Test 3

domingo, 8 de dezembro de 2024 13:40

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MET 330 Fluid Mechanics
Dr. Orlando Ayala
Fall 2024
Test 3

Take home – Due Monday December 9th, 2024, 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. The other ninety (90) points will come from the problem solutions. For this test, there is no need to present the test following the technical writing, but if you still like to do it, follow the attached rubric.
3. There are 3 main different parts. The first part is worth 90/2 points. Each of the other two parts are worth 90/4 points.
4. What you turn in should be only your own work. You cannot discuss the exam with anyone, except me. Call 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 CANVAS. 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.

The company that hired you to start the design of the system in the figure continues being happy with your work (NOTE: THE FIGURE IS NOT TO SCALE). The want to hire you again to continue with the design. Let us remember that the system was designed originally to deliver 60 °F water from the lower open channel to the upper open channel at a rate of 3.387 ft^3/s. They want you to complete the following tasks:

a. Redesign the pumped pipeline system to deliver at least 50% more of the original flow rate. **You cannot neglect the minor losses this time**. Again, the total suction pipe length is 11 ft, while the total discharge pipe length is 2500 ft. Before the redesign:

- Please adjust your work from the 2nd test to include the minor losses (adjust the spreadsheet).

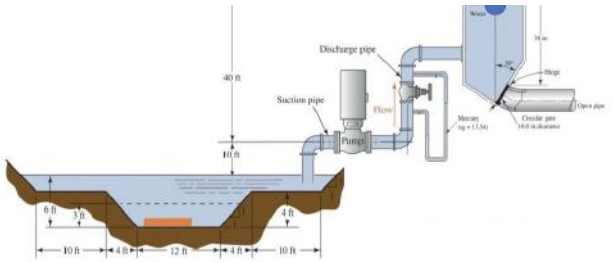
Now, for the redesign, you have two options:

- Replace the pump by a larger one while keeping the same diameter selected previously (2nd test). Determine the required new pump power (in HP) to accomplish the increased flow rate. Assume again a pump efficiency of 60%. You may use the adjusted spreadsheet.
- Use the **same pump power** you determined before (2nd test) and increasing the pipe size. Determine the appropriate commercial steel pipe to accomplish the increase flow rate. You must present the derived equation(s) you will use in excel for the iteration process.
-

b. The original discharge pipe needs to be supported. Your civil engineer colleague requires to know the relevant forces for the support design. Calculate the total horizontal and vertical forces in the **WHOLE** discharge pipe-elbows-valve system (IMPORTANT: this is from the pump outlet to the elevated open channel inlet – not just the elbow or elbows). Note: you might need the pump outlet pressure and the elevated channel inlet pressure for this task.

c. For the pump of the original design (2nd test) that includes the minor losses:

- Argue why you need a kinetic pump (instead of a positive displacement) is required and prove that the radial pump is the type of kinetic pump you need.
- Pre-select a SULZER pump that might satisfy the requirements and specify the overall characteristics of that pump:
  i. Pump suction, discharge size, and max impeller size.
  ii. Approximated required impeller diameter.
  iii. Approximated power and efficiency (your electrical engineer colleagues will need this info).
  iv. Actual pump size and weight (your civil engineer colleagues will need this info).
- Was the assumed 60% efficiency, correct?

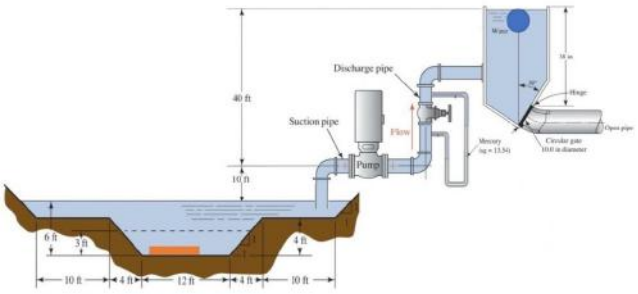


Problem solution rubric

	Exceeds Standard	Meets Standard	Approaches Standard	Needs Attention
	4	3	2	1
	10 points	7 points	4 points	0 points
1. 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.
2. 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.
3. 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.
4. 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.
5. 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.
6. 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.
7. 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.
8. 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.
9. 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.
10. 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.

Part A

Purpose: the purpose of this part is to redesing the pipeline system design on test 2, this time adding the minor losses to the system, after na increase of flow in it, and checking two different options of redesing.



Source: Robert Mott & Joseph Untener. Applied Fluid Mechanics, 8th edition. Person

(all data provided and from the previous exam)

Design Considerations:

- Normal atmospheric conditions
- Incompressible fluids
- Isothermal conditions

Materials:

- Water @60F
- Air @ 60F
- Steel pipe

Data and Variables:

- Mass flow = 5.0805 ft3/s
- L suction pipe= 11in
- L discharge pipe = 2500 feet
- Gama Water= 62.4 lb/ft3

- Efficiency of pump = 60%

Procedures:

- Calculate the minor losses in the system
- Make the necessary changes to the excel spreadsheet make on the last test.
- Calculate the power of a new pump required to maintain the new flow on the system.
- Make interations, for the other option of redesign, finding the new pump diameter to maintain the same pump existent before.

Calculations:

All previous calculations were made on excel with the formulas worked on test 2.
Only calculations made on this part were calculating minor losses:
The minor losses presented in this system were,

entrance loss $\rightarrow K_L = 0.78$

exit loss $\rightarrow K_L = 1.0$

valve loss $\rightarrow K_L = 8\,ft$

elbow loss (3x) $\rightarrow K_L = 30\,ft$

$$h_{minor\ losses} = h_{ent.} + h_{exit} + h_{valve} + 3 \times h_{elbow}$$

$$= 0.78\,\frac{V^2}{2g} + 1\,\frac{V^2}{2g} + 8ft\,\frac{V^2}{2g} + 3 \times 30ft\,\frac{V^2}{2g}$$

$$= \frac{V^2}{2g}\left[0.78 + 1 + 8ft + 3 \times 30ft\right]$$

In this case we are assuming that the valve being used is a gate valve.

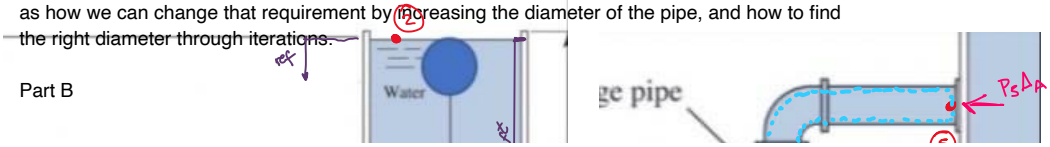
After calcualting the minor losses and adding to the final value of h in the excel sheet, it changes the final value for the pump power.
With the increase of flow and adding the minor losses it goes from 87.9HP to 236.993HP, as presented in the excel sheet that was given with this PDF for the exam 3.

For the second part, the procedure for the iteration was the same of finding the pump power in the first exam, but looking for the % difference of the pump power at the end with the pump power required in the exam 2 (87.9 HP) and after the iteration we can see that the diameter that fits based on Ayala's rule is the diameter of 0.9ft.

Iteration											
Diameter (ft)	A	V	Re	D/e	f	fT	Minor losses	hL	ha	P	% diff
0.6651	0.34743	14.623	803793.0675	4434	0.0152	0.0141	5.412819413	196.3175398	246.3175398	236.6314384	169.20%
0.3355	0.08840	57.469	1593450.877	2236.666667	0.0167	0.0163	89.34568872	6506.526577	6556.526577	6298.70011	7065.73%
1.25	1.22718	4.140	427682.2153	8333.333333	0.0150	0.0124	0.4114259126	8.406031582	58.40603158	56.10929403	-36.17%
1.5	1.76715	2.875	356401.8461	10000	0.0151	0.0120	0.195644199	3.436134683	53.43613468	51.33483155	-41.60%
1	0.78540	6.469	534602.7692	6666.666667	0.0149	0.0130	1.022645248	25.36780838	75.36780838	72.40407209	-17.63%
0.9	0.63617	7.986	594003.0769	6000	0.0150	0.0132	1.572410579	42.8953863	92.8953863	89.24240191	1.53%

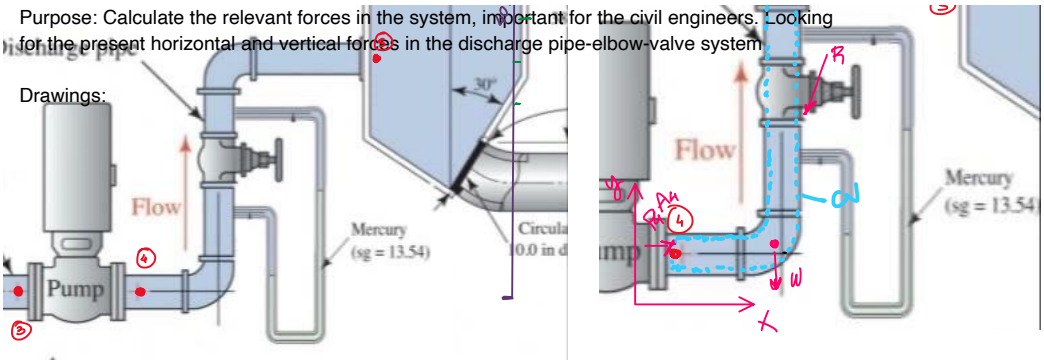
Analysis:
After making the correct adjustments with the addition of the minor losses and the chnage of flow, we were able to see how those two things affect the power required for the system, as well as how we can change that requirement by increasing the diameter of the pipe, and how to find the right diameter through iterations.

Part B



Purpose: Calculate the relevant forces in the system, important for the civil engineers. Looking for the present horizontal and vertical forces in the discharge pipe-elbow-valve system

Drawings:



in this case the values are (calculated on the excel sheet from previous exam)

$P_3 = -883.38$ lb/ft²

$P_4 = 14510.35$ lb/ft²

first, we have to find the pressure at point ⑤ (P_5), for that we assume that the distance between the top of the tank and the inlet is 25 inches

$$\frac{P_4}{\gamma} + \frac{V_4^2}{2g} + z_4 = \frac{P_5}{\gamma} + \frac{V_5^2}{2g} + z_5 + h_{L_{4-5}}$$

$$P_5 = \frac{\frac{P_4}{\gamma} + z_4 - z_5 - h_{L_{4-5}}}{\gamma}$$

$h_{L_{4-5}} = h_{pipe_{disc}} + 3h_{elbow} + h_{valve}$

based on the excel calculations done on part A. and with those values being

$h_{pipe_{disch}} = 190.068$

$3\,h_{elbow} = 3 \times 0.7233 = 2.1699$

$h_{valve} = 0.1929$

$h_{L_{4-5}} = 190.068 + 1.4466 + 0.1929 = 191.708$

now applying the values to the formula:

$$P_5 = \frac{\frac{14486.38}{62.4} - 40 + 2.08 - 191.708}{62.4}$$

$P_5 = 0.0404$ lb/ft² or 0.0003 psi

now we can look at the forces present in the water flow (right drawing present above)

now calculating the forces of the discharge pipe

$\Sigma F_x = \rho Q (V_{5x} - V_{4x})$

$P_4 A_4 - P_5 A_5 - R_x = \rho Q (V_{5x} - V_{4x})$

$R_x = (P_4 - P_5) \times A$

$R_x = (14486.83 - 0.0404) \times 0.3474$

$R_x = 5033.105$ lbf or 22388.4 N

$\Sigma F_y = \rho Q (V_{y_2} - V_{y_1})$

$-W - R_y = \rho Q (V_{y_2} - V_{y_1})$

$R_y = -W$

where $W = mg = \rho V g = \rho A L g$

$W = 62.4 \times 0.3474 \times 2500 \times 32.17$

$W = 1743433.85$

$R_y = -1743433.85$ lb or -7755180.13 N

Analysis: After proceding with this part, you could see how the forces work in the system, and how to procede to calcualte those, since those are important to the civil engineering point of view of any project and that information can be required when working in projects.

Part C

Purpose: the purpose of this part is to explain why the need of a kinetic, more specificaly a radial pump is required to this project in specific. And preselect the pump required in the SULZER catalog given to us using the correct tables and giving the right measurements of that specific pump.

At the end of the semester we talked about the different type of pumps.
In this scenarion being discussed in this exam, the best type of pump is the kinetic pump. This is because kinetic pumps are cheaper and smaller than positive displacement pumps Also, positive displacement pumps are more used for more viscous fluids, which is not our case since the fluid being used is water, and the same with fluids that go through different phases in the system, which is also not the case for our system, as we have the water in liquid form in the entire process. The kinetic pump also let us have a better control of Flow in the system, which is perfect having in mind that on part A of this exam we changed the flow of the system, and with a kinetic pump we don't have to worry about needing a different pump and having to replace it.
Now, the more specific case for this scenario is the type of kinetic pump we need is a radial pump. That's because they are good with mid and high pressures as well, they can accomodate with different flows and have a easier maintenance and operation of it.

now finding the pump head required for this case

we calculate it with the formula.

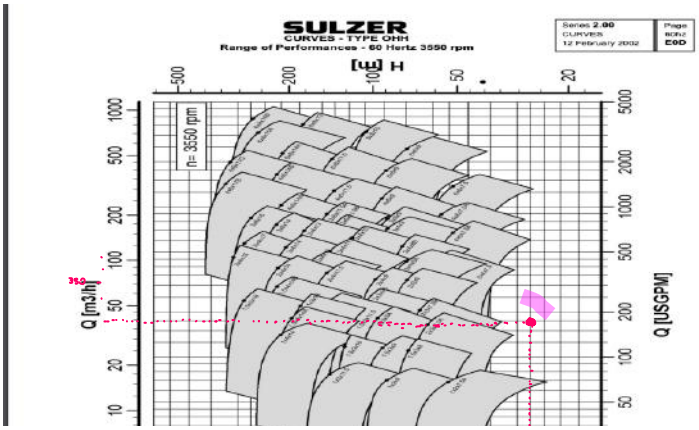
$\mathcal{P} = \gamma Q h_A$

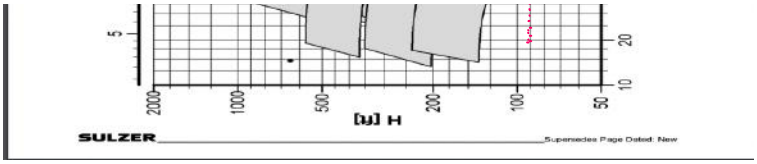
now, plotting the numbers we have

$49192.586 = 62.4 \times 3.387 \times h_A$

$h_A = 232.755$

using the SULZER catalog given to us to select the pump:





in this case the Q is $3.387\ ft^3/s$ which converting to gal/min is:

$3.387\ ft^3/s = 1520.19\ gal/min$

after looking at the best fit pump we can see that in this case it's the 6 x 6 x 9-1 pump

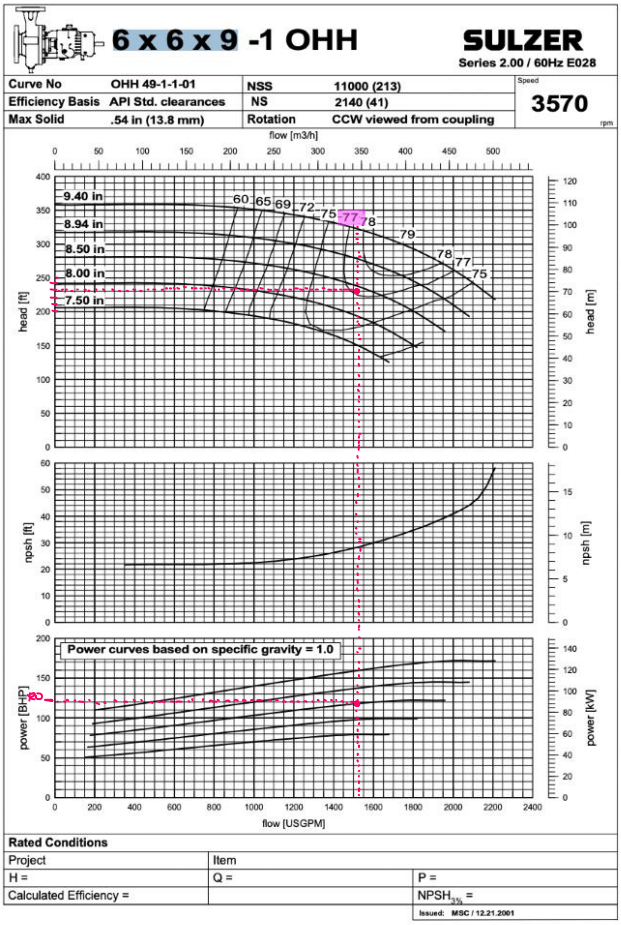
which has:

6 inch discharge connection

6 inch suction connection

9 inch max size of impeler

now to find the required impeler diameter, pump power and efficiency we look at the following table:

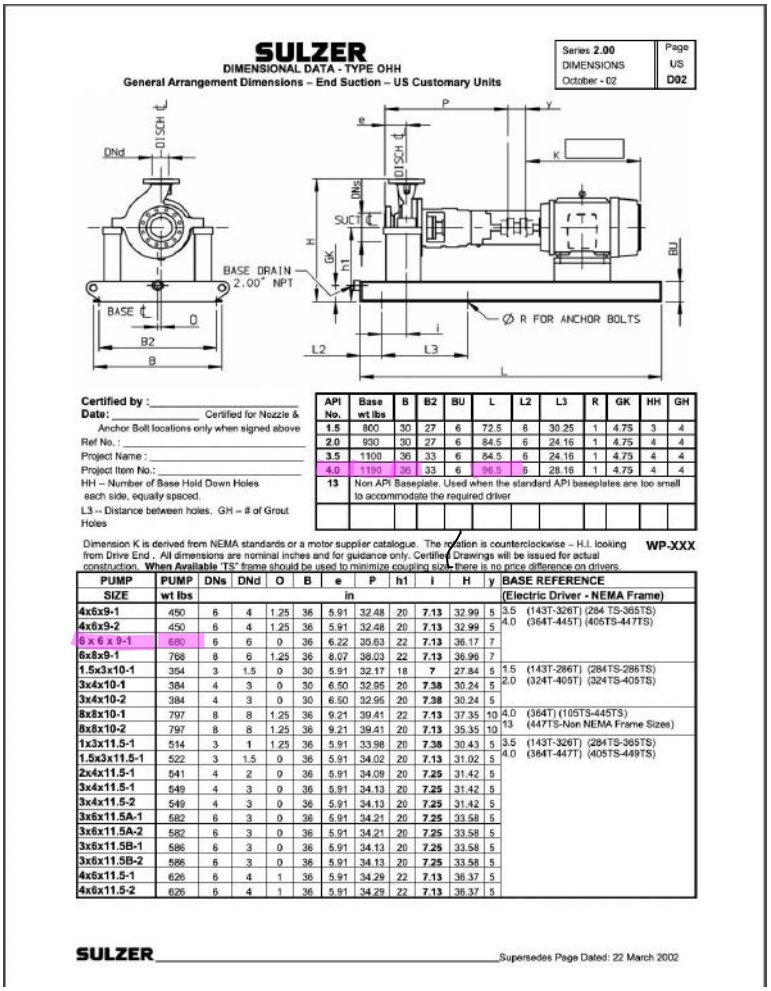


the required diameter point lands between 8.5 and 8 inch diameter, since it's closer to the 8.5 inch diameter we would close the valve to increase the pump head and then have the point exactly at the 8.5 inch diameter line.

Looking at the efficiency we have a 77% pump efficiency and at the bottom of the table we can see the pump

power, which is 120 HP.

And finally looking for the pump weight and dimensions:



SULZER

DIMENSIONAL DATA - TYPE OHH

General Arrangement Dimensions – End Suction – US Customary Units

Series 2.00	Page
DIMENSIONS	US
October - 02	D02

Certified by :_____
Date:_____ Certified for Nozzle & Anchor Bolt locations only when signed above
Ref No. :_____
Project Name : _____
Project Item No.:_____
HH – Number of Base Hold Down Holes each side, equally spaced.
L3 – Distance between holes. GH – # of Grout Holes

API No.	Base wt lbs	B	B2	BU	L	L2	L3	R	GK	HH	GH
1.5	800	30	27	6	72.5	6	30.25	1	4.75	3	4
2.0	930	30	27	6	84.5	6	24.16	1	4.75	4	4
3.5	1100	36	33	6	84.5	6	24.16	1	4.75	4	4
4.0	1190	36	33	6	96.5	6	28.16	1	4.75	4	4
13	Non API Baseplate. Used when the standard API baseplates are too small to accommodate the required driver										

Dimension K is derived from NEMA standards or a motor supplier catalogue. The rotation is counterclockwise – H.I. looking from Drive End . All dimensions are nominal inches and for guidance only. Certified Drawings will be issued for actual construction. When Available 'TS' frame should be used to minimize coupling size there is no price difference on drivers. **WP-XXX**

PUMP SIZE	PUMP wt lbs	DNs	DNd	O	B	e	P	h1	i	H	y	BASE REFERENCE (Electric Driver - NEMA Frame)
		in										
4x6x9-1	450	6	4	1.25	36	5.91	32.48	20	7.13	32.99	5	3.5 (143T-326T) (284 TS-365TS)
4x6x9-2	450	6	4	1.25	36	5.91	32.48	20	7.13	32.99	5	4.0 (364T-445T) (405TS-447TS)
6 x 6 x 9-1	680	6	6	0	36	6.22	35.63	22	7.13	36.17	7	
6x8x9-1	768	8	6	1.25	36	8.07	38.03	22	7.13	36.96	7	
1.5x3x10-1	354	3	1.5	0	30	5.91	32.17	18	7	27.84	5	1.5 (143T-286T) (284TS-286TS)
3x4x10-1	384	4	3	0	30	6.50	32.95	20	7.38	30.24	5	2.0 (324T-405T) (324TS-405TS)
3x4x10-2	384	4	3	0	30	6.50	32.95	20	7.38	30.24	5	
8x8x10-1	797	8	8	1.25	36	9.21	39.41	22	7.13	37.35	10	4.0 (364T) (105TS-445TS)
8x8x10-2	797	8	8	1.25	36	9.21	39.41	20	7.13	35.35	10	13 (447TS-Non NEMA Frame Sizes)
1x3x11.5-1	514	3	1	1.25	36	5.91	33.98	20	7.38	30.43	5	3.5 (143T-326T) (284TS-365TS)
1.5x3x11.5-1	522	3	1.5	0	36	5.91	34.02	20	7.13	31.02	5	4.0 (364T-447T) (405TS-449TS)
2x4x11.5-1	541	4	2	0	36	5.91	34.09	20	7.25	31.42	5	
3x4x11.5-1	549	4	3	0	36	5.91	34.13	20	7.25	31.42	5	
3x4x11.5-2	549	4	3	0	36	5.91	34.13	20	7.25	31.42	5	
3x6x11.5A-1	582	6	3	0	36	5.91	34.21	20	7.25	33.58	5	
3x6x11.5A-2	582	6	3	0	36	5.91	34.21	20	7.25	33.58	5	
3x6x11.5B-1	586	6	3	0	36	5.91	34.13	20	7.25	33.58	5	
3x6x11.5B-2	586	6	3	0	36	5.91	34.13	20	7.25	33.58	5	
4x6x11.5-1	626	6	4	1	36	5.91	34.29	22	7.13	36.37	5	
4x6x11.5-2	626	6	4	1	36	5.91	34.29	22	7.13	36.37	5	

SULZER Supersedes Page Dated: 22 March 2002

we can see the pump weights 680 lb.

and the skid required for that pump has the weight of 1190 lb, Length of 96.5 inches and base of 36 inches.

Analysis: after this part i was able to work with the information that was given to me and preselect the pump required for the system we been working on this entire semester throughout all three exams. Giving all the information about the pump selected and how did I work to show what pump would be the best fit for this scenario.