Devon Moore

MET 350

Dr. Ayala

November 19, 2021

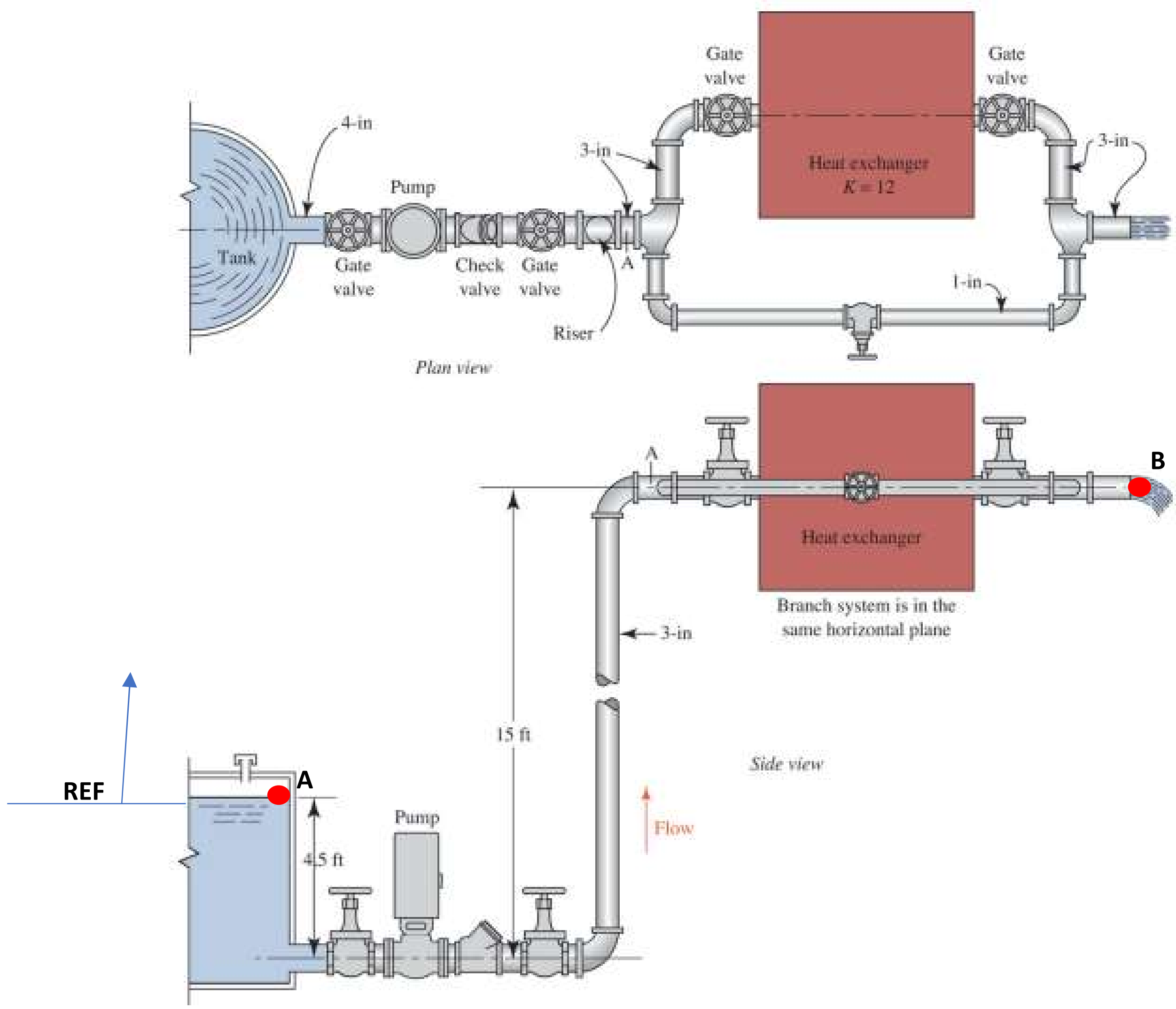
Exam 3 Pretest

A.

Purpose:

Determine the pump power when the bypass gate valve is closed.

Drawings and Diagrams:



Sources:

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Endmemo. EndMemo. (n.d.). Retrieved November 22, 2021, from http://www.endmemo.com/sconvert/galus_minft3_s.php.

Mott, R., Untener, J.A, "Applied Fluid Mechanics", 7th edition, Pearson Education, Inc (2015)

Design Considerations:

- Constant Properties
- Incompressible Fluids
- Water @ 160˚F
- Standard Elbows
- Reducer assumed to be 50-60 degree gradual from 3in to 1in
- Reduced assumed to be sudden with 3 m/s CV from 4in to 3in
- Expander assumed to be 60 degree gradual from 1in to 3in

Data & Variables:

- γ= 61 lb/ft^3
- v= 4.38E-6 ft^2/s
- Suction diameter 0.3355 ft
- Suction area 0.08840 ft^2
- Suction length 10 ft
- Discharge diameter 0.2557 ft
- Discharge area 0.05132 ft^2
- Discharge length 40 ft
- ΔZ= 10.5 ft
- K_{HE}= 12
- Left pipe diameter 0.2557 ft
- Left pipe area 0.05132 ft^2
- Left pipe length 8 ft
- Bypass pipe diameter 0.0874 ft
- Bypass pipe area 0.00600 ft^2
- Bypass pipe length 30 ft
- $K_{red\ 3\text{-}1}$ =0.079
- $K_{red\ 4\text{-}3}$ =0.14
- $K_{exp\ 1\text{-}3}$= 0.71
- K_{GV}= 8f_t
- K_{Tees}= 60f_t
- K_{elbows}= 30f_t
- K_{CV}= 100f_t
- $K_{Entrance}$= 0.5
- e = 0.00015
- n= 0.7
- Q= 275 GPM

Materials:

- Schedule 40 Steel pipe
- Water

Procedure:

1. Rearrange Bernoulli's to solve for pump head.
2. Solve for the pump head in the left branch.
3. Plug pump head into equation 13-2 from the textbook to determine pump power.
4. Use equation 13-4 from the textbook to determine the power input to the pump.

Calculations:

$$\frac{\cancelto{0}{P_A}}{\gamma} + \frac{\cancelto{0}{V_A^2}}{2g} + \cancelto{0}{z_A} = \frac{\cancelto{0}{P_B}}{\gamma} + \frac{V_B^2}{2g} + z_B + h_{L_{A-B}} + h_a$$

$$h_a = z_B + \frac{V_B^2}{2g} + h_{L_{AB}}$$

$$V = \frac{4Q}{\pi D^2} = \frac{4(0.6127\ ft^3/s)}{\pi\ 0.3355ft^2} = 6.93\ ft/s$$

$$h_{L_{pipes}} = f\frac{L}{D}\frac{V^2}{2g} = 0.0297\left(\frac{10ft}{0.3355ft}\right)\frac{6.93^2\ ft/s}{64.4\ ft/s} = 0.01955ft$$

$$f = \frac{(0.25)}{\left[\log\left\{\frac{1}{3.7\,D/\epsilon} + \frac{5.74}{N_R^{0.9}}\right]\right]^2} = \frac{0.25}{\left[\log\left[\frac{1}{3.7(223.67)} + \frac{5.74}{5.71E5^{0.9}}\right]\right]^2}$$

$$f = 0.0297$$

Minor Loss Example Calc:

$$h_{L_{gv}} = K\frac{V^2}{2g} = 8f_t\left(\frac{6.93\ ft/s^2}{64.4\ ft/s}\right) = 0.175ft$$

$$f_t = \frac{(0.25)}{\left[\log\left\{\frac{1}{3.7\,D/\epsilon}\right]\right]^2} = \frac{(0.25)}{\left[\log\left\{\frac{1}{3.7(223.67)}\right)\right]^2} = 0.0294$$

$$h_a = 10.5ft + \frac{11.93\ ft/s^2}{64.4\ ft/s} + 53.794 = 66.5ft$$

$$P_A = \gamma h_a Q = (61\ lb/ft^3)(66.5ft)(0.612703\ ft^3/s)$$
$$= 2485.745\ ft\text{-}lb/s \times 0.00181818 = 4.519\ HP$$

$$P_I = P_A/\eta = \frac{2485.745\ ft\text{-}lb/s}{0.7} = 3551.136\ ft\text{-}lb/s \times 0.00181818$$
$$= 6.45\ HP$$

Excel work:

Q	275	GPM	0.6127	ft^3/s
y	61	lb/ft^3		
viscosity	4.38E-06	ft^2/s		
delta_Z	10.5	ft		
n	0.7			
e	0.0015			
	4 in			
d_suction	0.3355	ft		
a_suction	0.0884	ft^2		
L_suction	10	ft		
Entrance Loss				
K	0.5			
V	6.930668	ft/s		
V^2/g	0.745872			
hL	0.372936	ft		
Gate Valve				
K	8			
D/e	223.6667			
ft	0.029365			
V	6.930668	ft/s		
V^2/g	0.745872			
hL	0.175219	ft		
Pipes				
Nr	5.31E+05			
D/e	223.6667			
f	0.0297			
V	6.930668	ft/s		
V^2/g	0.745872			
L/D	29.80626	ft		
hL	0.01955	ft		
Reducer				
K	0.14			
V	6.930668	ft/s		
V^2/g	0.745872			
hL	0.104422	ft		
3 in				
d_discharge	0.2557	ft		
a_discharge	0.05132	ft^2		
L_discharge	40	ft		

Elbows			**Left pipe (3 in)**		
K	30		d_left	0.2557	ft
D/e	170.4667		a_left	0.05132	ft^2
ft	0.031891		L_left	8	ft
V	11.9316	ft/s			
V^2/g	2.210607		**Heat Exchanger**		
hL	4.229957	ft	K	12	
			V	11.9316	ft/s
Gate Valve			V^2/g	2.21061	
K	8		hL	26.5273	ft
D/e	170.4667				
ft	0.031891		**Gate Valves**		
V	11.9316	ft/s	K	8	
V^2/g	2.210607		D/e	170.467	
hL	0.563994	ft	ft	0.03189	
			V	11.9316	ft/s
Check Valve			V^2/g	2.21061	
K	100		hL	1.69198	ft
D/e	170.4667				
ft	0.031891		**Elbows**		
V	11.9316	ft/s	K	30	
V^2/g	2.210607		D/e	170.467	
hL	7.049928	ft	ft	0.03189	
			V	11.9316	ft/s
Pipes			V^2/g	2.21061	
Nr	6.97E+05		hL	4.22996	ft
D/e	223.6667				
f	0.0296		**Tees Branch**		
V	11.9316	ft/s	K	60	
V^2/g	2.210607		D/e	170.467	
L/D	156.4333	ft	ft	0.03189	
hL	0.302826	ft	V	11.9316	ft/s
			V^2/g	2.21061	
hL_discharge	12.81883	ft	hL	8.45991	ft
hL_total	53.79918	ft			
			Pipes		
			Nr	6.97E+05	
			D/e	170.467	
			f	0.0321	
			V	11.9316	ft/s
			V^2/g	2.21061	
			L/D	31.2867	ft
			hL	0.07121	ft
			hl_left	40.9803	ft

ha_pump	66.5098	ft		
P_A	2485.8	ft-lb/s	4.51962	HP
P_I	3551.14	ft-lb/s	6.4566	HP

Summary:

The pump head is 66.5 ft. Using equation 13-2 we find Pa to be 2485.8 ft-lb/s which is 4.52 HP. Using equation 13-4 we find Pi to be 3551.14 ft-lb/s which is 6.45 HP.

Analysis:

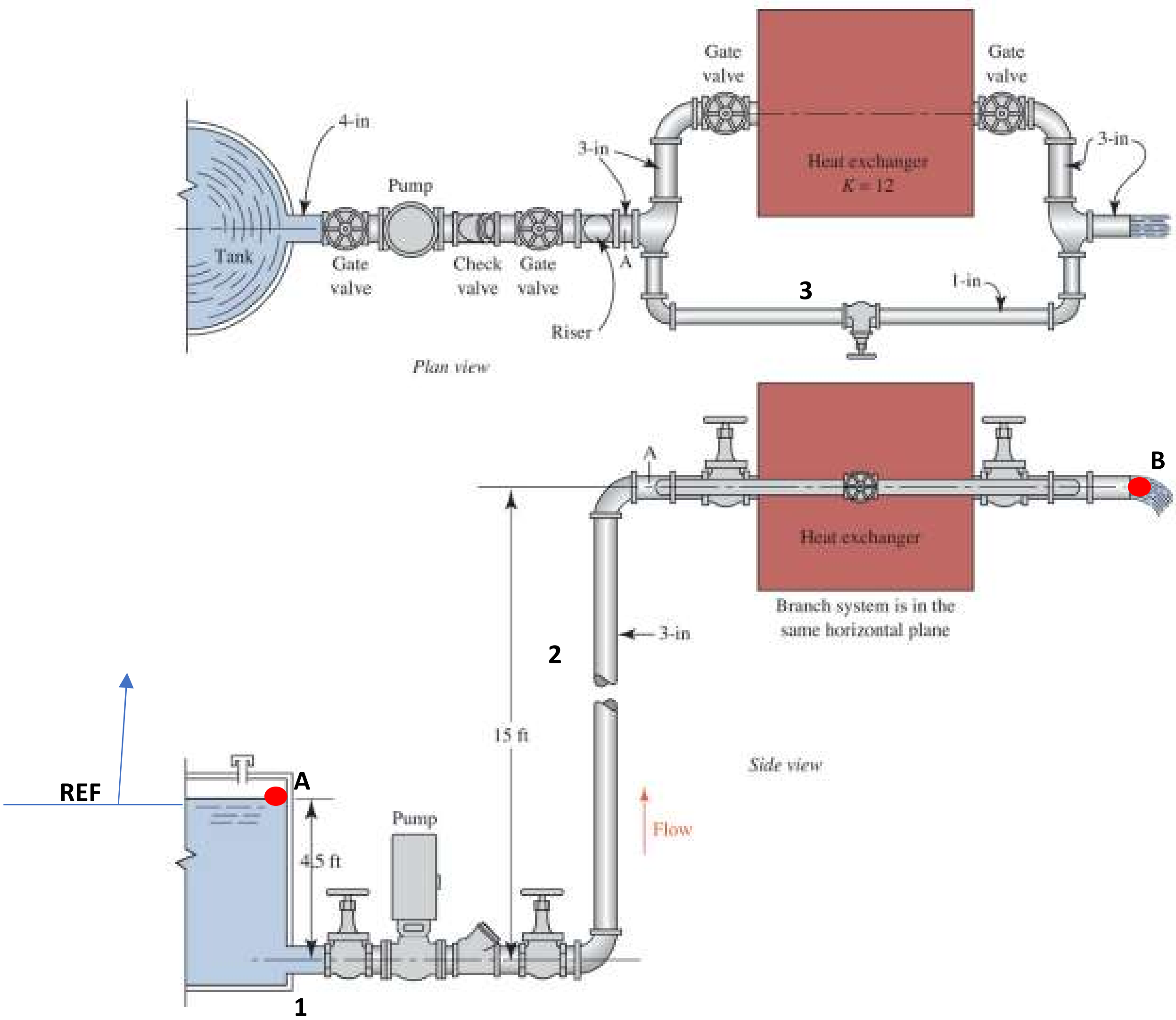
Only the losses in the suction, discharge, and heat exchanger branches are accounted for because the gate valve in the bypass branch is closed. Because ha is affected by energy losses, when the gate valve is opened, the pump head will increase if the flow rate is held constant.

B.

Purpose:

Determine the flow rate if the gate valve in the bypass line is at open to at different intervals.

Drawings and Diagrams:



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- Discharge length 40 ft
- ΔZ= 10.5 ft
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- Left pipe diameter 0.2557 ft
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- Left pipe length 8 ft
- Bypass pipe diameter 0.0874 ft
- Bypass pipe area 0.00600 ft^2
- Bypass pipe length 30 ft
- $K_{red\ 3\text{-}1}$ =0.079
- $K_{red\ 4\text{-}3}$ =0.14
- $K_{exp\ 1\text{-}3}$= 0.71
- K_{GV}= $8f_t$
- K_{Tees}= $60f_t$
- K_{elbows}= $30f_t$
- K_{CV}= $100f_t$
- $K_{Entrance}$= 0.5
- e = 0.00015
- n= 0.7
- GV ¼ L_e/D= 900
- GV ½ L_e/D= 160
- GV 3/4 L_e/D= 35

Materials:

- Schedule 40 Steel pipe
- Water

Procedure:

1. Using the pump power from part A and use equation 13-2 to replace pump head in Bernoulli's, rearrange Bernoulli's to solve for flow rate.
2. Calculate the energy losses for all the components
3. Starting with the gate valve fully closed solve for flow rate to verify it comes close to 275 GPM.
4. Next starting with the gate valve ¼ open use excel to iterate for each interval and solve for the flow rate in each branch
5. Add the flow rates to determine the total flow rate at each interval.

Calculations:

$$P_a = \gamma h_a Q \quad = \frac{P_a}{\gamma Q} = h_a$$

$$\frac{P_a}{\gamma Q} = Z_B + \frac{16 Q_2^2}{\pi^2 D_2^4} + h_{L_{A\text{-}B}}$$

h_L branch 2

$$K_{ent} \frac{16 Q_1^2}{\pi^2 D_1^4} \frac{1}{2g} + K_{gv} \frac{16 Q_1^2}{\pi^2 D_1^4} \frac{1}{2g} + f_1 \frac{L_1}{D_1} \frac{16 Q_1^2}{\pi^2 D_1^4} \frac{1}{2g} + K_{red} \frac{16 Q_1^2}{\pi^2 D_2^4} \frac{1}{2g}$$

$$+ 2\left(K_{elb} \frac{16 Q_1^2}{\pi^2 D_2^4} \frac{1}{2g}\right) + k_{gv} \frac{16 Q_2^2}{\pi^2 D_2^4} \frac{1}{2g} + k_{cv} \frac{16 Q_2^2}{\pi^2 D_2^4} \frac{1}{2g} + f_2 \frac{L_2}{D_2} \frac{16 Q_2^2}{\pi^2 D_2^4} \frac{1}{2g}$$

$$+ f_2 \frac{L_{2A}}{D_2} \frac{16 Q_2^2}{\pi^2 D_2^4} \frac{1}{2g} + K_{HE} \frac{16 Q_2^2}{\pi^2 D_2^4} \frac{1}{2g} + 2\left(k_{gv} \frac{16 Q_2^2}{\pi^2 D_2^4} \frac{1}{2g}\right) + 2\left(k_{elb} \frac{16 Q_2^2}{\pi^2 D_2^4} \frac{1}{2g}\right)$$

$$+ 2\left(k_{tee\ branch} \frac{16 Q_2^2}{\pi^2 D_2^4} \frac{1}{2g}\right)$$

h_L branch 3

$$K_{ent} \frac{16 Q_1^2}{\pi^2 D_1^4} \frac{1}{2g} + k_{gv} \frac{16 Q_1^2}{\pi^2 D_1^4} \frac{1}{2g} + f_1 \frac{L_1}{D_1} \frac{16 Q_1^2}{\pi^2 D_1^4} \frac{1}{2g} + k_{red} \frac{16 Q_1^2}{\pi^2 D_2^4} \frac{1}{2g}$$

$$+ 2\left(k_{elb} \frac{16 Q_1^2}{\pi^2 D_2^4} \frac{1}{2g}\right) + k_{gv} \frac{16 Q_2^2}{\pi^2 D_2^4} \frac{1}{2g} + k_{cv} \frac{16 Q_2^2}{\pi^2 D_2^4} \frac{1}{2g} + f \frac{L_2}{D_2} \frac{16 Q_2^2}{\pi^2 D_2^4} \frac{1}{2g}$$

$$+ f_3 \frac{L_3}{D_3} \frac{16 Q_3^2}{\pi^2 D_3^4} \frac{1}{2g} + 2\left(k_{tee\ main} \frac{16 Q_3^2}{\pi^2 D_3^4} \frac{1}{2g}\right) + k_{red} \frac{16 Q_3^2}{\pi^2 D_3^4} \frac{1}{2g} + k_{exp} \frac{16 Q_3^2}{\pi^2 D_3^4} \frac{1}{2g}$$

$$+ \left(L_e/D\right)\left(\frac{16 Q_3^2}{\pi^2 D_3^4}\right)$$

Example F_t

$$f_t = \frac{0.25}{\left[\log\left(\frac{1}{3.7(D/\epsilon)}\right)\right]^2} = \frac{0.25}{\left[\log\left(\frac{1}{3.7(594.26)}\right)\right]^2}$$

$$Q_3 = \sqrt{\frac{\frac{P_A}{\gamma Q} - Z_B - 39.45\, Q_1^2 - 921.17 f_2\, Q_1^2 - 59.22 f_1\, Q_1^2}{372.82 + 1440807 f_3 + (\frac{L}{D})\, 19.404}}$$

$$Q_2 = \sqrt{\frac{\frac{P_A}{\gamma Q} - Z_B - 39.45\, Q_1^2 - 921.172 f_2\, Q_1^2 - 59.22 f_1 Q_1^2}{184.23 f_2 \quad - 107.47}}$$

$$Q_T = Q_2 + Q_3$$

$$\% \text{diff} = \frac{Q_{1\,new} - Q_{1\,old}}{Q_{1\,new}} \times 100$$

$$Re = \frac{VD}{\nu}$$

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

$$\% \text{diff} = \frac{f_{new} - f_{old}}{f_{new}} \times 100$$

Excel Work:

	Part A	γ	61	lb/ft^3
	P_I	viscosity	4.38E-06	ft^2/s
	3551.1363	delta_Z	10.5	ft
		n	0.7	
PA	2485.7954	e	0.0015	
		V	5.88859	*Q_1^2
			4 in	
		d_suction	0.3355	ft
		a_suction	0.0884	ft^2
		L_suction	10	ft
		Entrance Loss		
		K	0.5	
		V	0	ft/s
		V^2/g	0	
		hL	0.99342	Q_1^2
		Gate Valve		
		K	8	
		D/e	223.667	
		ft	0.02936	
		hL	0.46675	Q_1^2
		Pipes		
		Nr	0.00E+00	
		D/e	223.667	
		f	#DIV/0!	
		V	0	ft/s
		V^2/g	0	
		L/D	29.8063	ft
		hL	59.2205	f_1*Q_1^2
		Reducer		
		K	0.14	
		V	0	ft/s
		V^2/g	0	
		hL	0.27816	Q_1^2
		3 in		
		d_discharge	0.2557	ft
		a_discharge	0.05132	ft^2
		L_discharge	40	ft

1 in			**Elbows**			**Left pipe (3 in)**		
d_bypass	0.0874	ft	K	30		d_left	0.2557	ft
a_bypass	0.006	ft^2	D/e	170.467		a_left	0.05132	ft^2
L_bypass	30	ft	ft	0.03189		L_left	8	ft
Gate Valve						**Heat Exchanger**		
K	8		hL	11.2677	Q_1^2	K	12	
D/e	58.2667							
ft	0.04591		**Gate Valve**					
1/4 Le/D	900		K	8		hL	70.6631	Q_2^2
1/2 Le/D	160		D/e	170.467				
2/3 Le/D	35		ft	0.03189		**Gate Valves**		
hL_1/4	19.8047	Q_3^2				K	8	
hL_1/2	19.8047	Q_3^2				D/e	170.467	
hL_2/3	19.8047	Q_3^2	hL	1.50236	Q_1^2	ft	0.03189	
hl_open	158.437	Q_3^2						
hl_close	0	Q_3^2	**Check Valve**					
Tees Branch			K	100		hL	3.00472	
K	60		D/e	170.467				
D/e	58.2667		ft	0.03189		**Elbows**		
ft	0.04591					K	30	
						D/e	170.467	
			hL	18.7795	Q_1^2	ft	0.03189	
hL	32.4393	Q_3^2						
Reducer						hL	11.2677	Q_2^2
K	0.079							
hL	34.0813	Q_3^2				**Tees Branch**		
						K	60	
expander			**Pipes**			D/e	170.467	
K	0.71		L/D	156.433	ft	ft	0.03189	
hL	306.3	Q_3^2	hL	921.172	f_1*Q_1^2			
Pipes			hL_discharge	31.8278	Q_1^2	hL	22.5354	
Nr	#DIV/0!		hL_suction	1.73833	Q_1^2			
D/e	58.2667		hL_suction pipe	59.2205	f_1*Q_1^2	**Pipes**		
f	#DIV/0!		hL_discharge pipe	921.172	f_2*Q_1^2	Nr	0.00E+00	
						D/e	170.467	
						f	#DIV/0!	
L/D	343.249	ft	hL_total	139.299	ft	V	0	
hL	148081	f_3*Q_3^2				V^2/g	0	
hL_bypass 1/4	372.821	Q_3^2				L/D	31.2867	ft
hL_bypass 1/2	372.821	Q_3^2			hL_3in pip	184.234397	f_2*Q_2^2	
hL_bypass 2/3	372.821	Q_3^2						
hL_bypass Ope	372.821	Q_3^2			hl_left	107.470977	Q^2	
hL_bypass Clos	372.821	Q_3^2						

			1/4 Open			
ITERATIO	1					
f1=	0.01					
f2=	0.01					
f3=	0.01					
				NEW		
ub-Iterati	Q1 (ft^3/s	RHS 01	RHS 02	Q1 (ft3/s)	%diff Q3	
1	0.149000	0.14801	0.00082	0.14883	-0.11%	
	0.620000	0.57619	0.04295	0.61914	-0.14%	
	V1 (ft/s)	V2 (ft/s)	V3 (ft/s)	Re1	Re2	Re3
	1.68543	2.88228	0.13705	1.29E+05	1.68E+05	2.73E+03
	NEW f1	NEW f2	NEW f3	%diff f1	%diff f2	%diff f3
	0.03038	0.03259	0.06049	-203.76%	-225.87%	-504.91%
ITERATIO	2					
f1=	0.03038					
f2=	0.03259					
f3=	0.06049					
				NEW		
ub-Iterati	Q1 (ft^3/s	RHS 01	RHS 02	Q1 (ft3/s)	%diff Q3	
1	0.586000	0.55192	0.03568	0.5876	0.27%	
	V1 (ft/s)	V2 (ft/s)	V3 (ft/s)	Re1	Re2	Re3
	6.62861	10.74789	5.94688	5.08E+05	6.27E+05	1.19E+05
	NEW f1	NEW f2	NEW f3	%diff f1	%diff f2	%diff f3
	0.02967	0.03211	0.04648	2.34%	1.47%	23.17%

ITERATIO	3					
f1=	0.02967					
f2=	0.03211					
f3=	0.04648					
				NEW		
ıb-Iterati	Q1 (ft^3/s	RHS 01	RHS 02	Q1 (ft3/s)	%diff Q3	
1	0.587596	0.55089	0.03704	0.58793	0.06%	
	V1 (ft/s)	V2 (ft/s)	V3 (ft/s)	Re1	Re2	Re3
	6.64667	10.72793	6.17416	5.09E+05	6.26E+05	1.23E+05
	NEW f1	NEW f2	NEW f3	%diff f1	%diff f2	%diff f3
	0.02967	0.03211	0.04646	0.00%	0.00%	0.04%
			1/2 Open			
ITERATIO	4					
f1=	0.02967					
f2=	0.03211					
f3=	0.04646					
				NEW		
ıb-Iterati	Q1 (ft^3/s	RHS 01	RHS 02	Q1 (ft3/s)	%diff Q3	
1	0.595000	0.53889	0.05621	0.5951	0.02%	
	V1 (ft/s)	V2 (ft/s)	V3 (ft/s)	Re1	Re2	Re3
	6.73042	10.49424	9.36947	5.16E+05	6.13E+05	1.87E+05
	NEW f1	NEW f2	NEW f3	%diff f1	%diff f2	%diff f3
	0.02966	0.03211	0.04629	0.01%	-0.01%	0.37%
			2/3 Open			
ITERATIO	5					
f1=	0.02966					
f2=	0.03211					
f3=	0.04629					
				NEW		
ıb-Iterati	Q1 (ft^3/s	RHS 01	RHS 02	Q1 (ft3/s)	%diff Q3	
1	0.598000	0.53397	0.06389	0.59786	-0.02%	
	V1 (ft/s)	V2 (ft/s)	V3 (ft/s)	Re1	Re2	Re3
	6.76435	10.39842	10.64938	5.18E+05	6.07E+05	2.13E+05
	NEW f1	NEW f2	NEW f3	%diff f1	%diff f2	%diff f3
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

			Fully Open			
ITERATIO	6					
f1=	0.02966					
f2=	0.03211					
f3=	0.04624					
				NEW		
ub-Iterati	Q1 (ft^3/s	RHS 01	RHS 02	Q1 (ft3/s)	%diff Q3	
1	0.597863	0.53419	0.06622	0.60041	0.43%	
	V1 (ft/s)	V2 (ft/s)	V3 (ft/s)	Re1	Re2	Re3
	6.76280	10.40269	11.03726	5.18E+05	6.07E+05	2.20E+05
	NEW f1	NEW f2	NEW f3	%diff f1	%diff f2	%diff f3
	0.02966	0.03211	0.04623	0.00%	0.00%	0.02%
			Fully Closed			
ITERATIO	7					
f1=	0.02966					
f2=	0.03211					
f3=	0.04623					
				NEW		
ub-Iterati	Q1 (ft^3/s	RHS 01	RHS 02	Q1 (ft3/s)	%diff Q3	
1	0.575000	0.57097	0	0.57097	-0.70%	
	V1 (ft/s)	V2 (ft/s)	V3 (ft/s)	Re1	Re2	Re3
	6.50419	11.11887	0.00000	4.98E+05	6.49E+05	0.00E+00
	NEW f1	NEW f2	NEW f3	%diff f1	%diff f2	%diff f3
	0.02967	0.03210	#DIV/0!	-0.04%	0.04%	#DIV/0!

Summary:

The total flow rate is approximately 0.59 ft^3/s. As the valve opens, Q3 increases. At ¼ open Q3 is 0.037 ft^3/s and increases to 0.066 ft^3/s when it is fully open.

Analysis:

Because Le/D is much larger when the valve is closest to being shut, it lowers Q3 because it is a large number in the denominator of the equation. When the valve is fully closed it will bring Q3 to zero as seen in part A.