Calculations

Test 3 - Fluids

$Q = 3.387 \frac{ft^3}{s}$ 60°F water

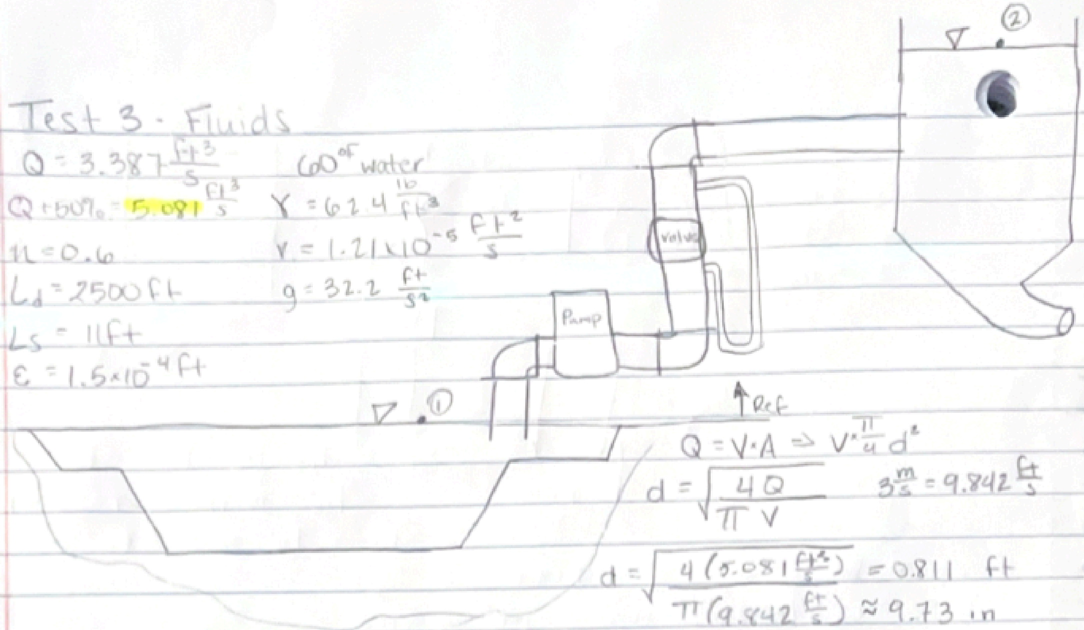
$Q + 50\% = 5.081 \frac{ft^3}{s}$ $\gamma = 62.4 \frac{lb}{ft^3}$

$\eta = 0.6$ $\nu = 1.21 \times 10^{-5} \frac{ft^2}{s}$

$L_d = 2500\ ft$ $g = 32.2 \frac{ft}{s^2}$

$L_s = 11\ ft$

$\varepsilon = 1.5 \times 10^{-4}\ ft$



$Q = V \cdot A \Rightarrow V \cdot \frac{\pi}{4} d^2$

$d = \sqrt{\frac{4Q}{\pi V}}$ $3 \frac{m}{s} = 9.842 \frac{ft}{s}$

$d = \sqrt{\frac{4(5.081 \frac{ft^3}{s})}{\pi (9.842 \frac{ft}{s})}} = 0.811\ ft \approx 9.73\ in$

8-in sch 40 pipe $D_i = 7.981\ in = 0.665\ ft$

$A = 0.3472\ ft^2$

$h_A + \frac{p_1}{\gamma} + \frac{v_1^2}{2g} + z_1 = \frac{p_2}{\gamma} + \frac{v_2^2}{2g} + z_2 + h_{L\,pipes} + 3(h_{L\,elbows}) + h_{L\,valve} + h_{L\,piped}$

$h_A = (z_2 - z_1) + h_{L\,pipes} + 3(h_{L\,elbow}) + h_{L\,valve} + h_{L\,piped}$ $V = \frac{Q}{A} = \frac{5.081 \frac{ft^3}{s}}{0.3472\ ft^3} = 14.6 \frac{ft}{s}$

$h_{L\,pipe\ suction} = f \frac{L}{D} \frac{V^2}{2g} = (1.52E\text{-}2)\left(\frac{11\ ft}{0.665\ ft}\right)\left(\frac{(14.6 \frac{ft}{s})^2}{2(32.2 \frac{ft}{s^2})}\right) = 0.832\ ft$ $Re = \frac{VD}{\nu} = \frac{(14.6 \frac{ft}{s})(0.665\ ft)}{(1.21 \times 10^{-5} \frac{ft^2}{s})}$

K = 30 ft
30(0.014)
0.42

$3 h_{L\,elbow} = K\left(\frac{V^2}{2g}\right) = 0.42 \left(\frac{14.6\ ft^2}{2(32.2 \frac{ft}{s^2})}\right) = 1.39\ ft \times 3 = 4.17\ ft$ $Re = 802{,}396.7$

$\frac{D}{\varepsilon} = \frac{0.665\ ft}{(1.5 \times 10^{-4}\ ft)} = 4433.3$

K = 340 ft
340(0.014)
4.76

$h_{L\,valve} = K\left(\frac{V^2}{2g}\right) = 4.76 \left(\frac{14.6\ ft^2}{2(32.2 \frac{ft}{s^2})}\right) = 15.76\ ft$ on excel $f = 1.52E\text{-}2$ $f_T = 0.014$

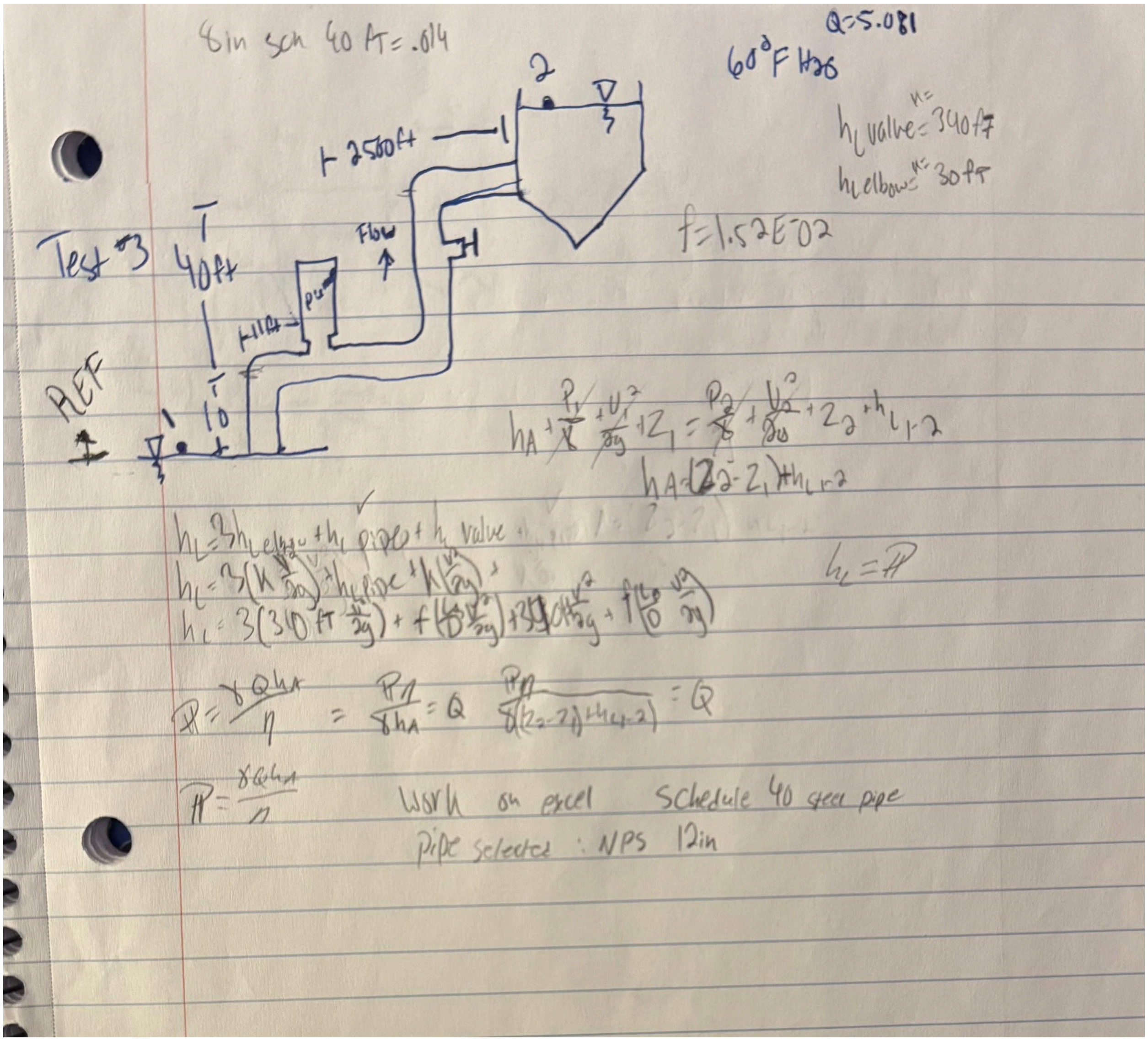
$h_{L\,discharge} = f \frac{L}{D} \frac{V^2}{2g} = (1.52E\text{-}2)\left(\frac{2500\ ft}{0.665\ ft}\right)\left(\frac{(14.6 \frac{ft}{s})^2}{2(32.2 \frac{ft}{s^2})}\right) = 189.14\ ft$

$h_A = (50\ ft - 0\ ft) + 0.832\ ft + (3 \times 1.39\ ft) + 15.76\ ft + 189.14\ ft$ (4.17 ft)

$h_A = 259.9\ ft$

$P = \frac{\gamma Q h_A}{\eta} = \frac{(62.4 \frac{lb}{ft^3})(5.081 \frac{ft^3}{s})(259.9\ ft)}{0.6} = 137{,}337.4 \frac{lb\,ft}{s} \div 550$

$= 250\ HP$



Materials

- Water at 60F
- 60% efficient pump
- 10-in schedule 40 steel pipe

Summary & Analysis

When considering redesign options for the given fluid system, there are three main approaches: increasing the flow rate with the current system, upgrading to a larger pump, or maintaining the current pump and replacing the pipes with larger ones. Each option impacts the system differently and has its advantages and challenges. If the flow rate is increased while keeping the current pump and pipe sizes, the system will face a significant rise in head loss, which increases with the square of the flow rate. This higher resistance will demand more energy from the pump, potentially exceeding its capacity and leading to decreased flow delivery or pump failure.

Replacing the pump with a larger one allows the system to handle higher flow rates effectively. The larger pump provides additional energy to overcome the increased head losses caused by higher flow rates. However, this requires greater pump power, resulting in higher operating costs.

Alternatively, maintaining the current pump and increasing the pipe diameter is a more cost-effective and efficient solution for moderate flow increases. Larger pipes significantly reduce head loss, as frictional losses decrease with the fifth power of the diameter. This reduction in head loss allows the pump to deliver higher flow rates without exceeding its power rating. Additionally, larger pipes lower the flow velocity, reducing wear and vibration, and improving system reliability.

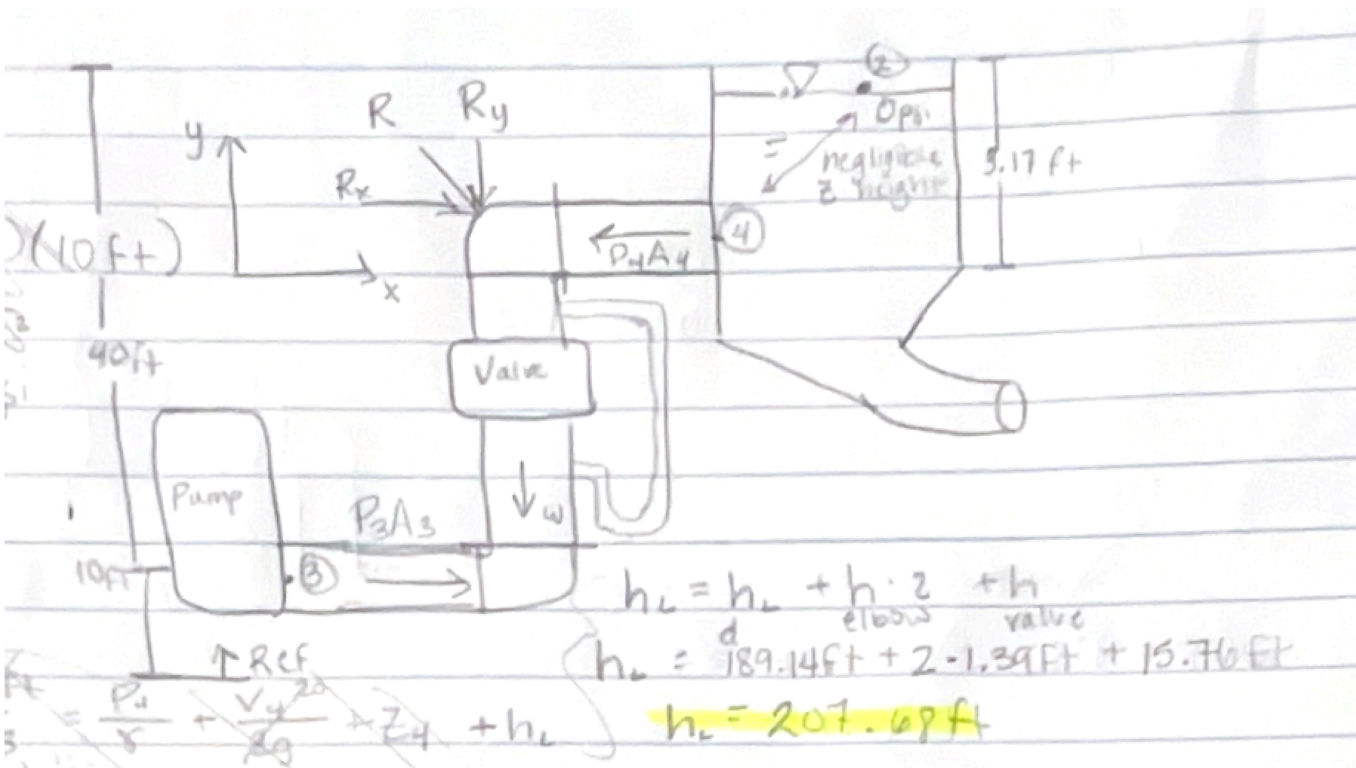
In summary, increasing flow rate without system modifications is not advisable due to the strain it places on the pump and pipes. For small to moderate flow increases, replacing the pipes with larger ones is the most efficient and cost-effective solution.

B

Purpose

The purpose of part b is to quantify the total horizontal and vertical focus in the whole discharge pipe-elbows-valve system for our civil colleague.

Drawings & Diagrams



Sources

- My notes
- Applied Fluid Mechanics 8th Edition, Robert L. Mott & Joseph A. Untener
- Canvas Module slides