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MET 330 Fluid Mechanics
Dr. Orlando Ayala
Spring 2021
Test 3

Take home – Due Sunday April 18th, 2021 before midnight.

READ FIRST

1. RELAX!!!! DO NOT OVERTHINK THE PROBLEMS!!!! There is nothing hidden. The test was designed for you to pass and get the maximum number of points, while learning at the same time. HINT: THINK BEFORE TRYING TO USE/FIND EQUATIONS (OR EVEN FIND SIMILAR PROBLEMS)

2. The total points on this test are one hundred (100). Ten (10) points are from your HW assignments. The other ninety (90) points will come from the problem solutions. Fort his test, there is no need to present the test following the technical writing, but if you still like to do it, follow the attached rubric.

3. There are 2 main different parts, each one is worth 90/2 points.

4. What you turn in should be only your own work. You cannot discuss the exam with anyone, except me. Call me, skype me, text me, email me, come to my office, if you have any question.

5. I do not read minds. You should be explicit and organized in your answers. Use drawings/figures. If you make a mistake, do not erase it. Rather use that opportunity to explain why you think it is a mistake and show the way to correct the problem.

6. You have to turn in your test ON TIME and ONLY through BLACKBOARD. You must submit the test solution in only one file, and it has to be a pdf file. You must also submit the excel spreadsheet. For the ePortfolio (which is optional) you are supposed to upload this artifact to your Google drive. I will provide more instructions later.

7. Do not start at the last minute so you can handle anything that could happen. Late tests will not be accepted. Test submitted through email will not be accepted either.

8. Cheating is completely wrong. The ODU Student Honor Pledge reads: "I pledge to support the honor system of Old Dominion University. I will refrain from any form of academic dishonesty or deception, such as cheating or plagiarism." By attending Old Dominion University, you have accepted the responsibility to abide by this code. This is an institutional policy approved by the Board of Visitors. It is important to remind you the following part of the Honor Code:

   IX. PROHIBITED CONDUCT

   A. Academic Integrity violations, including:

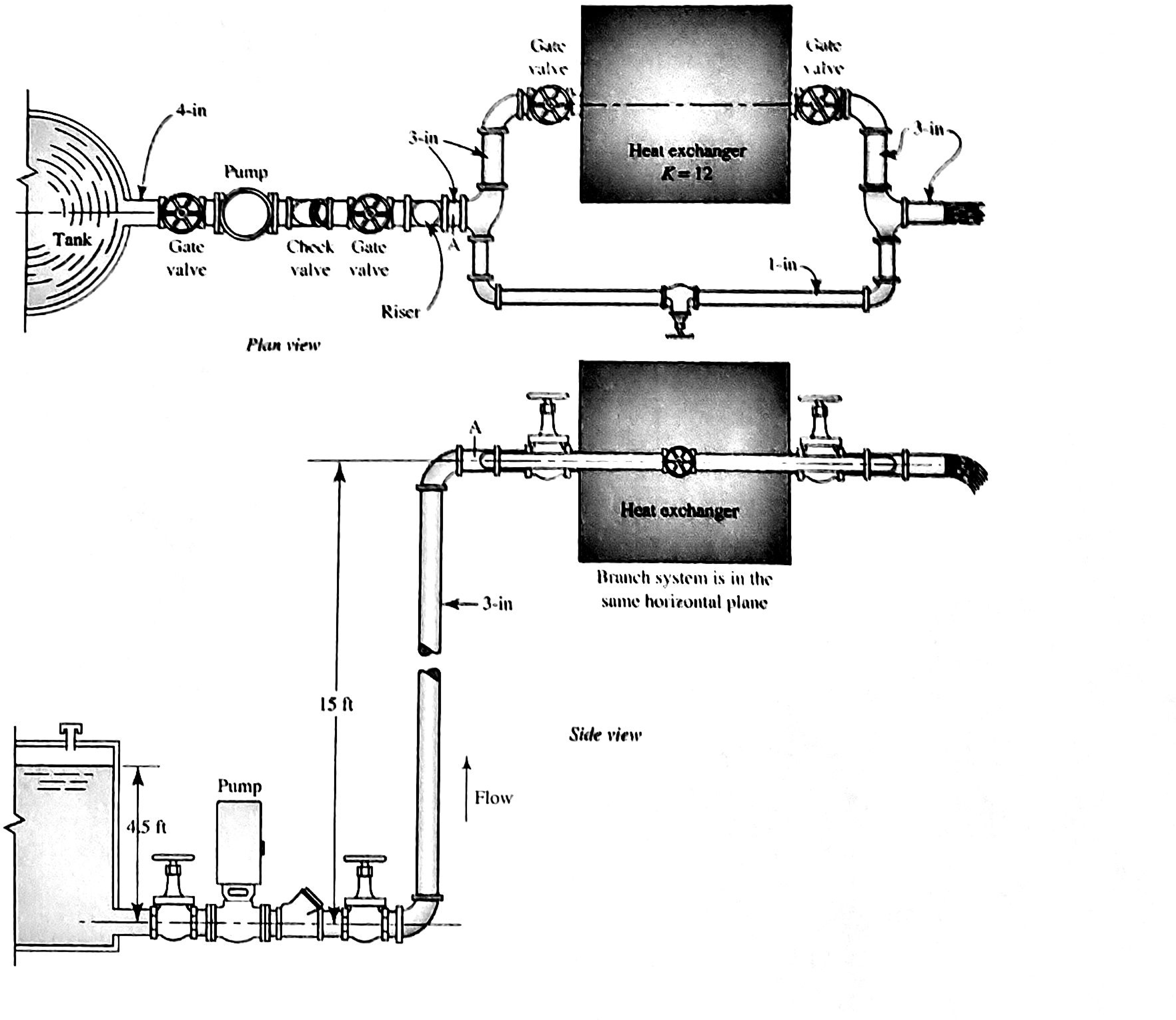
   1. *Cheating*: Using unauthorized assistance, materials, study aids, or other information in any academic exercise (Examples of cheating include, but are not limited to, the following: using unapproved resources or assistance to complete an assignment, paper, project, quiz or exam; collaborating in violation of a faculty member's instructions; and submitting the same, or substantially the same, paper to more than one course for academic credit without first obtaining the approval of faculty).

With that said, you are NOT authorized to use any online source of any type, unless is ODU related.

1. Another company hires you to specify the required pump for the system shown in the figure below. The system is a combination series/parallel system that operates as follows. Water at 160°F is drawn from a tank into the 4-in suction line of the pump. The suction line has a total length of 10 ft. The 3-in discharge line elevates the water 15 ft to the level of a large heat exchanger. The discharge line has a total length of 40 ft. The flow splits into two branches with the primary 3-in line feeding a large heat exchanger that has a K-factor of 12 based on the velocity head in the pipe. The total length of pipe in this branch is 8 ft. The 1-in line is a bypass around the heat exchanger with a total length of 30 ft and has a gate valve. The two lines join at the right and discharge to the atmosphere through a short 3-in pipe. All pipes are Schedule 40 steel. The tees in the picture were specially fabricated for this company and their corresponding K-factor is the same as the one presented in our book for tees.

   a. Calculate the pump power when the gate valve in the bypass is completely closed. The company requires a minimum flow rate of 275 gpm through the heat exchanger. Assume the pump efficiency to be 70%.

   b. Assuming the pump power remains the same, calculate the total flow rate if the gate valve in the bypass is ¼ open, ½ open, ¾ open, and fully open. For this part, you will use excel. You will vary the K value of the valve in one of the spreadsheet cells. Use table 10.4. This is not required, but you might want to test your spreadsheet by using a K value for a fully closed valve, you should get the 275 gpm again (within reasonable error).



Problem solution rubric

	Exceeds Standard	Meets Standard	Approaches Standard	Needs Attention
	4	3	2	1
	10 points	7 points	4 points	0 points
Purpose **5%**	The purpose of the section to be answered is clearly identified and stated.	The purpose of the section to be answered is identified, but is stated in a somewhat unclear manner.	The purpose of the section to be answered is partially identified, and is stated in a somewhat unclear manner.	The purpose of the section to be answered is erroneous or irrelevant.
Drawings & Diagrams **10%**	Clear and accurate diagrams are included and make the section easier to understand. Diagrams are labeled neatly and accurately.	Diagrams are included and are labeled neatly and accurately.	Diagrams are included and are labeled.	Needed diagrams are missing OR are missing important labels.
Sources **5%**	Several reputable background sources were used and cited correctly.	A few reputable background sources are used and cited correctly.	A few background sources are used and cited correctly, but some are not reputable sources.	Background sources are cited incorrectly.
Design considerations (assumptions, safety, cost, etc) **10%**	Design is carried out with applicable assumptions and full attention to safety and cost, etc.	Design is generally carried out with assumptions and attention to safety, cost, etc.	Design is carried out with some assumptions and some attention to safety, cost, etc.	Assumptions, safety and cost were ignored in the design.
Data and variables **5%**	All data and variables are clearly described with all relevant details.	All data and variables are clearly described with most relevant details.	Most data and variables are clearly described with most relevant details.	Data and variables are not described OR the majority lack sufficient detail.
Procedure **25%**	Procedure is described in clear steps. The step description is in a complete and easy to understand short paragraph.	Procedure is described in clear steps but the step description is not in a complete short paragraph.	Procedure is described in clear steps. The step description is in a complete short paragraph but it is difficult to understand.	Procedure is not described in clear steps at all.
Calculations **20%**	All calculations are shown and the results are correct and labeled appropriately. The units of all values are shown.	Some calculations are shown and the results are correct and labeled appropriately.	Some calculations are shown and the results labeled appropriately.	No calculations are shown OR results are inaccurate or mislabeled.
Summary **5%**	Summary describes the design, the relevant information and some future implications.	Summary describes the design and some relevant information.	Summary describes the design.	No summary is written.
Materials **5%**	All materials used in the design are clearly and accurately described.	Almost all materials used in the design are clearly and accurately described.	Most of the materials used in the design are clearly and accurately described.	Many materials are described inaccurately OR are not described at all.
Analysis **10%**	The design is discussed and analyzed. Argumentative predictions are made about what might happen in case of change in the operation and how the design could be change.	The design is discussed and analyzed. Argumentative predictions are made about what might happen in case of change in the operation.	The design is discussed and analyzed. No argumentative predictions are made about what might happen in case of change in the operation and how the design could be change.	The design is not discussed and analyzed.

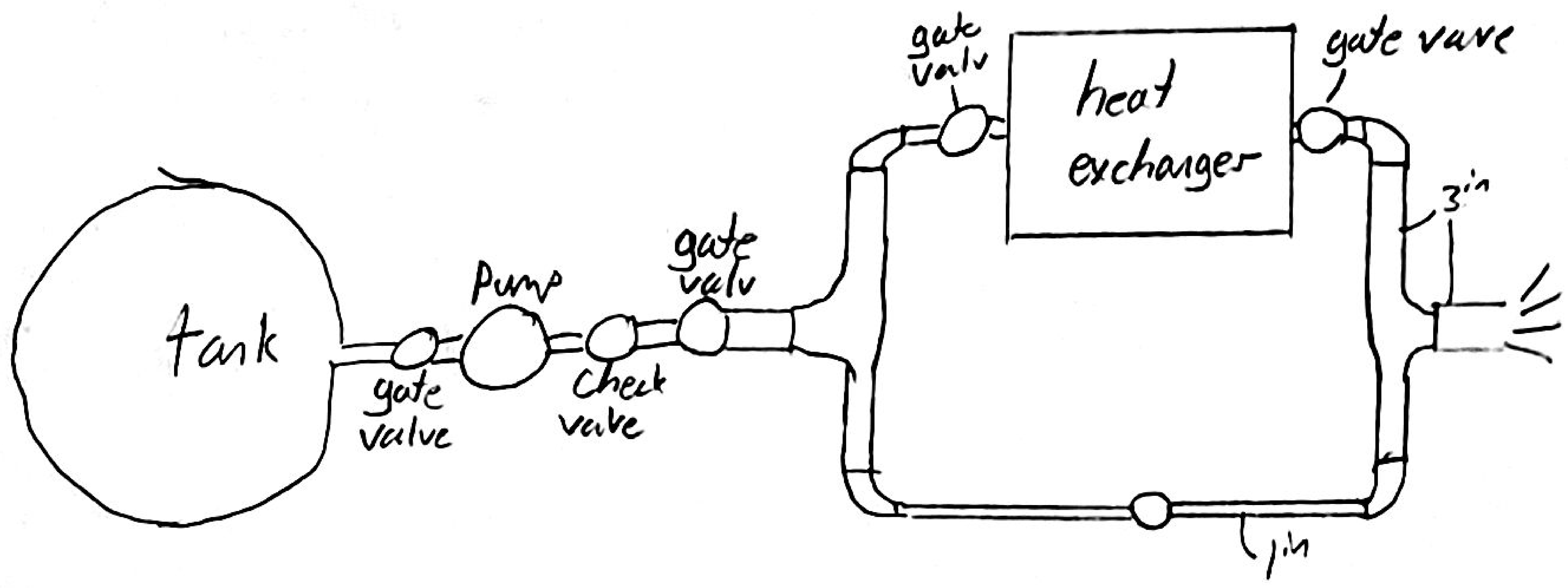
Test 3

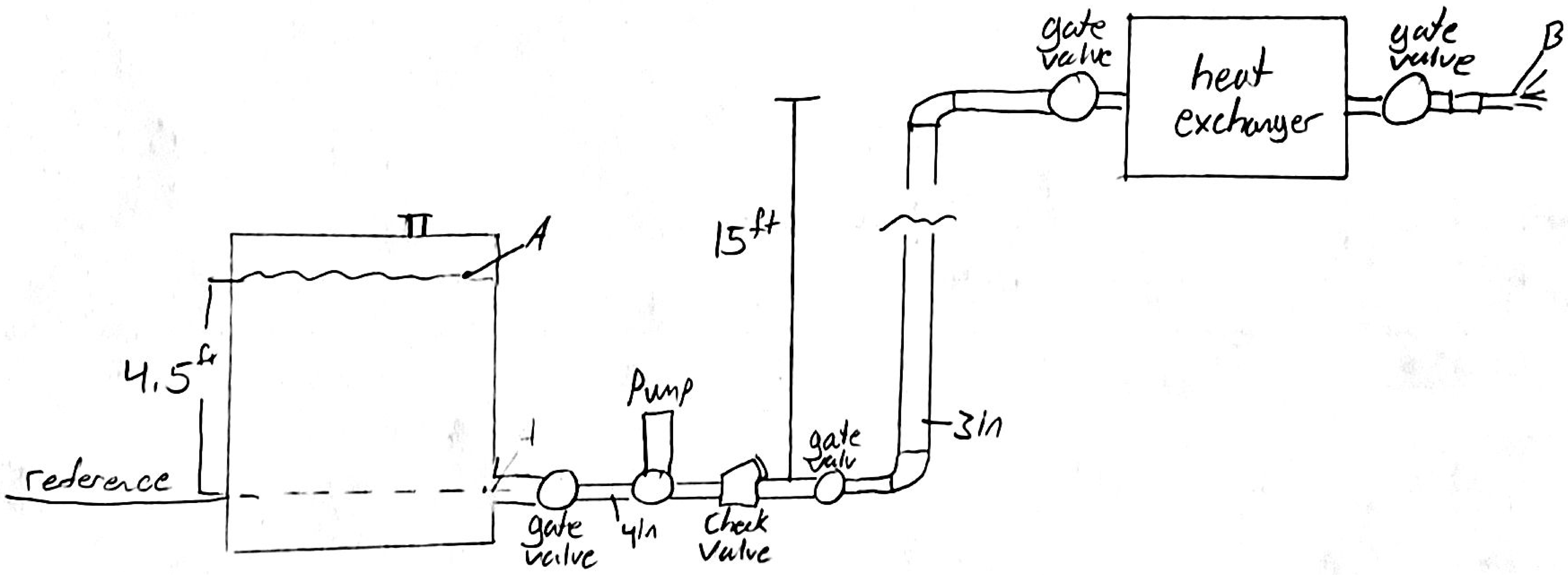
Purpose

A) Calculate pump power if the heat exchanger bypass is closed.

B) Calculate total flowrate if bypass valve is 1/4, 1/2, 3/4, and fully open

Drawings





Sources

- Mott. R., Untener, J.A., "Applied Fluid Mechanics", 7th edition, pearson education, Inc (2015)

Design Considerations

- Constant Tempature
- Incompressible fluid
- Steady state
- Newtonian fluid
- Constant properties

Materials

water at 160°F
Schedule 40 steel

Data & variables

Water temp = 160°F

$D_{suction} = 4 in$
$L_{suction} = 10 ft$

$D_{discharge} = 3 in$
$L_{discharge} = 40 ft$

$D_{Branch 1} = 3 in$
$L_{branch 1} = 8 ft$

$D_{branch 2} = 1 in$
$L_{branch 2} = 30$

$D_{branch 4} = 3 in$

heat exchanger $k = 12$

$Q_{min} = 275$ gpm

$\eta_p = 70\%$

dimensions in drawing

$\gamma_{water} = 61.0 \frac{lb}{ft^3}$

$\nu = 8.3 \times 10^{-6}$

$\varepsilon = 4.6 \times 10^{-5}$

Procedure

a) Compute all energy losses and then use bernoulli's to find pump head. Use pump equation to find pump power

B) Compute all energy losses including bypass pipe and then iterate to find total flow rate. Repeat for all four k values of bypass valve.

Calculations

A $h_a + \frac{P_1}{\gamma}^0 + \frac{V_1^2}{2g}^0 + z_1 = \frac{P_2}{\gamma}^0 + \frac{V_2^2}{2g} + z_2 + h_L$

$h_a = \frac{V_2^2}{2g} + z_2 - z_1 + h_L$

$Q = 275 \frac{gal}{min} (0.61 \frac{ft^3}{s})$ at heat exchanger

For series pipelines $Q_1 = Q_2$ ∴ $Q = 275 \frac{gal}{min} (0.61 \frac{ft^3}{s})$

$V_1 = \frac{Q}{A_1} = \frac{0.61}{0.0884} = 6.9 \frac{ft}{s}$

$V_2 = \frac{Q}{A_2} = \frac{0.61}{0.05132} = 11.88 \frac{ft}{s}$

$z_1 = 4.5 ft$ and $z_2 = 15 ft$

$Re_1 = \frac{V_1 D_1}{\eta} = \frac{6.9 \cdot 0.3355}{0.0000086} = 269180.23$

$\frac{D_1}{\varepsilon} = \frac{0.3355}{0.000046} = 7293.47$

$f_1 = \frac{0.25}{\left[\log\left(\frac{1}{3.7 \cdot 7293.47} + \frac{5.74}{269180.23^{0.9}}\right)\right]^2} = 0.016$

$f_{t1} = \frac{0.25}{\left[\log\left(\frac{1}{3.7 \cdot 7293.47}\right)\right]^2} = 0.0127$

$$Re_2 = \frac{V_2 D_2}{\eta} = \frac{11.88 \cdot 0.2557}{0.0000086} = 353222.79$$

$$\frac{D_2}{\varepsilon} = \frac{0.2557}{0.000046} = 5558.69$$

$$f_2 = \frac{0.25}{\left[\log\left(\frac{1}{3.7 \cdot 5558.69} + \frac{5.74}{353222.79^{0.9}}\right)\right]^2} = 0.0158$$

$$f_{t2} = \frac{0.25}{\left[\log\left(\frac{1}{3.7 \cdot 5558.69}\right)\right]^2} = 0.0134$$

$$h_L = h_{L\,ent} + h_{L\,gate1} + h_{L\,suc} + h_{L\,check} + 3h_{L\,gate2} + 6\,h_{L\,elbow} + h_{L\,dis} + h_{L\,exch} + h_{L\,branch1}$$

$$h_{L\,ent} = k_{ent} \cdot \frac{V_1^2}{2g} = 0.78\,\frac{(6.9)^2}{2.32.2} = 0.57$$

$$h_{L\,gate1} = k_{gate1}\frac{V_1^2}{2g} = 8 f_{t1}\frac{V_1^2}{2g} = 8 \cdot 0.0127\,\frac{6.9^2}{2 \cdot 32.2} = 0.075$$

$$h_{L\,suc} = f_1 \frac{L_1}{D_1} \cdot \frac{V_1^2}{2g} = 0.016 \cdot \frac{10}{0.3355} \cdot \frac{6.9^2}{2 \cdot 32.2} = 0.352$$

$$h_{L\,check} = 100 f_{t2}\frac{V_2^2}{2g} = 100 \cdot 0.0134 \cdot \frac{11.88^2}{2 \cdot 32.2} = 2.936$$

$$h_{L\,gate2} = 3 \cdot 8 \cdot f_{t2}\frac{V_2^2}{2g} = 24 \cdot 0.0134\,\frac{11.88^2}{2 \cdot 32.2} = 0.707$$

$$h_{L\,elbow} = 6 \cdot 20 f_{t2} \cdot \frac{V_2^2}{2g} = 120 \cdot 0.0134 \cdot \frac{11.88^2}{2.32.2} = 3.523$$

$$h_{L\,dis} = f_2 \frac{L_2}{D_2} \cdot \frac{V_2^2}{2g} = 0.0158 \cdot \frac{40}{0.2557} \cdot \frac{11.88^2}{2 \cdot 32.2} = 5.41$$

$$h_{L\,exch} = 12 \cdot \frac{V_2^2}{2g} = 12 \cdot \frac{11.88^2}{2.32.2} = 26.298$$

$$h_{L\,branch1} = f_2 \cdot \frac{L_{b1}}{D_{b1}} \cdot \frac{V_2^2}{2g} = 0.015 \cdot \frac{8}{0.2557} \cdot \frac{11.88^2}{2.32.2} = 1.083$$

$$h_L = 0.57 + 0.075 + 0.352 + 2.936 + 0.707 + 3.523 + 5.41 + 26.298 + 1.083$$

$$h_L = 40.954\,ft$$

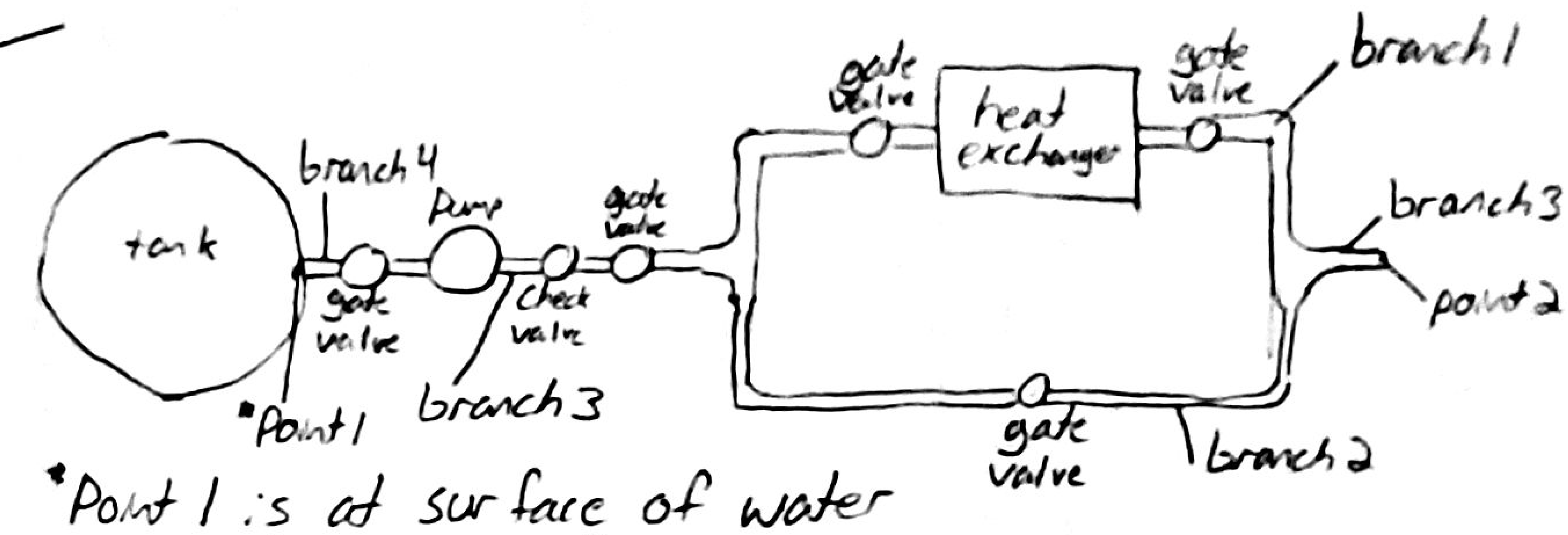
$$h_a = \frac{11.88^2}{2 \cdot 32.2} + 15 - 4.5 + 40.954$$

$$h_a = 53.645\,ft$$

$$P_p = \frac{\gamma \cdot Q \cdot h_a}{\eta} = \frac{61 \cdot 0.61 \cdot 53.645}{0.7 \cdot 550} = \underline{\underline{5.18\,hp}}$$

(550 — conversion)

B



*Point 1 is at surface of water
refer to page 1 for
aditional drawings

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

$$h_a + z_1 - z_2 = h_{L1} \quad \text{and} \quad h_a + z_1 - z_2 = h_{L2}$$

Branch 1

$$h_{L1} = h_{L\,ent} + h_{L\,gate4} + h_{L\,suc} + h_{L\,check} + h_{L\,gate3} + h_{L\,dis} + 2h_{L\,elbow3} + 2h_{L\,tee3} + 2h_{L\,gate1} + 2h_{L\,elbow1} + h_{L\,exch} + h_{L\,branch1}$$

Q_4:

$$h_{L\,ent} = k_{ent}\frac{V_4^2}{2g} = k_{ent}\cdot\frac{1}{g}\cdot\frac{8Q_4^2}{\pi^2 D_4^4}$$

$$h_{L\,gate4} = 8f_{t4}\frac{V_4^2}{2g} = 8f_{t4}\cdot\frac{1}{g}\cdot\frac{8Q_4^2}{\pi^2 D_4^4}$$

$$h_{L\,suc} = f_4\frac{L_4}{D_4}\cdot\frac{V_4^2}{2g} = f_4\frac{L_4}{D_4}\cdot\frac{1}{g}\cdot\frac{8Q_4^2}{\pi^2 D_4^4}$$

Q_3:

$$h_{L\,check} = 100f_{t3}\frac{V_3^2}{2g} = 100f_t\cdot\frac{1}{g}\cdot\frac{8Q_3^2}{\pi^2 D_3^4}$$

$$h_{L\,gate3} = 8f_{t3}\frac{V_3^2}{2g} = 8f_{t3}\cdot\frac{1}{g}\cdot\frac{8Q_3^2}{\pi^2 D_3^4}$$

$$h_{L\,elbow3} = 2\cdot 20f_{t3}\frac{V_3^2}{2g} = 40f_{t3}\cdot\frac{1}{g}\cdot\frac{8Q_3^2}{\pi^2 D_3^4}$$

$$h_{L\,dis} = f_3\cdot\frac{L_3}{D_3}\cdot\frac{V_3^2}{2g} = f_3\cdot\frac{L_3}{D_3}\cdot\frac{1}{g}\cdot\frac{8Q_3^2}{\pi^2 D_3^4}$$

$$h_{L\,tee} = 2\cdot 60f_{t3}\frac{V_3^2}{2g} = 120f_{t3}\cdot\frac{1}{g}\cdot\frac{8Q_3^2}{\pi^2 D_3^4}$$

Q_1:

$$h_{L\,gate1} = 2\cdot 8f_{t1}\frac{V_1^2}{2g} = 16f_{t1}\cdot\frac{1}{g}\cdot\frac{8Q_1^2}{\pi^2 D_1^4}$$

$$h_{L\,elbow1} = 2\cdot 20f_{t1}\frac{V_1^2}{2g} = 40f_{t1}\cdot\frac{1}{g}\cdot\frac{8Q_1^2}{\pi^2 D_1^4}$$

$$h_{L\,exch} = k\cdot\frac{V_1^2}{2g} = 12\cdot\frac{1}{g}\cdot\frac{8Q_1^2}{\pi^2 D_1^4}$$

$$h_{L\,branch1} = f_1\cdot\frac{L_1}{D_1}\cdot\frac{V_1^2}{2g} = f_1\cdot\frac{L_1}{D_1}\cdot\frac{1}{g}\cdot\frac{8Q_1^2}{\pi^2 D_1^4}$$

$$h_{L1} = \frac{8}{g\pi^2 D_4^4} Q_4^2 \left(k_{ent} + 8f_{t4} + f_4 \frac{L_4}{D_4}\right) + \frac{8}{g\pi^2 D_3^4} Q_3^2 \left(268 f_{t3} + f_3 \frac{L_3}{D_3}\right)$$
$$+ \frac{8}{g\pi^2 D_1^4} Q_1^2 \left(56 f_{t1} + 12 + f_1 \frac{L_1}{D_1}\right)$$

$h_L = h_a + z_1 - z_2$ from bernoulli's

$Q_4 = Q_3$ because they are a series pipeline

$$h_a + z_1 - z_2 = 2Q_3^2\left[\frac{8}{g\pi^2 D_4^4}\left(k_{ent} + 8f_{t4} + f_4 \frac{L_4}{D_4}\right) + \frac{8}{g\pi^2 D_3^4}\left(268 f_{t3} + f_3 \frac{L_3}{D_3}\right)\right]$$
$$+ \frac{8}{g\pi^2 D_1^4} Q_1^2 \left(56 f_{t1} + 12 + f_1 \frac{L_1}{D_1}\right)$$

(1) $$Q_1 = \sqrt{\frac{-2Q_3^2\left[\frac{8}{g\pi^2 D_4^4}\left(k_{ent} + 8f_{t4} + f_4 \frac{L_4}{D_4}\right) + \frac{8}{g\pi^2 D_3^4}\left(268 f_{t3} + f_3 \frac{L_3}{D_3}\right)\right] + h_a + z_1 - z_2}{\frac{8}{g\pi^2 D_1^4}\left(56 f_{t1} + 12 + f_1 \frac{L_1}{D_1}\right)}}$$

<u>Branch 2</u>

$$h_{L2} = h_{L\,ent} + h_{L\,gate4} + h_{L\,suc} + h_{L\,check} + h_{L\,gate3} + 2h_{L\,elbow3} + h_{L\,dis} + 2h_{L\,tee3} + h_{L\,red} + 2h_{L\,elbow2} + h_{L\,gate2} + h_{L\,exp} + h_{L\,branch2}$$

Q_4 —

$$h_{L\,ent} = k_{ent}\frac{V_4^2}{2g} = k_{ent}\cdot\frac{1}{g}\cdot\frac{8Q_4^2}{\pi^2 D_4^4}$$
$$h_{L\,gate4} = 8f_{t4}\frac{V_4^2}{2g} = 8f_{t4}\cdot\frac{1}{g}\cdot\frac{8Q_4^2}{\pi^2 D_4^4}$$
$$h_{L\,suc} = f_4\cdot\frac{L_4}{D_4}\cdot\frac{V_4^2}{2g} = f_4\cdot\frac{L_4}{D_4}\cdot\frac{1}{g}\cdot\frac{8Q_4^2}{\pi^2 D_4^4}$$

Q_3 —

$$h_{L\,check} = 100f_{t3}\frac{V_3^2}{2g} = 100f_{t3}\cdot\frac{1}{g}\cdot\frac{8Q_3^2}{\pi^2 D_3^4}$$
$$h_{L\,gate3} = 8f_{t3}\frac{V_3^2}{2g} = 8f_{t3}\cdot\frac{1}{g}\cdot\frac{8Q_3^2}{\pi^2 D_3^4}$$
$$h_{L\,elbow3} = 2\cdot 20f_{t3}\frac{V_3^2}{2g} = 40f_{t3}\cdot\frac{1}{g}\cdot\frac{8Q_3^2}{\pi^2 D_3^4}$$
$$h_{L\,dis} = f_3\cdot\frac{L_3}{D_3}\cdot\frac{V_3^2}{2g} = f_3\frac{L_3}{D_3}\cdot\frac{1}{g}\cdot\frac{8Q_3^2}{\pi^2 D_3^4}$$
$$h_{L\,tee} = 2\cdot 60f_{t3}\frac{V_3^2}{2g} = 120f_{t3}\cdot\frac{1}{g}\cdot\frac{8Q_3^2}{\pi D_3^4}$$

Q_2:

$$h_{L\,red} = k_{red}\frac{V_2^2}{2g} = k_{red}\cdot\frac{1}{g}\cdot\frac{8Q_2^2}{\pi^2 D_2^4}$$

$$h_{L\,elbow\,2} = 2\cdot 20f_{T2}\frac{V_2^2}{2g} = 40f_{T2}\cdot\frac{1}{g}\cdot\frac{8Q_2^2}{\pi^2 D_2^4}$$

$$h_{L\,gate\,2} = 900f_T\cdot\frac{V_2^2}{2g} = 900f_T\cdot\frac{1}{g}\cdot\frac{8Q_2^2}{\pi^2 D_2^4}$$

– This is the bypass valve, It will chang as it opes more

$$h_{L\,exp} = k_{exp}\frac{V_2^2}{2g} = k_{exp}\cdot\frac{1}{g}\cdot\frac{8Q_2^2}{\pi^2 D_2^4}$$

$$h_{L\,branch\,2} = f_2\frac{L_2}{D_2}\cdot\frac{V_2^2}{2g} = f_2\frac{L_2}{D_2}\cdot\frac{1}{g}\cdot\frac{8Q_2^2}{\pi^2 D_2^4}$$

$$h_{L2} = \frac{8}{g\pi^2 D_4^4}Q_4^2\left(k_{ent}+8f_{T4}+f_4\frac{L_4}{D_4}\right)+\frac{8}{g\pi^2 D_3^4}Q_3^2\left(268f_{T3}+f_3\frac{L_3}{D_3}\right)$$
$$+\frac{8}{g\pi^2 D_2^4}Q_2^2\left(k_{red}+k_{exp}+940f_{T2}+f_2\frac{L_2}{D_2}\right)$$

$h_{L2} = h_a + z_1 - z_2$ from bernoulli's

$Q_4 = Q_3$ because they are a series pipeline

$$h_a+z_1-z_2 = 2Q_3^2\left[\frac{8}{g\pi^2 D_4^4}\left(k_{ent}+8f_{T4}+f_4\frac{L_4}{D_4}\right)+\frac{8}{g\pi^2 D_3^4}\left(268f_{T3}+f_3\frac{L_3}{D_3}\right)\right]$$
$$+\frac{8}{g\pi^2 D_2^4}Q_2^2\left(k_{red}+k_{exp}+940f_{T2}+f_2\frac{L_2}{D_2}\right)$$

(2)
$$Q_2 = \sqrt{\frac{-2Q_3^2\left[\frac{8}{g\pi^2 D_4^4}\left(k_{ent}+8f_{T4}+f_4\frac{L_4}{D_4}\right)+\frac{8}{g\pi^2 D_3^4}\left(268f_{T3}+f_3\frac{L_3}{D_3}\right)\right]+h_a+z_1-z_2}{\frac{8}{g\pi^2 D_2^4}\left(k_{red}+k_{exp}+940f_{T2}+f_2\frac{L_2}{D_2}\right)}}$$

(3) $Q_3 = Q_1 + Q_2$ because parallel pipe line

$$Q_3 = \sqrt{\frac{-2Q_3^2\left[\frac{8}{g\pi^2 D_4^4}\left(k_{ent}+8f_{T4}+f_4\frac{L_4}{D_4}\right)+\frac{8}{g\pi^2 D_3^4}\left(268f_{T3}+f_3\frac{L_3}{D_3}\right)\right]+h_a+z_1-z_2}{\frac{8}{g\pi^2 D_1^4}\left(56f_{T1}+12+f_1\frac{L_1}{D_1}\right)}}$$
$$+\sqrt{\frac{-2Q_3^2\left[\frac{8}{g\pi^2 D_4^4}\left(k_{ent}+8f_{T4}+f_4\frac{L_4}{D_4}\right)+\frac{8}{g\pi^2 D_3^4}\left(268f_{T3}+f_3\frac{L_3}{D_3}\right)\right]+h_a+z_1-z_2}{\frac{8}{g\pi^2 D_2^4}\left(k_{red}+k_{exp}+940f_{T2}+f_2\frac{L_2}{D_2}\right)}}$$

Plan

1) Guess f_1, f_2, f_3, and f_4

   a) guess Q_3
   B) Compute RHS
   C) Compare RHS to LHS (% diff)
   D) If same = done If not = go to a

2) Compute Q_1 and Q_2

3) Compute Re_1, Re_2, Re_3 and Re_4

4) Compute new f_1, f_2, f_3, and f_4

5) Compare new f to guessed f

6) If same = done If not = go to 1

Excel time baby!

When bypass valve is 1/4 open, $Q_3 = 0.582 \frac{ft^3}{s}$

When bypass valve is 1/2 open, $Q_3 = 0.588 \frac{ft^3}{s}$

When bypass valve is 3/4 open, $Q_3 = 0.589 \frac{ft^3}{s}$

When bypass valve is fully open $Q_3 = 0.5906 \frac{ft^3}{s}$

Summary

The pump power when the bypass gate valve is closed is 5.18 hp.

The total flow rate when the bypass gate valve is 1/4 of the way open is 0.582 $\frac{ft^3}{s}$. The total flow rate when the bypass gate valve is 1/2 of the way open is 0.588 $\frac{ft^3}{s}$. The total flow rate when the bypass gate valve is 3/4 of the way open is 0.589 $\frac{ft^3}{s}$. The total flow rate when the bypass gate valve is fully open is 0.5906 $\frac{ft^3}{s}$.

Analysis

The total flow rate when the bypass valve is fully closed is higher than when the bypass valve is fully open. This is because the energy losses can be ignored because the Q in the equations is 0.

The total flow rate when the bypass valve is 3/4 open and fully open are very similar, I did not expect this. However, the difference in the friction coeffient is small campaired to the rest of the pipeline.

In order to do maintence on the heat exchanger or to remove it, the bypass needs to be open and the gate valves need to be shut. Because the by pass line is 1inch and the discharge valve is 3inch, the pump will have a sudden increase in pump head. To prevent this, the bypass line should be increased to a larger diameter.