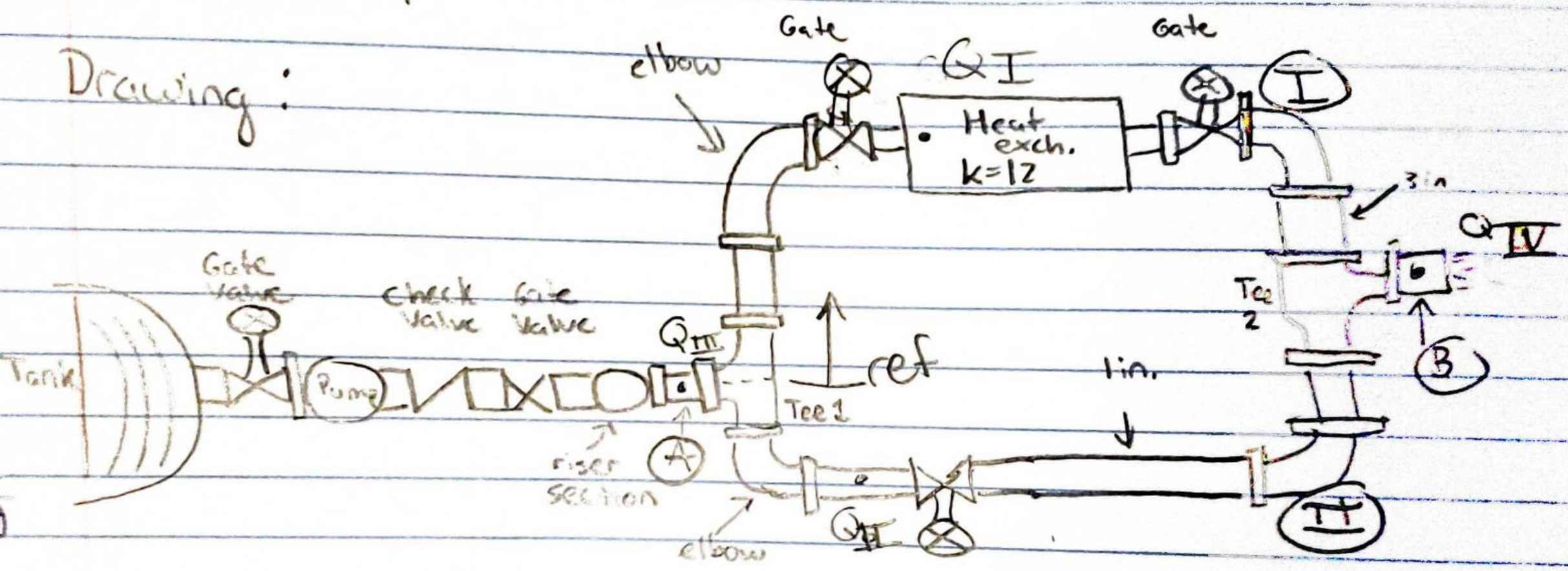
5)

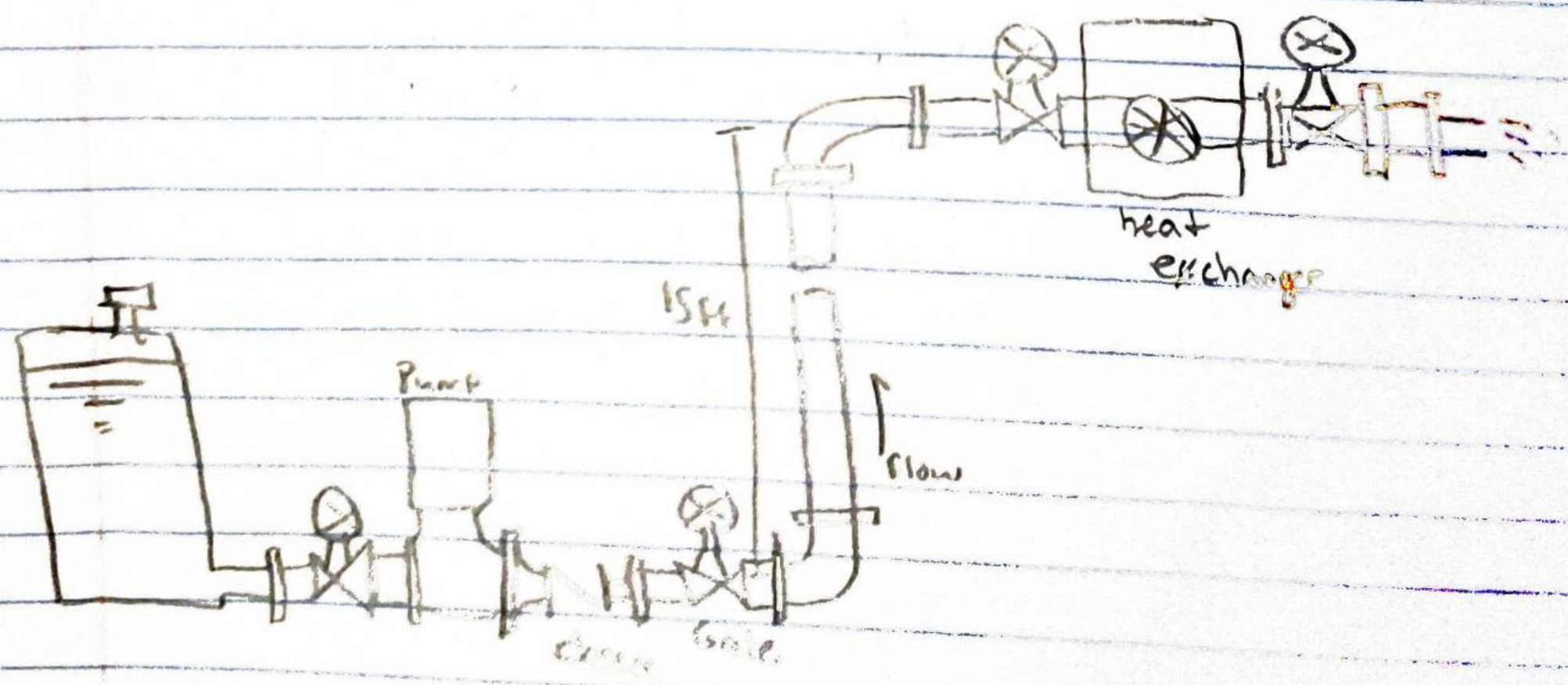
a.

Purpose: Calculate the pump power when the gate valve in the bypass line is completely closed.

b. Calculate the pump power & total flow rate when the bypass is $\frac{1}{4}, \frac{1}{2}, \frac{3}{4}$ & fully open.

Drawing:





Data & Variables

$L_{suct} = 10\,ft$, $L_a = 8\,ft$, $L_b = 30\,ft$ $L_{disch} = 40\,ft$

$NPS_a = 3\,in$, $D_a = 0.2557\,ft$, $NPS_b = 1\,in$, $D_b = 0.0874\,ft$

$T_{wat} = 160°F$, $\gamma = 61.0\ \frac{lb}{ft^3}$, $\rho = 1.90\ \frac{slugs}{ft^3}$, $\mu = 8.30 \times 10^{-6}\ \frac{lb_f}{ft^2}$, $\nu = 4.38 \times 10^{-6}\ \frac{ft^2}{s}$

$K_{Tee,1} = 60 f_T$, $K_{elbow} = 90 f_T$, $K_{Tee,2} = 20 f_T$, $K_{gate} = 8 f_T$

$K_{check} = 150 f_T$

$Q_{min} =$

$\frac{L_e}{D}$:

gate:
- full = 8
- $\frac{3}{4}$ = 35
- $\frac{1}{2}$ = 160
- $\frac{1}{4}$ = 900

swing check = 100 long elbow = 20 tee → = 20 tee ↱ = 60

f_T for 1in NPS = 0.027

f_T for 3in = 0.017

Design Considerations

- Constant Properties
- Incompressible Fluid
- Isothermal conditions
- Steady State
- Newtonian fluid

Materials

- Water @ 160°F
- sch. 40 stainless steel pipe

Objectives Covered

1) Compute select appropriate pump
2) Explain fluid dynamics in pipe
3) Identify & solve for different specific problems

Sources

Applied Fluid Mech. vol 7.

Procedure

Draw System, label reference, Pick Point A, B & Branch I, II

a.

1) Use energy equation for system

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

$$\downarrow$$

$$z_1 + h_A - h_L = z_2$$

$$h_A = z_2 - z_1 + h_L$$

2) $h_L = h_{L\,entrance} + h_{L\,suction} + h_{L\,gate}(2) + h_{L\,check\,valve}$

$+ h_{L\,disch} + h_{L\,exit} + h_{L\,hx\,branch}$

3) Calculate $\frac{V^2}{2g}$, $h_L = K\frac{V^2}{2g}$, $h_L = f\frac{L}{D}\frac{V^2}{2g}$

4) Calculate $P_A = h_A \gamma Q$

b. 1) Rearrange Bernoulli's Eq. for $\frac{\Delta P}{\gamma} = h_{L\,A-B}$

2) Calculate h_L for each branch:

I

$$h_{L\,Tee,1} + h_{L\,elbow_1} + h_{L\,pipe} + h_{L\,elbow_2} + h_{L\,Tee} + h_{L\,gate}(2) + h_{L\,hx}$$

$h_{L\,Tee,1} \to K\frac{V^2}{2g}$, $h_{L\,pipe} = f\frac{L}{D}\frac{V^2}{2g}$, $h_{L\,elbow_2} \to K\frac{V^2}{2g}$

II

$$h_{L\,pipe} + h_{L\,elbow_1} + h_{L\,elbow_2} + h_{L\,gate} + h_{L\,Tee_1} + h_{L\,Tee_2} + h_{L\,red} + h_{L\,exp}$$

3) Compute h_L for valves & fittings

- find $\frac{L_e}{D}$ then find f_T (table 10.5), compute $K = f_T\left(\frac{L_e}{D}\right)$, $h_L = K\frac{V^2}{2g}$

4) Compute h_L for pipe $h_L = f\frac{L}{D}\frac{V^2}{2g}$ (Use $V = \frac{Q}{A}$ for velocity)

5) Use these h_L equations to form

I
$$\frac{\Delta P}{\gamma} = K_{Tee,1}\frac{V^2}{2g} + K_{elbow}\frac{V^2}{2g} + f\frac{L}{D}\frac{V^2}{2g} + K_{elbow}\frac{V^2}{2g} + K_{Tee,2}\frac{V^2}{2g} + (2)\left(K_{gate}\frac{V^2}{2g}\right) + K_{hx}\frac{V^2}{2g}$$

II
$$\frac{\Delta P}{\gamma} = K_{Tee,1}\frac{V^2}{2g} + \left[K_{elbow}\frac{V^2}{2g} + f\frac{L}{D}\frac{V^2}{2g} + K_{gate}\frac{V^2}{2g} + K_{elbow}\frac{V^2}{2g}\right] + K_{Tee_2}\frac{V^2}{2g} + K_{red}\frac{V^2}{2g} + K_{exp}\frac{V^2}{2g}$$

$$V^2 = \frac{16Q^2}{\pi^2 D^4}$$

$$\therefore \text{I} \quad \frac{\Delta P}{\gamma} = 2.60 f_T \frac{1}{2g}\cdot\frac{16Q_{III}^2}{\pi^2 D_{III}^4} + \left(K_{hx} + K_{elbow}(2) + K_{gate}(2) + f\frac{L_I}{D_I}\right)\frac{1}{2g}\frac{16Q_I^2}{\pi^2 D_I^4}$$

6) Solve $\frac{\Delta P}{\gamma} = 120 f_T \cdot \frac{8}{g\pi^2 D_{III}^4} Q_{III}^2 + \left(K_{gate}(2) + K_{nx} + K_{elbow}(2) + f\frac{L_I}{D_I}\right)\frac{8}{g\pi^2 D_I^4} Q_I^2$ (I)

Solve for Q_{III}

7) Solve for $P_{pump\ power} = \frac{Q_{III} h_A \gamma}{\eta}$, $h_A = 15\ ft + (h_{L_{elbow}} \times 2) + h_{L_{disch\ pipe}}$

8) repeat steps iteratively by changing K value of gate valve in bypass branch.

Questions

Are the elbows long radius or regular?

If the gate valve in bypass is shut do we ignore the branch & calculate as series pipeline?

What values do we use for velocity when calculating the various system components head loss.

- How to find Q_{IV} & Q_{I} & Q_{II}

DATA

p1=	11520	lb/ft2
p2=	8640	lb/ft2
L=	600	ft
Z2=	25	ft
gamma=	61	lb/ft2
ν=	4.38E-06	ft2/s
e=	0.00015	ft
Q=	0.612703	ft3/s
Asuct	0.0884	ft^2
Adish	0.05132	ft^2
Dsuct (ft)	0.3355	ft
Ddisch	0.2557	ft

Vsuct(ft/s)	Re	D/e	f suct	fT
6.931024	5.31E+05	2236.667	0.0174	0.0163

Vdisch	Re	D/e	f disch	fT
11.93886	6.97E+05	1704.667	0.018057	0.0173

$D=\sqrt{(5\&(f(8LQ^2)/(g\pi^2))/((p_A-p_B)/\gamma-Z_{A))}}$

$Re=VD/\upsilon$

Relative roughness$=D/\epsilon$

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

$f=0.25/[\log(1/3.7(D/\varepsilon)+5.74/[Re]^{0.9})]^2$

%diff$=(f^{(old)}-f^{(new)})/f^{(old)}\times 100$