Colby Watts

MET 330 Test 3

4/12/24

Professor Ayala

Colby Watts 330 Test 3

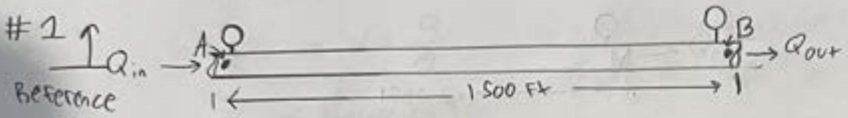
Purpose for Question 2 #1 and #2

#1. Determine the corresponding pressure drop

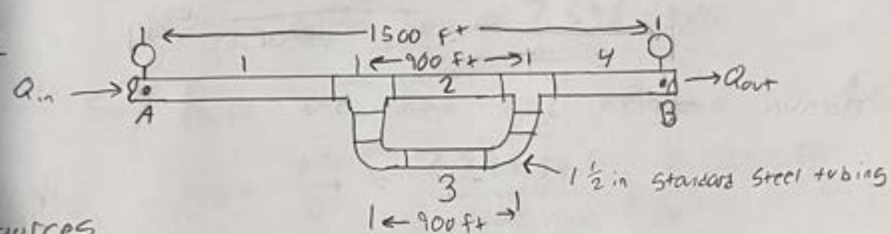
#2. What is the expected increase in flow rate through the system for the same pressure as in the original pipe? (Consider all minor losses.)

Drawings & Diagrams

#1



#2



Sources

- Applied Fluid mechanics Book
- Professor Ayala in class Solutions
- Slides and solutions given to us
- Conversion calculator
- Moody Chart Calculator
- Professor Ayala excel spread sheets

Design Considerations

It is a system that you would normally see in industry but it would have a gate valve instead to turn water off on one section.

Data & Variables

$D = 0.1558$ ft $\quad \nu = 1.05 \cdot 10^{-5}$ ft²/s $\quad A_2 = 1.91 \cdot 10^{-2}$ ft² $\quad A_3 = 1.02 \cdot 10^{-2}$ ft²

$L = 1500$ ft $\quad \varepsilon = 1.5 \cdot 10^{-5}$ ft $\quad L = 900$ ft $\quad D_3 = 0.1142$ ft $\quad Re = \frac{VD}{\nu}$

$\gamma = 62.3$ lb/ft³ $\quad K_{reduction} = 0.045$ (10.11) $\quad f_{T\,Tee} = 0.022$ 60 f_T $\quad V = \frac{Q}{A}$

$g = 32.2$ ft/s² $\quad K_{expansion} = 0.36$ (10.11) $\quad f_{T\,elbow} = 0.022$ 30 f_T

$f_{T\,pipe_2} = 0.019$ (10.5)

Question 2 Part 1

Determine pressure drop

$$\frac{P_A}{\gamma} + \frac{\cancel{V_A^2}}{\cancel{2g}} + \cancel{Z_A} = \frac{P_B}{\gamma} + \frac{\cancel{V_B^2}}{\cancel{2g}} + \cancel{Z_B} + h_L$$

$$\frac{\Delta P}{\gamma} = h_L$$

Finding velocity

$$Q = VA = V = \frac{Q}{A} \qquad Q = 65\,GPM = 0.1448\ ft^3/s$$

$$A = 1.907 \cdot 10^{-2}\ ft^2 \text{ (Appendix G)}$$

$$V = \frac{0.1448\ ft^3/s}{1.90 \cdot 10^{-2}\ ft^2} = 7.593\ ft/s$$

So now we can find Reynolds number

$$Re = \frac{VD}{\nu} = \frac{7.593\ ft/s \cdot 0.1558\ ft}{1.05 \cdot 10^{-5}\ ft^2/s}$$

$$Re = 1.13 \cdot 10^5$$

now to find relative roughness I use

$$\frac{D}{\varepsilon} = \frac{0.1558\ ft}{1.5 \cdot 10^{-5}} = 1.04 \cdot 10^4$$

So then using those I used a moody chart Calculator to get friction.

$$f = 0.017$$

Now with the friction factor I can calculate for energy loss in the pipe. I use this equation.

$$h_{L\,pipe} = f\left(\frac{L}{D}\right)\left(\frac{V^2}{2g}\right)$$

$$h_{L\,pipe} = 0.017\left(\frac{1500\,ft}{0.1558\,ft}\right)\left(\frac{7.593\,ft/s}{2 \cdot 32.2\,ft/s^2}\right)$$

$$h_{L\,pipe} = 146.5\,ft$$

Then I can use bernoulli's equation that I derived.

$$\Delta P = \gamma h_{L\,pipe}$$

$$\Delta P = \underline{62.3\,lb/ft^3 \cdot 146.5\,ft} = \boxed{9129\,lbf/ft^2} \text{ or } \underline{63.39\,Psig}$$

Question 2 Part 2

The first thing to do is apply bernoulli's

$$\frac{P_A}{\gamma} + \cancel{\frac{V_A^2}{2g}} + \cancel{Z_A} = \frac{P_B}{\gamma} + \cancel{\frac{V_B^2}{2g}} + \cancel{Z_B} + h_L$$

The velocities cancel because the flow rate at A & B must be equal. Also, Z_A & Z_B cancel because there is no elevation.

$$\frac{P_A - P_B}{\gamma} = h_L \qquad \frac{\Delta P}{\gamma} = h_L$$

Now we have to find and compute for energy losses at branch 2 on my diagram.

Now when looking at branch 2 I see 2 Tees and the pipe as an energy loss. Now to compute for energy losses in the pipe and the Tee's. We can use

$$\frac{\Delta P}{\gamma} = \underbrace{f_2\left(\frac{L}{D}\right)\left(\frac{V_2^2}{2g}\right)}_{h_{L\,pipe}} + \underbrace{2(20 f_T)\left(\frac{V_2^2}{2g}\right)}_{h_{L\,Tee}}$$

To get f_2 I assumed the value so I can iterate and find the actual value. f_T is gathered from the table in the book. Now knowing $Q = VA$ we can derive the equation

$$\frac{\Delta P}{\gamma} = f_2\left(\frac{L}{D}\right) + 2(20 f_T)\left(\frac{1}{2g}\right)\left(\frac{1}{A_2^2}\right) Q_2^2$$

now plugging in the values and not assuming.

$$\frac{\Delta P}{\gamma} = 0.0222\left(\frac{1500 ft}{.1558 ft}\right) + 2(20(0.019))\left(\frac{1}{2 \cdot 32.2}\right)\left(\frac{1}{1.91E\text{-}2}\right) Q_2$$

Now to solve for Q_2 we move the equation and simplify.

$$Q_2 = \sqrt{\left(\frac{0.0234\,\Delta P}{\gamma}\right)\left(\frac{1}{(0.0222)\left(\frac{1500}{.1558}\right)+0.76}\right)}$$

$\Delta P = 9129\ lbf/ft^2$ From Part 1

$\gamma = 62.3\ lb/ft^3$

So $Q_2 = \underline{0.12668\ ft^3/s} = \underline{56.82\ gpm}$

Now to find the flow rate in branch three we need energy losses as well and I see the pipe, 2 Tee's, 2 elbows and reduction and expansion.

$$\underset{h_L \text{ pipe}}{f_3\left(\frac{L}{D}\right)\left(\frac{V_3^2}{2g}\right)} + \underset{2(h_L \text{Tee})}{2(60f_T)\left(\frac{V_3^2}{2g}\right)} + \underset{h_L \text{ reduction}}{0.045\left(\frac{V_3^2}{2g}\right)} + \underset{2\, h_L \text{elbow}}{2(30f_T)\left(\frac{V_3^2}{2g}\right)} + \underset{\text{expansion}}{0.36\left(\frac{V_3^2}{2g}\right)}$$

Now what I will do is plug in values and rearrange my equation.

$$\frac{\Delta P}{\gamma} = \frac{1}{2g}\frac{1}{A_3^2}Q_3^2\left(f_3\left(\frac{L}{D}\right) + 2(60f_T) + 0.045 + 2(30f_T) + 0.36\right.$$

$$\frac{\Delta P}{\gamma} = \frac{1}{2(32.2)} \cdot \frac{1}{1.02E^{-2}} Q_3\left(f_3\left(\frac{900\,ft}{0.1142\,ft}\right) + 2(60(0.022) + 0.045 + 2(30(0.022) + 0.36\right)$$

$$\frac{\Delta P}{\gamma} = \frac{1}{2(32.2)} \cdot \frac{1}{1.02E^{-2}} Q_3\left(f_3\,(7880.9 + 4.365\right)$$

$$Q_3 = \sqrt{\left(\frac{0.00675 \cdot \Delta P}{\gamma}\right)\left(\frac{1}{f_3(7880.9 + 4.365)}\right)}$$

Now plugging in the values for the change in pressure, specific weight and f.

$$Q_3 = \sqrt{\left(\frac{0.00675 \cdot 9129\ lbf/ft^2}{62.3\ lb/ft^3}\right)\left(\frac{1}{(0.024)(7880.9 + 4.365)}\right)}$$

$$Q_3 = \underline{0.07122\ ft^3/s} \text{ or } \underline{31.97\ gpm}$$

Now these Q values were found after doing 6 iterations. Now to find the increase in flow rate.

$$56.82\ gpm + 31.97\ gpm = 88.79\ gpm - 65\ gpm$$

So the increase of flow rate is $\boxed{23.79\ gpm}$

Summary

The flow rate at branch 2 that I found is 56.82 gpm and the flow rate that I found in branch 3 is 31.97 gpm. So, the total flow rate is 88.79 gpm and a total increase of 23.79 gpm.

Materials

2-inch standard steel tubing

$1\frac{1}{2}$-inch standard steel tubing

water at 70°F

Analysis

The worst part of this test was assuming the f value and iterating and guessing new f values. With these assumptions it gives us a good idea on the limits a system can actually take on as a whole or by itself. Also, if we were given a water temperature then the answer would be a lot different.