HW 3.1&3.2

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

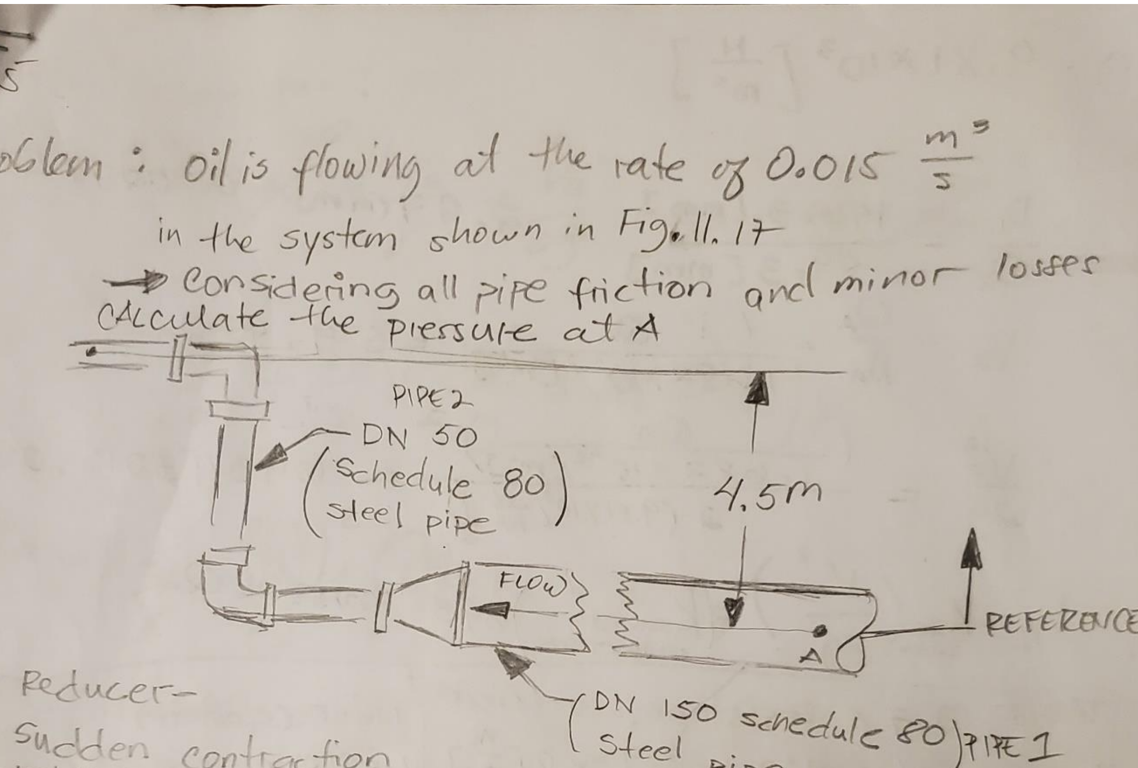


TABLE F.2 Schedule 80

Nominal Pipe Size		Outside Diameter		Wall Thickness		Inside Diameter			Flow Area		
NPS (in	DN (mm)	(in)	(mm)	(in)	(mm)	(in)	(ft)	(mm)	(ft^2)	(m^2)	
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 $[\frac{N}{m^2}]$

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

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

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

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

$$h_L = K_{\substack{sudden\\contractn}}\left(\frac{V_2^2}{2g}\right) = (K_{\substack{sudden\\contraction}}) \, 69343015.05 \, Q_A^2$$

TABLE 10.7A Resistance coefficient / TABLE (CLOSEST)
Assuming: $V_2 = 7.9 \,[\frac{m}{s}] \approx 8 \,[\frac{m}{s}]$ / $V_2 = 9 \,[\frac{m}{s}]$
$\frac{D_1}{D_2} = 2.97 \approx 3.0$
Resistance coefficient $k = 0.35$

* $K_{ELBOW} = 30 f_T$

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

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

* Floxion:

Q Find $P_A = ?$

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

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

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

$$P_A = \left(\left(\frac{12{,}500{,}000 [\frac{N}{m^2}]}{8800 [\frac{N}{m^3}]} \right) - \left(\frac{\frac{Q_A}{1.682 \times 10^{-2} [m^2]}}{2(9.81 \times 10^3 [\frac{N}{m^2}])} \right) + \left(\frac{\frac{Q_B}{1.905 \times 10^{-3} [m^2]}}{2(9.81 \times 10^3 [\frac{N}{m^3}])} \right) + 180 [m] + 8 [m] \right.$$

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

$$P_A = 1420.45 - \left(\frac{Q_A}{1160468.49} \right) + \left(\frac{Q_B}{10299212.6} \right) + 192.5 [m] + h_L$$

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

* $h_L = ?$ Energy losses = ?

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

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

*

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

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

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

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

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

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

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

Assuming $V_B = 2$ $\%\text{Diff} = 100.00\%$

$V_B = 742$ $\%\text{ Diff} = 74136.93\%$

$V_B = 0.89$ $\%\text{ Diff} = -11\%$

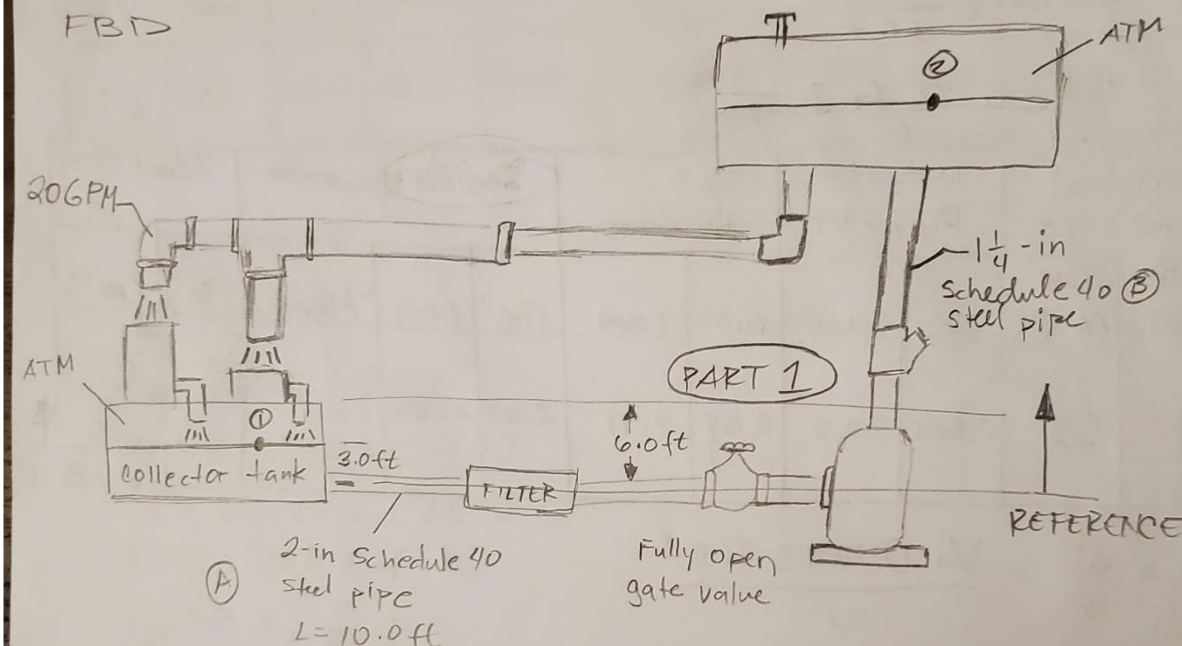
$\boxed{V_B = 1}$ $\%\text{ Diff} = 0\%$

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

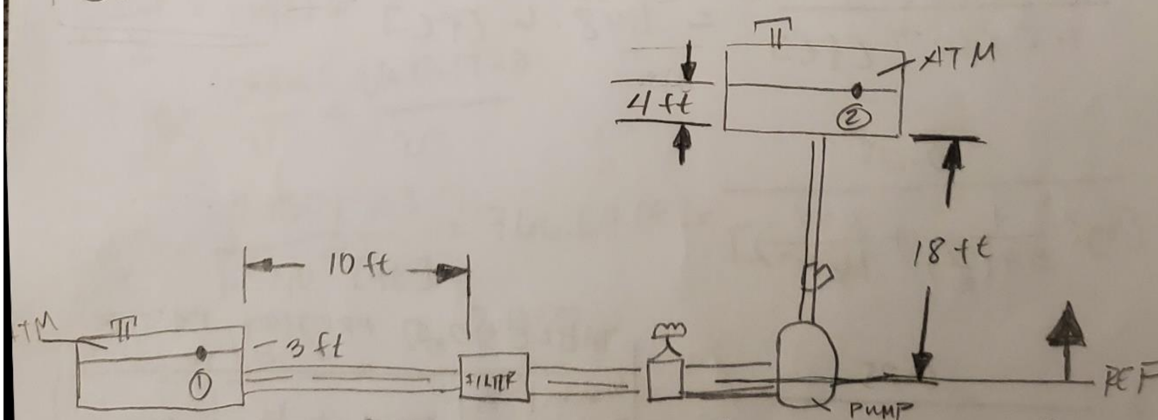
11.23

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



$$h_{A_1} + \cancel{\frac{P_{A_1}}{\gamma_1}}^{0} + \cancel{\frac{V_A^2}{2g}}^{0} + z_A = \cancel{\frac{P_{B_1}}{\gamma}}^{0} + \cancel{\frac{V_{B_1}^2}{2g}}^{0} + z_{B_1} + h_{L_1} + \cancel{h_{R_1}}^{0}$$

* 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 (A)

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}

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

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

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

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

TABLE 10.5 FRICTION FACTOR

Nominal Pipe size [in]	FRICTION FACTOR F_T
2	0.019

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

Norminal 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	9.65×10^{-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 $\left(\frac{L_e}{D}\right) = 8$

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

* SWING CHECK VALUE

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

* 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

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

$$h_A = 19[ft] + 0.5\frac{\left(\frac{Q_A}{A_A}\right)^2}{2g} + 2\left(f_A \frac{L_A}{D_A}\frac{\left(\frac{Q_A}{A_A}\right)^2}{2g}\right) + K_{FILTER}\left(\frac{\left(\frac{Q_A}{A_A}\right)^2}{2g}\right) + .152\left(\frac{\left(\frac{Q_A}{A_A}\right)^2}{2g}\right) + 1.9\left(\frac{\left(\frac{Q_B}{A_B}\right)^2}{2g}\right) +$$

$$f_B \frac{L_B}{D_B}\frac{\left(\frac{Q_B}{A_B}\right)^2}{2g} + (1.0)\left(\frac{\left(\frac{Q_B}{A_B}\right)^2}{2g}\right)$$

$$h_A = 19 - 0.5\frac{\left(\frac{Q_A}{A_A}\right)^2}{2g} - 2\left(\frac{0.25}{\left[\log\left(\frac{1}{3.7\left(\frac{D_A}{\varepsilon}\right)} + \frac{5.74}{N_R^{0.9}}\right)\right]^2}\right)\frac{L_A}{D_A}\frac{\left(\frac{Q_A}{A_A}\right)^2}{2g} - K_{FILTER}\left(\frac{\left(\frac{Q_A}{A_A}\right)^2}{2g}\right) - .152\left(\frac{\left(\frac{Q_A}{A_A}\right)^2}{2g}\right) = 1.9\left(\frac{\left(\frac{Q_B}{A_B}\right)^2}{2g}\right) +$$

$$\left(\frac{0.25}{\left[\log\left(\frac{1}{3.7\left(\frac{D_B}{\varepsilon}\right)} + \frac{5.74}{N_{R_B}^{0.9}}\right)\right]^2}\right)\frac{L_B}{D_B}\frac{\left(\frac{Q_B}{A_B}\right)^2}{2g} + (1.0)\left(\frac{\left(\frac{Q_B}{A_B}\right)^2}{2g}\right)$$

$$h_A - 19 - \left(0.5 + 2\left(\frac{0.25}{\left[\log\left(\frac{1}{3.7\frac{D_B}{\varepsilon}} + \frac{5.74}{N_R^{0.9}}\right)\right]^2}\right)\frac{L_A}{D_A} + K_{FILTER} + .152\right)\left(\frac{\left(\frac{Q_A}{A_A}\right)^2}{2g}\right) =$$

$$\left(1.9 + \left(\frac{0.25}{\left[\log\left(\frac{1}{3.7\left(\frac{D_B}{\varepsilon}\right)} + \frac{5.74}{N_{R_B}^{0.9}}\right)\right]^2}\right)\frac{L_B}{D_B} + (1.0)\right)\left(\frac{\left(\frac{Q_B}{A_B}\right)^2}{2g}\right)$$

$$Q_B = \sqrt{\frac{-19-(0.5+2\ \ldots}{1.9+\ \ldots}}$$

QA=	0.02	M3/S
G=	9,810.00	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
LENGTH=	4.50	M
PB	12500000	N/M2
SW	8800	N/M3

VB	PA	PB/SW	VA/2G	QB	VB/2G	ZB	PIPE1
2.00	223,584.66	1,420.45	0.00	1,049.87	28.09	192.50	221,943.62
742.37	233,982.90	1,420.45	0.00	389,695.18	10,426.32	192.50	221,943.62
0.89	223,569.08	1,420.45	0.00	467.19	12.50	192.50	221,943.62
1.00	223,570.62	1,420.45	0.00	524.93	14.04	192.50	221,943.62

REDUCER	FB	PIPE2	VB	% DIFF
0.00	0.02	1,100,488,671.69	742.37	100.00%
0.00	0.02	1,100,488,671.69	204,564,400.65	74136.93%
0.00	0.02	1,100,488,671.69	245,244.93	-11.00%
0.00	0.02	1,100,488,671.69	275,556.11	0.00%

10.000000	FT	QA=	0.044543	(FT3/s)
20.000000	FT	QB=	0.022272	(FT3/s)
0.023330	FT2	KFILTER	1.85	
0.010390	FT2	HA=	34	FT
0.172300	FT	PA	57.5	N/FT^3
0.115000	FT			
32.200000	FT/S^2			
0.000150	FT			
19.000000	FT			
64,100.000000				

	Assume						Assume	
Iteration	QA (FT3/s)	ReA	(DA/e)1	f1	fT1	NUM	f2	(DB/e)2
1	0.044543	5.90E-03	8.71E-04	0.0287	1.90E-01	-289.4433087	0.010000	1.30E-03
	0.022272	2.95E-03	8.71E-04	0.0253	1.19E+00	-266.0002663	0.046592	1.30E-03

fT2	DEN	QB (FT3/s)	Re2	f2	%diff2	PA NEW	%diff2
1.90E-01	343.1932	0.022272	1.64E+03	0.0466	365.91%		
1.19E+00	813.9753	1.85	1.37E+05	0.0466	0.00%		