%

$V_B = 742$ $\quad$ % Diff = 74136.93%

$V_B = 0.89$ $\quad$ % Diff = −11%

$\boxed{V_B = 1}$ $\quad$ % Diff = 0%

$$\boxed{P_A = 223570.6\left[\frac{N}{m^2}\right]}$$

11.20

$$\frac{\cancel{P_A}}{\gamma} + \frac{\cancel{V_A^2}}{2g} + z_A = \frac{\cancel{P_B}}{\gamma} + \frac{\cancel{V_B^2}}{2g} + \cancel{z_B} + h_{L\,A\to B}$$

$$z_A = f\left(\frac{L_B}{D_B}\right)\left(\frac{1}{2g}\right)\left(\frac{16 Q^2}{\pi^2 D^4}\right) + K_{valve} + K_{elbow}$$

$$D = \left(\left(f\left(\frac{L_B}{2g}\right)\left(\frac{16(Q^2)}{\pi^2 \, z_A}\right)\right) + K_{valve} + K_{elbow}\right)^{1/5}$$

12.30 I $Q_1 = Q_2 + Q_3$.

II $\frac{\Delta P}{\gamma} = f_1 \frac{L_1}{D_1} + 2k_{tee}\Big)\left(\frac{8 Q_1}{g\pi^2 D_1^4}\right) + \left(f_2 \frac{L_2}{D_2}\right)\frac{8 Q_2^2}{g\pi^2 D_2^4}$

III $\left(\frac{\Delta P}{\gamma} = f_1 \frac{L_1}{D_1} + 2k_{tee}\right)\left(\frac{8 Q_1}{g\pi^2 D_1^4}\right) + \left(f_3 \frac{L_3}{D_3} + 3K_{elbow} + K_{valve}\right)\frac{8 Q_3}{g\pi D_3^4}$

II $\Delta P = \left(\frac{f_1 L_1}{D_1} + 2k_{tee}\right)\left(\frac{8 Q_1^2}{g\pi^2 D_1^4}\right) + \left(f_2 \frac{L_2}{D_2}\right)\frac{8 Q_2^2}{g\pi^2 D_2^4} \Big/ \gamma$

III $\Delta P = \left(\frac{f_1 L_1}{D_1} + 2k_{tee}\right)\left(\frac{8 Q_1^2}{g\pi^2 D_1^4}\right) + \left(f_2 \frac{L_3}{D_3}\right)\frac{8 Q_3}{g\pi^2 D_3^4} \Big/ \gamma$