Purpose

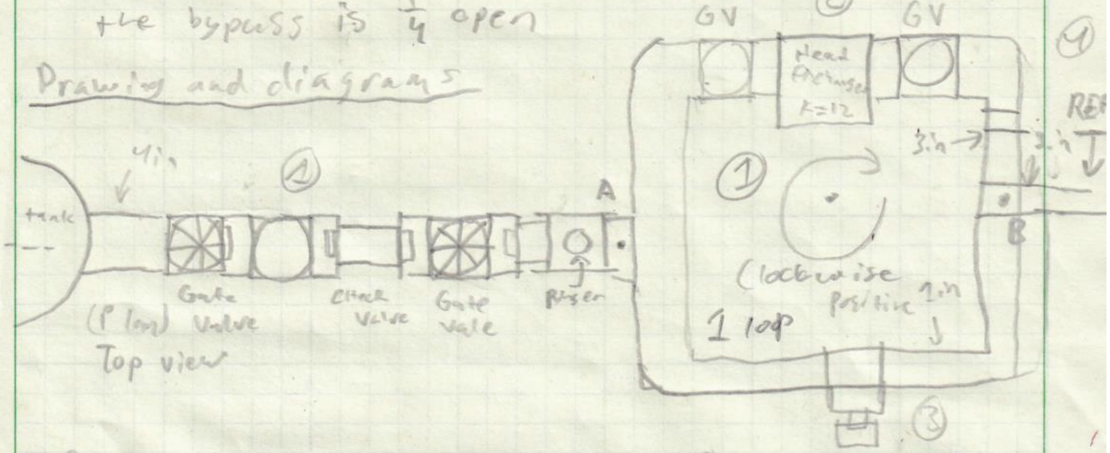
We are given a pump system, with very specific measurements in each pump.

(a) Only use Hardy Cross method. Must find the flow rates in each branches

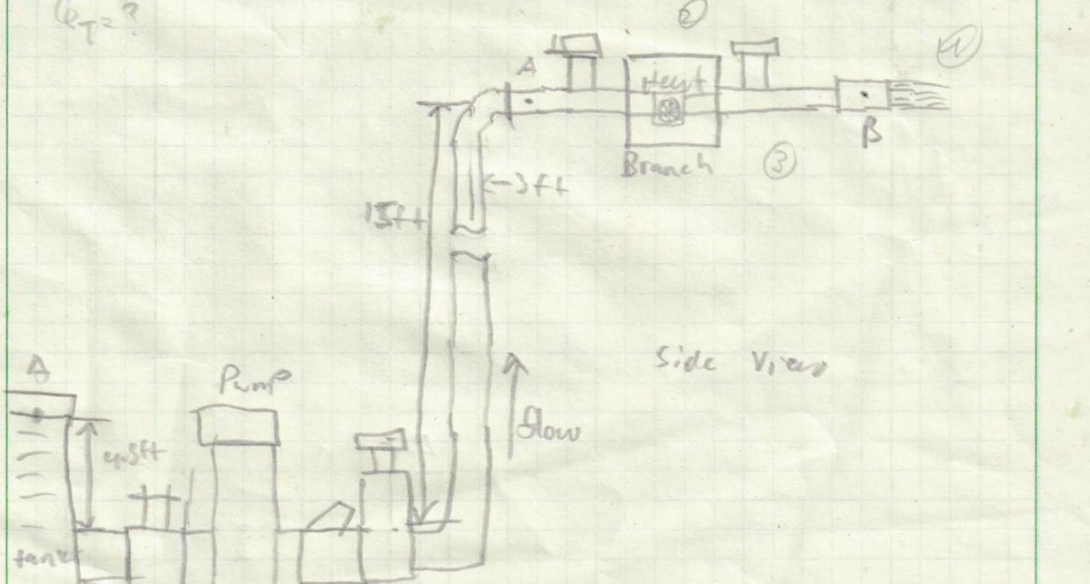
(b) Calculate the pump head

(c) Calculate the total flow rate if the gate valve in the bypass is ¼ open

Drawing and diagrams



$Q_T = ?$



Sources

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

Design Considerations

- All pipes are Schedule 40 steel system
- Different types of pipes are used.
- Two different views : plan and side view.
- Pump head remains the same
- Use equivalent length to treat the heat exchanger

Data variables

$g = 32.2$ ft/s, $\gamma = 62.4$ lb/s $\varepsilon = 1.3\times10^{-4}$.
from a 4in Suction

Water @ 160°F $Q = 275$ gal/min

Total length suction line = 0ft

Discharge line has total length of 40ft

primary 3in line feeding into large heat exchanger

Heat exchanger K = 12 Pipe branch = 8 ft

1in bypass total length = 30ft

All pipes are Schedule 40 steel.

Pipe size	OD	Wall thickness	ID	Flow area
1in	1.315in	0.133	1.049in/0.0874ft	0.006 ft²
3in	3.5 in	0.203	2.469 in/0.2058 ft	0.03326 ft²
4in	4.5 in	0.237	4.026 in/0.3355 ft	0.08840 ft²

Materials

- Water
- Pipes that have water constantly flowing

Procedure

(a) We have to use Hardy cross method to find the flow rate of each branch. Recognize that I have to use K=12 on the heat exchanger. need to Follow the process of the Hardy cross method

- Express energy losses within this section
- Find the loop within the branches.
- Calculate the values based on each pipe

(b) Calculate the pump head. Recognize the energy losses within the pipe that's connected to the heat. Find any contraction between pipes. Find total energy losses Use Bernoulli's equation to find the pump head equation. After solving for pump equation, find the values needed to solve the pump head

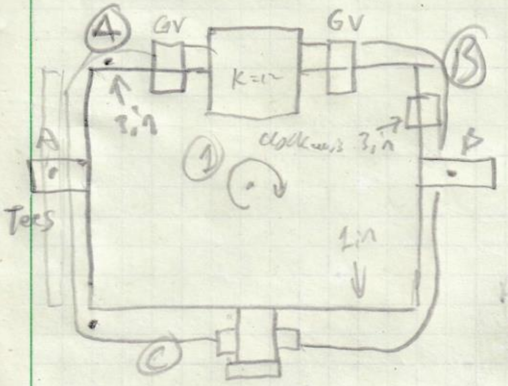
(c) We are calculating the total flow rate. Get the result of the pump head. Apply this when finding the total flow rate if the valve is $\frac{1}{4}$ open.
We try and get 3 equations with 3 unknowns that solve for the total flowrate.
We assume values such as f_1 & f_2. Compute the Q values, V values, and Re values. Find the real values for f_1 & f_2. Last, find the % difference < 1%

(a)

Calculations

Gate valve = 8 in $f_T = 0.016$

From table 10.4. $K = (8.1)(0.016)$ $K = 0.128$



Equivalent length

$K = 12$ with flow through Branch

$K = \left(\frac{Le}{D}\right)(f_T)$

$\frac{Le}{D} = 60$

$Q = 275$ gal/min

Hardy cross method

There is only 1 loop.

Node law $\sum_{n} Q_i = 0$

$K_L = \frac{8 f_T}{g \pi^2} \frac{Le}{D}$

$$KAC = \frac{8(0.016)}{(32.2 ft^2/s)\pi^2}(60.) = \boxed{0.0241 \; s^2/ft}$$

2 gate valves

$$KAB = \frac{8(0.016)}{(32.2 ft^2/s)\pi}(12) = \boxed{4.0332 \; s^2/ft}$$

· Calculate pump head

~~Use~~ Bernoulli's first then find pump head

Energy loss from pump ✓

$$h_A + \frac{p_A}{\gamma} + \frac{v_A^2}{2g} + \overset{0}{\cancel{z_A}} = \underset{0}{\cancel{\frac{p_B}{\gamma}}} + \frac{v_B^2}{2g} + z_B + h_{L\,AB}$$

Solve for pump head

$f_T = 0.016$

$\frac{L}{D} = 8\ ft$

$$h_A = -\frac{p_A}{\gamma_{water}} + \frac{v_B^2 - v_A^2}{2g} + z_B + h_{L\,AB}$$

(0.0207) − 41.45

$$h_A = -\cancel{\frac{p_A}{\gamma}} + \underset{(-0.651)}{\frac{v_B^2 - v_A^2}{2g}} + z_B + f\frac{L}{D}\frac{v_C^2}{2g} + k_{elbow}\frac{v_C^2}{2g} + k_{valve}\frac{v_B^2}{2g}$$

Q=VA

Elbow

$f_T = 0.016$

$$V_A = \frac{4Q}{\pi D^2} = \frac{4(0.3326\ ft^3/s)}{\pi(0.2557\ ft^2)^2} = 6.4769\ ft^2$$

3 in

$$V_B = \frac{4Q}{\pi D^2} = \frac{4(0.08840\ ft^3)}{\pi(0.8840\ ft)^2} = 0.144\ ft^2$$

4 in

$$V_C = \frac{4Q}{\pi D^2} = \frac{4(0.006)}{\pi(0.0974)^2} = 1.00\ ft^2$$

14.895

2 in

0.07812S

1.656×10^{-4}

$$h_A = \frac{5\ \frac{lb}{ft}}{64.0\ \frac{lb}{ft^2}} - 0.651 + 15\ ft + (0.016)\left(8\ in\ \frac{1\ ft}{min}\right)\left(\frac{1}{2(32.2\ ft/s)}\right)$$

$\frac{L_e}{D} \times f_T$

standard elbow

check valve

$$+\ 30(0.016)\frac{1}{2(32.2\ ft^2/s)} + 100(0.016)\left(\frac{0.0207\ ft^2}{2(32.2\ \frac{ft^2}{s})}\right)$$

$$\boxed{h_A = 14.9\ ft}$$

Calculate the flow rate if gate valve is open to $\frac{1}{4}$

There are 4 of these gate valves. Looking at 1

Recongnize that $\frac{\Delta P_{AB}}{\gamma} = h_L$

$$\frac{\Delta P_{AB}}{\gamma} = f_1 \frac{L_1}{D_1}\frac{V_1^2}{2g} + 4 K_{elbows}\frac{V_1^2}{2g}$$

Equations for the unknowns.

1. $$\frac{\Delta P_{AB}}{\gamma} = \left(f_1 \frac{L_1}{D_1} + 4 K_{elbows}\right)\frac{1}{2g}\frac{16 Q_1^2}{\pi^2 D_1^4}$$

2. $$\frac{\Delta P_{AB}}{\gamma} = \left(f_2 \frac{L_2}{D_2} + 4 K_{elbows} + f_2 \frac{L_{eq}}{D_2}\right)\frac{1}{2g}\frac{16 Q_2^2}{\pi^2 D_2^4}$$

3. $$\boxed{Q_3 = Q_1 + Q_2}$$ This the equation we need to solve for the total flow rate

Solve for the Q's

$$Q_3 = \sqrt{\frac{\frac{\Delta P_{AB}}{\gamma}\frac{8}{g}\frac{1}{\pi^2 D_1^4}}{\left(f_1 \frac{L}{D} + 4 K_{elbow}\right)}} + \sqrt{\frac{\frac{\Delta P_{AB}}{\gamma}\frac{8}{g}\frac{1}{\pi^2 D_2^4}}{\left(f_2 \frac{L_2}{D_2} + 4 K_{elbow} + f_2\left(\frac{L}{D}\right)\right)}}$$

Find % difference as $\% diff = \frac{f_1 - f_1^{new}}{f_1} \times 100$

$$= \frac{f_2 - f_2^{new}}{f_1} \times 100$$

Analysis

This system is a mixture of different type of pumps/valves that have water continously flow. The idea was to solve and perdict the system's flow rate. Calculating specific parts of system based on the parts given.

Summary

Pump head is 14.9ft

That A has the values 0.0241 s^2/ft and 4.033 s^2/ft

Part C has the equation given.