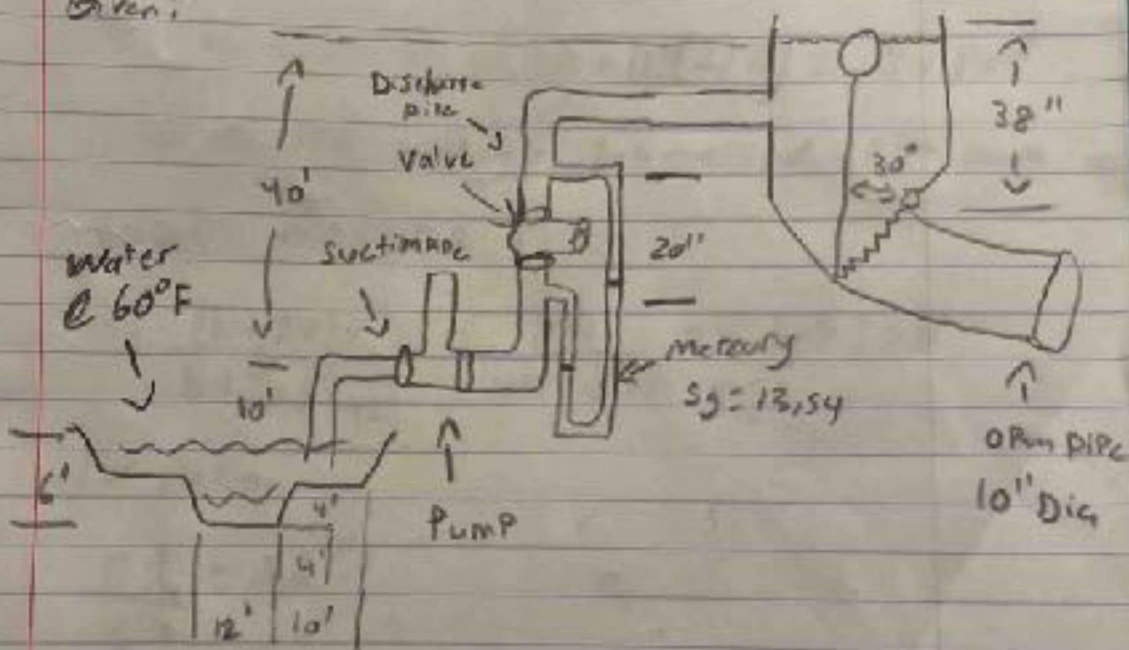
Test 1

Tyler Gray

MET 330

Purpose: Design a system to deliver 60°F water from an open channel to an elevated open channel at 3.387 ft³/s

Given:



Pump efficiency = 60%
Suction pipe length = 11 ft
Discharge pipe length = 2500 ft
Valve resistance = K = 5.3

Solution :

Area of ~~the~~ open channel

Trapizoid :

$$A = (b+2y)y = (40+(1)(2)2) = 84\ ft^2$$

as the Dike was only submerged 2ft Deep

hydraulic radius = R =

$$R = \frac{(b+2y)y}{b+2y\sqrt{1+z^2}} = \frac{84}{40+4\sqrt{1+1^2}} = 1.8398$$

For design

$$\frac{nQ}{S^{1/2}} = AR^{2/3}$$

it was not specified but n was taken as clean excaved earth n = 0.022 from table 14.1

Slope was not specified so typical slope of 1% was used

Solving For Q

$$\frac{0.022\,Q}{0.01^{1/2}} = (84)(1.8398)^{2/3}$$

$$\frac{0.022\,Q}{0.01^{1/2}} = 126.123$$

$0.022\,Q = 12.612$

$Q = 573.28\ ft^3/min$

$\boxed{Q = 9.555\ ft^3/s}$

Max Flow rate given by Open Channel must not exceed

this Q is used to solve for pipe diameter using bernoulli's equation & Q=VA

Fo Q=VA

We = want a Fluid velocity of close to 3m/s or 9.84 ft/s

Suction Pipe is 11 ft with 1 90° bend
Discharge Pipe is 2500 ft

$$h_A + \frac{P_1}{\gamma_1} + \frac{v_1^2}{2g} + z_1 = \frac{P_2}{\gamma_2} + \frac{v_2^2}{2g} + z_2 + h_{L_{12}}$$

Determine: required Pump power in HP
Assume 60% η

$$h_A + \frac{P_1}{\gamma_1} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\gamma_2} + \frac{V_2^2}{2g} + Z_2 + h_{L12}$$

$$P_m = \frac{P_A}{n_A} = \frac{\gamma Q h_A}{n_A}$$

$$h_A = \cancel{\frac{P_2 - P_1}{\gamma}} + \frac{\cancel{V_2^2} - \cancel{V_1^2}}{2g} + Z_2 - Z_1 + h_{L12}$$

open channel

$Q = VA$

$8.5995 = 9.84 A$

$A = 0.344 ft^2$

K was Given as 5.3

h_L can be solved using the equation

$$h_{L12} = f \frac{L}{D} \frac{V^2}{2g} + 3 \times K \frac{V^2}{2g}$$

elbows 90°

it was specified that a schedule 40 pipe was used because this was from table F.1

From table F.1

$A = 0.344 ft^2 \approx 0.317 ft^2$

a 8 in nominal pipe size was selected based from the chart

with an inside diameter of $0.6354 ft = D$

$R_e = \frac{VD}{\nu}$ 60°F water

$\nu = 1.21 \times 10^{-5}$ from table A.2

$R_e = \frac{(9.84 ft/s)(0.6354 ft)}{1.21 \times 10^{-5}} = 516721.98 = 5.17 \times 10^5$

ε = assumed steel pipe $= 1.5 \times 10^{-4} ft$

$\frac{D}{\varepsilon} = \frac{0.6354}{1.5 \times 10^{-4}} = \underline{4236}$

From Moody's chart

$f = 0.016$

Plugging those found values into h_L equation gives

$$h_L = 0.016 \frac{2500+11}{0.6354} \times \frac{9.84^2}{2(32.2)} + 3\left(5.3 \times \frac{9.84^2}{2(32.2)}\right)$$

$$h_L = 63.23 \times 1.504 + 23.91$$

$$h_L = 118.98 \text{ Ft}$$

$$h_A = Z_2 - \cancel{Z_1} + 118.98$$

$$h_A = 50 \text{ Ft} + 118.98 \text{ ft}$$

$$h_A = 168.98 \text{ Ft}$$

Knowing Pump head I can solve for hydrolic required Power using

$$P_A = \gamma Q h_a$$

$$P_A = (62.4)(3.387)(168.98)$$

$$P_A = 35713 \frac{\text{lb-Ft}}{\text{s}} \times \frac{1 \text{ HP}}{550 \text{ lb-ft}} = 64.9 \text{ HP}$$

assuming $\eta = 60\%$

$$\boxed{P_{ump} = \frac{64.9}{.6} = 108.2 \text{ Hp}}$$ A

$$\frac{\Delta P}{\gamma} = K\frac{V^2}{2g} = h_L$$

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

$\Delta P = \gamma h$ for mecury

$$\frac{Q^2}{2g}\left(\underbrace{\cancel{\frac{1}{A_A^2} - \frac{1}{A_B^2}}}_{}\right)^{\text{same } \varnothing} = \frac{P_B - P_A}{\gamma} + Z_A - \overset{20\,in}{Z_B}$$

$$\frac{P_B - P_A}{\gamma_{water}} = Z_A - Z_B + \left(1 - \frac{Sg_{Hg}}{Sg_W}\right)h$$

$$Q^2 = 2g\left(1 - \frac{Sg_{Hg}}{Sg_W}\right)h + Z_A - Z_B$$

$$h = \frac{Q^2 - (Z_A - Z_B)}{1 - \frac{Sg_{Hg}}{Sg_W}}$$

$$h = \frac{3.387^2 - 1.66\,ft}{1 - \frac{1}{13.54}} = 10.58\,in$$

$$h = \frac{3.387^2 - 1.666}{1 - \frac{1}{13.52}} = 10.58\,in$$

$$\frac{10.58\,in}{20\,in} = 0.529 = 52.9\%$$ B

Sources: "Applied Fluid mechanics"
Robert L. Mott / Joseph A. Untener

Material list:

Steel pipe schedule 40 8in nominal size
Pump
U-Tube manometer
mercury
water @ 60°F

Analysis:

This design is assuming a steady flow open channel and pump efficiency is calculated at 60%. results could vary based on things changing such as

- increased / decreased water temp
- change in open flow chanel
- Pump efficiency dropping over time

Summary:

Water was to be moved from a lower open channel to a elevated open channel. The flow rate was to be $3.387 \, ft^3/s$ to be delivered. Alternative pump selection and their flow rates was calculated with excel and a graph was created to visualize the relationship as by request. This could be benifical if in the future a different flow rate was asked for. The graph and calculations would give the new pumps required HP while still taking consideration of the rest of the design.