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MET 330 Fluid Mechanics
Dr. Orlando Ayala
Spring 2021
Test 1

Take home – Due Sunday February 21st 2021 before midnight.

READ FIRST

1. RELAX!!!! DO NOT OVERTHINK THE PROBLEMS!!!! There is nothing hidden. The test was designed for you to pass and get the maximum number of points, while learning at the same time. HINT: THINK BEFORE TRYING TO USE/FIND EQUATIONS (OR EVEN FIND SIMILAR PROBLEMS)

2. The total points on this test are one hundred (100). Ten (10) points are from your HW assignments, and ten (10) other points are based on the basis of technical writing. The other eighty (80) points will come from the problem solutions. For the technical writing I will follow the attached rubric.

3. There are 3 main different parts, each one is worth 80/3 points.

4. What you turn in should be only your own work. You cannot discuss the exam with anyone, except me. Call me, skype me, text me, email me, come to my office, if you have any question.

5. I do not read minds. You should be explicit and organized in your answers. Use drawings/figures. If you make a mistake, do not erase it. Rather use that opportunity to explain why you think it is a mistake and show the way to correct the problem.

6. You have to turn in your test ON TIME and ONLY through BLACKBOARD. You must submit the test solution in only one file, and it has to be a pdf file. You must also submit the excel spreadsheet. For the ePortfolio (which is optional) you are supposed to upload this artifact to your Google drive. I will provide more instructions later.

7. Do not start at the last minute so you can handle anything that could happen. Late tests will not be accepted. Test submitted through email will not be accepted either.

8. Cheating is completely wrong. The ODU Student Honor Pledge reads: "I pledge to support the honor system of Old Dominion University. I will refrain from any form of academic dishonesty or deception, such as cheating or plagiarism." By attending Old Dominion University, you have accepted the responsibility to abide by this code. This is an institutional policy approved by the Board of Visitors. It is important to remind you the following part of the Honor Code:

   IX. PROHIBITED CONDUCT

   A. Academic Integrity violations, including:

   1. *Cheating*: Using unauthorized assistance, materials, study aids, or other information in any academic exercise (Examples of cheating include, but are not limited to, the following: using unapproved resources or assistance to complete an assignment, paper, project, quiz or exam; collaborating in violation of a faculty member's instructions; and submitting the same, or substantially the same, paper to more than one course for academic credit without first obtaining the approval of faculty).

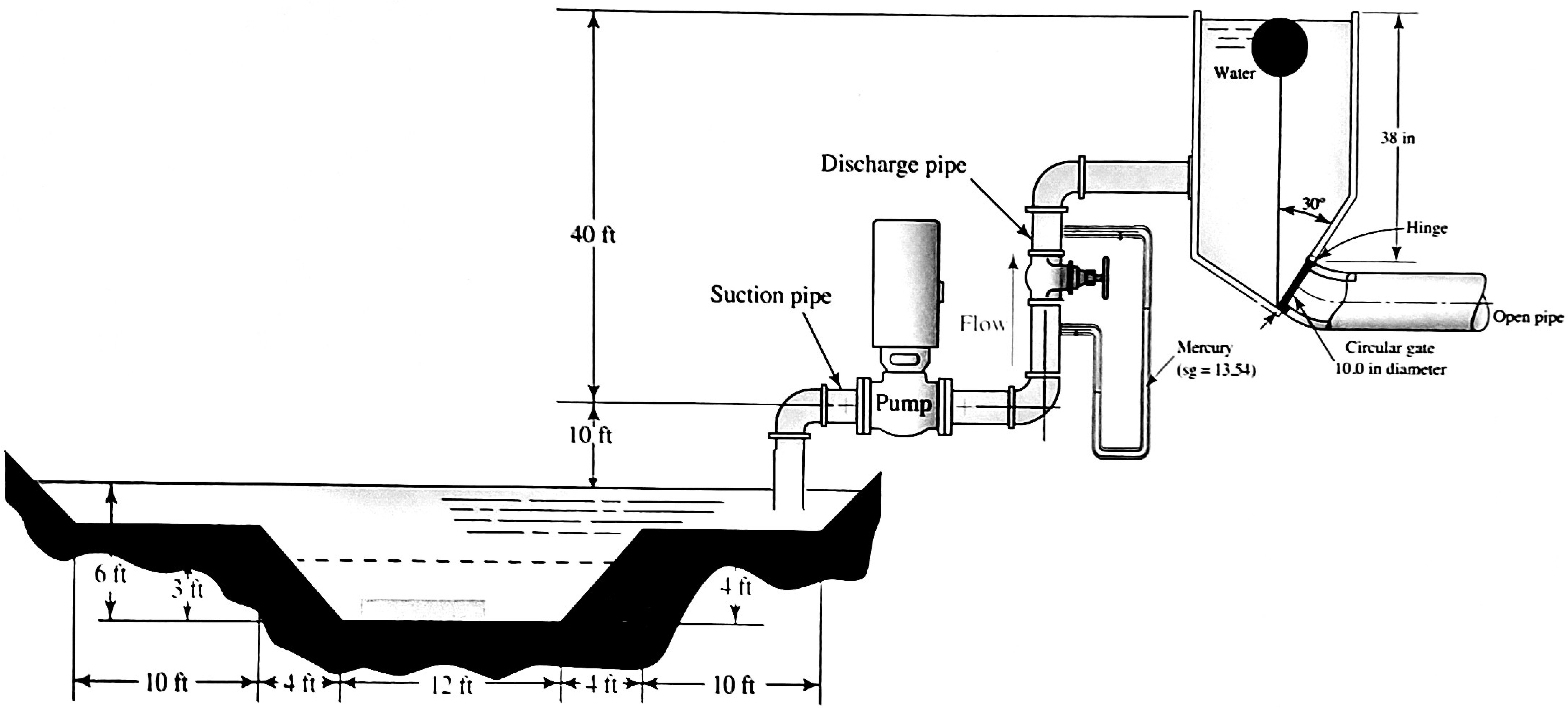
With that said, you are NOT authorized to use any online source of any type, unless is ODU related.

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 (PLEASE NOTE THAT THE FIGURE IS NOT SCALED). The company requires to deliver 3.387 ft^3/s of water from the lower open channel to the upper open channel.

a. Determine the required pump power (in HP). Assume a pump efficiency of 60%. The total suction pipe length is 11 ft, while the total discharge pipe length is 2500 ft. The valve resistance coefficient (K) is 5.3. You must first select a pipe diameter from table F1 in the appendix of the book. Select a diameter such as the fluid flow velocity in the pipe is close to 3 m/s. The company would like you to do all your work by hand but also, they need you to create an excel spreadsheet to run automatically all calculations. You must make sure the excel solutions match the hand calculations.

b. The company needs to monitor the valve performance, and for that they would like to use an on-site U-tube manometer as shown in the figure. What would be the reading (a.k.a. the deflection) in the U-tube manometer? Basically, the manometer measures the pressure drop due to energy losses in the valve, and they are computed following: $\frac{\Delta p}{\gamma} = K\frac{V^2}{2g}$. The distance between the two taps where the U-tube manometer is connected to the pipe is 20 inches. The company would like you to do all your work by hand but also, they need you to create an excel spreadsheet to run automatically all calculations. You must make sure the excel solutions match the hand calculations.

c. The company would like you to use the spreadsheet to check what would be the design under different operation conditions. Determine the pump power (in HP) and the manometer reading for different flow rate values (create a table with a range of flow rates from 0 to 4 ft^3/s). Assume the pump efficiency does not depend on the flow rate. Make a plot of the required pump power vs flow rate. Using the plot, determine the flow rate when the required pump power is half of the required pump power you computed before. Also determine the manometer reading for when the required pump power is half of the required pump power you computed before.



Water
38 in
Discharge pipe
30°
Hinge
40 ft
Suction pipe
Flow
Pump
Open pipe
Mercury
(sg = 13.54)
Circular gate
10.0 in diameter
10 ft
6 ft
3 ft
4 ft
10 ft
4 ft
12 ft
4 ft
10 ft

Problem solution rubric

	Exceeds Standard 4 10 points	Meets Standard 3 7 points	Approaches Standard 2 4 points	Needs Attention 1 0 points
Purpose **5%**	The purpose of the section to be answered is clearly identified and stated.	The purpose of the section to be answered is identified, but is stated in a somewhat unclear manner.	The purpose of the section to be answered is partially identified, and is stated in a somewhat unclear manner.	The purpose of the section to be answered is erroneous or irrelevant.
Drawings & Diagrams **10%**	Clear and accurate diagrams are included and make the section easier to understand. Diagrams are labeled neatly and accurately.	Diagrams are included and are labeled neatly and accurately.	Diagrams are included and are labeled.	Needed diagrams are missing OR are missing important labels.
Sources **5%**	Several reputable background sources were used and cited correctly.	A few reputable background sources are used and cited correctly.	A few background sources are used and cited correctly, but some are not reputable sources.	Background sources are cited incorrectly.
Design considerations (assumptions, safety, cost, etc) **10%**	Design is carried out with applicable assumptions and full attention to safety and cost, etc.	Design is generally carried out with assumptions and attention to safety, cost, etc.	Design is carried out with some assumptions and some attention to safety, cost, etc.	Assumptions, safety and cost were ignored in the design.
Data and variables **5%**	All data and variables are clearly described with all relevant details.	All data and variables are clearly described with most relevant details.	Most data and variables are clearly described with most relevant details.	Data and variables are not described OR the majority lack sufficient detail.
Procedure **25%**	Procedure is described in clear steps. The step description is in a complete and easy to understand short paragraph.	Procedure is described in clear steps but the step description is not in a complete short paragraph.	Procedure is described in clear steps. The step description is in a complete short paragraph but it is difficult to understand.	Procedure is not described in clear steps at all.
Calculations **20%**	All calculations are shown and the results are correct and labeled appropriately. The units of all values are shown.	Some calculations are shown and the results are correct and labeled appropriately.	Some calculations are shown and the results labeled appropriately.	No calculations are shown OR results are inaccurate or mislabeled.
Summary **5%**	Summary describes the design, the relevant information and some future implications.	Summary describes the design and some relevant information.	Summary describes the design.	No summary is written.
Materials **5%**	All materials used in the design are clearly and accurately described.	Almost all materials used in the design are clearly and accurately described.	Most of the materials used in the design are clearly and accurately described.	Many materials are described inaccurately OR are not described at all.
Analysis **10%**	The design is discussed and analyzed. Argumentative predictions are made about what might happen in case of change in the operation and how the design could be change.	The design is discussed and analyzed. Argumentative predictions are made about what might happen in case of change in the operation.	The design is discussed and analyzed. No argumentative predictions are made about what might happen in case of change in the operation and how the design could be change.	The design is not discussed and analyzed.

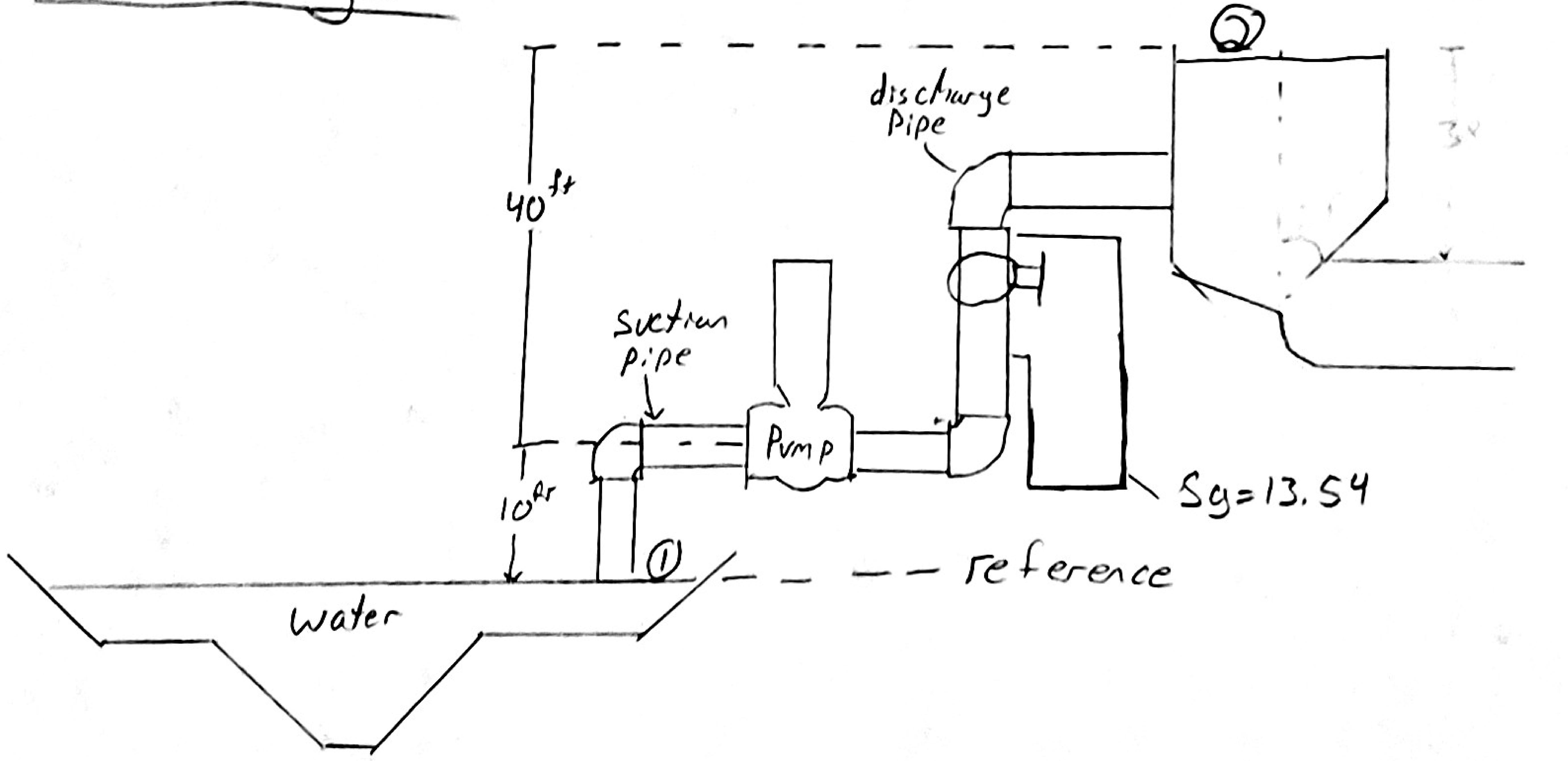
Purpose

ⓐ Determine the required pump power to deliver $3.387 \frac{ft^3}{s}$, through the system, to the upper champer.

Ⓑ Determine the reading on the U-tube meter and develope spreadsheet to automatically run calculations.

Ⓒ Determine both pump power and U-tube meter readings for flow rates between $0 \frac{ft^3}{s}$ to $4 \frac{ft^3}{s}$.

Drawings



Sources

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

Design Considerations

- Constant Tempature
- Incompressible Fluids
- Steady State

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Data & Variables

$T_{water} = 60°F$ $Q = 3.387 \frac{ft^3}{s}$

$\varepsilon_{pump} = 60\%$ $L_{suction} = 11^{ft}$

$L_{discharge} = 2500^{ft}$ $K = 5.3$

$V = 3 \frac{m}{s} = 9.812 \frac{f}{s}$ ∴ $D_{pipe} = 8^{in}$ schedule 40

Procedure

- I will assign reference at surface of water.
- I will assign point 1 and 2 at surface of lower water and upper water because that is where I know the most information.
- I will use Bernoulli's equation, accounting for energy lost from pipes, to find h_a
- I will need to use Reynolds number and relative friction to find the friction factor.

Calculations

A)

$$h_a + \frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + h_r + h_L + z_2$$

$$h_a = h_L + z_2$$

$$h_L = h_{L\,pipe} + h_{L\,elbows} + h_{L\,valve} + h_{L\,exit}$$

$$h_{L\,pipe} = f \cdot \frac{L}{D} \cdot \frac{V^2}{2g}$$

$$N_R = \frac{V \cdot D}{\nu} = \frac{9.8425 \frac{f}{s} \cdot 0.6651^{ft}}{1.21 \times 10^{5} \frac{ft^2}{s}}$$

$$N_R = 5.409 \times 10^5$$

$$R_r = \frac{D}{\varepsilon} = \frac{0.6651^{ft}}{1.5 \times 10^{-4} ft} = 4434$$

based on MOODY CHART

$$f = 0.016$$

$$h_{L\,pipe} = 0.016 \cdot \frac{2511^{ft}}{0.6651^{ft}} \cdot \frac{(9.8425 \frac{f}{s})^2}{2 \cdot 32.2 \frac{f}{s^2}} = \underline{90.86^{ft}}$$

$$h_{L\,elbows} = 3 \cdot k \cdot \frac{v^2}{2g}$$

$$k = 30\, f_T$$

$$f_T = \frac{0.25}{\left[\log\left(\frac{1}{3.7(\frac{D}{\varepsilon})}\right)\right]^2}$$

$$f_T = 0.014$$

$$K = 0.422$$

$$h_{L\,ellbows} = 3 \cdot 0.422 \cdot \frac{(9.8425\frac{ft}{s})^2}{2 \cdot 32.2\frac{ft}{s^2}}$$

$$h_{L\,elbows} = \underline{1.9044^{ft}}$$

$$h_{L\,exit} = k \cdot \frac{v^2}{2g} = 1 \cdot \frac{(9.8425\frac{ft}{s})^2}{2 \cdot 32.2\frac{ft}{s^2}} = \underline{1.5^{ft}}$$

$$h_{L\,valve} = k\frac{v^2}{2g} = 5.3 \cdot \frac{(9.8425\frac{ft}{s})^2}{2 \cdot 32.2\frac{ft}{s^2}} = \underline{7.97^{ft}}$$

$$h_L = 90.86 + 1.9044 + 1.5 + 7.97$$

$$h_L = 102.23^{ft}$$

$$h_a = 102.23^{ft} + 50^{ft}$$

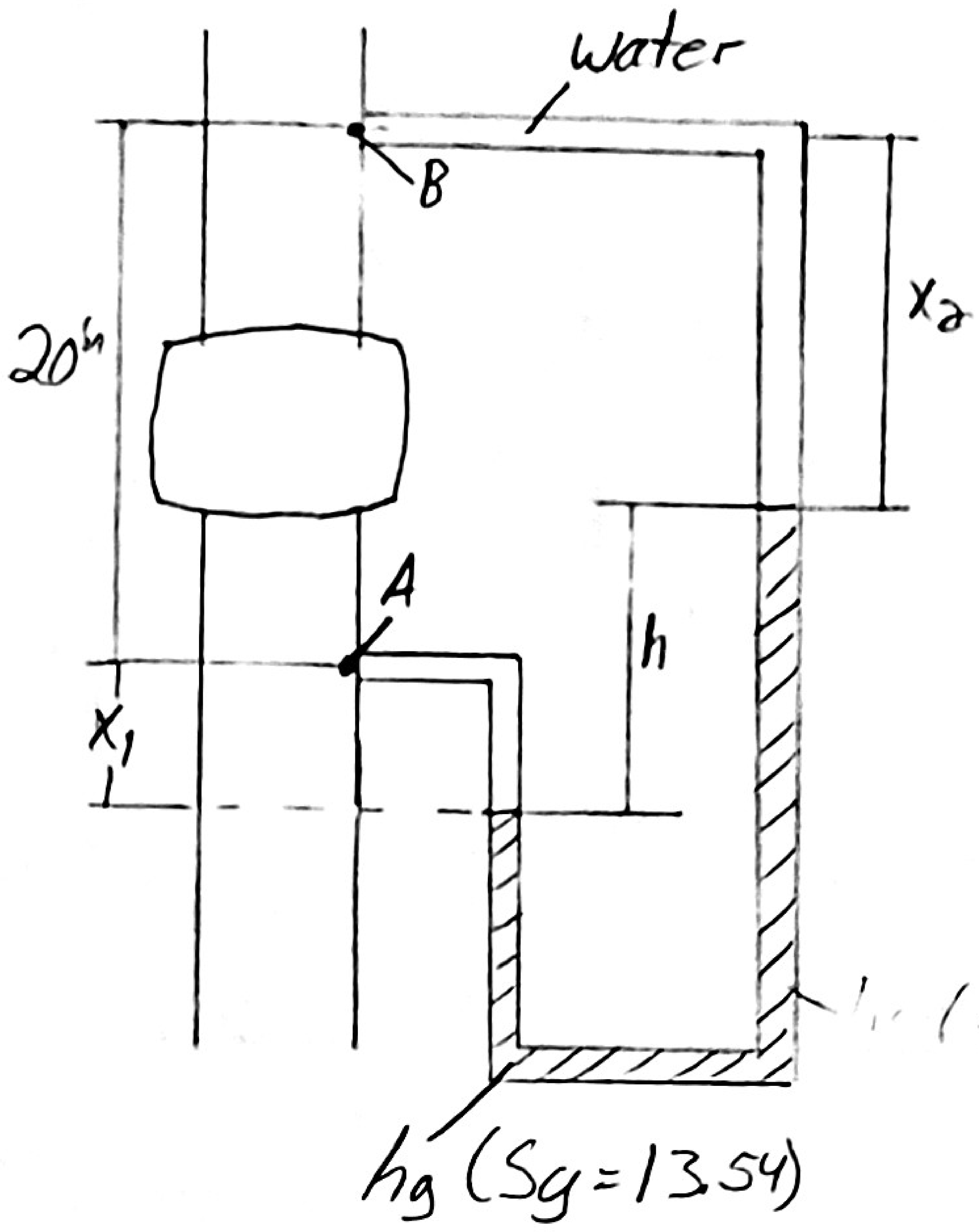
$$h_a = 152.23^{ft}$$

$$P_m = \frac{\gamma \cdot Q \cdot h_a}{\eta_P} = \frac{(62.4\frac{lb}{ft^3})(3.387\frac{ft^3}{s})(152.23^{ft})}{0.60}$$

$$P_m = \underline{\underline{53\,622.71\ HP}}$$

B)

Enlarged View of U-tube



– using gamma·h equation

$$P_a + (x_1 \cdot \gamma_w) - (h \cdot \gamma_{hg}) - (x_2 \cdot \gamma_w) = P_B$$

$$x_1 \cdot \gamma_w - h \cdot \gamma_{hg} - x_2 \cdot \gamma_w = P_B - P_A$$

$$x_1 - \frac{\gamma_{hg} \cdot h}{\gamma_w} - x_2 = \frac{P_B - P_A}{\gamma_w} \quad (1)$$

– geometrical relationship

$$x_1 + 20^{in} = h + x_2 \Rightarrow x_1 = h + x_2 - 20^{in} \quad (2)$$

– pressure drop due to valve

$$\frac{\Delta P}{\gamma_w} = K\frac{V^2}{2g} = 5.4 \cdot \frac{(9.8425 \frac{ft}{s})^2}{2 \cdot 32.2 \frac{ft}{s^2}}$$

$$\frac{\Delta P}{\gamma_w} = 7.96^{ft} \quad (3)$$

putting eq (2) in eq (1)

$$h + x_2 - 20^{in} - \left(\frac{Sg_{hg} \cdot \gamma_w}{\gamma_w} \cdot h\right) - x_2 = -\frac{\Delta P}{\gamma_w}$$

$$h - 13.54h = -7.96^{ft} + 20^{in} \cdot \frac{1^{ft}}{12^{in}}$$

$$-12.54h = -6.294^{ft}$$

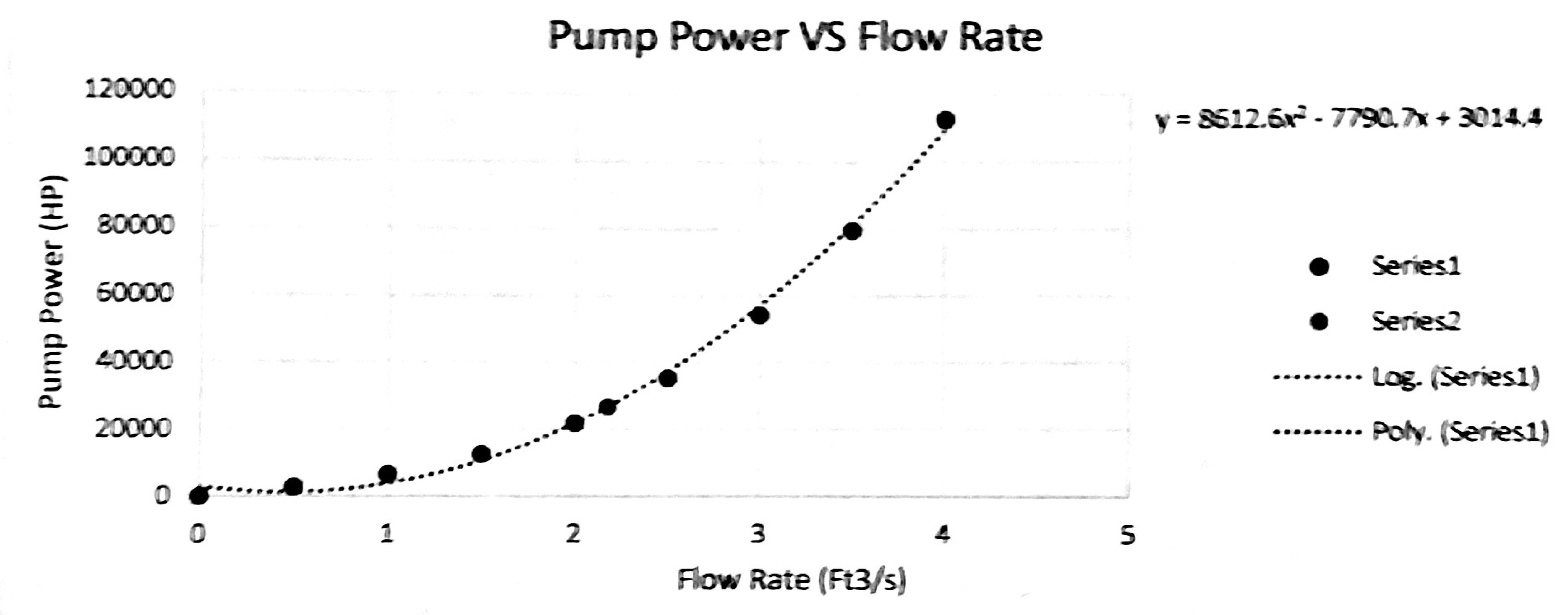
$$h = 0.5019^{ft} = \underline{6.022^{in}}$$

C) I have made a table of the flow rates, Pump power, and the deflection of the U-tube

I then used this table to plot a graph.

I set a trend line and used it's equation to find the flow rate value for pump power = 26811.355. After this, I computed the deflection of the U-tube for a flow rate of Q = 2.175.

Flow rate (ft3/s)	Pump power (HP)	Manometer reading (m)
0	0	0
0.5	2779.430	-1.431
1	6635.441	-0.941
1.5	12644.612	-0.124
2	21883.524	1.019
2.5	35428.759	2.489
3	54356.895	4.285
3.5	79744.514	6.409
4	112668.195	8.859
2.175	26811.355	1.496



Summary

- The required pump power is 53622.7 Hp
- The deflection in the U-tube is 6.022in
- The flow rate for half the first pump power is 2.175 $\frac{ft^3}{s}$ and the U-tube deflection is 1.496in

Materials

- Pump
- Valve
- pipes - 8in schedul 40
- Water
- mecury

Analysis

- Part A requires that the major and minor losses are acounted for. Thus giving and accurat pump power
- Part B requires that the gamma·h equation be used in combination with the geometrial relationships of the pipe and U-tube
- Part C requires extensive use of excel. After the graph was plotted, I used the equation of the trendline to find the value of the flow rate.