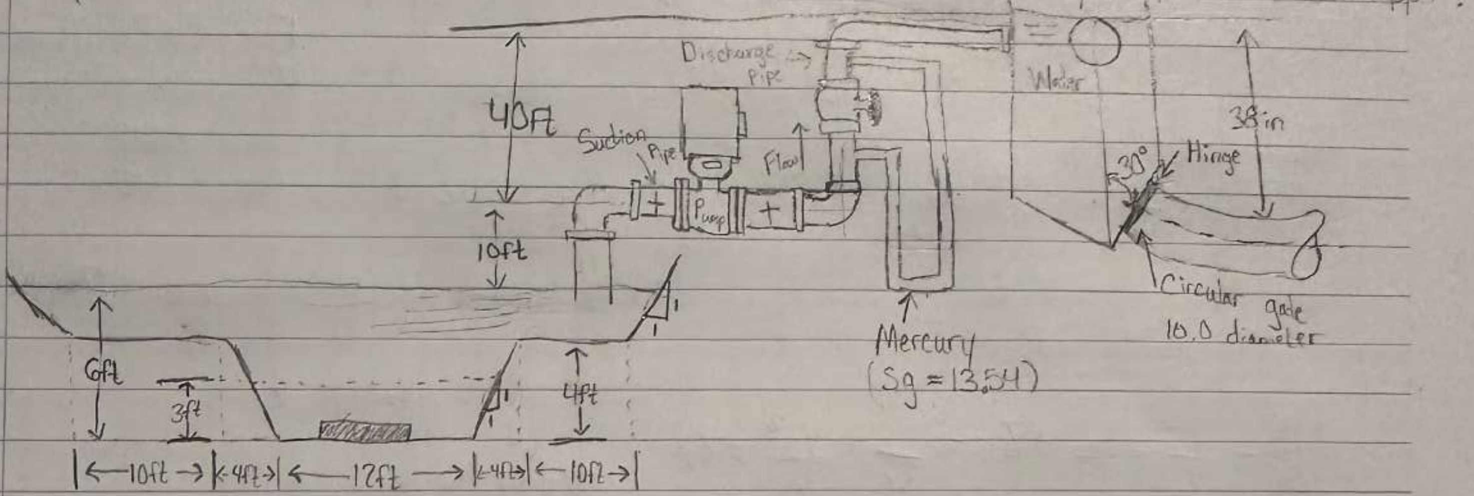
MET Fluid Mechanics Test 1

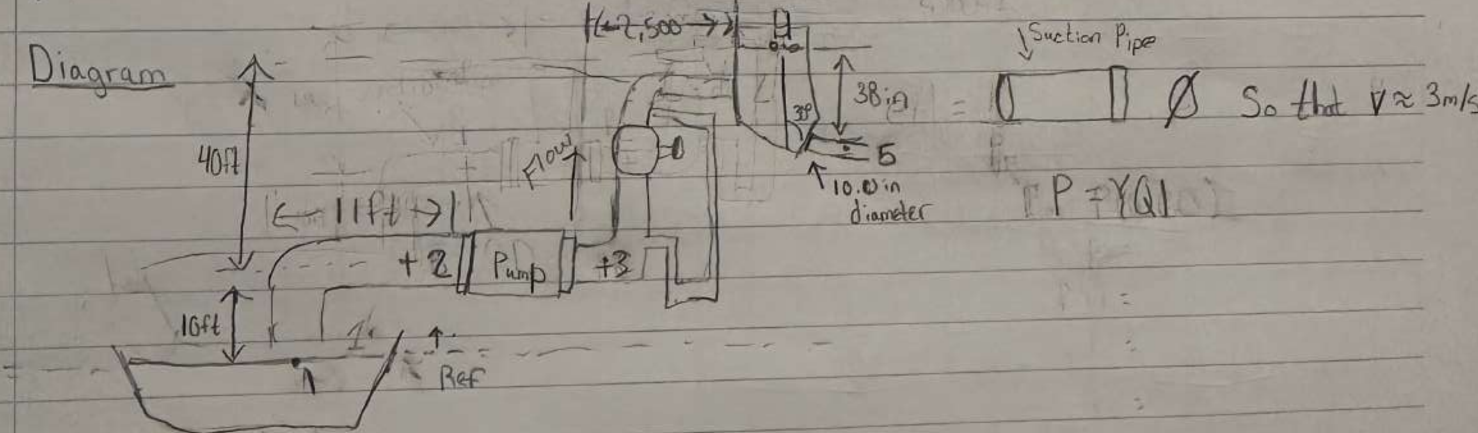
A company hires you to design a system to deliver 60°F water from a large open channel to another elevated one, as depicted in the figure. The Company requires to deliver 3.387 ft^3/s of water from the lower open channel to the upper.



a **Purpose**

Determine the required pump power assuming a pump effeciency of 60%. Chosing a pipe diameter that allows the fluid velocity within the pipe is near 3m/s

Diagram



Sources

- Mott & Untener "Applied Fluid Mechanics". 7th Edition Pearson Education, Inc, (2015)

$h_L = K\frac{V}{2g}$

Design Considerations

- $V \approx 3m/s$
- Pump Effeciency of 60%
- Incompressible Fluids
- Isothermal with T = 60°F

Data & Variables

$\gamma_{H_2O} = 62.4\ lb/ft$ $Q = 3.387\ ft^3/s$

$K = 2.5$

Procedure:

I will first find a pipe diameter utilizing table F1 in the appendix to obtain a fluid flow velocity around 3m/s. Will apply general energy equation with respects valve resistance to find the required pump power to deliver water to the upper channel.

Calculations:

$Q_A = 3.387\,ft^3/s \left| \frac{0.02831\,m^3}{1\,ft^3} \right| = 0.0959\,m^3/s$

$Q_1 = Q_2$

$0.0959\,m^3/s = A_2 V_2$

$0.0959\,m^3/s = \frac{\pi D_{i2}^2}{4}(3.0\,m/s)$

$0.383\,m^3/s = D_{i2}^2 (9.42\,m/s)$

$\sqrt{D_{i2}} = \sqrt{0.04066}$

$D_{i2} = 0.202\,m \left(\frac{3.2808\,ft}{1\,m}\right)\left(\frac{12\,in}{1\,ft}\right) = 7.94''$

For Suction Pipe

8'' Schedule 40 Pipe

$D_{o2} = 8.625''$

$D_{i2} = 7.981''$

$Q_A = A_B V_B$

$3.387\,ft^3/s = \frac{\pi}{4}\left(7.981''\left(\frac{1\,ft}{12\,in}\right)\right)^2 V_B$

$3.387\,ft^3/s = 0.347\,V_B$

$V_B = 9.761\,ft/s$

$P_1 = 0,\ V_1 = 0,\ Z_1 = 0$

$\cancel{\frac{P_1}{\gamma}} + \frac{V_1^2}{2g} - h_L + Z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + Z_2$

$-(Z_1 - Z_2) - \cancel{V_1^2/2g} = \frac{P_2}{\gamma} + \cancel{\frac{V_2^2}{2g}} + Z_2$

$-10\,ft = \frac{P_2}{62.4\,lb/ft^3} + 10\,ft$

$62.4\,lb/ft^3(-10) = P_2$

$P_2 = -1248\,lb/ft^2$

$V_4 = 0,\ P_4 = 0,\ Z_4 = 50\,ft$

$Z_3 = 0$

$h_L = k\frac{V_3}{2g}$

$\frac{P_3}{\gamma} + \frac{V_3^2}{2g} - h_L + Z_3 = \frac{P_4}{\gamma} + \frac{V_4^2}{2g} + Z_4$

$\frac{P_3}{62.4\,lb/ft^3} + \frac{(9.761\,ft/s)}{2(32.2\,ft/s^2)} - \frac{(5.3)(9.761\,ft/s)}{2(32.2\,ft/s^2)} = 50\,ft$

$\frac{P_3}{62.4\,lb/ft^3} = 50.6517 \quad P_3 = 3{,}160\,lb/ft^2$

$h_A = \frac{P_3 - P_2}{\gamma} + (Z_3 - Z_2) + \cancel{\frac{V_3^2 - V_2^2}{2g}}$

$h_A = \frac{3{,}160\,lb/ft^2 + 1{,}248\,lb/ft^2}{62.4\,lb/ft^3} - 10\,ft$

$h_A = 70.65\,ft - 10\,ft$

$h_A = 60.65\,ft$

$P_A = h_A \gamma Q$

$= (60.65\,ft)(62.4\,lb/ft^3)(3.387\,ft^3/s)$

$P_A = (13{,}211.002\,lb\text{-}ft/s)\left(\frac{1\,hp}{550}\right)$

$P_A = 23.3\,hp$

$e_M = \frac{23.3001\,hp}{P_I}$

$0.6 = \frac{23.3001\,hp}{P_I}$

$P_I = 38.84\,hp$

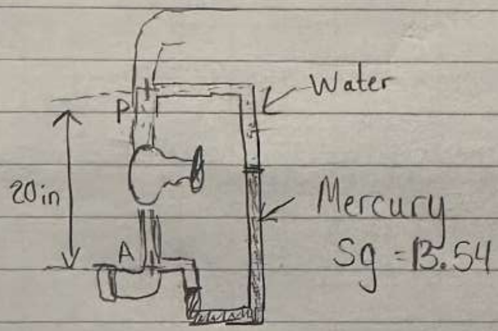
Summary: With a pipe of 8" Schedule 40. It is required that the pump runs at 38.84 hp at an efficiency of 60%.

Materials: H_2O, 8" Schedule 40

Analysis: It wasn't the most efficient way of finding the hp of the pump. The required hp initial seemed high but upon looking at the size of the channel it seem reasonable.

b.) Purpose: To determine the reading or deflection in the U-tube manometer.

Diagram:



Sources:

- Mott & Untener "Applied Fluid Mechanics." 7th Edition Pearson Education, In (2015)

Design Considerations:

- $T = 60°F$
- Incompresible Fluids
- Isothermal

Data & Variables:

$\gamma_{H_2O} = 62.4\,lb/ft^3$ $\quad sg = 13.54$

$K = 5.3$

Procedure: To measure valve performance I will obtain the pressure drop by utilizing the following formula $\frac{\Delta P}{\gamma} = \frac{V^2}{2g}$

Calculations:

$$\Delta P = \frac{\left(K\frac{V^2}{2g}\right)}{\gamma_{oil}} = \frac{\frac{5.3\,(9.761\,ft/s)^2}{2(32.2\,ft/s^2)}}{(13.54)(62.4\,lb/ft^3)}$$

$\Delta P = 0.009\,lb/ft^2$

Summary: Utilizes the distance between where the U-tube manometer is connected to the pipe. The pressure drop for the system was 0.009 lb/ft^2

Materials: H_2O, Manometer, Mercury

Analysis: Upon reviewing pressure drop for the system, it seems the valve has a profound effect on how manometer reads. The distance between was the deciding variable since there weren't any other height values for the Mercury.

C. Purpose: Make a spread sheet that would perform Pump Power under different operating conditions

Diagram: On Excel File

Sources: Mott & Untener "Applied Fluid Mechanics". 7th Editions Pearson Education, Inc (2015

Design Considerations:
* Must cover range of flow rates 0 to 4 ft^3/s * Incompressible
* Assuming Effeciency doesn't depend on Flowrate

Data & Variables:
$T = 60°F$ $\gamma_{H_2O} = 62.4 lb/ft^3$
$K = 2.5$

Procedure: To determine pump power spreadsheet will need calculations from Combining Bernoulli's equation & general energy equation

Calculations:
On Excel Sheet

Summary: For Best Fit equation of Required Power Vs Flowrate I got an equation of $y = 6.88x$

Materials: Flowrate of H_2O,

Analysis: There is a linear relationship between horsepower and flowrate. Meaning if you require an increase in Volumetric Flow you'll need an increase in horsepower in your pump to account for it.