Name: Doris Bock

MET 330 Fluid Mechanics
Dr. Orlando Ayala
Summer 2023
FINAL Test

DUE DATE: Saturday August 5th before midnight

READ FIRST

1. RELAX!!!! DO NOT OVERTHINK THE PROBLEM!!!! 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 ninety (90). The other 10 points will come from the HW assignments.
3. There is only one problem and I will divide the 90 points among the different tasks.
4. PLEASE READ CAREFULLY THE TASKS AND INFORMATION BEFORE THE TASKS. Take notes while you read. You will NOT need everything stated on the project description section.
5. The test is open book, open notes. You cannot use online sources (only ODU related ones).
6. What you turn in should be only your work. You cannot discuss the exam with anyone else, except me. For those off campus, call me if you need help (302-397-4981).
7. 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.
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, even if it is ODU related.

HONOR CODE

I pledge to follow the Honor Code and to obey all rules for taking exams and performing homework assignments as specified by the course instructor.

I understand that when asked to follow the Honor Code on exams or homework assignments I must follow the rules below.

1. When following the Honor Code a student must work entirely alone on exams.

2. When following the Honor Code a student may not share information about any aspect of the exam with other members of the class, other faculty members, or other people who has not already taken the exam this year, or its equivalent in future years.

3. When following the Honor Code a student must direct all questions concerning the exam or homework assignment to the course instructor or teaching assistant.

4. When following the Honor Code it is the student's responsibility to obtain clarification from the instructor if there are questions concerning the requirements of the Honor Code.

5. When following the Honor Code a student can only access websites related to ODU (such as Blackboard, etc.) while taking the test.

6. When following the Honor Code a student cannot access, neither ask for help, from websites such as coursehero, chegg, and any other similar website, while taking the test.

I understand that failure to follow this Honor Code imply that the professor will immediately report my case for academic dishonesty to the ODU Office of Student Conduct & Academic Integrity.

Student Name: Dario Baxter

Student Signature: Dario Baxter

Date: ______________________

TASKS

After the previous engineer left the consulting company, you got hired to continue his work on a project described on the next pages. The previous engineer designed the tanks and decided their locations (sketched in figure 1). You are in charge now of designing the pipeline of the system taking the coolant from the railroad tank to the storage tank (PLEASE, note that you are in charge of only one system). **The transfer must occur in not less than 6 hours.** The specific tasks for this design you are in charge of are:

1. Specify the layout of the piping system (make a hand drawing of it). For the pipe layout consider the distances shown in figure 1 and some of the requirements (such as frost line) in the project description. Propose the material type of the pipe and its diameter. From the layout get the pipe length required. Please remember that for a pumped system, the pipe size is chosen with the critical velocity criteria and the desired flow rate. Remember the pipe size requirement by the company.
2. Specify the number, type, material, and size of all valves, elbows, and fittings. Please remember that for a pumped system, the pipe size (and therefore fitting sizes) is chosen with the critical velocity criteria and the desired flow rate.
3. Develop the hydraulic analysis of all parts of the system; this is to compute the energy losses due to pipe friction and minor losses. You should list the energy losses of the suction pipe, the discharge pipe, and the total.
4. What are the preliminary requirements of the pump (i.e. pump head and flow rate)?
5. Argue why you need a kinetic pump (instead of a positive displacement) and prove that the radial pump is the type of kinetic pump you need.
6. Select the appropriate SULZER pump (use affinity laws when required). Specify the exact point of operation of the pump. Include pump curves with the system curve and point of operation. Keep in mind that if you are required to use affinity laws to get the curves at another rpm, you can just scale the y- and x- axis appropriately of the pump H-Q curve. YOU MUST INCLUDE THE PUMP CURVE WITH THE SYSTEM CURVE DRAWN ON TOP OF IT!
7. Specify electrical motor requirement for our pump for our electrical engineering colleagues. Recall that we specify the power of the electrical motor as about 1.10 times the power required by the pump.
8. Evaluate the NPSH available for your design and demonstrate that your pump will not suffer cavitation.
9. Prepare a list of materials. Include everything you designed/selected. The list should contain the materials of the system as well as all the equipment (pump).

PROJECT DESCRIPTION

Continental AG is planning for a new manufacturing facility. As part of the new plant, there will be an automated machining line in which five machines will be supplied with coolant from the same reservoir.

The layout of the planned facility is shown in figure 1. The following data, design requirements, and limitations are given.

1. New coolant is delivered to the plant by railroad tank cars carrying 15,000 gal each. A storage tank for new coolant must be specified.

2. The reservoir for the automated machining system must have a capacity of 1000 gal.

3. The 1000-gal tank is normally emptied once per week. Emergency dumps are possible if the coolant becomes overly contaminated prior to the scheduled emptying.

4. The dirty fluid is picked up by truck only once per month.

5. A holding tank for the dirty fluid must be specified.

6. The plant is being designed to operate two shifts per day, 7 days a week.

7. Maintenance is normally performed during the third shift.

8. The building is one-story high with a concrete floor.

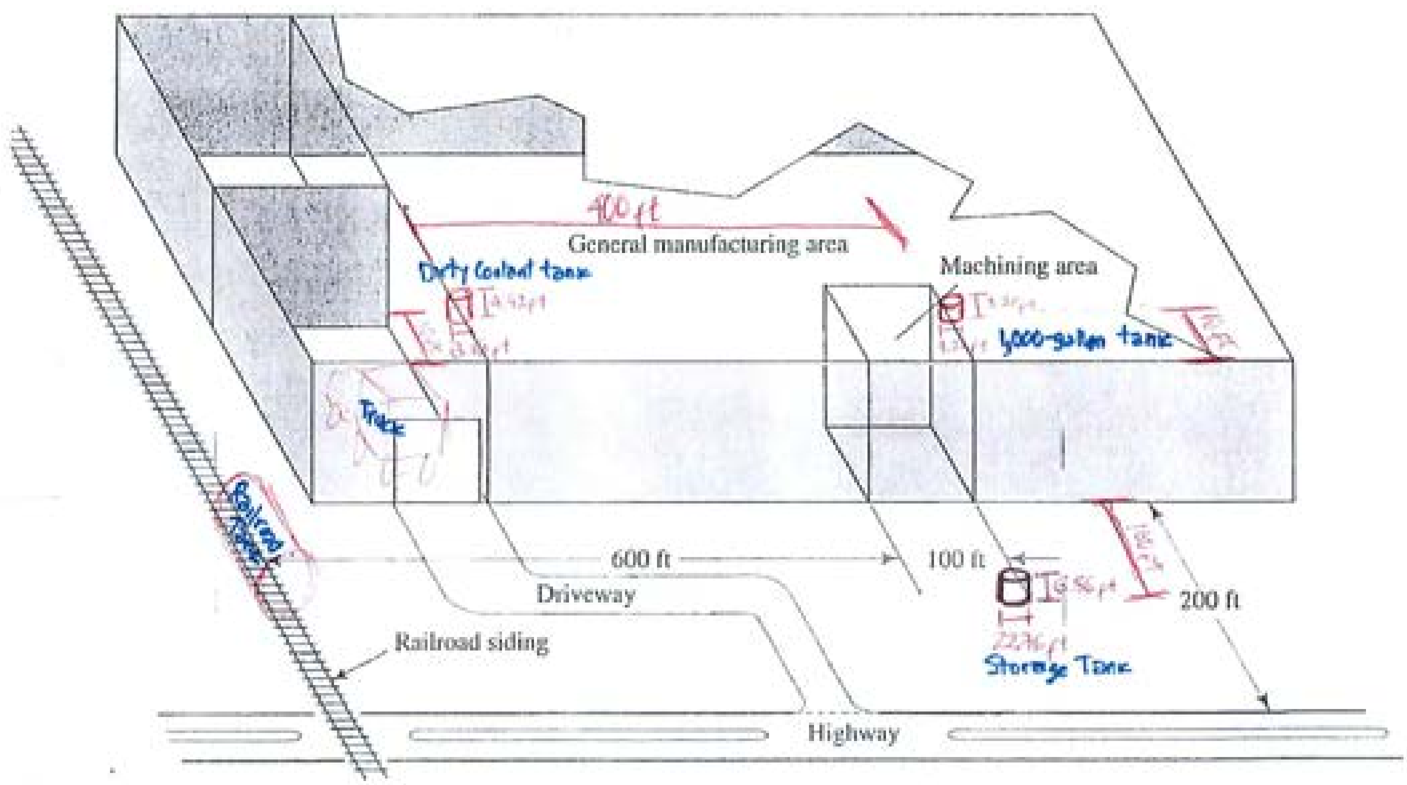
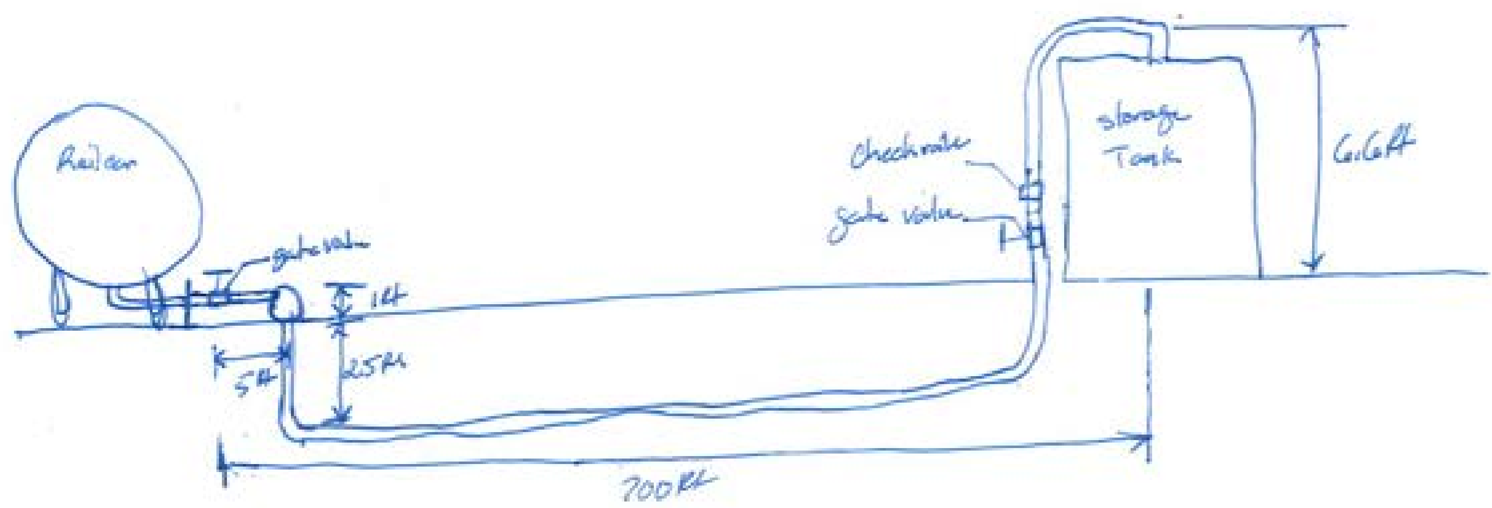


FIGURE 1. Plot plan of a hypothetical factory building for the design problem.



Railcar
gate valve
1ft
5ft
25ft
700ft
Checkvalve
gate valve
storage
Tank
6.6ft

Purpose

Design pipe system to pump fluid from railcar to storage tank

Design considerations

- Incompressible fluids
- Isothermic process
- Steady state
- frost line = 30in = 2.6 ft

Data and variables

Maximum flowrate to empty railcar in 6 hrs = 2500 gph = 0.09283 ft^3/s

Storage tank

D = 22.76 ft
H = 6.56 ft
V = 20,000 gallons

1½ sch 40

ID = 0.1342 ft
A = 0.01414 ft^2
$\varepsilon = 1.5 \times 10^{-4}$ ft

Fluid at 70°F

$\nu = 1.05 \times 10^{-5} \frac{ft^2}{s} \times 1.5$

$\gamma = 62.3 \frac{lb}{ft^3} \times 0.94$

Bill of materials

1½ sch 40 = 714 ft
1½ 90° elbow = 5
1½ gate valve = 2
1½ check valve = 1

- Information needed to design the system

90° elbow – $k = 20 f_t$
Gate valve – $k = 8 f_t$
Check valve – $K = 100 f_t$

$$V = \frac{Q}{A} = \frac{0.09283}{0.01414} = 6.565 \ ft/s$$

$$N_R = \frac{vD}{\nu} = \frac{6.565(0.1342)}{(1.05 \times 10^{-5}) \times 1.5} = 55,937$$

$$\frac{D}{\varepsilon} = \frac{0.1342}{1.5 \times 10^{-4}} = 895$$

$$f_t = \frac{0.25}{\log\left(\frac{1}{3.7(D/\varepsilon)}\right)^2} = 0.071$$

$$f = \frac{0.25}{\left(\log\left(\frac{1}{3.7(D/\varepsilon)} + \frac{5.74}{N_R^{0.9}}\right)\right)^2} = 0.0242$$

- Determining pipe size using critical velocity criteria 3 m/s = 9.84252 ft/s

$$A = \frac{Q}{V} = \frac{0.09283 \ ft^3/s}{9.84252 \ ft/s} = 0.00943$$

$$D = \left(\frac{4A}{\pi}\right)^{1/2} = \left(\frac{4(0.00943)}{\pi}\right)^{1/2} = 0.10957 \leq 1½$$

Design considerations

Pipe starts 3ft above ground to recieve fluid from railcar.

- pipe will connect to the top of the tank.

2 sch 40 = 714 ft

$K_{elbow} = 30 f_T$
$= 30(0.071)$
$= 1.42$

$K_{entrance} = 0.5$

$K_{gate\ valve} = 8 f_T$
$= 8(0.071)$
$= 0.568$

$K_{check\ valve} = 100 f_T$
$= 100(0.071)$
$= 7.1$

- First I'll determine the pump needed to Pump the fluid from the Railcar to the storage this will require at minimum 2500 gph to meet the 6hr demand.

- First I'll determine the amount of head and minor losses within the pipe.

$$h = (6.6ft + 25ft) - (3ft + 25ft)$$
$$= 3.6ft$$

$$h_L = K_{entrance}\frac{v^2}{2g} + 4 \times K_{elbows}\frac{v^2}{2g} + 2 \times K_{gate\ valve}\frac{v^2}{2g} + K_{check\ valve}\frac{v^2}{2g} + f\left(\frac{L}{D}\right)\left(\frac{v^2}{2g}\right)$$

$$= \left(\frac{6.565^2}{2(32.2)}\right)\left(0.5 + 4 \times 1.42 + 2 \times 0.568 + 7.1 + 0.024\left(\frac{714ft}{0.134ft}\right)\right)$$

$$= 46.77\ ft$$

- Total head on this section of pipe

$$h_a = 3.6ft + 96.77\ ft$$
$$= 100.37\ ft$$

$h_a = 100.37 ft$

$Q = 2500 gph = 41.667 gpm$

Pump = 1x3x11.5

$$\text{Power required} = h_a \gamma Q$$
$$= 100.37ft(62.3\ lb/ft^3 \times 0.94)(0.0928\ ft^3/s)$$
$$= 545.5\ \frac{lb\,ft}{s}$$
$$= 1.01\ hp \times 1.10$$
$$= 1.11\ hp = 0.828\ kW$$

Final BOM

1½ sch40 = 714 ft

1½ 90° elbow = 5

1½ gate valve = 2

1½ check valve = 1

Pump = SULZER 1x3x11.5

$NPSH_A = h_{sp} \pm h_s - h_f - h_{vp}$

$h_{sp} = \frac{P_{abs}}{\gamma}$

$= \frac{2116.21}{(62.3 \times 0.94)}$

$= 36.14 \text{ ft}$

$h_s = +1 \text{ ft}$

$h_{vp} = 61.71(1.5)$ at 70°F

$= \frac{92.565}{(62.3 \times 0.94)}$

$= 1.58$

$h_f = k_{entran} \frac{v^2}{2g} + k_{valve} \frac{v^2}{2g} + f\left(\frac{L}{D}\right)\left(\frac{v^2}{2g}\right)$

$= \left(\frac{6.565^2}{2(32.2)}\right)\left(0.5 + 1.42 + 0.0242\left(\frac{5 \text{ ft}}{0.1342}\right)\right)$

$= 1.89 \text{ ft}$

$NPSH_A = 36.14 \text{ ft} + 1 \text{ ft} - 1.89 - 1.58$

$= 33.67 \text{ ft}$

$N_s = \frac{N\sqrt{Q}}{H^{3/4}}$

$= \frac{3550\sqrt{41.6667}}{96.77^{3/4}}$

$= 742.71$

$D_s = \frac{DH^{1/4}}{\sqrt{Q}}$

$= \frac{3 \cdot (96.77)^{1/4}}{\sqrt{41.6667}}$

$= 1.45$

- With a N_s of 742.71 and a D_s of 1.45 a Radial pump would be best becase the peramaters would be best suited for radial flow. But we need a kenetic pump becase they are simpler and easier to maintain and can produces high flow rates.

Q	H
30	355
40	330
50	290

· I'll use the curve of 9.13 in to create my pump curve

$$H_1 = 365 + 2.5Q_1 - 7.5Q_1^2$$ – from excel

$D_1 = 9.13\text{ in} = \frac{9.13}{12}\text{ ft}$

$$Q_2 = Q_1 \times \frac{D_1}{D_2}$$

$$H_2 = H_1 \times \left(\frac{D_2}{D_1}\right)^2$$

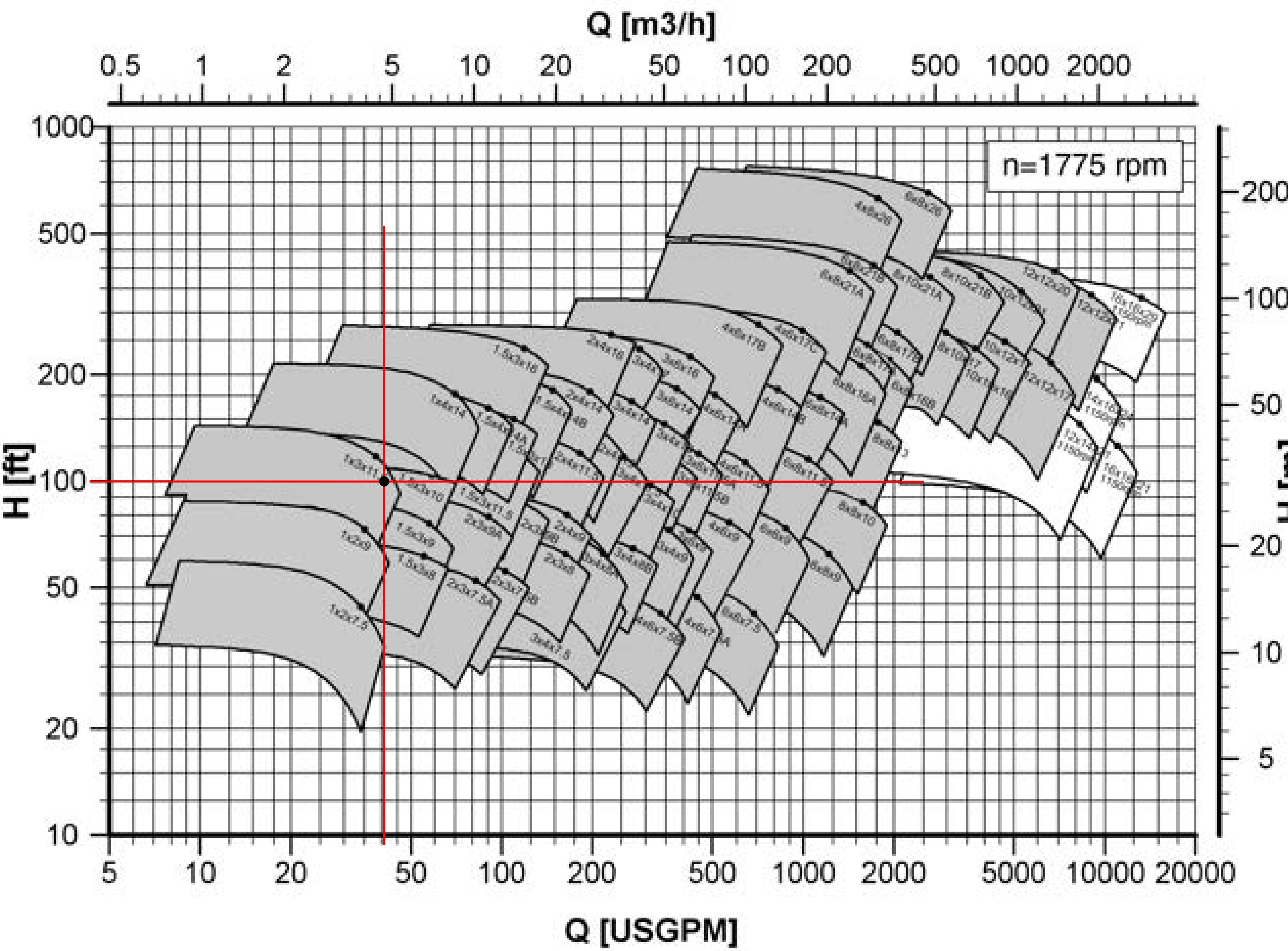
$$H_2 = 365\left(\frac{D_2}{D_1}\right)^2 - 2.5\,Q_2\left(\frac{D_2}{D_1}\right) - 7.5\,Q_2^2$$

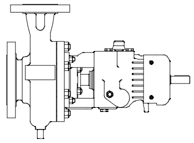
$$100.37 = 365\left(\frac{D_2}{\left(\frac{9.13}{12}\right)}\right)^2 - 2.5(0.09283)\left(\frac{D_2}{\left(\frac{9.13}{12}\right)}\right) - 7.5(0.09283)^2$$

$D_2 = 0.399\text{ ft}$

$= 4.79\text{ in}$

SULZER
CURVES - TYPE OHH
Range of Performances - 60 Hertz



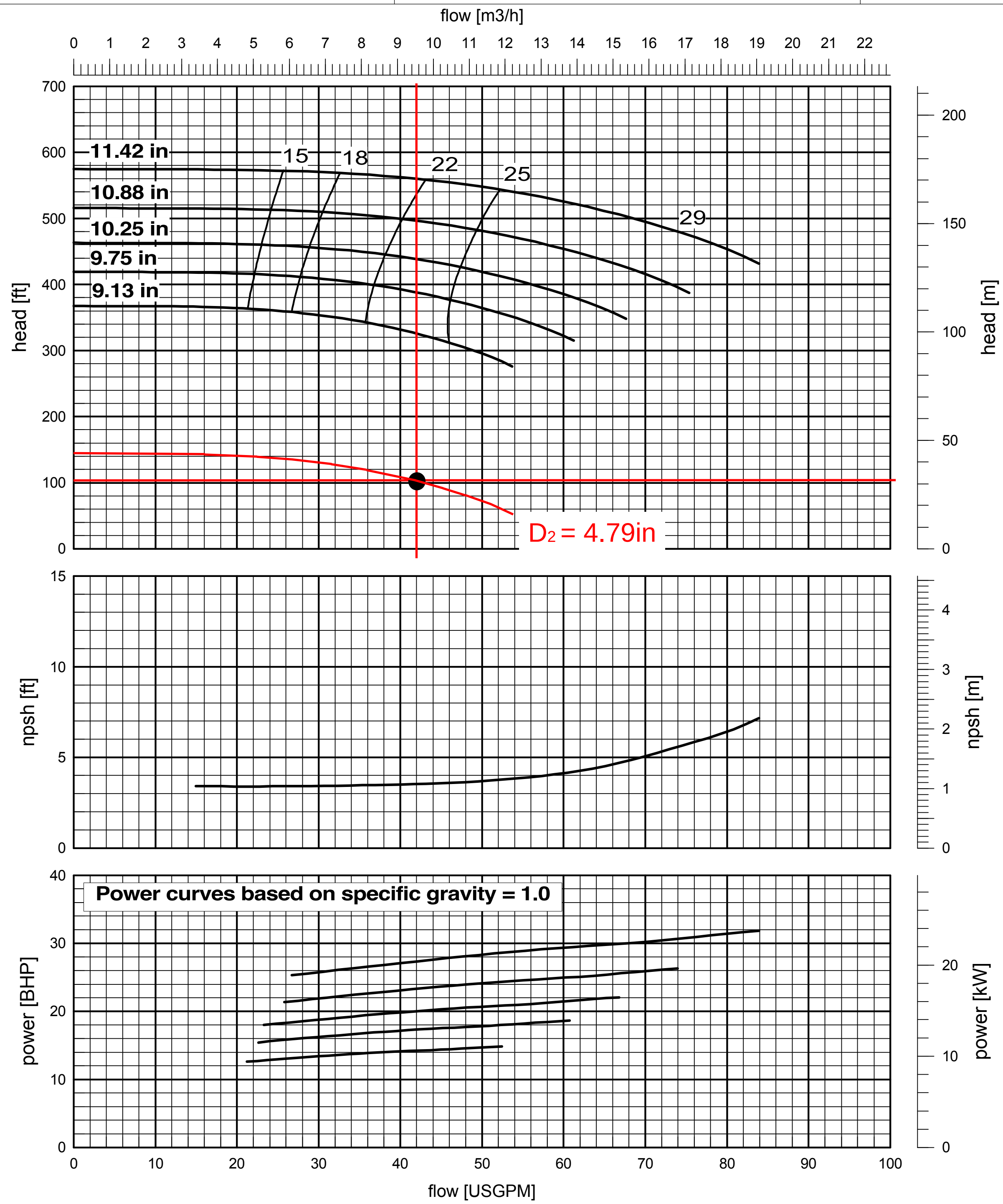


1 x 3 x 11.5 -1 OHH

SULZER

Series 2.00 / 60Hz E035

Curve No	**OHH 35-1-1-02**	**NSS**	**8210 (159)**	Speed
Efficiency Basis	**API Std. clearances**	**NS**	**310 (6)**	**3550**
Max Solid	**.12 in (3 mm)**	**Rotation**	**CCW viewed from coupling**	rpm



Rated Conditions		
Project	Item	
H =	Q =	P =
Calculated Efficiency =		$NPSH_{3\%}$ =

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