

**PRAIRIE VIEW A&M UNIVERSITY
ROY G. PERRY COLLEGE OF ENGINEERING
DEPARTMENT OF CHEMICAL ENGINEERING
CHEG 3101 – CHEMICAL ENGINEERING LABORATORY I
SPRING 2022**

- I. COURSE DESCRIPTION IN ABET FORMAT**
- II ASSESSMENT RESULTS FOR CURRENT AND PAST THREE PERIODS**
Program Outcomes Assessed in Course
Assessment Summary of Class Semester Averages for Outcomes
End of Semester Course Outcomes Assessment Reports
- II. TESTS**
Summary of Topics covered by Test
Original Test Questions & Master Solution/grading scheme used
(Summary of topics can be a separate page or include on the assignment itself)
Above Average (Graded original work)
Average (Graded original work)
Below Average (Graded original work)
- III. QUIZZES**
Summary of Topics covered by Quiz
Original Quiz Questions & Master Solution/grading scheme used
Above Average (Graded original work)
Average (Graded original work)
Below Average (Graded original work)
- IV. HOMEWORK ASSIGNMENTS**
Summary of Topics covered by Homework
Original Homework Questions & Master Solution/grading scheme used
Above Average (Graded original work)
Average (Graded original work)
Below Average (Graded original work)
- V. LABORATORY REPORTS**
Summary of Topics covered by lab
Laboratory Handout/Instructions and Grading Scheme
Above Average (Graded original work)
Average (Graded original work)
Below Average (Graded original work)
- VI. PROJECT**
Summary of Topics Covered by Project
Project Problem Statement and Grading Scheme
Above Average (Graded original work)
Average (Graded original work)
Below Average (Graded original work)

[Include any other evaluation used and omit any method above method (Test, Quizzes, Homework, Laboratory and Project reports) that was not used]

CHEG 3101: CHEMICAL ENGINEERING LAB I

- | | |
|--|--|
| 1. Course number and name: | CHEG 3101-P01 Chemical Engineering Lab I |
| 2. Credits, contact hours, categorization: | 1 credit hours; 3 contact hours; engineering topic |
| 3. Instructor's or course coordinator's name: | Keisha Antoine |
| 4. Textbook: Title: | None |
-
- | | |
|---|-------------|
| <p style="margin-left: 40px;">Author:</p> <p style="margin-left: 40px;">Publisher, Year & Edition:</p> <p style="margin-left: 20px;">a. Other Supplemental material</p> | <p>None</p> |
|---|-------------|
-
- 5. Specific course information**
- | | |
|--|--|
| a. Brief description of the content of the course (catalog description) | Quantitative experimental study of properties of fluids, fluid mechanics, metering, and heat transfer. Operation and evaluation of equipment, techniques of graphical and statistical data analysis. Study of elements and methods of scientific inquiry and investigation, experimental data analysis, modeling and simulation, and dissemination of scientific results, including: design of experiments, product and process design, model validation and verification, literature survey and review techniques, and effective technical reporting modes. Strong emphasis is placed on safety. |
| b. Prerequisites or | Undergraduate level PHYS 2125 Minimum Grade of C or Undergraduate level PHYS 2511 Minimum Grade of C and (Undergraduate level PHYS 2126 Minimum Grade of C or Undergraduate level PHYS 2521 Minimum Grade of C) and (Undergraduate level CHEM 1112 Minimum Grade of C or Undergraduate level CHEM 1021 Minimum Grade of C) and (Undergraduate level COMM 1311 Minimum Grade of C or Undergraduate level COMM 1003 Minimum Grade of C) and (Undergraduate level ENGL 1302 Minimum Grade of C or Undergraduate level ENGL 1133 Minimum Grade of C or Undergraduate level ENGL 1143 Minimum Grade of C or Undergraduate level ENGL 2311 Minimum Grade of C) |
| Co-requisites | CHEG 3301 , CHEG 3304 , MATH 3302 |
| c. *Indicate whether a required, elective, or selected elective (as per definition provided) course in the program | Required |
-
- 6. Specific goals for the course**
- | | |
|---|---|
| a. specific outcomes of instruction (e.g. The student will be able to explain the significance of current research about a particular topic.) | <p>Students will be able to :</p> <p>(1) Break down experiments into process maps, understand experiment objectives, sketch mode of operation and flow of materials to convey that understanding in written process narratives.</p> <p>(2) Analyze technical data and convert raw data into information through graphing or tabulating data. Transform data by using relevant theoretical relationships or proposing empirical formulas.</p> <p>(3) Demonstrate ability to work in teams.</p> |
| b. Explicitly indicate which of the | This course addresses: |

student outcomes listed in Criterion 3 or any other outcomes are addressed by the course.

3. An ability to communicate effectively with a range of audiences
5. An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives

6. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions

7 Brief list of topics to be covered

Review of Syllabus (2)
Drawing process maps (2)
Drawing and labeling graphs (1)
Tables, Data analysis (2)
Design of Experiments, Preparing Lab Reports (2)
Focus on Procedure and Results, First Experiment (3)
Focus on Abstract and Conclusion, Third Experiment (2)
Putting it all Together, Fourth Experiment (3)
Special Labs (4)

II ASSESSMENT RESULTS FOR CURRENT AND PAST THREE PERIODS

Program Outcomes Assessed in this course

Outcome 3:

An ability to communicate effectively with a range of audiences, orally. An ability to communicate effectively with a range of audiences (written technical communication)

Outcome 5:

An ability to (1) function effectively on a team whose members together (1) provide leadership, create a collaborative and inclusive environment, (3) establish goals, plan tasks, and meet objectives.

Outcome 6:

An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions

Assessment Summary of Class Semester Averages for Outcomes (Should be provided for Fall 2020 through Spring 2022 Assessment Period)

Outcomes	3	5	6
Semester	Semester Class Average (%)	Semester Class Average (%)	Semester Class Average (%)
Spring 2022	75.5	77.1	75.4
Comments on Trend of Data (Improving or deteriorating)	Only one course instance assessed by this instructor Class average meets expected average	Only one course instance assessed by this instructor Class average exceeds expected average	Only one course instance assessed by this instructor Class average meets expected average

*Expected Semester Class Average = 70% (or as defined by the program)
Ideal Semester Class Average = 75% (or as defined by the program)

End of Semester Course Assessment Reports Fall 2020 and Last Three Assessment Periods.

Each summary contains the following Information

1. Performance Statistics

- Total number of students in class
- The class average performance (**stated as %**) in each course outcome assessed in this class and the **two previous times course was assessed**.
- The acceptable class average for the class in each outcome area as set by your Department.
- Percentage of students who scored below the expected average in each outcome.

2. Implementation Summary

- Brief summary of plans implemented during the semester based on last assessment report

3. Perceived Problems

- Instructor's **critical evaluation** of perceived problems that affected students' performance. **Realistic problems should be identified throughout the semester and summarized in this section of the report.**

4. New Plans for Addressing Problems

- Instructor's plans for addressing the perceived problems the next time the class is taught. **These should be specific enough for another instructor to implement. Most of these should be things that, you, the instructor can implement to help students to improve. Be creative.**

5. Overall Trend over last three assessment periods

- Instructors summary of overall performance trend for each outcome measured over the last three periods.

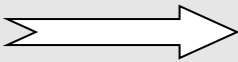
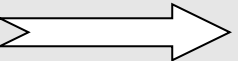
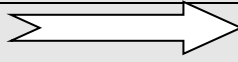
5. Were Expectations Met?

- Answer **YES** if the **class average was above the expected average** and the **stated percentage of students** scored at or above the expected average, else answer **NO**.

Table 2.1 END OF SEMESTER COURSE OUTCOME ASSESSMENT REPORT
CHEG3101-P01 Chemical Engineering Laboratory I
SPRING 2022 SEMESTER

Report Prepared by: Dr. Keisha Antoine

Report Date: May 22, 2022

Semester	Analysis Type	Number of Students	Outcome 6 Ability to design and conduct experiments.			Outcome 5 (old Outcome d) Ability to function on multi-disciplinary teams.			Outcome 3 (old Outcome g) Oral & Written Communication		
			Expected Average	Class Average	% Students Meeting Expected Average	Expected Average	Class Average	% Students Meeting Expected Average	Expected Average	Class Average	% Students Meeting Expected Average
Spring 2022	Direct	14	75	75.4	57	75	77.1	57	75	75.5	50
Implementation Summary			As all groups did the same lab each week in which lab was conducted, students were given a summary lecture of the lab theme and lab objectives. Additionally, during a non-lab week, student groups were made to present their understanding of the lab which they had performed the week before, in front of the entire class. This activity was ungraded, thus creating a safe environment for the students to make all the mistakes upfront. It was an opportunity for me to guide their thinking and data interpretation. It also provided an opportunity for the students to learn from each other.			Formed student groups early in the semester and halfway through the semester, formed new groups. In this way, the students had enough time to gel into a group in both instances and to have the opportunity to work with others in cases where the group dynamics were not the most positive. Used graded reports as proxy for group performance. All groups were responsible for performing the same lab at the same time. This meant that the different student groups could also consult each other on the same labs. The final lab was one where I gave general expectations of the objectives and the student groups would then develop the lab procedure and plan a time with the senior lab coordinator to conduct the lab.			Lab report format distributed to students and discussed. There were several classes on how to prepare reports/presentations. The grading scheme varied depending on the aspects of the lab report that were being emphasized at any one time. The module breakdown was: 1) Procedure & Results 2) Theory & Discussion 3) Abstract & Conclusion 4) Putting it All Together. Roughly 50% of the marks were allocated to the topics of a module under study for a lab report.		
Perceived Problems			The students are competent in following equipment SOP and the laboratory manual to obtain their data. Data analysis and data manipulation using tools like EXCEL need improvement.			Students have knowledge of the technical subject matter, but need to be reminded of it before heading into the lab to perform the experiment.			Students are having difficulty writing logical conclusions and do not adequately comment on the results.		
Plans for Addressing Problems			The development of this course was done to address the perceived problems above, which trickled into their senior lab courses. The implementation summary described for each outcome was carried out thereby mitigating perceived problems.			Continue implementation scheme described above and fine tune.			1. Will use anonymized actual reports to demonstrate what makes a good report. 2. Instructor will discuss the reports with the students after the first submission, and thereafter at pre-determined times.		
Overall Trend over Periods			NO DATA. FIRST ASSESSMENT OF THIS COURSE BY THIS INSTRUCTOR.			NO DATA. FIRST ASSESSMENT OF THIS COURSE BY THIS INSTRUCTOR.			NO DATA. FIRST ASSESSMENT OF THIS COURSE BY THIS INSTRUCTOR.		

CHEMICAL ENGINEERING LABORATORY I SPRING 2022

Title of Assignment: Evaluating performance of a shell-and-tube heat exchanger in parallel flow for various cold flow rates

TOPICS COVERED IN LAB 1

Lab 1 covered the following topics:

1. Focus on Procedure and Results aspects of the lab report. Emphasis that Procedure needs to demonstrate how the students' will conduct the experiment to obtain the pertinent data to achieve their experimental objective.
2. Emphasis on technical understanding of the data that they would obtain. Students need to demonstrate that they can correctly plot or tabulate the data and describe the data to the reader.

NOTE: Pages T1 through T8 should be repeated for each Test and Similarly for all the other assignments in the course binder

CHEMICAL ENGINEERING LABORATORY I

SPRING 2022

Title of Assignment: Evaluating performance of a shell-and-tube heat exchanger in parallel flow

LAB 1

ABOVE AVERAGE

Above Average Student Original Graded Assignment

NO STUDENT SAMPLES AVAILABLE FOR ABOVE AVERAGE

AVERAGE

Average Student Original Graded Assignment



Lab #1 Parallel Shell & Tube Heat Exchanger

Jevaun Christie

Cedric Sanhouldi

Cinthia Sahin

Ebonie

Prince

CHEG 3101 P01 Chemical Engineering Lab I

Group 1

February 21, 2022

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Abstract

Heat exchangers allow the transfer of heat from one place to another, usually between two (2) or more fluids. Heat transfer between the fluid streams is intensified by the use of several multiple shell & tube passes. The purpose of our experiment was to evaluate the efficiency of the shell and tube exchanger by finding and interpreting the Heat emitted (Q_h), the heat absorbed (Q_c), the mean temperature, The LMTD and the mean transfer coefficient. Data for this analysis were recorded for three (3) different flow rates. Our finding below revealed that as cold flow decreases the heat exchanger performance increases.

Theory

Parallel flow exchangers are often used in oil and chemical industries and are appropriate for high pressure application. In this type of heat exchanger two (2) fluid streams (cold and hot) flow side by side from the inlet to the outlet. The heat transfer performance is determined by the heat transfer coefficient which is the ratio between the heat transfer to the max possible heat transfer. In order to determine the heat coefficient, it is imperative that we find the heat emitted, heat absorbed, mean temperature and LMTD.

Heat emitted: Heat released from the hot fluid. $Q_h = m_h \times C_p \times \Delta T$, m is the mass flow rate and C is the specific heat capacity

Heat absorbed: Heat absorbed from the cold fluid. $Q_c = m_c \times C_c \times \Delta T$

Mean temperature efficiency: Average efficiency between the hot and cold circuit. $\eta_{\text{mean}} = \frac{\eta_h + \eta_c}{2}$

With $\eta_h = \frac{T_{h1} + T_{h2}}{T_{h1} + T_{c1}} \times 100$ (temperature efficiency in hot circuit)

$\eta_c = \frac{T_{c2} + T_{c1}}{T_{h1} - T_{c1}} \times 100$ (temperature efficiency in cold circuit)

LMTD: Heat driving force that create the heat transfer:

$$LMTD = \frac{(T_{h2} + T_{c2}) - (T_{h1} - T_{c1})}{\ln\left(\frac{T_{h2} - T_{c2}}{T_{h1} - T_{c1}}\right)}$$

Heat transfer coefficient: measure performance of exchanger. The higher the number the better

$$U = \frac{Q}{A \times LMTD} \quad Q = Q_h = Q_c \text{ (closed system)} \quad ; \quad A = \text{heat transfer area}$$

Procedures

1. Connect the heat exchanger for a parallel flow and a heater tank temperature of 60 degrees celsius.
2. Using VDAS, create a blank results table making sure the correct heat exchanger was selected.
3. Using a thermometer to record the ambient air temperature.
4. Use the operated flow control valves to set hot and cold rates for the first trial.
5. Record the hot and cold temperature.
6. Repeat the procedures to complete the other trials

Results

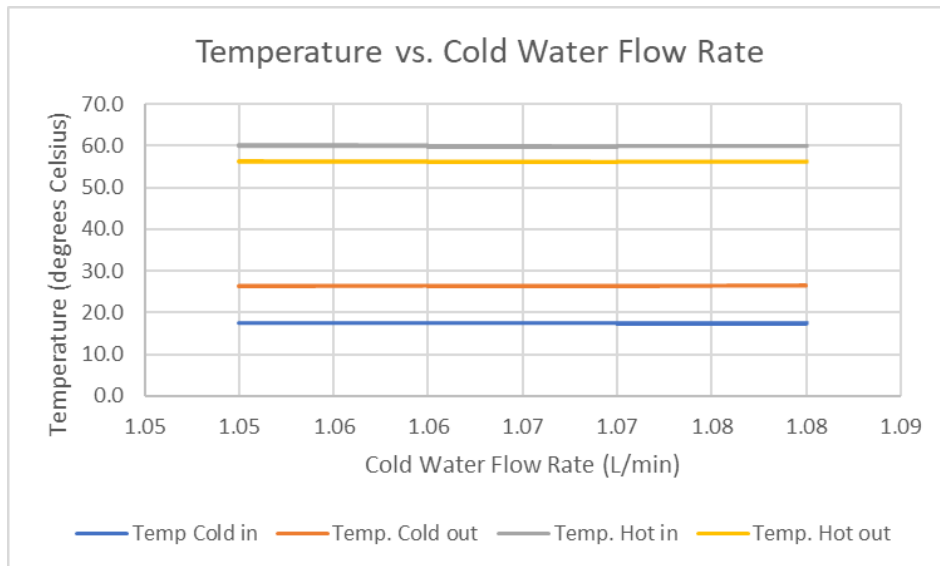


Figure 1: Temperature vs. Group 1 Cold Water Flow Rate

The graph shows the temperatures for cold in, cold out, hot in, and hot out. All with respect to the cold flow rate used by group 1.

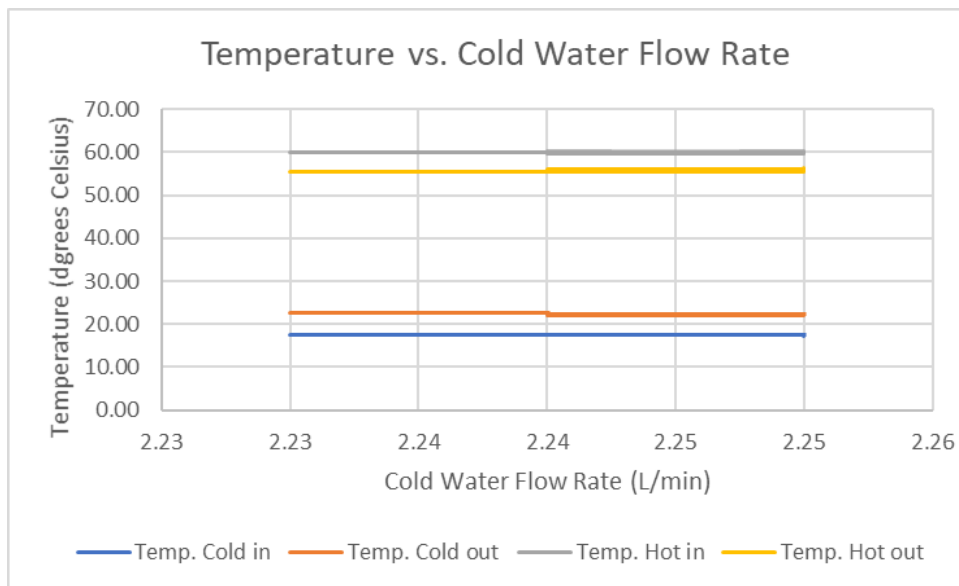


Figure 2: Temperature vs. Group 2 Cold Water Flow Rate

The graph shows the temperatures for cold in, cold out, hot in, and hot out. All with respect to the cold flow rate used by group 2

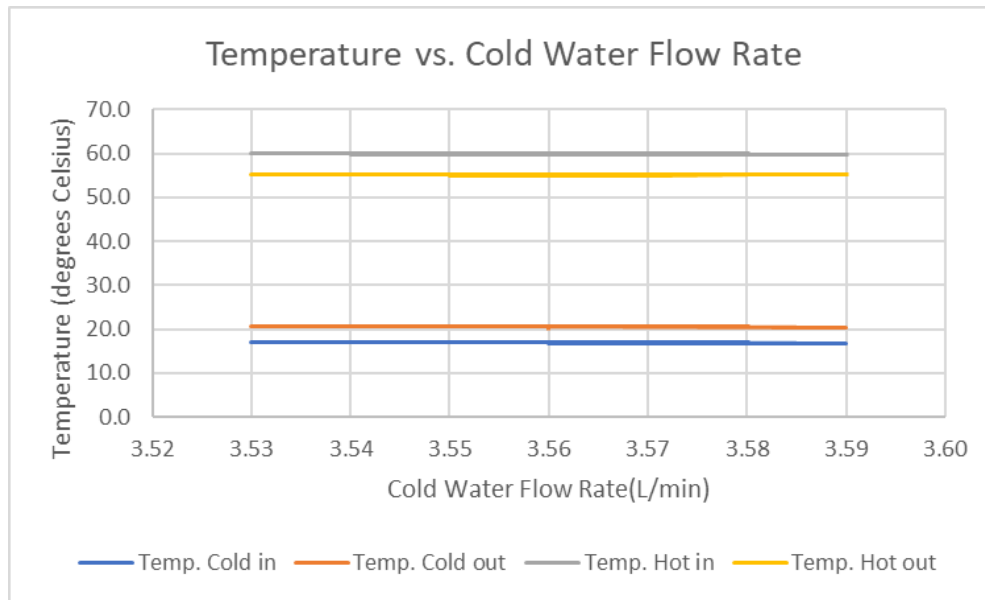


Figure 3: Temperature vs. Group 3 Cold Water Flow Rate

The graph shows the temperatures for cold in, cold out, hot in, and hot out. All with respect to the cold flow rate used by group 3

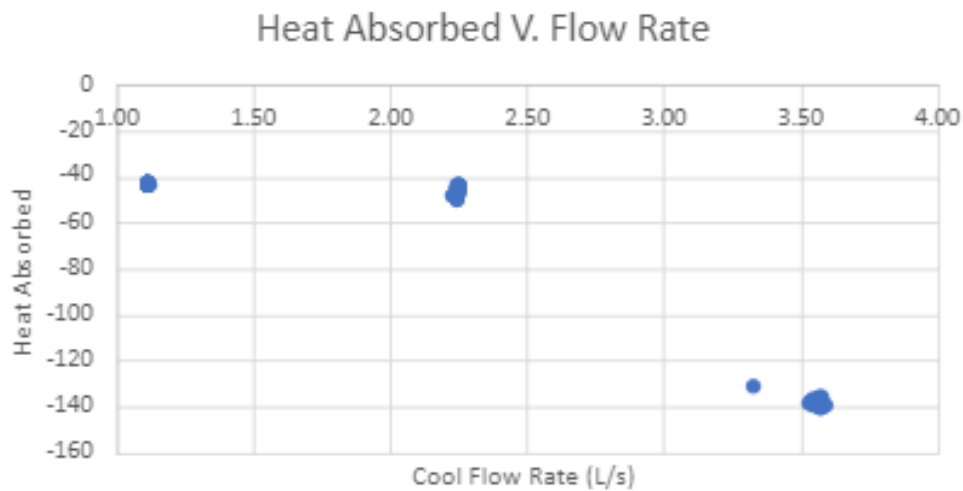


Figure 4. Heat Absorbed (Q_a)

In figure 4 the relationship between the heat absorbed and the flow rate of cool water is depicted. As the flow rate of the cool water was increased there was significantly less heat absorbed.

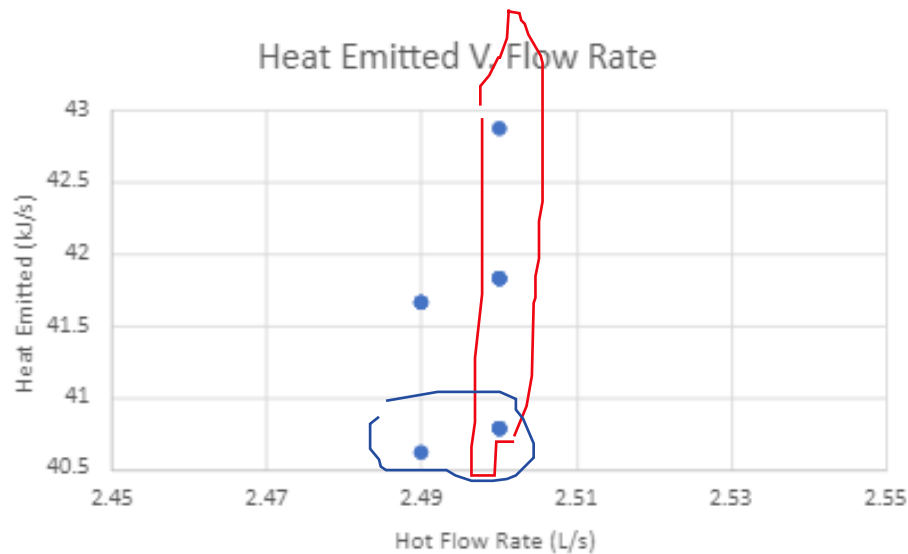


Figure 5. Heat Emitted (Q_e)

Figure 5 show the relationship between the hot water flow and heat emitted. The flow rate of hot water was kept constant or close to constant though out the experiment leaving a staggering amount of heat emitted.

Discussion

The results obtained from the three experiments and the heat absorbed/ emitted graphs shows that group 1 flow rate provides a better overall heat transfer coefficient than the other two groups. Given that the main objective was to evaluate the performance of the shell and tube exchanger by varying the cold mass flow rates. Must be noted that our flow rates for hot in and hot out were constant. The rate of heat transfer is dependent on the mass flow rate, the relationship is directly proportional. The spacing between Temperature cold in and Temperature cold out also illustrate the heat transferred because heat transferred and change in temperature are directly proportional. Therefore, by studying figure 1, 2, 3, Figure 1 displays a greater change in temperature between Cold in and Cold out. Furthermore, this greater change in temperature allows for a greater heat transfer among the shell and tube heat exchanger system.

Conclusion

The purpose of this experiment was to analyze the performance of the shell heat exchanger at different mass flow rates by the use of a parallel flow. Three (3) different flow rates were used for this experiment and the data collected revealed that the lower the cold flow rate, the higher the heat coefficient (U) which is used to determine performance of the exchanger. In the future, the use of many more flow rates could be helpful to reinforce the results of the experiment. Overall, we were able to study the effects of different cold flow rates in a heat exchanger and concluded that as cold flow decreases the heat exchanger performance increases.

BELOW AVERAGE

Below Average Student Original Graded Assignment

Prairie View A&M University

Shell and Tube Heat Exchanger Lab Report

By

Shelton Amaram

Ezranequia Tatmon

Maya Spears

Clement Adeyemi and

Ariel Kinsey

CHEG 3101

Dr. Antoine

February 21, 2022

Abstract

The aim of our project to determine how different cold flow rates affect the heat exchangers efficiency in a parallel flow. The heat exchanger used in this experiment was a TD360c heat exchanger. It is comprised of a large tube surrounding several smaller tubes. The way it works is that one water circuit passes through the bundle while the other passes through the shell creating a turbulent flow. At the same time this happens, heat is transferred between them. The advantages of this heat exchanger are that it is simple to use and can work at high pressures. Due to those reasons, it is the most used heat exchanger used in chemical plants today.

Theory

Heat exchangers are used in industries to heat or cool products by exchanging heat from one media to the other.

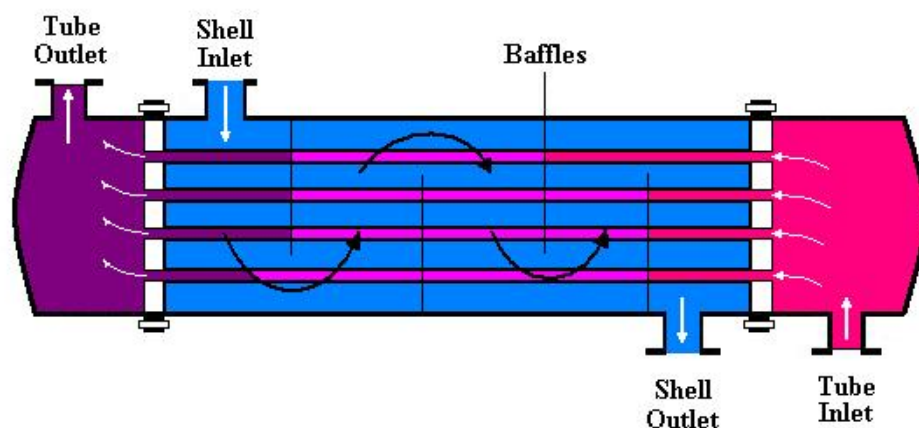


Fig. 1: Diagram of a shell and tube heat exchanger

There are 4 types:

- Double Tube Heat Exchangers
- Shell and Tube Heat Exchangers
- Tube in Tube Heat Exchangers
- Plate Heat Exchangers

Our experiment used a shell and tube heat exchanger featuring a closed system undergoing parallel flow, i.e., co-current flow where both fluids are moving in the same direction; hence, we will focus on that.

Shell and tube heat exchangers consist of a large pressure vessel, also known as a shell with a bundle of tubes inside it. While one fluid flows through the inside of the tubes, the other flows over the tubes to transfer heat between the two fluids.

As shown by the graph below, the cooling relationship of the two fluids is logarithmic; there is a significant temperature difference at the inlet, with the cold fluid never surpassing the hot fluid in temperature even at its lowest point. The considerable temperature difference makes the device susceptible to thermal stresses. While that is a disadvantage, it makes up for it in that there is minimal pressure loss, and it is relatively easy/cheap to build.

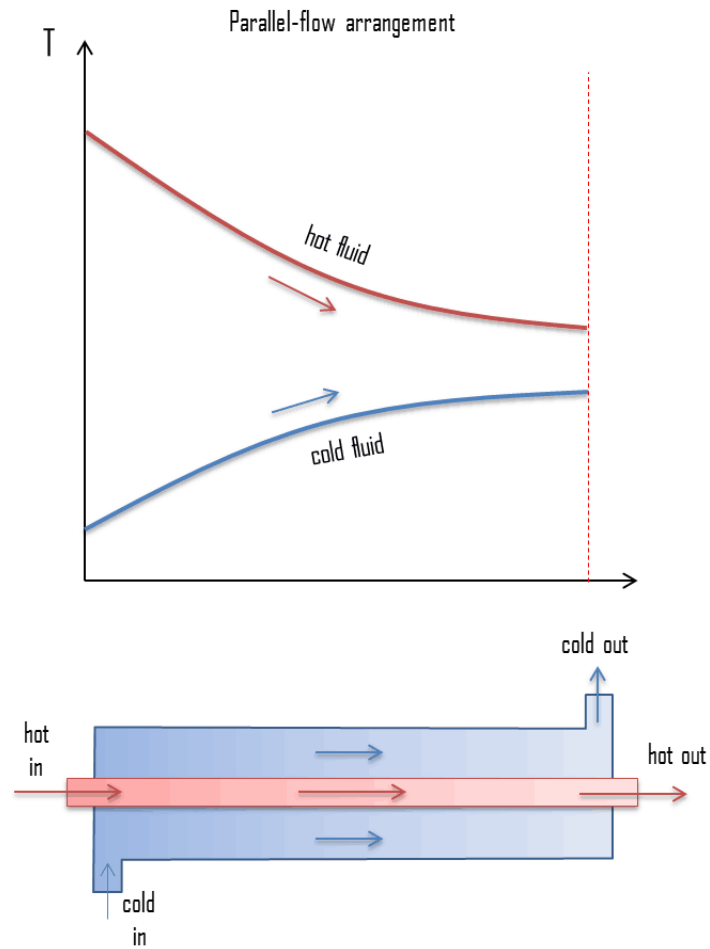


Figure 2: Diagram of a heat exchanger undergoing parallel flow

Key Formulas

Equation 1: Average Temperature (Hot)

$$T_{H_{avg}} = \frac{T_{H_1} + T_{H_2}}{2}$$

T_{H_1} = Temperature of Thermocouple 1 (Hot) [$^{\circ}\text{C}$]

T_{H_2} = Temperature of Thermocouple 2 (Hot) [$^{\circ}\text{C}$]

Equation 2: Average Temperature (Cold)

$$T_{C_{avg}} = \frac{T_{C_1} + T_{C_2}}{2}$$

$T_{C_1} = \text{Temperature of Thermocouple 1 (Cold)} [^{\circ}\text{C}]$

$T_{C_2} = \text{Temperature of Thermocouple 2 (Cold)} [^{\circ}\text{C}]$

Equation 3: Efficiency (Hot)

$$\eta_H = \frac{T_{H_1} - T_{H_2}}{T_{H_1} - T_{C_1}} \cdot 100\%$$

$T_{H_1} = \text{Temperature of Thermocouple 1 (Hot)} [^{\circ}\text{C}]$

$T_{H_2} = \text{Temperature of Thermocouple 2 (Hot)} [^{\circ}\text{C}]$

$T_{C_1} = \text{Temperature of Thermocouple 1 (Cold)} [^{\circ}\text{C}]$

Equation 4: Efficiency (Cold)

$$\eta_C = \frac{T_{C_2} - T_{C_1}}{T_{H_1} - T_{C_1}} \cdot 100\%$$

$T_{C_2} = \text{Temperature of Thermocouple 2 (Cold)} [^{\circ}\text{C}]$

$T_{C_1} = \text{Temperature of Thermocouple 1 (Cold)} [^{\circ}\text{C}]$

$T_{H_1} = \text{Temperature of Thermocouple 1 (Hot)} [^{\circ}\text{C}]$

Equation 5: Mean Temperature Efficiency

$$\bar{\eta} = \frac{\eta_H + \eta_C}{2}$$

$\eta_H = \text{Efficiency (Hot)}$

$\eta_C = \text{Efficiency (Cold)}$

Equation 6: Heat Emitted (Cold Temperatures)

$$\dot{Q}_e = \dot{m}_{cold} \cdot C_{p_{cold}} \cdot \Delta T_{cold}$$

$$\dot{m}_{cold} = \text{Mass flow rate of cold} \left[\frac{L}{min} \right]$$

$$C_{p_{cold}} = \text{Heat capacity of cold} \left[\frac{J}{kg \cdot K} \right]$$

$$\Delta T_{cold} = \text{Change in temperature of cold} [^{\circ}C]$$

Equation 7: Heat Absorbed (Hot Temperatures)

$$\dot{Q}_a = \dot{m}_{hot} \cdot C_{p_{hot}} \cdot \Delta T_{hot}$$

$$\dot{m}_{hot} = \text{Mass flow rate of hot} \left[\frac{L}{min} \right]$$

$$C_{p_{hot}} = \text{Heat capacity of hot} \left[\frac{J}{kg \cdot K} \right]$$

$$\Delta T_{hot} = \text{Change in temperature of hot} [^{\circ}C]$$

Equation 8: Energy Balance

$$C_{EB} = \frac{\dot{Q}_a}{\dot{Q}_e}$$

$$\dot{Q}_a = \text{Heat absorbed} [W]$$

$$\dot{Q}_e = \text{Heat emitted} [W]$$

Equation 9: Log Mean Temperature Difference

$$\Delta T_{LMTD} = \frac{(T_{H_2} - T_{C_2}) - (T_{H_1} - T_{C_1})}{\ln \left(\frac{T_{H_2} - T_{C_2}}{T_{H_1} - T_{C_1}} \right)}$$

$$T_{H_1} = \text{Temperature of Thermocouple 1 (Hot)} [^{\circ}C]$$

$$T_{H_2} = \text{Temperature of Thermocouple 2 (Hot)} [^{\circ}C]$$

$T_{C_1} = \text{Temperature of Thermocouple 1 (Cold)} [^{\circ}\text{C}]$

$T_{C_2} = \text{Temperature of Thermocouple 2 (Cold)} [^{\circ}\text{C}]$

Equation 10: Heat Transfer Coefficient

$$U = \frac{\dot{Q}_e}{A \cdot \Delta T_{LMTD}}$$

$\dot{Q}_e = \text{Heat emitted [W]}$

$A = \text{Area [m}^2\text{]}$

$\Delta T_{LMTD} = \text{Log Mean Temperature Difference [}^{\circ}\text{C]}$

Procedure

Before entering the lab, we had to complete a few essential safety procedures. Even though this lab did not involve any harsh chemicals or possess the risk of liquid splashback, we all wore our safety goggles while in the lab. We also wore long sleeves and pants and closed-toe shoes to comply with lab protocol. Since we were the second group to complete the experiment, there was not too much we had to do once we entered the lab. We first had to insert a jump drive into the computer connected to the heat exchanger to track and save the data easily. Next, we double-checked to ensure the heat exchanger was still set to parallel flow and changed the cold flow rate by turning the valve. We decided that our cold flow rate would be 2.22 (± 0.005). After changing the cold flow rate, we recorded our data on the computer and set a timer for 5 minutes to measure the hot and cold temperatures flowing out.

Results

The first step of this experiment was to obtain the raw data from the other groups. In the tables shown below, the raw data is listed.

Raw Data for Team 1

T_{H1} (°C)	T_{H2} (°C)	Avg. T_H (°C)	T_{C1} (°C)	T_{C2} (°C)	Avg. T_C (°C)	η_H (%)	η_C (%)	C_{pH} (	C_{pC}	$\dot{Q}_e$ (W)	$\dot{Q}_a$ (W)	C_{eb}	η_{avg} (%)	LMTD (°C)	U (W/m ² °C)
60.2	56.5	58.4	17.4	26.4	21.9	8.64	21.0	4.183	4.181	-6.59×10^{-4}	6.35×10^{-4}	-1.04	14.8	36.1	-9.13×10^{-4}

Raw Data for Team 2

T_{H1} (°C)	T_{H2} (°C)	Avg. T_H (°C)	T_{C1} (°C)	T_{C2} (°C)	Avg. T_C (°C)	η_H (%)	η_C (%)	C_{pH} (J*kg	C_{pC}	$\dot{Q}_e$ (W)	$\dot{Q}_a$ (W)	C_{eb}	η_{avg} (%)	LMTD (°C)	U (W/m ² °C)
60.2	56.2	58.2	17.3	22.0	19.7	9.32	11.0	4.184	4.182	-7.37×10^{-5}	6.84×10^{-4}	-0.928	10.2	38.4	-9.60×10^{-4}

Table 1: Calculations formed with team 1's data

Raw Data for Team 3

T_{H1} (°C)	T_{H2} (°C)	Avg. T_H (°C)	T_{C1} (°C)	T_{C2} (°C)	Avg. T_C (°C)	η_H (%)	η_C (%)	C_{pH}	C_{pC}	$\dot{Q}_e$ (W)	$\dot{Q}_a$ (W)	C_{eb}	η_{avg} (%)	LMTD (°C)	U (W/m ² °C)
59.9	55.2	57.6	17.1	20.7	18.9	11	8.41	4.184	4.182	-8.93×10^{-4}	8.02×10^{-4}	-0.89	9.71	38.5	-6.88×10^{-4}

Table 2: Calculations formed with team 2's data

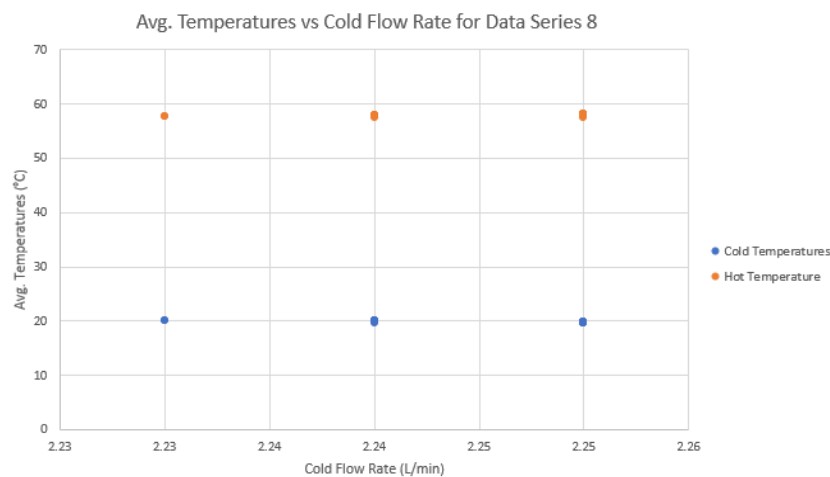
Table 3: Calculations formed with team 3's data

After this data was collected, we used the equations from our theory to calculate the heat emitted, heat absorbed, mean temperature efficiencies, energy balance coefficient, log mean temperature difference and our heat exchanger coefficient. Upon completion of these calculations, we plotted our average hot and cold temperatures versus the cold flow rate, which

the

the

within



will show how cold flow rate effected the temperatures of heat exchanger the five minutes. In the

graph below, the averages and cold flow rate is plotted for Data Series 8.

Figure 1: Graphical representation of Team 2 average temperature and cold flow rate

Additionally, we plotted this graph for the Team 1 and 3 respectively, which can be seen in the appendix of the report. Observing this graph, you can see that average hot and cold temperatures fluctuated around the $2.23(\frac{L}{min})$ through $2.25(\frac{L}{min})$ which is shows the marginal error of ± 0.005 . The graph also shows a liner progression of the average temperatures both hot and

cold, at which for a higher temperature the cold flow rate increases as well. In Figures 2 and 3, you can see the same trend as well. However, for Figure 3, there is a jump within the averages in between the flow rates of $3.35(\frac{L}{min})$ and $3.50(\frac{L}{min})$. We believe this is from the flow rate being changed while the data was being recorded. The graph then stabilizes at $3.53(\frac{L}{min})$ and is displayed like the other two figures before.

Discussion

The main goal of this experiment was to observe how the cold flow rate affects the heat exchanger performance. The heat exchanger we used was a TD360C in parallel flow with our flow rate set to $2.22 (\pm 0.005)$. We obtain our data for our hot and cold temperatures for five minutes during this experiment. Once we received our raw data, we calculated the heat emitted, heat absorbed, mean temperature efficiencies, energy balance coefficient, log mean temperature difference, and our heat exchanger coefficient. These calculations were imperative in understanding our data and the experiment's goal. First, we calculated the heat emitted ($\dot{Q}_e$) using equation six from our theory section. Finding this result allowed us to see how much heat left the system within the five minutes. We also calculated the heat absorbed ($\dot{Q}_a$) from equation 7. This also showed the amount of heat absorbed into the system during the experiment. Using the results from our heat emitted and absorbed, we obtained our energy balance coefficient (C_{EB}), which shows the ratio of heat absorbed to emitted. Next, we found our mean temperature efficiencies using the hot and cold efficiencies from Equations 4 and 5, which is the ratio at which the heat exchanger performed. Finally, we found our log mean

temperature difference to find the heat exchanger coefficient. The log mean temperature difference is the maximum mean temperature difference that the heat exchanger can achieve. The heat exchanger coefficient is the proportionality of the heat flux and driving force for heat flow, which explains how well the heat exchanger works. Overall, our results pertained to the overall performance of the TD360C heat exchanger.

Conclusion

In conclusion, the scatter plots for Team 1 and Team 2's data were more similar than when we compared the data to Team 3's data. We came to an agreement that due to human error; Team 3 may have not set their flow rate to the value in which they wanted for the experiment and decided to change it after a couple seconds. Additionally, we saw that the overall heat transfer coefficient for each team was negative. This meant that the heat flux was in a different direction than that of the driving temperature difference, which was the log mean temperature difference. Overall, we feel that we were able to accomplish the aim of the experiment and accurately report our data.

Appendix

Raw Data for Team 1

T_{H1} (°C)	T_{H2} (°C)	Avg. T_H (°C)	T_{C1} (°C)	T_{C2} (°C)	Avg. T_C (°C)	η_H (%)	η_C (%)	C_{pH}	C_{pC}	$\dot{Q}_e$ (W)	$\dot{Q}_a$ (W)	C_{eb}	η_{avg} (%)	LMTD (°C)	U (W/m ² K)
60.2	56.5	58.4	17.4	26.4	21.9	8.64	21.0	4.183	4.181	-6.59×10^{-4}	6.35×10^{-4}	-1.04	14.8	36.1	-9.13×10^{-4}

Table 1: Raw data for team 1

Raw Data for Team 2

T_{H1} (°C)	T_{H2} (°C)	Avg. T_H (°C)	T_{C1} (°C)	T_{C2} (°C)	Avg. T_C (°C)	η_H (%)	η_C (%)	C_{pH}	C_{pC}	$\dot{Q}_e$ (W)	$\dot{Q}_a$ (W)	C_{eb}	η_{avg} (%)	LMTD (°C)	U (W/m ² K)
60.2	56.2	58.2	17.3	22.0	19.7	9.32	11.0	4.184	4.182	-7.37×10^{-5}	6.84×10^{-4}	-0.928	10.2	38.4	-9.60×10^{-4}

Table 2: Raw data for team 2

Raw Data for Team 3

T_{H1} (°C)	T_{H2} (°C)	Avg. T_H (°C)	T_{C1} (°C)	T_{C2} (°C)	Avg. T_C (°C)	η_H (%)	η_C (%)	C_{pH}	C_{pC}	$\dot{Q}_e$ (W)	$\dot{Q}_a$ (W)	C_{eb}	η_{avg} (%)	LMTD (°C)	U (W/m ² K)
59.9	55.2	57.6	17.1	20.7	18.9	11	8.41	4.184	4.182	-8.93×10^{-4}	8.02×10^{-4}	-0.89	9.71	38.5	-6.88×10^{-4}

Table 3: Raw data for team 3

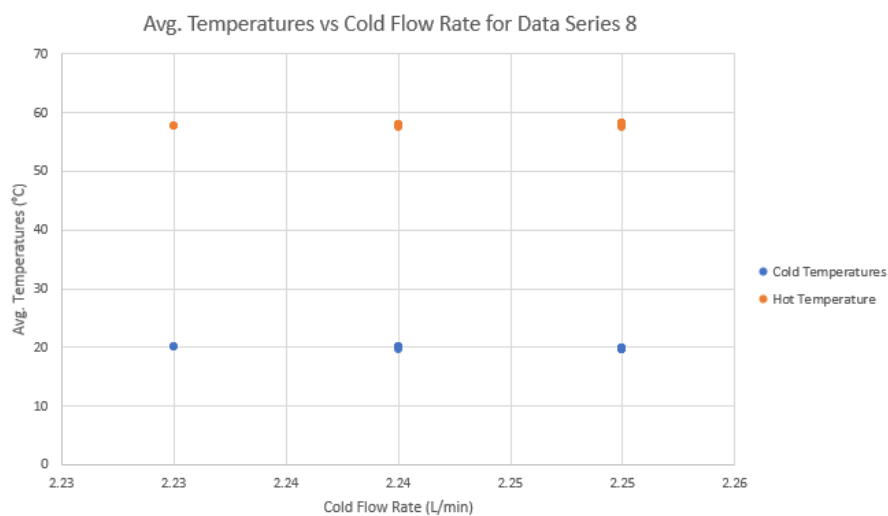


Figure 1: Graphical representation of Team 2 average temperature and cold flow rate

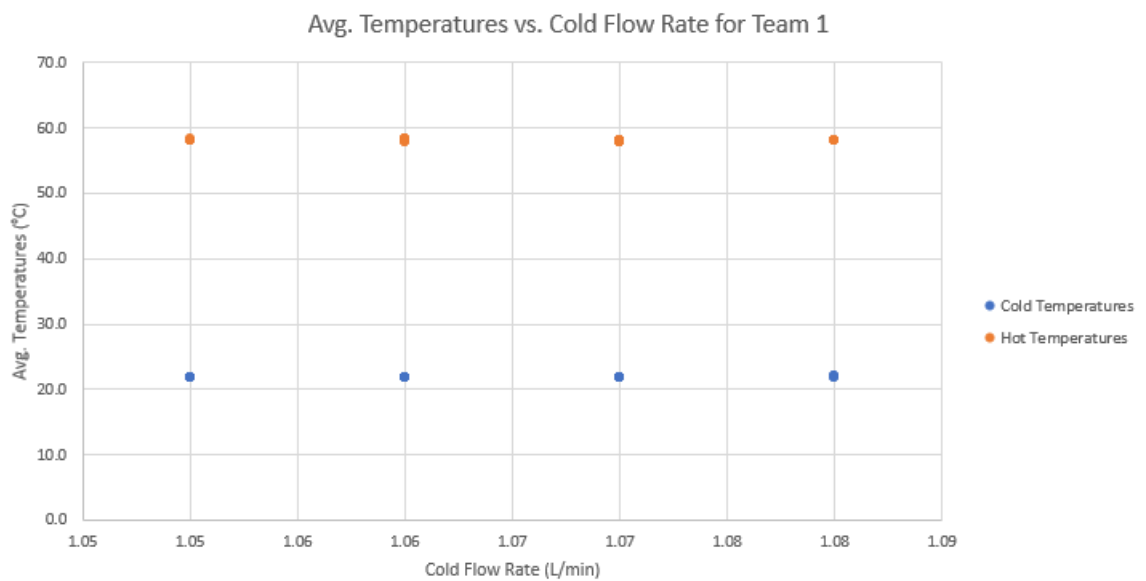


Figure 2: Graphical representation of Team 1 average temperature and cold flow rate.

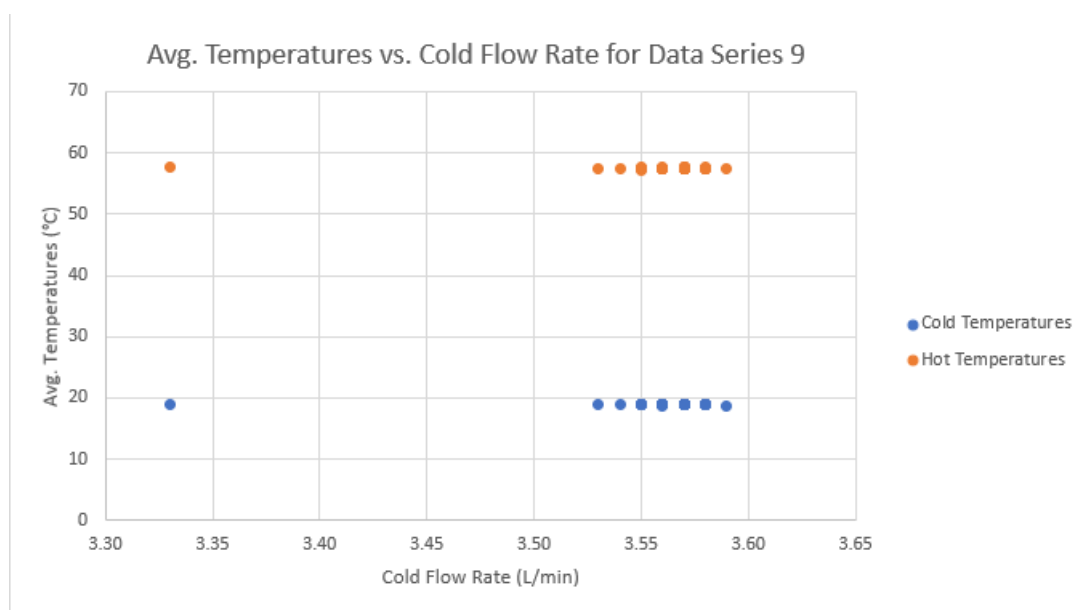


Figure 3: Graphical representation of Team 3 average temperature and cold flow rate

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- C. Halego. (2011, June 11) Basics of Industrial Heat Transfer. Chemical Engineering of Washington University. [Online manual] Available at:
http://www.cheresources.com/heat_transfer_basics.html/

CHEMICAL ENGINEERING LABORATORY I SPRING 2022

Title of Assignment: Evaluating performance of a shell-and-tube heat exchanger in countercurrent flow for various cold flow rates

TOPICS COVERED IN LAB 2

Lab 2 covered the following topics:

1. Focus on Theory and Discussion aspects of the lab report. Use of the Theory to set the relevance and theoretical background for the eventual analysis of data obtained during the course of the experiment.
2. Use of Discussion to explain the results obtained and trends observed with inclusion of sample calculations. Discussion weaves together what was introduced in the Theory section with the students' own experimental data and observations.

Repeated this section for each Quiz and Similarly for all the other assignments in the course binder

CHEMICAL ENGINEERING LABORATORY I
SPRING 2022

Title of Assignment: Evaluating performance of a shell-and-tube heat exchanger in countercurrent flow

LAB 2

ABOVE AVERAGE

Above Average Student Original Graded Assignment

Roy G. Perry
College of Engineering



CHEG 3101 - Chemical Engineering Lab I

Experiment 2: Shell and Tube Heat Exchanger Countercurrent Flow

Instructor: Dr. Keisha Antoine

Kiara Graham

Isis Solomon

Britton Andrews

Dynasty Stephenson

Anh Nguyen

Edgar Mendoza

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Figure 6: Mean Temperature Efficiency vs. Flow Rate for 5 Minutes

Figure 7: Overall Heat Transfer Coefficient for Flow Rate of 2.84L/min, 3.14L/min, 4.27L/min

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Table 3: Mean Value for Overall Heat Transfer Coefficient

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Abstract

Shell and tube heat exchangers are widely used in industrial processes. The equipment's primary application is transferring heat between fluids without mixing them. In this experiment, the performance of a TD360c shell and tube heat exchanger was analyzed in countercurrent flow configuration utilizing different cold flow rates while keeping the hot temperature and the hot water flow rate constant. The cold-water flow used during the experiment was set to three different flow rates. It was found that the mean temperature efficiency was the highest at the slowest cold flow rate, whereas the overall heat transfer coefficient could not be determined to be the highest with either slowest or the fastest flow. As a result, the highest performance of the heat exchanger was achieved with a slow cold flow rate by using mean temperature efficiency parameter. A relationship between the overall heat transfer coefficient and varying cold flow rates could not be determined. Therefore, another experiment with different cold flow rates' conditions is suggested to establish and confirm the overall performance of the heat exchanger.

Theory

Shell and tube heat exchangers are the primary equipment used to exchange thermal properties of fluid in process applications. One fluid is fed into smaller tubes while another fluid is fed into the shell side. Knowledge of heat exchanger is crucial in determining the heat duty and improving the energy efficiency of a system. Figure 1 is the apparatus utilized in this experiment, a TD360c shell and tube heat exchanger.

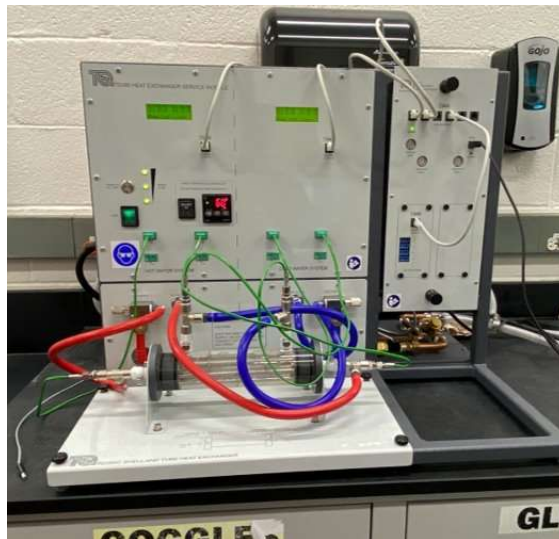


Figure 1: TD360c Shell and Tube Heat Exchanger

In this experiment, the countercurrent flow configuration, two fluids entering the heat exchanger in opposite direction, was studied. The hot fluid flowed from the left-hand position in red tubes, and the cold flow started in the right-hand position in blue tubes.

Figure 2 illustrates the schematic diagram of the shell and tube heat exchanger, which hot water (fluid 1) flows into the system from left to right while cold water (fluid 2) flows from right to left.

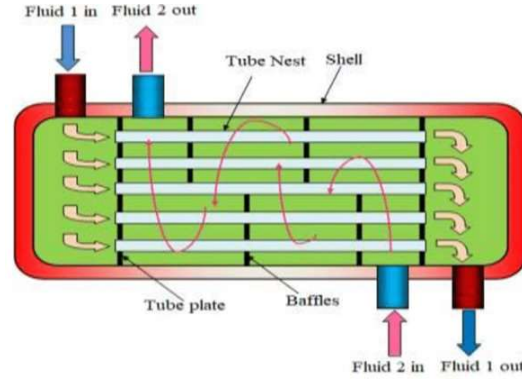


Figure 2: Shell and Tube Heat Exchanger Schematic Diagram

Figure 3 is the temperature profile of the countercurrent flow shell and tube heat exchanger. The hot fluid enters at temperature T_{H1} and leaves at T_{H2} while cold fluid enters at temperature T_{C1} and leaves at T_{C2} .

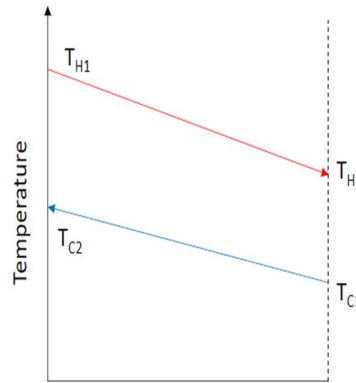


Figure 3: Temperature Profile of Countercurrent Flow Configuration

The average temperature difference hot and cold circuits at each end of the heat exchanger is calculated using the logarithmic mean temperature difference (LMTD). LMTD in Kelvin is the driving force that creates the heat transfer, defined by:

$$LMTD = \frac{(T_{H2} - T_{C2}) - (T_{H1} - T_{C1})}{\ln \left(\frac{T_{H2} - T_{C2}}{T_{H1} - T_{C1}} \right)} \quad (1)$$

where T_{H1} and T_{H2} are hot temperature inlet and outlet respectively; T_{C1} and T_{C2} are cold temperature inlet and outlet respectively.

The hot water emits heat energy $\dot{Q}_e$ (J/s), defined by:

$$\dot{Q}_e = \dot{m}c_p\Delta T_H = \rho\dot{V}c_p\Delta T_H$$

where $\dot{m}$ is the mass flow of water (kg/s); ρ is the density of water (taken as 1 kg/L); c_p is the special heat capacity of water at 1 atm (4.2J/kg*K); $\dot{V}$ is the volumetric flow rate (L/s); ΔT_H is the temperature difference of inlet and outlet hot stream (K).

The performance of shell and tube heat exchanger is then determined by the overall heat transfer coefficient U (W/m².K). The coefficient refers to how well heat is conducted through a series of

resistant mediums. It is vital to understand how heat is transferred when there is resistance, especially in engineering disciplines such as chemical engineering. The heat transfer coefficient can provide insight on how to produce the most efficient systems that are cost-effective. The higher the coefficient, the better the performance of that heat exchanger.

$$U = \frac{\dot{Q}_e}{A \times LMTD} \quad (2)$$

where $\dot{Q}_e$ is the heat energy hot water emitted (J/s); A is the total area of heat transfer (m^2); LMTD is the logarithmic mean temperature difference.

The mean temperature efficiency $\bar{\eta}$ (%) is another useful parameter to use for the performance of the heat exchanger. The results from the heat exchanger efficiency provide a new way for the design and analysis of heat exchangers. It is taken as the average between efficiency of the hot and cold circuits. The higher the mean temperature efficiency, the better the performance of the heat exchanger.

$$\bar{\eta} = \frac{\eta_H + \eta_c}{2} \quad (3)$$

Where the temperature efficiency of the hot circuit η_H is the ratio between the change in temperature of the hot flow and the temperature difference between the inlet temperature of hot and cold flow.

$$\eta_H = \frac{T_{H1} - T_{H2}}{T_{H1} - T_{C1}} \times 100$$

And the temperature efficiency of the cold circuit η_c is the ratio between the change in temperature of cold flow and the temperature difference between the inlet temperature of hot and cold flow.

$$\eta_c = \frac{T_{C1} - T_{C2}}{T_{H1} - T_{C1}} \times 100$$

Procedures

The experiment was carried out with the following steps. The heat exchanger connection and valve was prepared for countercurrent flow. The pump was turned on and the tank's heater temperature was set to 60°C. The hot flow rate was set to 2.4 L/min using hand-controlled valve. The hot water's temperature and the flow rate would be kept constant during the experiment. The temperature for the cold flow rate was measured at the inlet of the heat exchanger of 15.8°C. The cold flow rate was set to three different values 2.84 L/min, 3.14 L/min, and 4.27 L/min using hand-controlled valve. For each different cold flow rate, temperatures of inlet and outlet T_{H1} , T_{H2} , T_{C1} , and T_{C2} were recorded with Versatile Data Acquisition System (VDAS) for five minutes in ten second intervals.

Results and Discussion

Figure 4 is the temperature profile of the heat exchanger operating at cold inlet temperature of 19.6°C and flow rate of 3.14 L/min . It is clearly that the shell and tube heat exchanger was functioning correctly as the hot water temperature dropped from 60°C to 55°C while the cold-water flow temperature increased from 15.8°C to 20°C .

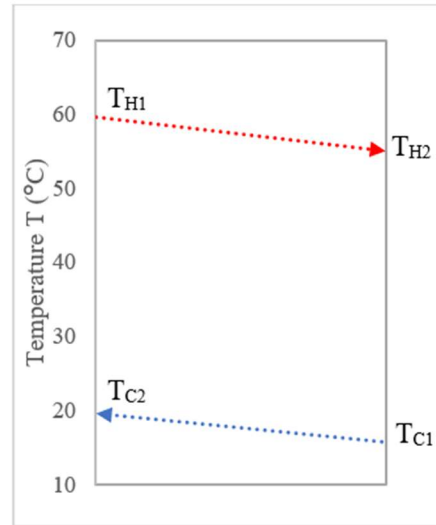


Figure 4: Temperature Profile for Cold Flow Rate of 3.14 L/min

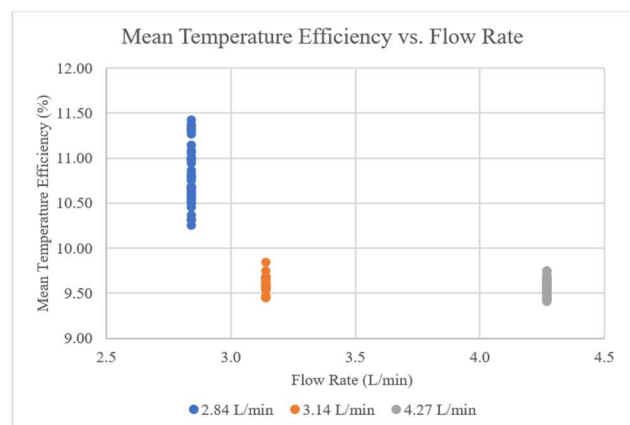
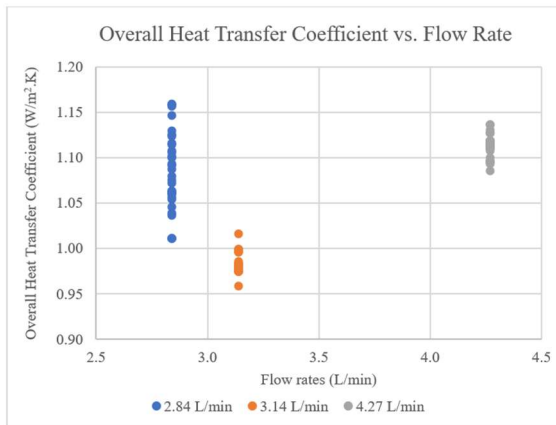


Figure 6: Overall Heat Transfer Coefficient vs. Flow Rate Figure 5: Mean Temperature Efficiency vs. Flow Rate for 5 Minutes for 5 Minutes

Figure 5 and Figure 6 illustrate the performance of heat exchanger using overall heat transfer coefficient and mean temperature efficiency vs. cold flow rate, respectively. The two graphs' purpose is to visualize the data calculated using equation (2) for overall heat transfer coefficient U and equation (3) for mean temperature efficiency $\bar{\eta}$.

However, with the **spread out of data** shown in Figure 5 and Figure 6, it is difficult to analyze the performance of the heat exchanger. Therefore, with the mean and deviation calculations of the data points and error bars system, Figure 7 and Figure 8 demonstrate a clear picture of the relationship between the heat transfer coefficient vs. cold flow rate, and the mean temperature efficiency vs. flow rate, respectively.

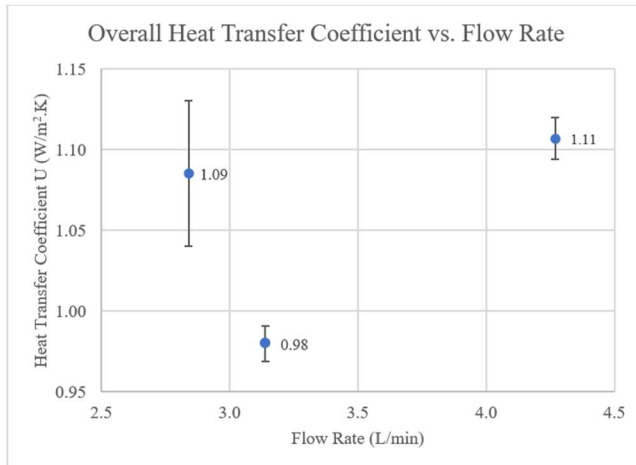


Figure 8: Overall Heat Transfer Coefficient for Flow Rate of 2.84L/min, 3.14L/min, 4.27L/min

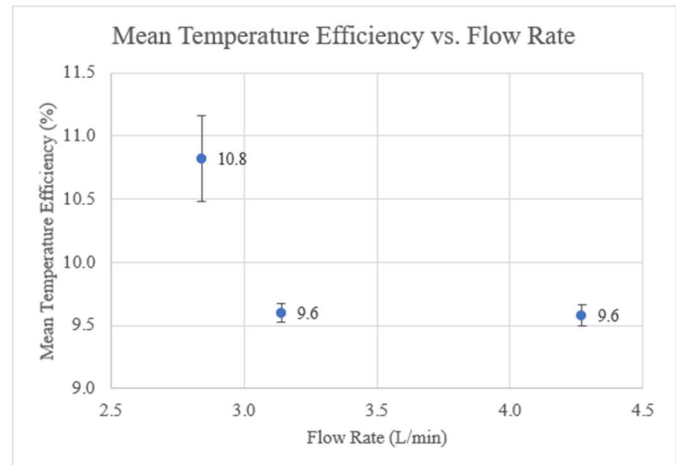


Figure 7: Mean Temperature Efficiency for Flow Rate of 2.84L/min, 3.14L/min, 4.27L/min

The cold flow rate of 4.28 L/min has the highest average heat transfer coefficient of 1.11 W/m².K. Nevertheless, the flow rate of 2.84 L/min has an average coefficient of 1.09 W/m².K. Therefore, the best performance of the heat exchanger cannot be determined with three choices of flow rate in this experiment.

It is noticeable that the cold flow rate of 2.84 L/min brings in the average highest mean temperature efficiency of 10.8% while the flow rates of 3.14 L/min and 4.27 L/min both give the mean temperature efficiency of 9.6%. **Therefore, the slowest cold flow rate will provide the highest mean temperature efficiency, which means the performance of the shell and tube heat exchanger is the best with the slowest cold flow rate.**

Conclusion

A heat exchanger is the equipment where heat transfer **is taken place** between two flows of fluids without mixing them. For this experiment, we determined the performance of the shell and tube heat exchanger using overall heat transfer coefficient and mean temperature efficiency. **The cold flow rate of 4.27L/min gave the highest overall heat transfer coefficient, 1.11 W/m².K,** but the cold flow rate of 2.48L/min gave the best result of mean temperature efficiency of 10.8%. The relationship between the cold flow rates and the performance of the heat exchanger is in inconclusive since the flow rates were close together. The future recommendation is to have a wide range of cold flow rates to be able to determine the relationship and the overall performance of the heat exchanger.

References

“TD360 Bench-top Heat Exchangers.” Accessed 2022.

Appendix

Table 1: Calculation Data for LMTD, Mean Temperature Efficiency, Overall Heat Transfer Coefficient

Cold			Hot								
Temp 1 (°C)	Temp 2 (°C)	Flow (L/min)	Temp 1 (°C)	Temp 2 (°C)	Flow (L/min)	LMTD (°C)	η_H	η_c	η	Q_e (W)	U (W/m ² .K)
15.8	20.4	2.84	58.7	53.5	2.42	37.79	12.12	10.72	11.42	0.88	1.17
15.8	20.4	2.84	58.7	53.6	2.43	37.84	11.89	10.72	11.31	0.87	1.15
15.8	20.4	2.84	58.9	53.7	2.42	37.99	12.06	10.67	11.37	0.88	1.16
15.8	20.4	2.84	59.0	53.8	2.42	38.09	12.04	10.65	11.34	0.88	1.16
15.8	20.4	2.84	59.1	53.9	2.43	38.19	12.01	10.62	11.32	0.88	1.16
15.7	20.4	2.84	59.2	54.1	2.43	38.39	11.72	10.80	11.26	0.87	1.13
15.8	20.4	2.84	59.3	54.2	2.42	38.45	11.72	10.57	11.15	0.86	1.12
15.8	20.4	2.84	59.1	54.1	2.42	38.30	11.55	10.62	11.09	0.85	1.11
15.8	20.3	2.84	59.0	54.0	2.42	38.25	11.57	10.42	11.00	0.85	1.11
15.8	20.3	2.84	59.2	54.1	2.42	38.40	11.75	10.37	11.06	0.86	1.12
15.8	20.3	2.84	59.2	54.2	2.42	38.45	11.52	10.37	10.94	0.85	1.10
15.8	20.3	2.84	59.4	54.3	2.41	38.60	11.70	10.32	11.01	0.86	1.11
15.8	20.3	2.84	59.5	54.4	2.42	38.70	11.67	10.30	10.98	0.86	1.12
15.8	20.2	2.84	59.5	54.5	2.42	38.81	11.44	10.07	10.76	0.85	1.09
15.8	20.3	2.84	59.5	54.5	2.42	38.76	11.44	10.30	10.87	0.85	1.09
15.8	20.2	2.84	59.4	54.5	2.43	38.76	11.24	10.09	10.67	0.83	1.08
15.7	20.2	2.84	59.3	54.4	2.42	38.71	11.24	10.32	10.78	0.83	1.07
15.7	20.2	2.84	59.6	54.6	2.42	38.96	11.39	10.25	10.82	0.85	1.09
15.7	20.2	2.84	59.7	54.8	2.42	39.11	11.14	10.23	10.68	0.83	1.06
15.7	20.2	2.84	59.7	54.8	2.42	39.11	11.14	10.23	10.68	0.83	1.06
15.7	20.2	2.84	59.7	54.7	2.41	39.06	11.36	10.23	10.80	0.84	1.08
15.8	20.2	2.84	59.7	54.8	2.42	39.07	11.16	10.02	10.59	0.83	1.06
15.7	20.2	2.84	59.5	54.7	2.41	38.97	10.96	10.27	10.62	0.81	1.04
15.7	20.2	2.84	59.4	54.6	2.42	38.86	10.98	10.30	10.64	0.81	1.05
15.8	20.1	2.84	59.6	54.7	2.42	39.02	11.19	9.82	10.50	0.83	1.06
15.7	20.1	2.84	59.7	54.8	2.42	39.17	11.14	10.00	10.57	0.83	1.06
15.7	20.1	2.84	59.8	54.9	2.42	39.27	11.11	9.98	10.54	0.83	1.06
15.7	20.1	2.84	59.7	54.9	2.42	39.22	10.91	10.00	10.45	0.81	1.04
15.7	20.1	2.84	59.9	55.0	2.42	39.37	11.09	9.95	10.52	0.83	1.05
15.7	20.1	2.84	59.8	55.1	2.42	39.37	10.66	9.98	10.32	0.80	1.01
15.7	20.1	2.84	59.8	55.1	2.42	39.37	10.66	9.98	10.32	0.80	1.01
15.8	20.1	2.84	59.7	55.0	2.41	39.23	10.71	9.79	10.25	0.79	1.01
15.8	20.1	2.84	59.7	54.9	2.41	39.17	10.93	9.79	10.36	0.81	1.03
15.8	19.6	3.14	59.7	55.2	2.41	39.61	10.25	8.66	9.45	0.76	0.96
15.8	19.6	3.14	59.7	55.1	2.40	39.55	10.48	8.66	9.57	0.77	0.98
15.8	19.6	3.14	59.7	55.1	2.40	39.55	10.48	8.66	9.57	0.77	0.98
15.8	19.6	3.14	59.7	55.1	2.41	39.55	10.48	8.66	9.57	0.78	0.98
15.8	19.6	3.14	59.7	55.1	2.41	39.55	10.48	8.66	9.57	0.78	0.98
15.8	19.6	3.14	59.6	55.0	2.40	39.45	10.50	8.68	9.59	0.77	0.98
15.8	19.6	3.14	59.6	55.0	2.40	39.45	10.50	8.68	9.59	0.77	0.98
15.8	19.6	3.14	59.7	55.0	2.40	39.50	10.71	8.66	9.68	0.79	1.00
15.8	19.6	3.14	59.8	55.1	2.40	39.60	10.68	8.64	9.66	0.79	1.00
15.8	19.6	3.14	59.8	55.2	2.40	39.65	10.45	8.64	9.55	0.77	0.97
15.8	19.6	3.14	59.7	55.1	2.40	39.55	10.48	8.66	9.57	0.77	0.98
15.8	19.6	3.14	59.6	55.0	2.40	39.45	10.50	8.68	9.59	0.77	0.98
15.8	19.6	3.14	59.6	55.0	2.40	39.45	10.50	8.68	9.59	0.77	0.98
15.8	19.6	3.14	59.5	54.9	2.40	39.35	10.53	8.70	9.61	0.77	0.98
15.8	19.6	3.14	59.5	54.9	2.40	39.35	10.53	8.70	9.61	0.77	0.98
15.8	19.6	3.14	59.5	54.9	2.41	39.35	10.53	8.70	9.61	0.78	0.99
15.8	19.6	3.14	59.5	54.9	2.40	39.35	10.53	8.70	9.61	0.77	0.98
15.8	19.6	3.14	59.5	54.9	2.40	39.35	10.53	8.70	9.61	0.77	0.98
15.8	19.6	3.14	59.5	54.9	2.40	39.35	10.53	8.70	9.61	0.77	0.98

15.8	19.6	3.14	59.6	55.0	2.41	39.45	10.50	8.68	9.59	0.78	0.98
15.8	19.6	3.14	59.7	55.1	2.40	39.55	10.48	8.66	9.57	0.77	0.98
15.8	19.6	3.14	59.8	55.2	2.40	39.65	10.45	8.64	9.55	0.77	0.97
15.8	19.7	3.14	59.9	55.2	2.40	39.64	10.66	8.84	9.75	0.79	1.00
15.8	19.7	3.14	59.8	55.2	2.40	39.60	10.45	8.86	9.66	0.77	0.98
15.8	19.6	3.14	59.8	55.2	2.40	39.65	10.45	8.64	9.55	0.77	0.97
15.8	19.6	3.14	59.8	55.2	2.41	39.65	10.45	8.64	9.55	0.78	0.98
15.8	19.6	3.14	59.7	55.1	2.40	39.55	10.48	8.66	9.57	0.77	0.98
15.8	19.6	3.14	59.7	55.1	2.40	39.55	10.48	8.66	9.57	0.77	0.98
15.8	19.7	3.14	59.7	55.1	2.40	39.50	10.48	8.88	9.68	0.77	0.98
15.9	19.7	3.14	59.8	55.1	2.40	39.50	10.71	8.66	9.68	0.79	1.00
15.8	19.7	3.14	59.8	55.2	2.40	39.60	10.45	8.86	9.66	0.77	0.98
15.9	19.7	3.14	59.9	55.2	2.40	39.60	10.68	8.64	9.66	0.79	1.00
15.8	19.7	3.14	60.0	55.2	2.40	39.69	10.86	8.82	9.84	0.81	1.02
15.9	19.7	3.14	59.9	55.3	2.39	39.65	10.45	8.64	9.55	0.77	0.97
15.9	19.7	3.14	59.9	55.3	2.39	39.65	10.45	8.64	9.55	0.77	0.97
15.8	19.6	3.14	59.8	55.2	2.40	39.65	10.45	8.64	9.55	0.77	0.97
15.8	19.7	3.14	59.7	55.1	2.40	39.50	10.48	8.88	9.68	0.77	0.98
15.8	19.7	3.14	59.7	55.1	2.40	39.50	10.48	8.88	9.68	0.77	0.98
15.9	19.7	3.14	59.7	55.1	2.40	39.45	10.50	8.68	9.59	0.77	0.98
15.8	19.7	3.14	59.7	55.1	2.40	39.50	10.48	8.88	9.68	0.77	0.98
15.8	19.6	3.14	59.7	55.2	2.40	39.61	10.25	8.66	9.45	0.76	0.95
15.9	19.7	3.14	59.7	55.2	2.40	39.50	10.27	8.68	9.47	0.76	0.96
15.9	19.1	4.27	59.8	54.6	2.39	39.55	11.85	7.29	9.57	0.87	1.10
15.9	19.1	4.27	59.6	54.4	2.40	39.35	11.90	7.32	9.61	0.87	1.11
15.9	19.1	4.27	59.5	54.3	2.40	39.25	11.93	7.34	9.63	0.87	1.11
15.9	19.1	4.27	59.5	54.3	2.40	39.25	11.93	7.34	9.63	0.87	1.11
15.9	19.1	4.27	59.5	54.3	2.40	39.25	11.93	7.34	9.63	0.87	1.11
15.9	19.1	4.27	59.5	54.2	2.40	39.20	12.16	7.34	9.75	0.89	1.14
15.9	19.1	4.27	59.4	54.2	2.40	39.15	11.95	7.36	9.66	0.87	1.12
15.9	19.1	4.27	59.3	54.2	2.40	39.10	11.75	7.37	9.56	0.86	1.10
15.9	19.1	4.27	59.3	54.1	2.40	39.05	11.98	7.37	9.68	0.87	1.12
15.9	19.1	4.27	59.3	54.1	2.40	39.05	11.98	7.37	9.68	0.87	1.12
15.9	19.1	4.27	59.3	54.1	2.40	39.05	11.98	7.37	9.68	0.87	1.12
15.9	19.1	4.27	59.3	54.1	2.40	39.05	11.98	7.37	9.68	0.87	1.12
15.9	19.1	4.27	59.3	54.2	2.40	39.10	11.75	7.37	9.56	0.86	1.10
15.9	19.0	4.27	59.4	54.2	2.40	39.20	11.95	7.13	9.54	0.87	1.11
15.9	19.1	4.27	59.5	54.2	2.40	39.20	12.16	7.34	9.75	0.89	1.14
15.9	19.1	4.27	59.5	54.3	2.40	39.25	11.93	7.34	9.63	0.87	1.11
15.9	19.1	4.27	59.7	54.4	2.40	39.40	12.10	7.31	9.70	0.89	1.13
15.9	19.1	4.27	59.8	54.5	2.40	39.50	12.07	7.29	9.68	0.89	1.13
15.9	19.1	4.27	59.8	54.5	2.40	39.50	12.07	7.29	9.68	0.89	1.13
15.9	19.1	4.27	59.7	54.5	2.40	39.45	11.87	7.31	9.59	0.87	1.11
15.9	19.1	4.27	59.6	54.4	2.40	39.35	11.90	7.32	9.61	0.87	1.11
15.9	19.1	4.27	59.5	54.4	2.39	39.30	11.70	7.34	9.52	0.85	1.09
15.9	19.1	4.27	59.5	54.3	2.40	39.25	11.93	7.34	9.63	0.87	1.11
15.9	19.1	4.27	59.4	54.3	2.40	39.20	11.72	7.36	9.54	0.86	1.09
15.9	19.1	4.27	59.4	54.2	2.40	39.15	11.95	7.36	9.66	0.87	1.12
15.9	19.1	4.27	59.3	54.2	2.40	39.10	11.75	7.37	9.56	0.86	1.10
15.9	19.1	4.27	59.3	54.2	2.40	39.10	11.75	7.37	9.56	0.86	1.10
15.9	19.1	4.27	59.3	54.1	2.40	39.05	11.98	7.37	9.68	0.87	1.12
15.9	19.1	4.27	59.3	54.2	2.40	39.10	11.75	7.37	9.56	0.86	1.10
15.9	19.1	4.27	59.4	54.2	2.40	39.15	11.95	7.36	9.66	0.87	1.12
15.9	19.1	4.27	59.4	54.2	2.39	39.15	11.95	7.36	9.66	0.87	1.11
15.9	19.1	4.27	59.5	54.3	2.40	39.25	11.93	7.34	9.63	0.87	1.11
15.9	19.1	4.27	59.5	54.3	2.40	39.25	11.93	7.34	9.63	0.87	1.11
15.9	19.1	4.27	59.5	54.4	2.40	39.30	11.70	7.34	9.52	0.86	1.09
15.9	19.1	4.27	59.5	54.4	2.40	39.30	11.70	7.34	9.52	0.86	1.09

15.9	19.1	4.27	59.6	54.4	2.40	39.35	11.90	7.32	9.61	0.87	1.11
16.0	19.1	4.27	59.6	54.4	2.40	39.30	11.93	7.11	9.52	0.87	1.11
15.9	19.1	4.27	59.6	54.4	2.40	39.35	11.90	7.32	9.61	0.87	1.11
15.9	19.1	4.27	59.6	54.4	2.39	39.35	11.90	7.32	9.61	0.87	1.11
15.9	19.1	4.27	59.5	54.3	2.40	39.25	11.93	7.34	9.63	0.87	1.11
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16.0	19.1	4.27	59.4	54.2	2.40	39.10	11.98	7.14	9.56	0.87	1.12
16.0	19.1	4.27	59.4	54.2	2.40	39.10	11.98	7.14	9.56	0.87	1.12
16.0	19.1	4.27	59.4	54.3	2.40	39.16	11.75	7.14	9.45	0.86	1.09
15.9	19.1	4.27	59.4	54.3	2.40	39.20	11.72	7.36	9.54	0.86	1.09
15.9	19.1	4.27	59.4	54.3	2.40	39.20	11.72	7.36	9.54	0.86	1.09
16.0	19.1	4.27	59.4	54.3	2.40	39.16	11.75	7.14	9.45	0.86	1.09
15.9	19.1	4.27	59.5	54.3	2.40	39.25	11.93	7.34	9.63	0.87	1.11
15.9	19.1	4.27	59.5	54.3	2.40	39.25	11.93	7.34	9.63	0.87	1.11
15.9	19.1	4.27	59.5	54.4	2.40	39.30	11.70	7.34	9.52	0.86	1.09
16.0	19.1	4.27	59.6	54.4	2.40	39.30	11.93	7.11	9.52	0.87	1.11
16.0	19.1	4.27	59.6	54.4	2.40	39.30	11.93	7.11	9.52	0.87	1.11
15.9	19.1	4.27	59.6	54.5	2.40	39.40	11.67	7.32	9.50	0.86	1.09
16.0	19.1	4.27	59.6	54.5	2.40	39.36	11.70	7.11	9.40	0.86	1.09
15.9	19.1	4.27	59.6	54.5	2.40	39.40	11.67	7.32	9.50	0.86	1.09
15.9	19.1	4.27	59.6	54.4	2.39	39.35	11.90	7.32	9.61	0.87	1.11
16.0	19.1	4.27	59.5	54.4	2.40	39.26	11.72	7.13	9.43	0.86	1.09
16.0	19.1	4.27	59.4	54.3	2.40	39.16	11.75	7.14	9.45	0.86	1.09
16.0	19.1	4.27	59.4	54.3	2.40	39.16	11.75	7.14	9.45	0.86	1.09
16.0	19.1	4.27	59.4	54.2	2.40	39.10	11.98	7.14	9.56	0.87	1.12
16.0	19.1	4.27	59.4	54.3	2.40	39.16	11.75	7.14	9.45	0.86	1.09

Table 2: Mean Value for Mean Temperature Efficiency

Flow rate (L/min)	Mean Temperature Efficiency	Standard deviation
2.8	10.8	0.338129
3.1	9.6	0.073912
4.3	9.6	0.080587

Table 3: Mean Value for Overall Heat Transfer Coefficient

Flow rate (L/min)	Heat Transfer Coefficient	Standard deviation
2.8	1.09	0.044809
3.1	0.98	0.011063
4.3	1.11	0.012767

Table 4: Temperature Profile for Inlet and Outlet Temperature of Hot and Cold Water

Flow rate (L/min)	Hot Temperature (°C)	Cold Temperature (°C)	Note
2.84	59.42	20.24	TH1/TC2
	54.46	15.76	TH2/TC1
3.14	59.71	19.63	TH1/TC2
	55.1	15.81	TH2/TC1
4.27	59.48	19.1	TH1/TC2
	54.31	15.92	TH2/TC1

AVERAGE

Average Student Original Graded Assignment

Prairie View A&M University

Shell and Tube Heat Exchanger in Counter-Current
Configuration:

Analysing the Effect of Cold Flow Rates to the Heat Exchanger
Performance

By

Shelton Amaram

Maya Spears

Ariel Kinsey

Clement Adeyemi

Ezranequia Tatmon

Willie Conner

CHEG 3101

Dr. Antoine

March 7, 2022

Abstract

The aim of the experiment is to determine how different cold flow rates effect the heat exchanger performance in a counter current flow configuration. The equipment used in this experiment was a TD360c heat exchanger. To study the effects of the different cold flow rates, ~~we will be using~~ the heat transfer coefficient ($U, \frac{W}{m^2 \cdot K}$) as our metric of comparison. After careful analysis of the data, it was determined that there was a directly proportional relationship between cold flow rates and the heat transfer coefficient.

Theory

Heat exchangers, as shown in Figure 1, are used in industries to heat or cool products by exchanging heat from one media to the other.

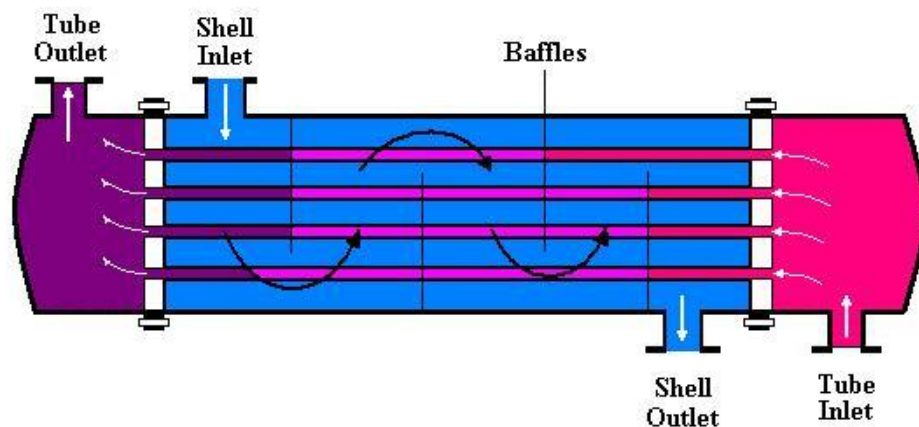


Figure 1: Diagram of a shell and tube heat exchanger in counter current flow.

There are four types of heat exchangers:

- Double Tube Heat Exchangers
- Tube in Tube Heat Exchangers
- Plate Heat Exchangers
- Shell and Tube Heat Exchangers

The experiment used a shell and tube heat exchanger featuring a closed system undergoing counter-current flow, where both fluids are moving in opposite directions.

Shell and tube heat exchangers consist of a large pressure vessel, which is the shell, with a bundle of tubes inside it. While one fluid flows through the inside of the tubes, the other fluid flows through the shell to transfer heat between the two fluids. The advantages of this heat exchanger are its simplicity and ability to work at high pressures. Due to these reasons, it is the most used heat exchanger in chemical plants today.

As shown by the graph below, the cooling relationship of the two fluids is logarithmic. There is a significant temperature difference at the inlet, with the cold fluid never surpassing the hot fluid in temperature even at its lowest point. The considerable temperature difference makes the device susceptible to thermal stresses. While that is a disadvantage, it makes up for it in that there is minimal pressure loss, and it is relatively easy/cheap to build.

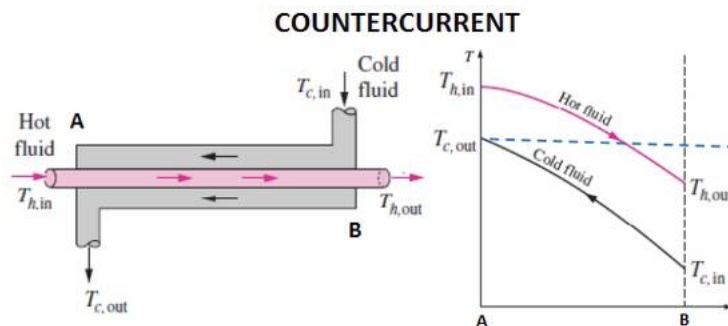


Figure 2(a & b respectively): Diagram of a heat exchanger in counter current flow and the temperature profile.

Key Formulas

The following formulas are essential in solving for the heat transfer coefficient. The average cold and hot temperatures (formula 1 and 2) are used to find the specific heat capacity at each interval.

Formula 1: Average Temperature (Hot)

$$T_{H_{avg}} = \frac{T_{H_1} + T_{H_2}}{2} (^{\circ}\text{C})$$

Formula 2: Average Temperature (Cold)

$$T_{C_{avg}} = \frac{T_{C_1} + T_{C_2}}{2} (^{\circ}\text{C})$$

Specific Heat Capacity (Formula 3) which is the ratio of the change in heat and temperature, is used to find the heat absorbed and emitted by the system (C. Halego).

Formula 3: Specific Heat Capacity (Hot & Cold)

$$\frac{C_p \text{ (at } T^{\circ}\text{C)}}{C_p \text{ (at } 15^{\circ}\text{C)}} = 0.996185 + 0.0002874 \left(\frac{T + 100}{100} \right)^{5.26} + 0.011160 \times 10^{-0.036T} \left(\frac{J}{kg * K} \right)$$

The heat emitted formula and log mean temperature difference are both used to find the heat transfer coefficient. The heat emitted is the heat that is released by the hot water and eventually absorbed by the cold water. The log mean temperature difference as shown in Figure 2b is the considerable temperature difference between the hot and the cold. The cold fluid will never surpass the hot fluid in temperature, even at its lowest point. While this considerable temperature difference is a disadvantage because it makes the heat exchanger to thermal stress, it makes up for this with minimum pressure loss.

Formula 4: Heat Emitted (Hot Temperatures)

$$\dot{Q}_e = m_{hot} \cdot C_{p_{hot}} \cdot \Delta T_{hot} (W)$$

Formula 10: Log Mean Temperature Difference

$$\Delta T_{LMTD} = \frac{(T_{H_2} - T_{C_2}) - (T_{H_1} - T_{C_1})}{\ln \left(\frac{T_{H_2} - T_{C_2}}{T_{H_1} - T_{C_1}} \right)} (K)$$

The heat transfer coefficient measures how efficient a heat exchanger works and the heat transfer between the wall and boundary layers (C. Halego).

Formula 11: Heat Transfer Coefficient

$$U = \frac{\dot{Q}_e}{A \cdot \Delta T_{LMTD}} \left(\frac{W}{m^2 \cdot K} \right)$$

Procedure

The objective of this lab was to record the hot and cold temperatures over five minutes to allow the machine to come to steady state and observe any variances during that time. First, the machine was powered on and ensured to be in the counter current configuration. Then, the machine was set to 60°C and time was given to allow it to reach that temperature. The hot flow rate was left constant, but there were three different cold flow rates used in this experiment: $2.83 \left(\frac{L}{min} \right) (\pm 0.005)$, $4.28 \left(\frac{L}{min} \right) (\pm 0.005)$, and $1.52 \left(\frac{L}{min} \right) (\pm 0.005)$. After changing the cold flow rate, the computer recorded the data using Versatile Data Acquisition System (VDAS).

Results and Discussion

The aim of this experiment was to observe the various cold flow rates and the effect on the heat exchanger performance. The data was recorded for five minutes to allow that system to reach steady state at the different cold flow rates. In Figure 3 below, the hot and cold temperatures are shown compared to time, this also shows the temperature gradient for a counter current system. The temperature is plotted versus time to observe the variations in the temperatures.

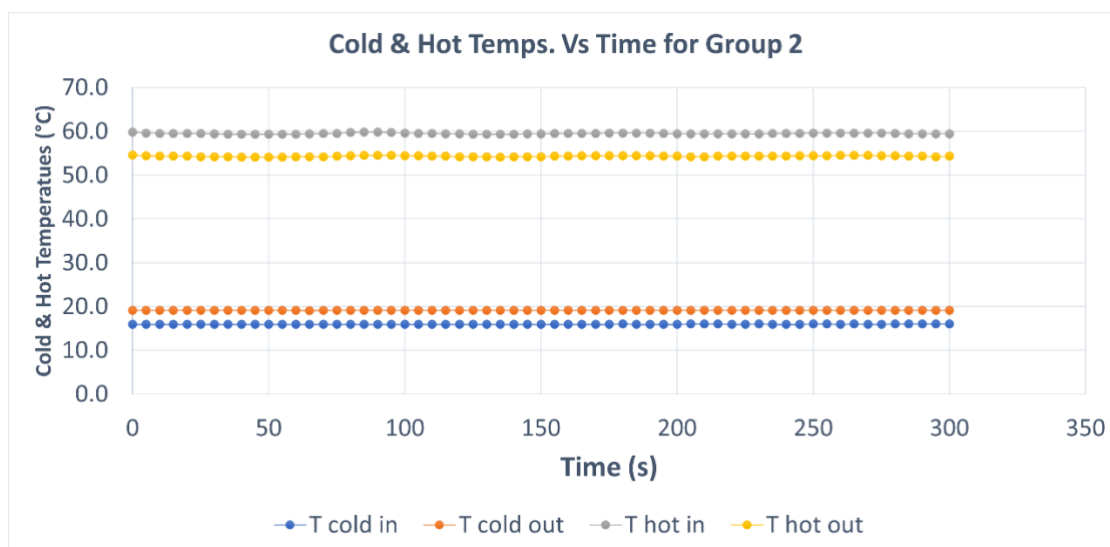


Figure 3 - Raw data- Temperature vs. Time

The raw data that was collected above is then used to calculate the log mean temperature difference (Formula 10), which is a variable in the heat transfer coefficient equation (11).

Formula 10 is important because it is used as the temperature driving force for the heat transfer in heat exchangers. In the sample below, the calculation of the log mean temperature difference can be seen.

$$\Delta T_{LMTD} = \frac{(T_{H_2} - T_{C_2}) - (T_{H_1} - T_{C_1})}{\ln\left(\frac{T_{H_2} - T_{C_2}}{T_{H_1} - T_{C_1}}\right)}$$

$$\Delta T_{LMTD} = \frac{(54.6 - 19.1) - (59.8 - 15.9)}{\ln\left(\frac{54.6 - 19.1}{59.8 - 15.9}\right)}$$

$$\Delta T_{LMTD} = 35.2 \text{ K}$$

After the heat transfer coefficient was calculated for each interval of the temperature differences, it was then compared to the various cold flow rates. In Figure 4 below, this comparison can be seen.

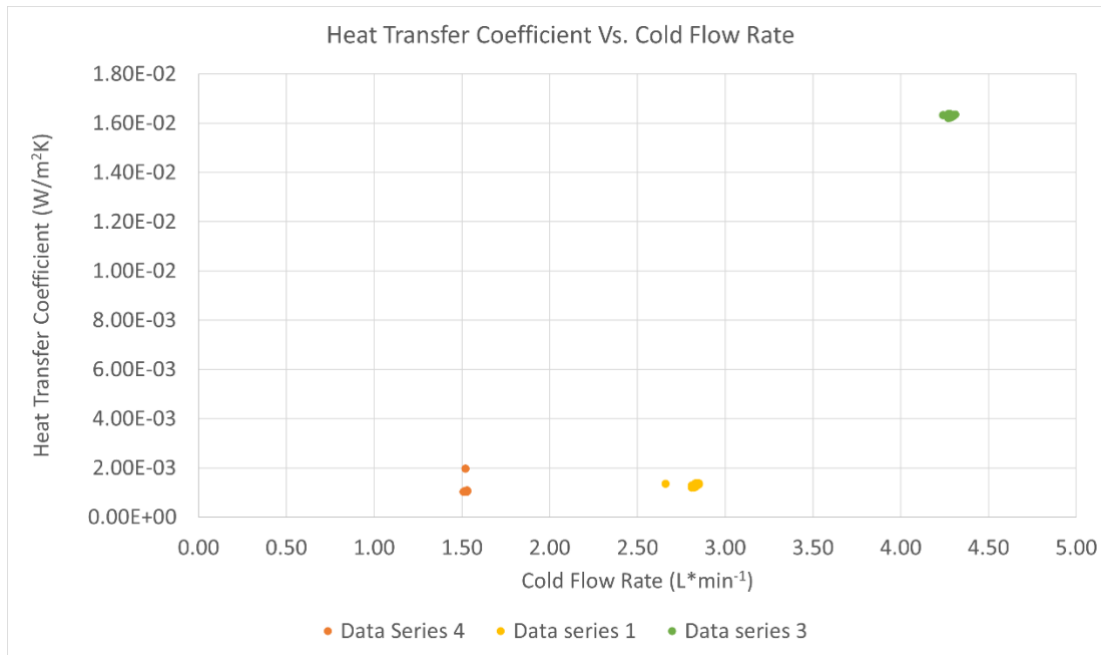


Figure 4 - The heat transfer coefficients versus the cold flow rates.

Once the data was observed, it was decided that the overall effect of the cold flow rate compared the heat transfer coefficient is a directly proportional relationship between the two. As the cold flow rate increases, the heat transfer coefficient also increases.

As shown in Figure 4, the cold rate $4.28 \left(\frac{L}{min}\right) (\pm 0.005)$ had the highest heat transfer coefficient meaning that at this cold flow rate, the heat exchanger was the most efficient and

had the best performance. At the lowest flow rate, $1.52 \left(\frac{L}{min}\right) (\pm 0.005)$, the heat transfer coefficient was also the lowest. At this cold flow rate, the heat exchanger would be less efficient. When looking at Figure 4, the heat transfer coefficient is seen to be significantly lower than the heat transfer coefficient of the cold flow rate $4.28 \left(\frac{L}{min}\right) (\pm 0.005)$. This confirms the observation that there is a directly proportional relationship between the cold flow rate and the heat transfer coefficient. The cold flow rate of $2.83 \left(\frac{L}{min}\right) (\pm 0.005)$, performs better than that of $1.52 \left(\frac{L}{min}\right) (\pm 0.005)$, however because it is not the highest flow rate within the data series, the heat exchanger would not perform at its highest due to these conditions.

Conclusion

After careful analysis, the aim of the experiment which was to determine how different cold flow rates effect the heat transfer coefficient was achieved. ~~The procedure was followed diligently and allowed raw data to be collected using VDAS.~~ The raw data was then used to calculate the different parameters to ultimately calculate the heat transfer coefficient. It was then determined that there is a directly proportional relationship between the cold flow rate and heat transfer coefficient. The heat transfer coefficient increases, as the cold flow rate increases, and vice versa. This also means that the heat exchanger efficiency increases as the cold flow rate increases. These observations helped to establish $4.28 \left(\frac{L}{min}\right) (\pm 0.005)$ as the best cold flow rate. ~~To reflect on the experiment,~~ in the future to ensure that the observation is correct, more cold flow rates should be tested.

Appendix

Formula 5: Heat Absorbed (Cold Temperatures)

$$\dot{Q}_a = \dot{m}_{cold} \cdot C_{p_{cold}} \cdot \Delta T_{cold} \text{ (W)}$$

Formula 6: Efficiency (Hot)

$$\eta_H = \frac{T_{H_1} - T_{H_2}}{T_{H_1} - T_{C_1}} \cdot 100\%$$

Formula 7: Efficiency (Cold)

$$\eta_C = \frac{T_{C_2} - T_{C_1}}{T_{H_1} - T_{C_1}} \cdot 100\%$$

Formula 8: Mean Temperature Efficiency

$$\bar{\eta} = \frac{\eta_H + \eta_C}{2}$$

Formula 9: Energy Balance

$$C_{EB} = \frac{\dot{Q}_a}{\dot{Q}_e}$$

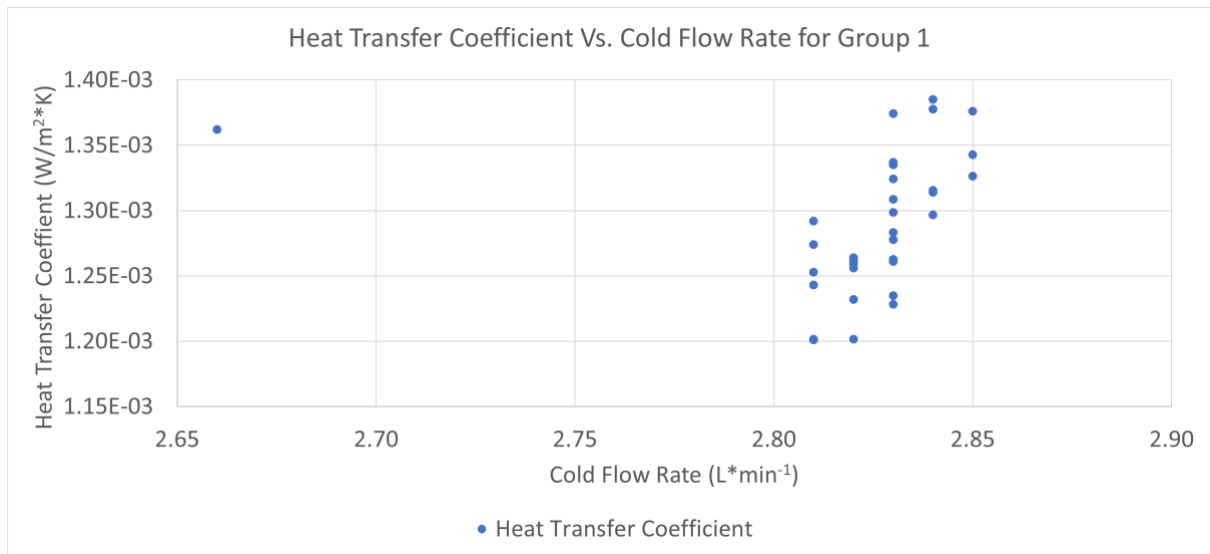


Figure 5 - Heat Transfer Coefficient versus the Cold flow rate for data series 1

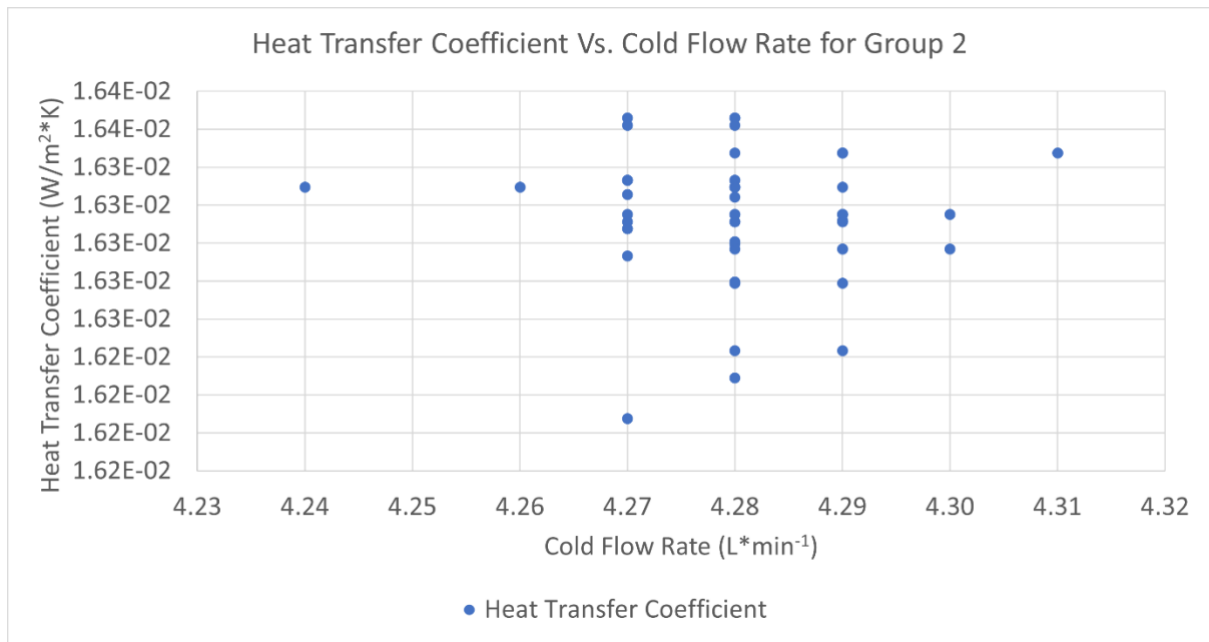


Figure 6 - Heat Transfer Coefficient versus the Cold flow rate for data series 3

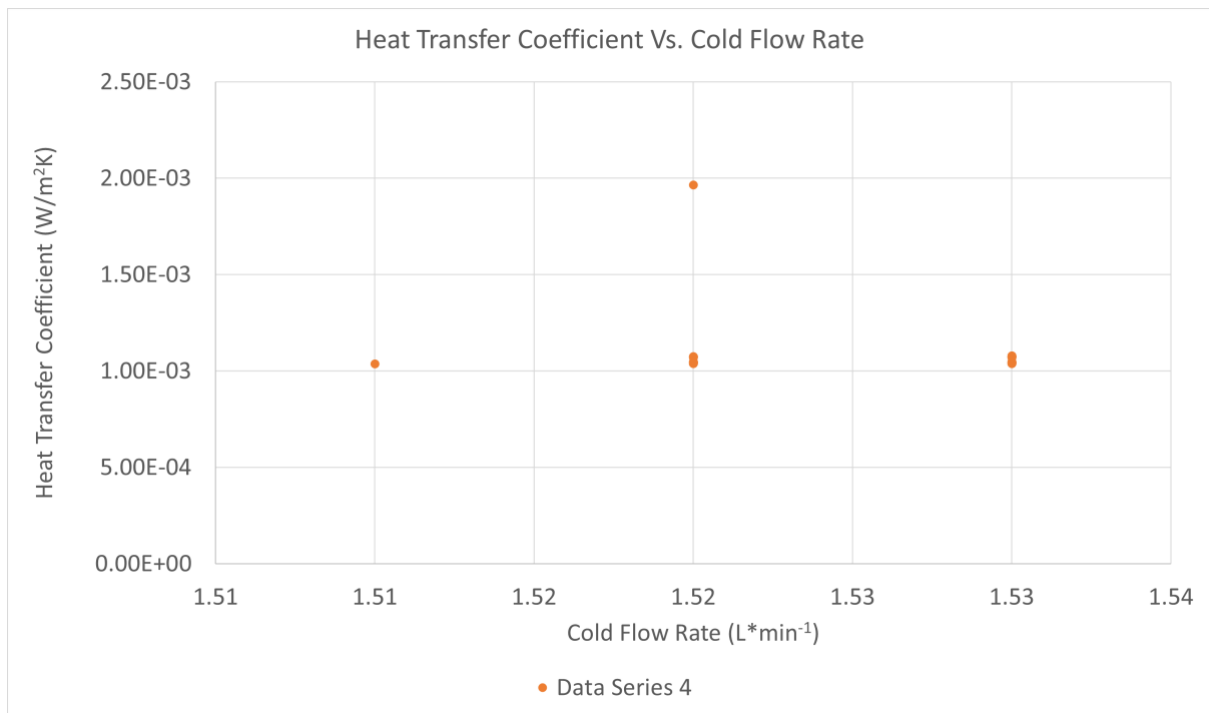


Figure 7 - Heat Transfer Coefficient versus the Cold flow rate for data series 4

References

- Geankoplis, Christie J., and A.Allen Hersel. *Transport Processes and Separation Process Principles: Christie John GEANKOPLIS, A. Allen Hersel and Daniel H. Lepek*. Vol. 5, Prentice Hall Professional Technical Reference, 2018.
- C. Halego. (2011, June 11) Basics of Industrial Heat Transfer. Chemical Engineering of Washington University. [Online manual] Available at:
http://www.cheresources.com/heat_transfer_basics.html/

BELOW AVERAGE

Below Average Student Original Graded Assignment

NO STUDENT SAMPLES AVAILABLE FOR BELOW AVERAGE

CHEMICAL ENGINEERING LABORATORY I SPRING 2022

Title of Assignment: Measuring the temperature-dependence of viscosity of ethanol using the Ubbelohde viscometer.

TOPICS COVERED IN LAB 3

Lab 3 covered the following topics:

1. Focus on Abstract and Conclusion aspects of the lab report. Use of the Abstract to introduce the reader to the experiment theme and its technical relevance. Abstract gives an overall summary with highlights of important results.
2. Use of Conclusion to summarize the entire report with a bit more information on the critical results and explanation. Conclusion also includes future looking statements and make some recommendations about how the outcome can be improved.

Repeated this section for each Homework and Similarly for all the other assignments in the course binder

CHEMICAL ENGINEERING LABORATORY I
SPRING 2022

Title of Assignment: Measuring the temperature-dependence of viscosity of ethanol using the Ubbelohde viscometer.

LAB 3

ABOVE AVERAGE

Above Average Student Original Graded Assignment

Roy G. Perry

College of Engineering



CHEG 3101 - Chemical Engineering Lab I

Experiment 3: The Effect Temperature has on the Viscosity of Ethanol

Instructor: Dr. Keisha Antoine
Kiara Graham
Isis Solomon
Cedric Sanhouidi
Shelton Amaram

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Figure 1: Ubbelohde Viscometer

Figure 2: Dynamic Viscosity vs Temperature

Abstract

The purpose of this experiment was to analyze the effect of temperature changes on the dynamic viscosity of ethanol. This experiment was conducted in a laboratory with three (3) different Ubbelohde viscometers following the ASTM standards; 0C B800 Cannon, 0B M339 Cannon, and 0B M338 Cannon with constants of $0.003 \text{ mm}^2/\text{s}^2$, $0.005 \text{ mm}^2/\text{s}^2$, and $0.004 \text{ mm}^2/\text{s}^2$. Data was collected at different temperatures following an ascending order (low –room -high temperature) and it is safe to say that as temperature increases, dynamic viscosity of ethanol decreases. For the low temperature of 8°C , dynamic viscosity was $0.0016 \text{ Pa}\cdot\text{s}$; this viscosity decreased to $0.0013 \text{ Pa}\cdot\text{s}$ when temperature was increased to 35°C and then decreased even further to $0.0005 \text{ Pa}\cdot\text{s}$ once temperature reached the high of 68°C .

Theory

A viscometer is a device that measures resistance to internal flow of a fluid. For this experiment three (3) different viscometers were used. Each viscometer has a different constant. The 0C B800 Cannon viscometer has a constant value of $0.003 \text{ mm}^2/\text{s}^2$, 0B M339 Cannon viscometer has a constant value of $0.005 \text{ mm}^2/\text{s}^2$, and the 0B M338 Cannon viscometer with a constant of $0.004 \text{ mm}^2/\text{s}^2$. The American Society for testing and Materials (ASTM) is an international standards organization. These standards are throughout the world, the viscometer used for this experiment is credible and can be trusted.

Dynamic viscosity is the measurement of fluid's resistance to flow. This is an important measure to understand how the fluid will move when it comes to contact with solid boundaries. Temperature has a major effect on the viscosity of liquid and usually there is an increase in

dynamic viscosity when temperature decreases and vice versa. The first part of this experiment consisted of recording efflux time of ethanol drop; then multiply efflux time by viscometer's constant to find kinematic viscosity and lastly multiply the kinematic viscosity by ethanol's density to find dynamic viscosity.

Kinematic Viscosity (ν in m^2/s)

$$\nu = K \times T$$

Dynamic viscosity (μ in $\text{Pa}\cdot\text{s}$ or $\text{kg}/\text{m}\cdot\text{s}$)

$$\mu = \rho \times \nu$$

ρ : density (kg/m^3)

T: Efflux time (s)

K: viscometer constant

Kinematic viscosity tells how quick a liquid is moving while dynamic viscosity represents the amount of force needed to make a liquid flow at a given rate.

Procedures

The experiment was conducted with the following steps. Place the viscometer onto holder and into a constant temperature bath. Looking at figure 1 charge the viscometer by pouring enough ethanol through tube L to fill the lower reservoir until the liquid meniscus is between

minimum and maximum fill lines marked on reservoir. Allow 15 mins for sample to come to bath temperature. Place a finger over tube M and apply suction to tube N until liquid reaches the center of bulb D, remove suction from tube N. Remove finger from tube M and place over tube N until the excess drops away. Remove finger and measure efflux time. Repeat for multiple temperatures with a range of high, medium, and low.

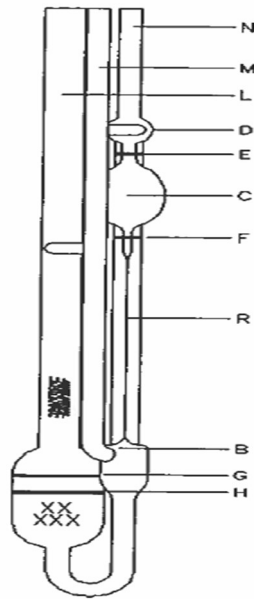


Figure 1: Ubbelohde Viscometer

Results and Discussion

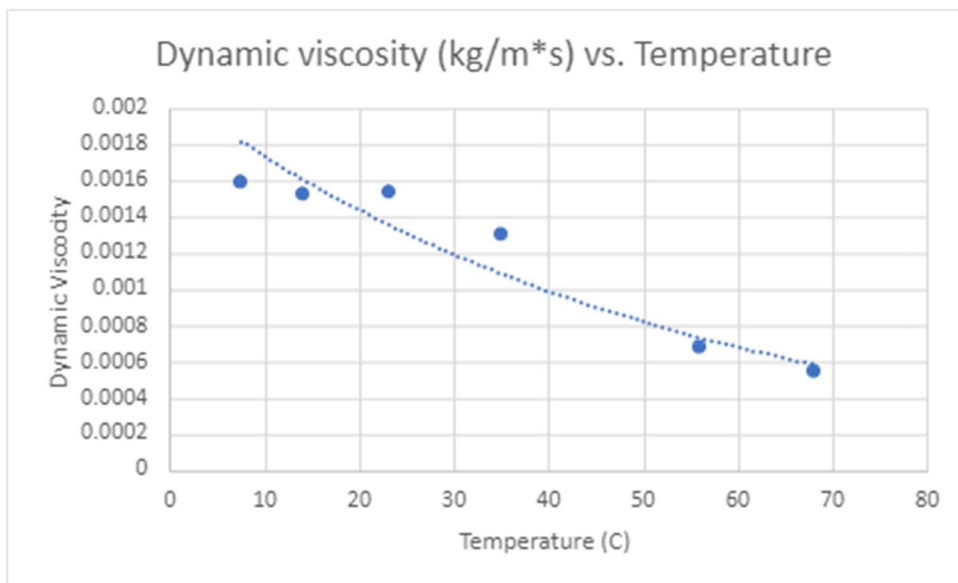


Figure 2: Dynamic Viscosity vs Temperature

A graphical representation of the results obtained is clearly shown above. As the temperature increases, ethanol's dynamic viscosity decreases. This happens because the more ethanol is heated, the more speed its particles gain allowing a faster interaction therefore viscosity is reduced. When first looking at the raw data versus time, it did not look as if the theory that as temperature increases, dynamic viscosity decreases is true. This was because, from raw data, the times for the hotter and lower temperatures were less than the time for room temperatures. Once the time was multiplied by each viscometer constant corresponding to its temperature, it was clear that the dynamic viscosity decreased as temperature increased.

In the temperature range from 0°C to 30°C, our dynamic viscosity did not change by much, so it was not clear at that point if our observation was true. In the next temperature range from 30°C to 80°C it was shown clearly that there was a bigger difference in the dynamic viscosity values than at the cooler temperatures. Due to this observation, it can also be said that

at higher temperatures the dynamic viscosity changes at a higher rate than it does at lower temperatures.

Conclusion

In conclusion, a viscometer measures the resistance to internal flow of a fluid. The three (3) viscometers used in this experiment were: 0C B800 Cannon, 0B M339 Cannon, and 0B M338 Cannon with constants of $0.003 \text{ mm}^2/\text{s}^2$, $0.005 \text{ mm}^2/\text{s}^2$, and $0.004 \text{ mm}^2/\text{s}^2$. The goal of the experiment was to calculate the dynamic viscosity of ethanol which would determine the amount of force needed by the fluid to overcome its own molecular friction. Figure 2 above shows an inverse relationship between the dynamic viscosity of ethanol and the temperature of the water used during the experiment. This is expected because the relationship between temperature and dynamic viscosity is an inverse relationship. A recommendation for the future would be to insulate the bath so there is no amount of energy loss resulting in a change in temperature.

References

www.britannica.com

www.sciencedirect.com

Appendix

Temp (C)	Time (s)	Constant (mm ² /s ²)	Constant(m ² /s ²)	Kinematic viscosity(m ² /s)	density(kg/m ³)	Dynamic viscosity (kg/m*s)
7.5	398	0.005073	5.073E-09	2.01905E-06	789	0.001593034
14	383	0.005073	5.073E-09	1.94296E-06	789	0.001532995
23	650	0.003	0.000000003	0.00000195	789	0.00153855
35	552	0.003	0.000000003	0.000001656	789	0.001306584
56	176	0.004937	4.937E-09	8.68912E-07	789	0.000685572
68	142	0.004937	4.937E-09	7.01054E-07	789	0.000553132

AVERAGE

Average Student Original Graded Assignment

Roy G. Perry
College of Engineering



CHEG 3101 - Chemical Engineering Lab I

Experiment 3: Dynamic Viscosity Dependent on Temperature of Ethanol

Instructor: Dr. Keisha Antoine

Dynasty Stephenson

Anh Nguyen

Edgar Mendoza

Maya Spears

Ariel Kinsey

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Figure 2: The Ubbelohde Viscometer

Figure 3: Experiment Set-Up

Figure 4: The Ubbelohde Diagram

Figure 5: Experimental Data of Viscosity of Ethanol vs. Temperature

Abstract

Viscosity refers to relative motion between layers of a fluid and measures the fluid's resistance to flow. The aim of this experiment was to determine the relationship of dynamic viscosity (μ) of ethanol and temperature. The equipment used in the experiment was a Ubbelohde viscometer which employs a capillary-based method of measurement. According to the American Society for Technical Materials (ASTM) D445, IP 71, and ISO 3104 (Cannon), the Ubbelohde viscometer calculates kinematic and dynamic viscosity by measuring the efflux time and multiplies that number by the respective constants of each specific Ubbelohde viscometer to get the kinematic viscosity. The kinematic viscosity is then used to find the dynamic viscosity of ethanol. It was found that the dynamic viscosity of ethanol was 1.61mPa.s at 7.5°C while it was 0.49mPa.s at 68°C. These results show that the viscosity of ethanol has an inverse relationship with temperature.

Theory

Viscosity is a measure of a fluid's resistance to flow. It is an important parameter in most engineering production stages because it is a critical factor in choosing the size of piping systems and other equipment. Understanding the viscosity of a fluid also helps alleviate friction loss in a process. There are two types of viscosity: dynamic viscosity and kinematic viscosity.

Dynamic viscosity μ (cP or mPa.s) is the force a fluid needed to overcome friction, defined by:

$$\mu = v\rho \quad (1)$$

where v is the kinematic viscosity (cSt or mm²/s) and ρ is the density of a fluid (g/mm³).

Kinematic viscosity v (cSt or mm²/s) is an internal resistance of fluid under gravitational force, defined by:

$$v = \frac{\mu}{\rho} \quad (2)$$

where μ is the dynamic viscosity and ρ is the density of a fluid.

Ubbelohde viscometers can only measure the kinematic viscometer of transparent, Newtonian fluids. To be in accordance with this rule, liquid ethanol was chosen as the measuring fluid. Liquid ethanol is a Newtonian fluid commonly known as ethyl alcohol or simply as alcohol. It is widely known for being blended with gasoline in order to make motor vehicle fuel. Figure 1 shows the relationship between ethanol and temperature by different methods. The graph demonstrates that as the temperature increases, the viscosity of liquid ethanol decreases.

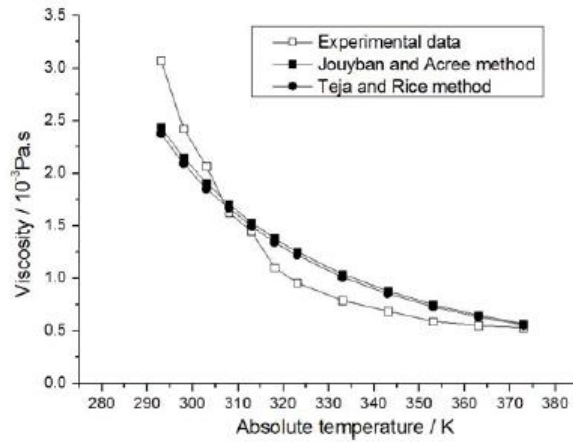


Figure 1: Viscosity of Ethanol vs Temperature

In this experiment, the Ubbelohde viscometer was used to measure the kinematic viscosity of ethanol according to ASTM D445, IP 71, and ISO 3104, shown in Figure 1.



Figure 2: The Ubbelohde Viscometer

To determine the relationship between dynamic viscosity of ethanol and temperature, the efflux time is first found by measuring the time ethanol travels through a given distance in the viscometer. Kinematic viscosity is then calculated by the following equation:

$$v = kt \quad (3)$$

where k is the viscometer constant (mm^2/s^2) and t is the efflux time (s). Then dynamic viscosity of the fluid is determined by equation (1).

Below is the calculation of both kinematic and dynamic viscosity of ethanol at 7.5°C , with the travel time measuring 398s and the viscometer constant being $0.005073 \text{ mm}^2/\text{s}^2$.

$$\text{Kinematic viscosity } v = kt = 0.005073 \left(\frac{\text{mm}^2}{\text{s}^2} \right) \times 398 \text{ s} = 2.02 \left(\frac{\text{mm}^2}{\text{s}} \right).$$

$$\text{Dynamic viscosity } \mu = v\rho = 2.02 \left(\frac{\text{mm}^2}{\text{s}} \right) \times 799.8 \left(\frac{\text{kg}}{\text{m}^3} \right) \times \frac{1 \text{ m}^2}{1000^2 \text{ mm}^2} = 1.61 (\text{mPa.s}).$$

Procedures

1. Charge the viscometer with the ethanol through tube L
2. Prepare a cold-water bath of 7.5°C
3. Hold the viscometer and place into the water bath
4. Wait for about 20 minutes for the ethanol sample to reach bath temperature
5. Place a finger over tube M and suction from tube N until the sample reaches the center of bulb D
6. Once the sample was centered, remove the finger, and allow the sample to fall from line E to F and measure the time it took
7. Repeat steps 2-6 for the other temperatures (in a range of $5\text{-}70^{\circ}\text{C}$)

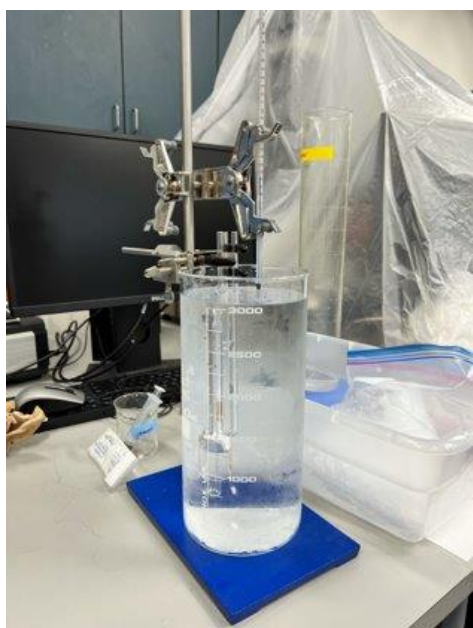


Figure 3: Experiment Setup

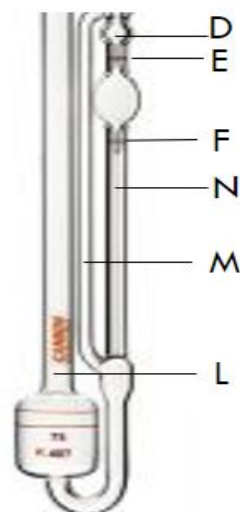


Figure 4: The Ubbelohde Diagram

Results and Discussion

Figure 5 displays the viscosity of ethanol at temperatures in the range of 5°C – 70°C. It shows that as temperature increases the viscosity decreases.

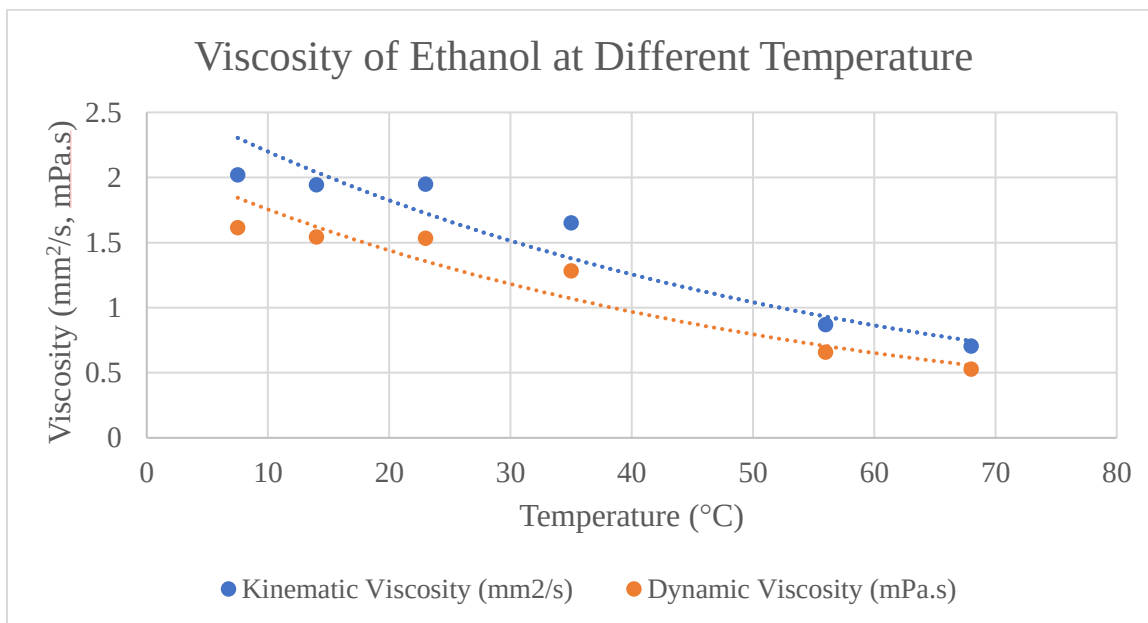


Figure 3: Experimental Data of Viscosity of Ethanol vs. Temperature

The graph displays a similar trend as Figure 1, which confirms the inverse relationship between the kinematic and dynamic viscosity of ethanol and temperature. This relationship can be explained by the increase in the energy level and distance of the ethanol molecules while the temperature rises. This increasing distance causes a decrease in the intermolecular attraction which ultimately decreases the viscosity of the solution.

Conclusion

In this experiment, the kinematic viscosity of ethanol was calculated by measuring the efflux time to determine the relationship between dynamic viscosity and temperature. After experimentation and analysis of the measured data, it was found that both kinematic and dynamic viscosity shared an inverse relationship with temperature. Both decreased as the temperature increased. There were some limitations during the experiment- including the bath temperature, the data set, and the depiction of the fluid moving. It is recommended that the experiment should be repeated at more temperature data points to build a mathematical model, with added insulation for the water baths, and employ a camera to measure a precise efflux time.

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Mecholic. “Why Does the Viscosity of Liquids Decrease with Increasing Temperature, While That of Gases Increases with Increasing Temperature?” Mecholic,
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Cannon Instrument Company. *Ubbelohde Viscometer*. <https://cannoninstrument.com/manual-glass-viscometers/ubbelohde-viscometer.html> [Accessed 21 March 2022]

Appendix

Temperature (°C)	Time (sec)	Constant (mm ² /s ²)	Kinematic Viscosity (mm ² /s)	Density (kg/m ³)	Density (g/ml)	Dynamic Viscosity (mPa.s)
7.5	398	0.005073	2.019054	799.8	0.7998	1.614839
14	383	0.005073	1.8962874	794.4	0.7944	1.506411
23	650	0.003	1.890126	786.7	0.7867	1.486962
35	551	0.003	1.643022	776.4	0.7764	1.275642
56	176	0.004937	0.759034128	757.9	0.7579	0.575272
68	143	0.004937	0.660452112	746.8	0.7468	0.493226

BELOW AVERAGE

Below Average Student Original Graded Assignment



Lab #3 Determination of Dynamic Viscosity of Ethanol using an Ubbelohde Viscometer

Britton Andrews

Cinthia Sahin

Clement Adeyemi

Jevaun Christie

CHEG 3101 P01 Chemical Engineering Lab I

Group 1

March 28, 2022

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Abstract

In this experiment, an Ubbelohde viscometer was used to measure the kinematic viscosity of ethanol. The Ubbelohde viscometer uses a capillary-based method to find the kinematic viscosity of fluids. ~~It is intended to measure~~ how long it takes for a fluid to flow through a tube, under the effect of gravity.

For this analysis, the time to efflux through points above and below the timing/chronograph bulb. Once the efflux was found, the kinematic viscosity was calculated by multiplying the efflux time by the corresponding viscometer constant.

Lastly, the dynamic viscosity was found by multiplying the kinematic viscosity by the density of ethanol. The experiment was successfully conducted and revealed that the dynamic viscosity of ethanol decreased as the temperature of ethanol increased.

Theory

Viscosity is a measure of a substance's resistance to motion under an applied force. It is important in the field of engineering as it determines the energy that is required for a fluid's movement. Its measurements are often differentiated as either kinematic or dynamic viscosity.

A key difference between dynamic viscosity and kinematic viscosity is that dynamic viscosity determines the force needed to make the fluid flow at a certain rate while kinematic viscosity illustrates how fast the fluid is moving when the force is applied. In this experiment, an analysis was conducted on how change in temperature affects the dynamic viscosity of ethanol by calculating the kinematic viscosity and the dynamic viscosity.

Key Formula for Calculating Viscosity

Kinematic Viscosity

$$\nu = \frac{\mu}{\rho}$$

Where,

$$\nu = \text{Kinematic Viscosity} \left(\frac{m}{s^2} \right)$$

$$\mu = \text{Dynamic Viscosity} \left(\frac{kg}{ms} \right)$$

$$\rho = \text{Density} \left(\frac{kg}{m^3} \right)$$

Dynamic Viscosity

From the formula of kinematic viscosity,

$$\nu = \frac{\mu}{\rho}$$

$$\mu = \nu \times \rho$$

Where,

$$\nu = \text{Kinematic Viscosity} \left(\frac{m}{s^2} \right)$$

$$\mu = \text{Dynamic Viscosity} \left(\frac{kg}{ms} \right)$$

$$\rho = \text{Density} \left(\frac{kg}{m^3} \right)$$

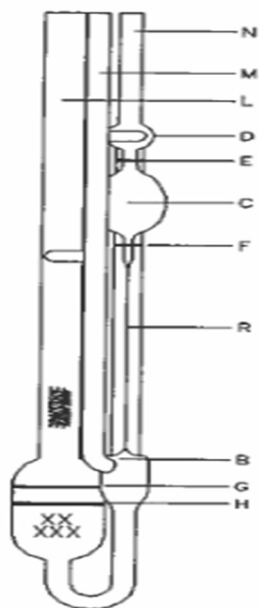


Figure 1: Diagram of Ubbelohde Viscometer (Canon Instrument Company)

Procedure

1. Place the viscometer into a holder and constant temperature bath
2. Charge the viscometer with ethanol through L to fill reservoir between the minimum and maximum lines.
3. Let the sample sit for 10 to 15 minutes to reach bath temperature
4. Put a finger over tube M and apply suction to tube N until the liquid reaches past bulb D.
5. Removed finger from tube M.
6. Once the liquid reached point E start the timer and end timer at point F.
7. Repeat for different constant temperature baths.

Safety

For this lab, certain safety precautions were taken to ensure a safe experiment. The safety measures were as follows:

1. Lab coats were worn to prevent chemicals from getting onto the skin.
2. Goggles were worn over the eye to mitigate foreign substances from entering the eye.
3. Masks were worn to limit the spread of COVID-19.
4. Special care was taken when handling the beaker, thermometer and viscometer to mitigate cuts.

Results and Discussion

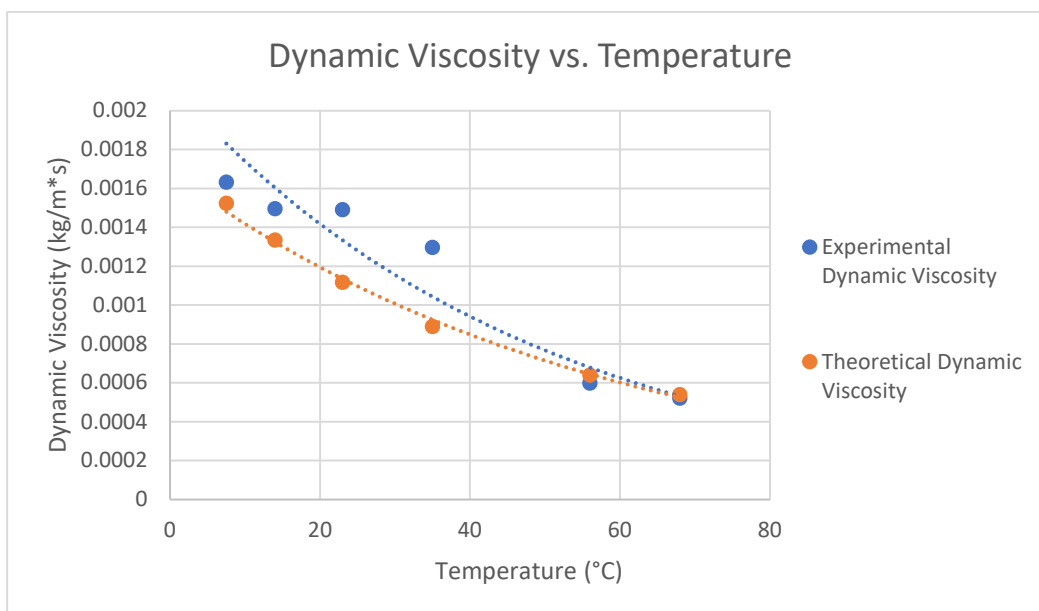


Figure 2: Graph showing Dynamic Viscosity as a function of Temperature

The graph above shows the effect of temperature on the dynamic viscosity of ethanol. For comparison, the theoretical dynamic viscosity for ethanol is displayed alongside the experimental (actual) viscosity.

The results obtained from the experiment show the effects of different bath conditions on the viscosity of ethanol. The lower set of temperatures was operated with a cold bath, the median set temperatures was operated with a room-temperature bath, and the last set of temperatures was operated with a hot bath.

As the temperature increases, the dynamic viscosity of ethanol decreases. This is a representation of an inverse relationship.

Note: there is an exponential decrease signifying a gradual change in viscosity

Conclusion

The purpose of this lab was to determine the dynamic viscosity of ethanol under three separate bath conditions (cold, room temperature, and hot). It was determined that the viscosity of ethanol decreased as the temperature of ethanol increases, thus illustrating how viscosity has an inverse relationship to temperature.

To further understand the relationship between viscosity and temperature, subsequent experiments with other fluids would need to be conducted to help in confirming the relationship between viscosity and temperature.

One recommendation for future experiments is to use a system with cameras, sensors and MATLAB that automatically detects the meniscus shown below. This system will increase efficiency by reducing the time spent constantly checking for the fluid's level and increase accuracy by mitigating parallax errors.

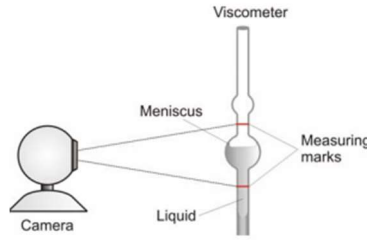


Figure 3: Diagram of Proposed Viscometer Camera System

References

Fig. 3. Will, Christian. "Automated Measurement of Viscosity with Ubbelohde Viscometers, Camera Unit and Image Processing Software." *Cenam.mx*. Centro Nacional De Metrología, 24 Oct. 2008. Web. 27 Mar. 2022.

Appendix

Example from Hot Water Bath data:

For 56°C:

$$\text{kinematic viscosity} \left(\frac{\text{m}^2}{\text{s}} \right) = \text{time} (\text{s}) * \text{constant} \left(\frac{\text{m}^2}{\text{s}^2} \right)$$

$$\text{kinematic viscosity} = 7.590 * 10^{-7} \frac{\text{m}^2}{\text{s}} = 153.774 \text{ s} * (4.937 * 10^{-9} \frac{\text{m}^2}{\text{s}^2})$$

$$\text{dynamic viscosity} \left(\frac{\text{kg}}{\text{m} * \text{s}} \right) = \text{kinematic viscosity} \left(\frac{\text{m}^2}{\text{s}} \right) * \text{density} \left(\frac{\text{kg}}{\text{m}^3} \right)$$

$$\text{dynamic viscosity} = 5.989 * 10^{-4} \frac{\text{kg}}{\text{m} * \text{s}} = 7.590 * 10^{-7} \frac{\text{m}^2}{\text{s}} * 789 \frac{\text{kg}}{\text{m}^3}$$

CHEMICAL ENGINEERING LABORATORY I SPRING 2022

Title of Assignment: Determining the performance characteristics of a centrifugal pump.

TOPICS COVERED IN LAB 4

Lab 4 covered the following topics:

1. Covers all aspects reviewed in Labs 1 – 3, i.e., Abstract, Theory, Procedure, Results & Discussion and Conclusion and ties it all together.
2. Starting from general lab objectives, the students had to develop their own procedure to perform this lab. This enabled the students to focus more strongly on teamwork and planning of the work.

**Repeated this section for each Laboratory Experimental Report and
Similarly for all the other assignments in the course binder**

CHEMICAL ENGINEERING LABORATORY I
SPRING 2022

Title of Assignment: Determining the performance characteristics of a centrifugal pump.

LAB 4

ABOVE AVERAGE

Above Average Student Original Graded Assignment

NO STUDENT SAMPLES AVAILABLE FOR ABOVE AVERAGE

AVERAGE

Average Student Original Graded Assignment

Roy G. Perry

College of Engineering



CHEG 3101 - Chemical Engineering Lab I

Experiment 4: Understanding the Performance of a Centrifugal Pump

Instructor: Dr. K. Antoine

Dynasty Stephenson
Anh Nguyen
Edgar Mendoza
Maya Spears
Ariel Kinsey

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- Figure 3: Schematic of Continuous-flow System Using a Centrifugal Pump
- Figure 4: Control Knob for Pump Speed
- Figure 5: Flow Rate vs. % Close at Different RPM
- Figure 6: Pump Performance at 1600RPM
- Figure 7: Head vs. Flow Rate at Different Pump Speed
- Figure 8: Efficiency of the Pump at Different Speeds
- Figure 9: Pump Power at Different Speeds

Abstract

Centrifugal pumps transport liquids by converting rotational kinetic energy to hydrodynamic energy of the liquid flow. They are reliable and cost-effective. They have a minimal environmental impact and can achieve a wide range of flow rates and pressures. Knowledge of pumps is crucial as they are widely used in the chemical processing industries. This experiment aims to analyze the performance of a centrifugal pump at a specified pump speed (RPMs) with up to four varying flow rates and evaluate pump power (W), pump efficiency (%), ~~pump speed (rpm)~~, and head (m) vs. flow rate (L/min). At 1600RPM, the head produced was 2.6m for a flow rate of 28.1L/min and 3.7m for a flow rate of 18.6L/min. At 2800RPM, the head produced was 7.4m for a flow rate of 50L/min and 13.4m for a flow rate of 41.2L/min. The data revealed an inverse relationship between the head and the flow rates. The results also suggested a direct connection between the pump speed, the power, and the flow rates.

Theory

The most common centrifugal pump is the volute pump, which has three main components: suction, discharge, and an impeller. The fluid enters through the low-pressure area with an impeller rotating at high speed. As the rotor turns, momentum is transferred to the fluid that pushes the fluid outwardly, and a vacuum is created in the low-pressure area. The liquid with high kinetic energy is forced into the pump's volute, and the kinetic energy is converted to fluid pressure. There are three main pump characteristics used to determine the pump's performance vs. the volumetric flow rate of the fluid.

- Pump head H (m): Measurement of differential pressure between the inlet and outlet flow
- Power P_m (W): Mechanical power input by the pump
- Efficiency E (%): The ratio of the hydraulic power delivered to the fluid and the power input by the pump
- Volumetric flow rate Q (L/min): Rate at which fluid is flowing into the pump

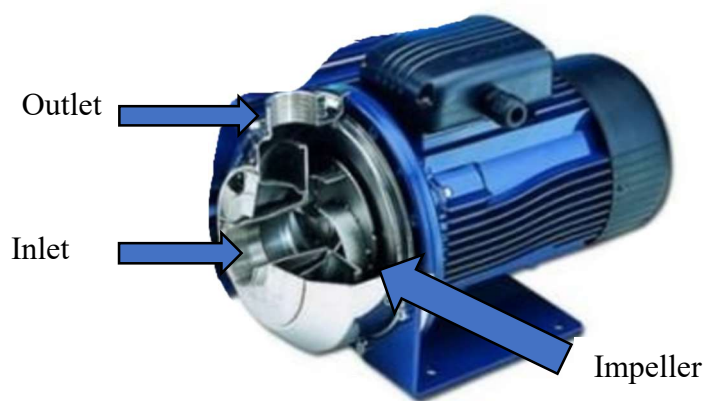


Figure 1: Lowara CEAM 70/3/A Centrifugal Pump

The total head can be described as the change in total head produced based on the work done by the pump, where:

Total Head = Change in the static head + Change in velocity head + Change in elevation

$$H_t = H_s + H_v + H_e$$

where $H_s = \frac{P_{out} - P_{in}}{\rho g}$

where P_{in} = fluid pressure at inlet (Pa); P_{out} = fluid pressure at outlet (Pa)

$$H_v = \frac{(V_{out} - V_{in})^2}{2g}$$

where V_{in} = fluid velocity at the inlet; V_{out} = fluid velocity at outlet

$$H_e = h_{in} - h_{out} = 0$$

where h_{in} = the height of the inlet; h_{out} = the height of the outlet. For Edibon Computer Controlled Centrifugal Pump Bench, "PBCC," H_v is small compared to H_s ; therefore, $H_t \approx H_s$.

Power input is the mechanical power required to be input to the pump as the equation can derive calculations

$$P_m = 2\pi n\tau \quad (2)$$

where,

P_m = rotational force x angular distance

n = rotational speed of the pump (rps)

τ = shaft torque (N.m)

Furthermore, the efficiency of the pump can be calculated as

$$E = \frac{P_h}{P_m} \times 100\% \quad (3)$$

where,

$P_h = H_t Q \rho g$ = hydraulic power imparted to fluid (W)

Q = volumetric flow rate (L/s)

P_m = mechanical power absorbed by pump (W)

Each of these parameters is measured at constant pump speed and is plotted against the volumetric flow rate Q throughout the pump.

A graphical representation of pump performance is shown in Figure 2.

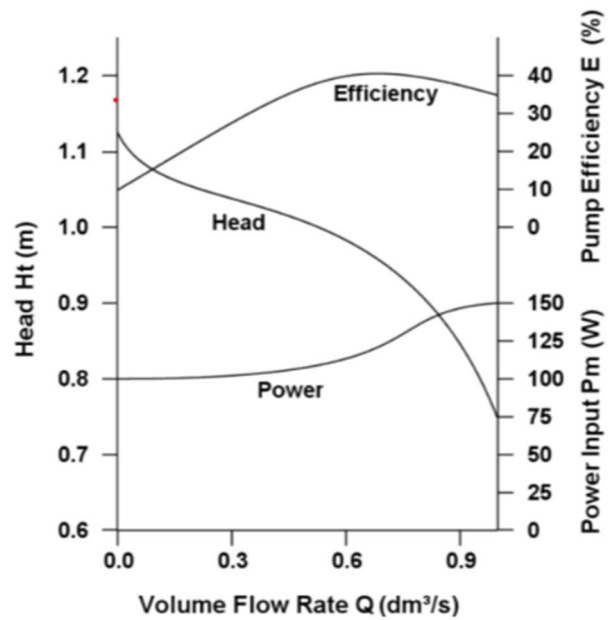


Figure 2: A Graphical Representation of Pump Performance

Procedure

The experiment was conducted using EDIBON Computer Controlled Centrifugal Pump Bench, shown in Figure 3.

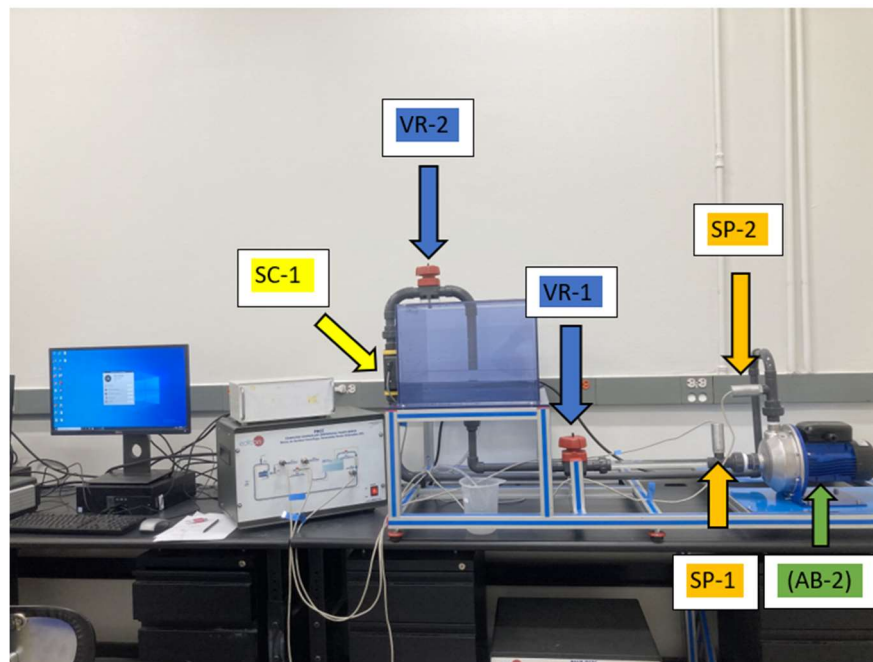


Figure 3: Schematic of Continuous-flow System Using a Centrifugal Pump

1. Fill the tank with sufficient water (approximately 4 gallons)
2. Align the system for operation by fully opening the suction flow control valve (VR-1) and discharge flow control valve (VR-2)
3. Start the Lowara centrifugal pump (AB-2) from the Edibon computer program and confirm no abnormal noise, leakage, or vibrations
4. Set the pumps speed (RPM) to 1600rpm by rotating the control knob, shown in Figure 4, or typing it in the box given
5. Confirm there was water flow
6. Record pump RPM, inlet (SP-1), outlet (SP-2) pressures, flow rate sensor (SC-1), torque, and calculate efficiency, hydraulic power, mechanic power, and height
7. Record five different flow rates at the given RPM by having valve VR-2 fully open, 18%, 36%, 54.5%, and 72.7% closed, respectively

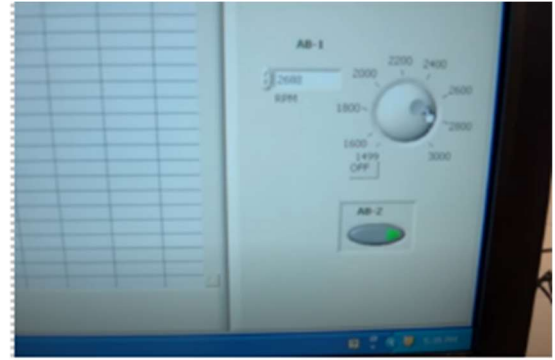


Figure 4: Control Knob for Pump Speed

Results and Discussion

Figure 5 illustrates how much the valve closed affects the flow rate of fluid discharge. There is a downward flow rate trend for each pump speed; the higher the percentage of valve closed, the lower the flow rate. However, there is a slight difference in the flow rate from the fully open to about 50% closed, while there is a high flow rate decrease toward 73% closed.

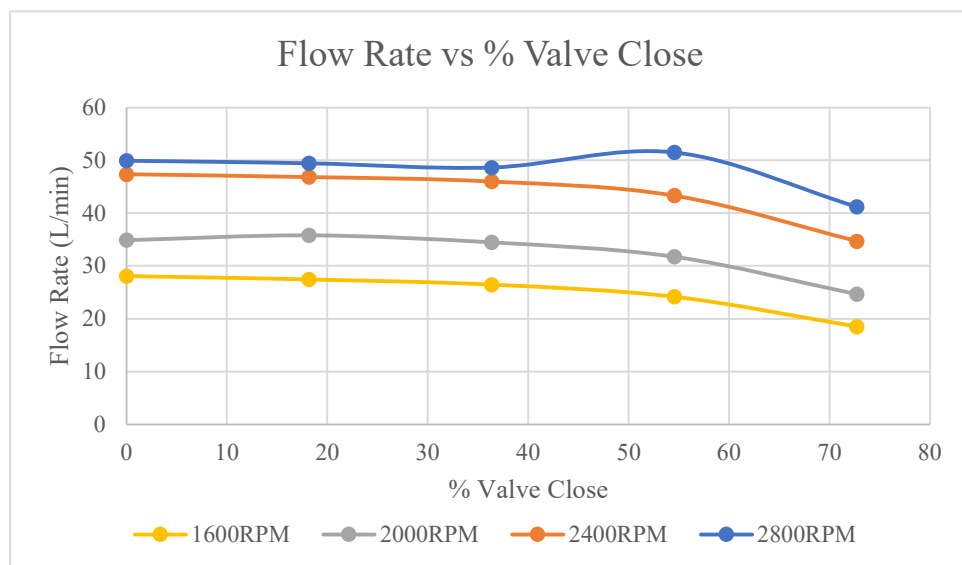


Figure 5: Flow Rate vs. % Close at Different RPM

Another interesting thing that can be seen from the graph is that each pump speed produces a different range of flow rates. At 1600RPM, the pump discharges 18-28L/min of water, whereas it

discharges 41-50L/min of water at 2800RPM. This can be explained as the speed of the pump increases, the mechanical power from the pump transferring to the fluid increases (which means more energy from the pump shaft power is transferred to the fluid), and the flow rate of the fluid increases. It concludes that there is a direct relationship between the pump's speed, the pump's power, and the flow rate of the fluid.

Figure 6 shows the pump's performance at 1600RPM, including head, efficiency, and pump power vs. flow rate. Compared to the theory, as the flow rate increases, the head decreases, and the pump's power increases. However, the pump's efficiency in the experiment stays between 20.5% and 22.7%. Compared to the performance curves at 2000RPM, 2400RPM, and 2800RPM (shown in the appendix), this pump consistently performs over the speed range of 1600-2800RPM.

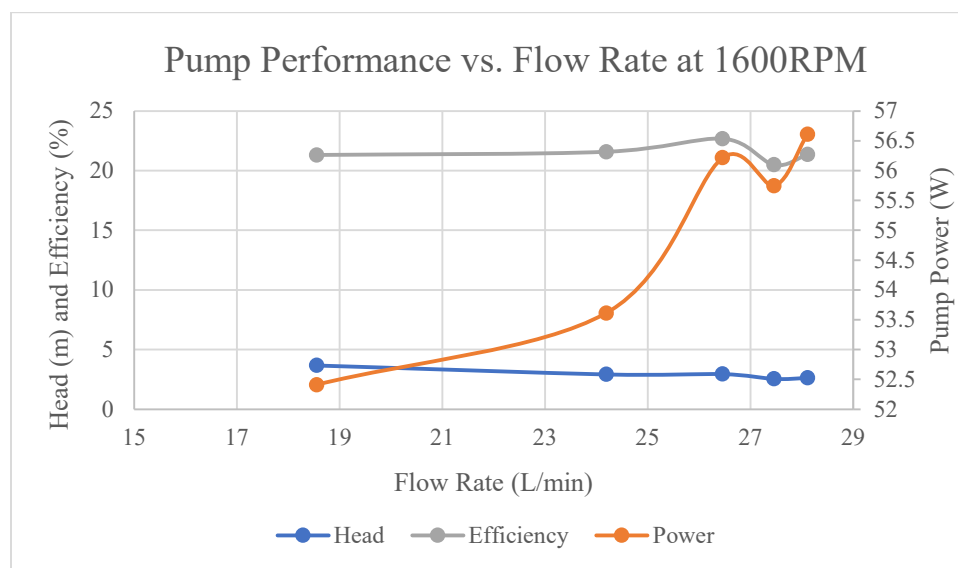


Figure 6: Pump Performance at 1600RPM

Figure 7 shows the relationship between the head and the flow rates at different pump speeds. As the speed increases, the flow rate increases. This agrees with the conclusion from Figure 5; each pump speed has its own flow rate range. At the same time, it clearly shows the inverse relationship between head and flow rate, shown in Figure 6. Figure 7 also exhibits the difference between head for each pump speed. The head produced by higher speeds is higher than the one made by lower speeds.

Additionally, this graph provides that it has its flow rates at different speeds even though the valve was open at the same number of turns. This is because, though turning the valve to open or close changes the flow rate, the speed of the pump will determine the flow rate leaving the system.

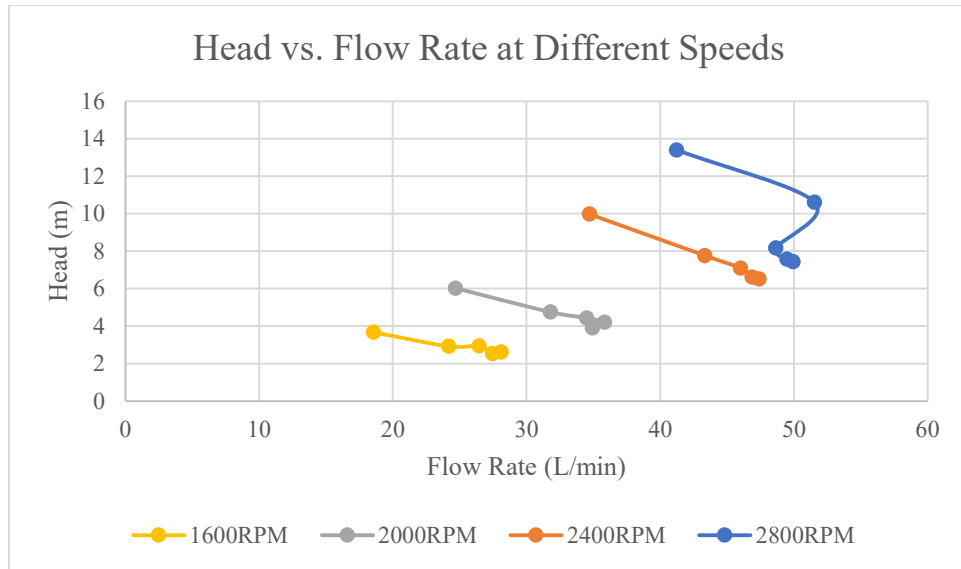


Figure 7: Head vs. Flow Rate at Different Pump Speeds

Figure 8 displays the efficiency of the pump at four different speeds. The graph does not clearly define the overall efficiency of the pump performance. However, it shows a direct relationship when the discharge valve is fully open, demonstrated by each starting point for each line. RPM and flow rates directly relate to efficiency because as RPM and flow rates increase, power output rises faster than mechanical power loss. Then again, this graph shows that each RPM has its own range of flow rates which refers in Figure 5.

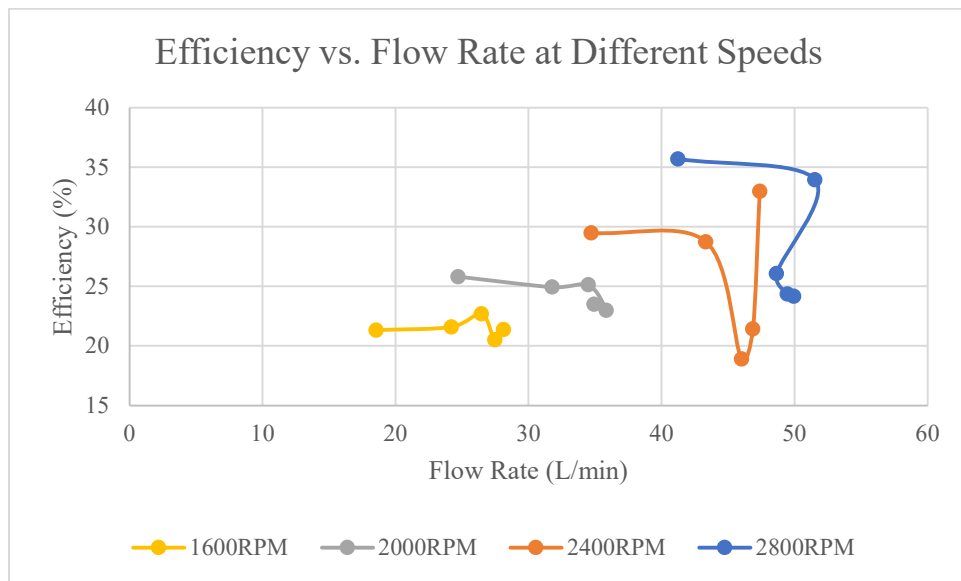


Figure 8: Efficiency of the Pump at Different Speeds

Figure 9 shows the pump's power at different speeds and flow rates. Like Figure 6, in figure 9, the pump power and its speed have a direct relationship. As the pump power increases, the speed of the pump rises, causing the flow rate to increase. Nevertheless, at 1600RPM, 2000RPM, and 2800RPM, the pump power stays consistent throughout the experiment while the power fluctuates at 2400RPM.

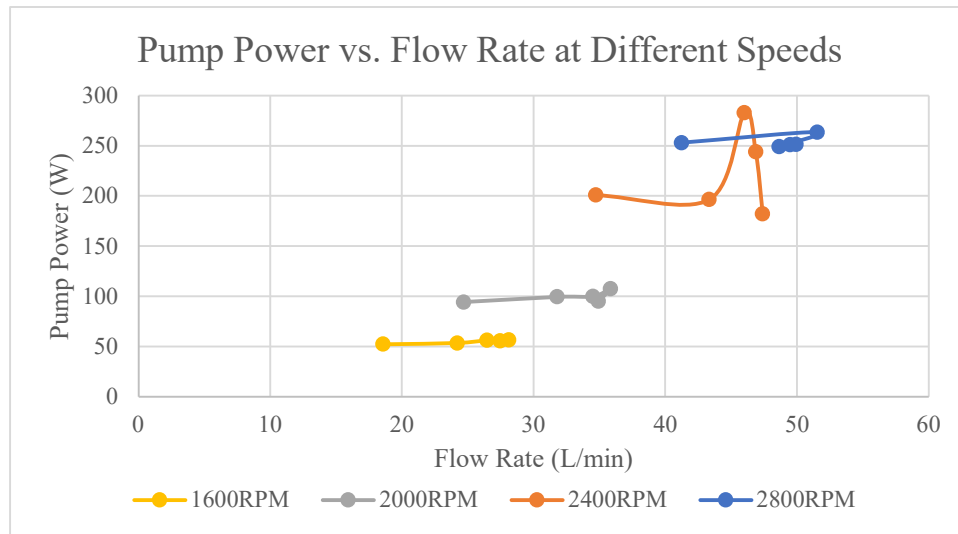


Figure 9: Pump Power at Different Speeds

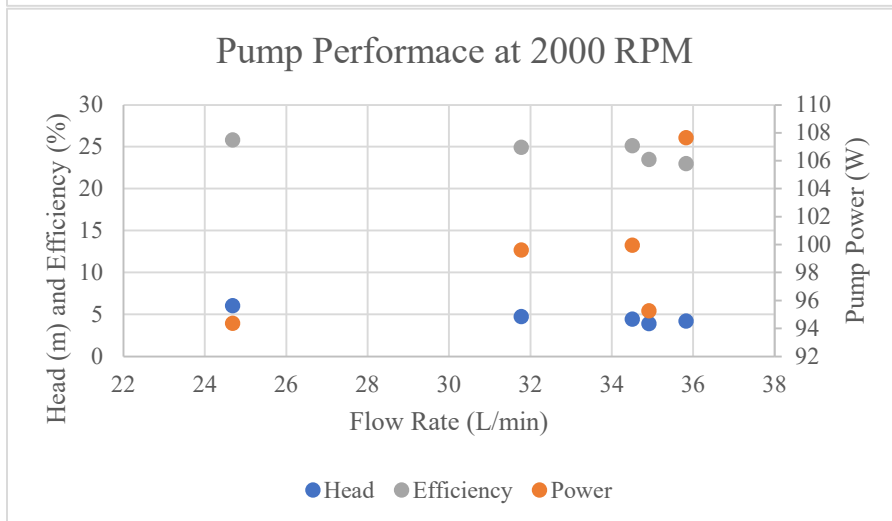
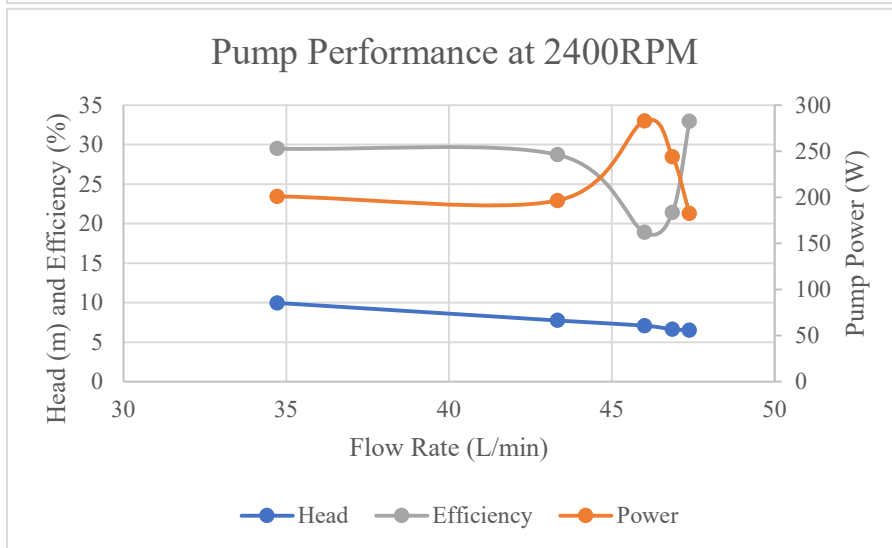
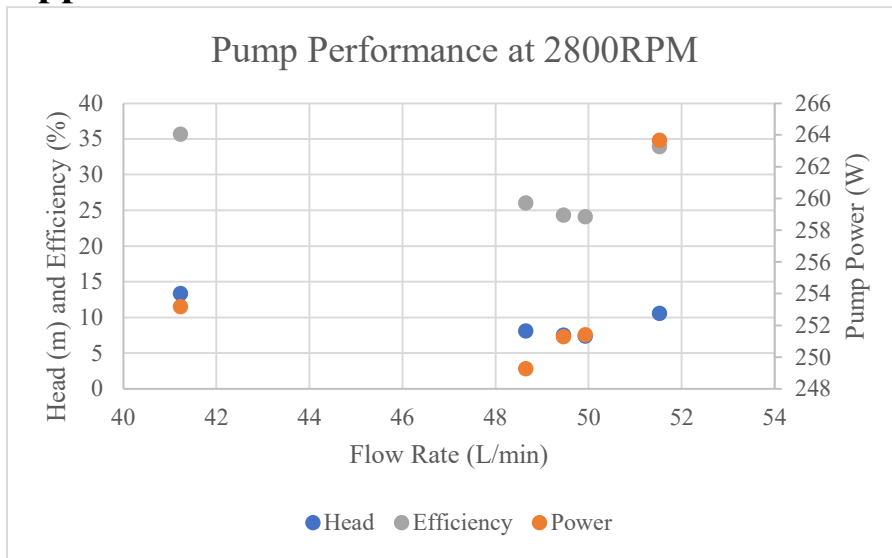
Conclusion

In this experiment, the pump's performance was studied for different pump speeds and different flow rates for each speed. In comparing these characteristics to the various flow rates, it was noted that there was an inverse relationship between the total head and the flow rates. However, the pump power depicts a direct relationship with its speed. The results also proved a direct relationship between pump speed and the flow rates and between pump speed and the head. The pump's efficiency increases with the flow rate and the speed, yet it does not show the best performance. One recommendation is to study the pump with one chosen rotational speed and a more comprehensive range of water flow rates.

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Appendix



BELOW AVERAGE

Below Average Student Original Graded Assignment

Roy G. Perry
College of Engineering

62/100



CHEG 3101 - Chemical Engineering Lab 1

**Lab Report #4: Analyzing the Performance
of the Centrifugal Pump**

Due Date: April 20, 2022

Instructor: Dr. Keisha Antoine

Ezzy Tatmon

Prince Riley

Willie Conner Jr.

Ebonie Henderson

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Introduction 5/10

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Generally speaking, a pump is used to **grow the strain of a liquid**, adding energy to the water. The Centrifugal Pump Bench, "PBCB", is a bench-top unit consists of a centrifugal pump, a feed water tank, circulation pipes, regulation valves, as well as the enough control elements for the pump experiments two manometer and a flow sensor. A frequency inverter for the pump, provides the possibility of regulation and measuring the pump motor speed, as well as the measurement of the torque transferred. The pump is installed in a pipes system **which avoids the permanent water spending during the operation because it is a closed circuit**. The Centrifugal Pump Bench, "PBCB", allows the measurement of the most typical parameters of the centrifugal pump.

This is unclear. Use your own words.

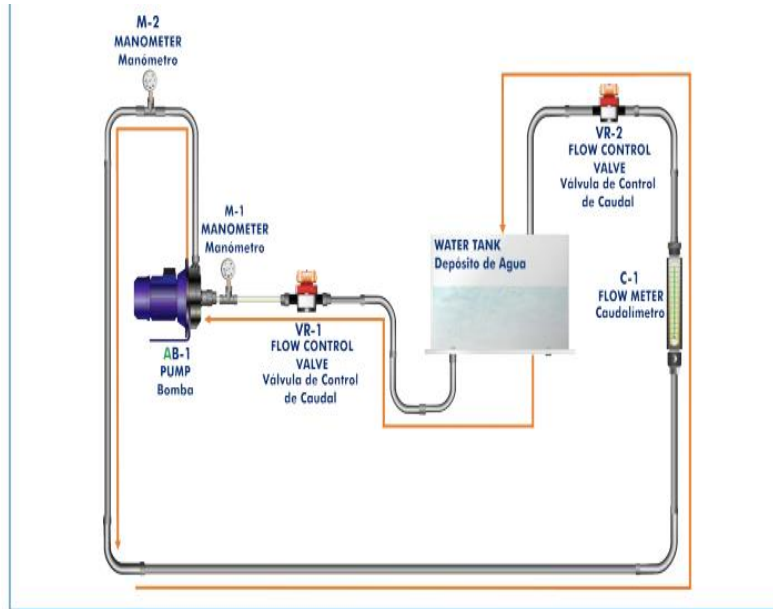
The aim of this final project is to analyze the performance of the centrifugal pump. Observe the flow rate, revolutions per min (RPM) and the pump efficiency. Utilizing the pump to expand the tension of a fluid, adding energy to the water driven framework to move the liquid from a lower pressure zone to a higher tension zone.

Theory 8/15

Centrifugal Pump Bench

It is clear that you just copied what you read in the lab manual. Use your own words. Try to understand for yourselves what the equipment is supposed to do.

This hydraulic pump is a generator machine able to communicate energy to the fluid that circulates through its interior. The test unit consists of one centrifugal pump, an interface, a control pane, and circulation pipes with valves at the inlet and outlet of pumps, two pressure sensors, a rotameter and speed sensor. Among all hydraulic pumps, they are the most versatile due to the ability to adapt them to great conditions of exploitation (powers, flows, elevation heights, liquids, materials, etc).



Key Equations

—*p: Relative Pressure [P]

—*H: Energy per unit of weight or height [m]

These are not equations.

—Ht: Total or manometric height of the pump [m]

—V: Average speed of the fluid (m/s)

—*z: height geometric level [m]

—*Q: Flow [m^3/s]

—*F: Transmitted forces from motor stator to bedplate [N]

—*M: Mechanic torque [$\text{N} \times \text{m}$]

—*n;w: Turn speed [rev/min];] rad/s]

—*N: Power [W]

—*h: Total efficiency of the pump

—*D: Diameter of the runner [m]

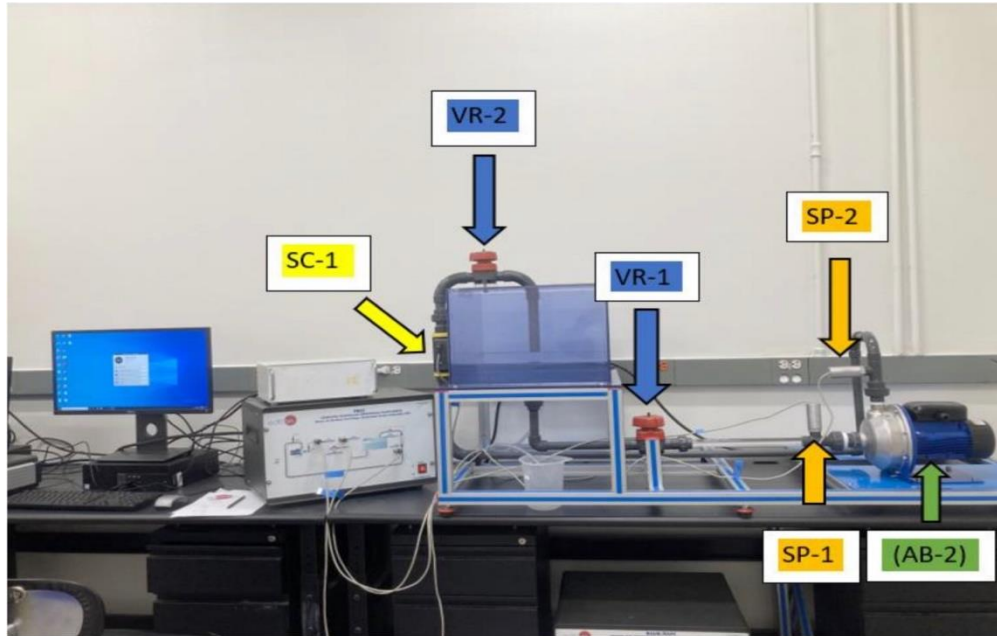


Figure 2: Schematic of Continuous-flow System Using a Centrifugal Pump

Procedure 15/15

Reference your schematic.

1. Fill the tank with sufficient water, around 4 gallons.
2. Align the system for operation by fully opening the suction flow control by the suction flow control valve (VR-1) and discharge flow control (VR-2).
3. Start the Lowara centrifugal pump (AB-2) from the Edibon computer program and confirm no abnormal noise, leakage, or vibrations.
4. Determine the number of revolutions it would take to close the valve on the pump fully.
5. Decide how many different RPMs and flow rates are needed to collect data.

6. Start collecting data for the first rpm with the valve fully open. To collect data, press **AVERAGE**, then **ACQUIRE**.
7. Collect data for 1800 RPMs with the complete revolution closed valve.
8. Collect data for 1800 RPMs with the 1 ½ revolutions closed valve.
9. Collect data for 1800 RPMs with the 2 ½ revolutions closed valve.
10. Return the valve to open and choose a second rpm entirely.
11. Start collecting data for the second rpm with the valve fully open.
12. Collect data for 2300 RPMs with the two complete revolutions closed valve.
13. Collect data for 2300 RPMs with the valve 2 ½ revolutions closed.
14. Collect data for 2300 RPMs with the valve 3 ½ revolutions closed.
15. Return the valve to open and choose a third rpm entirely.
16. Start collecting data for the third rpm with the valve fully open.
17. Collect data for 2800 RPMs with the 1 ½ complete revolution closed valve.
18. Collect data for 2800 RPMs with the valve two revolutions closed.
19. Collect data for 2800 RPMs with the valve four revolutions closed.
20. Return the valve to open fully.
21. Press **STOP** on the data collecting software.

Results and Discussion 30/50

For this Experiment we will comparing flow rate of water and its effects on Head, efficiency and power in a centrifugal pump.

Figure 1. Figure captions are supposed to go below the graphs.
Graph 1.

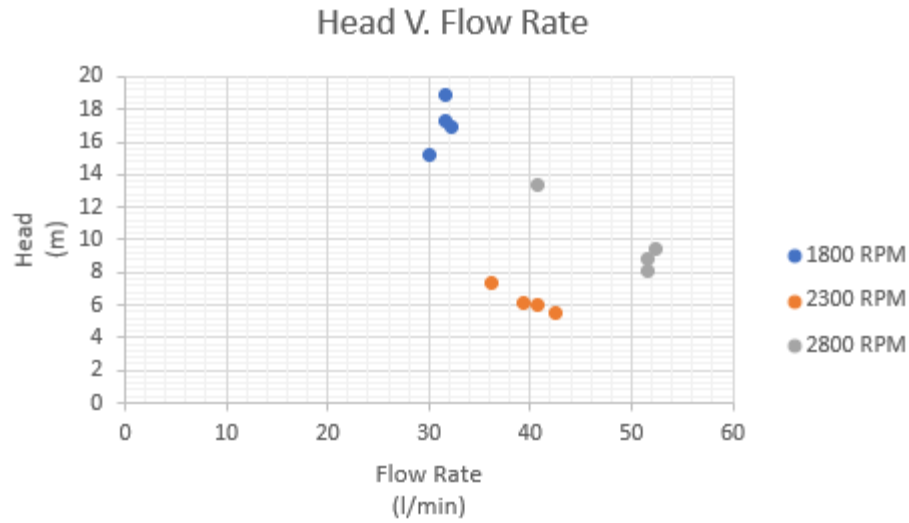
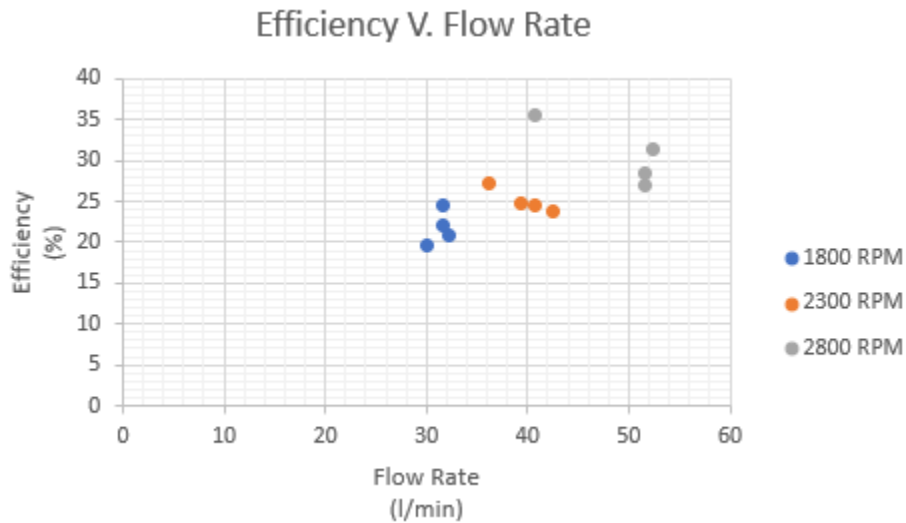


Figure 1.

From the graph above, you can decipher lower flow rate that leads to a higher head from a lower rpm.

Besides that, there is not a definitive comparison between flow and head within a centrifugal pump.

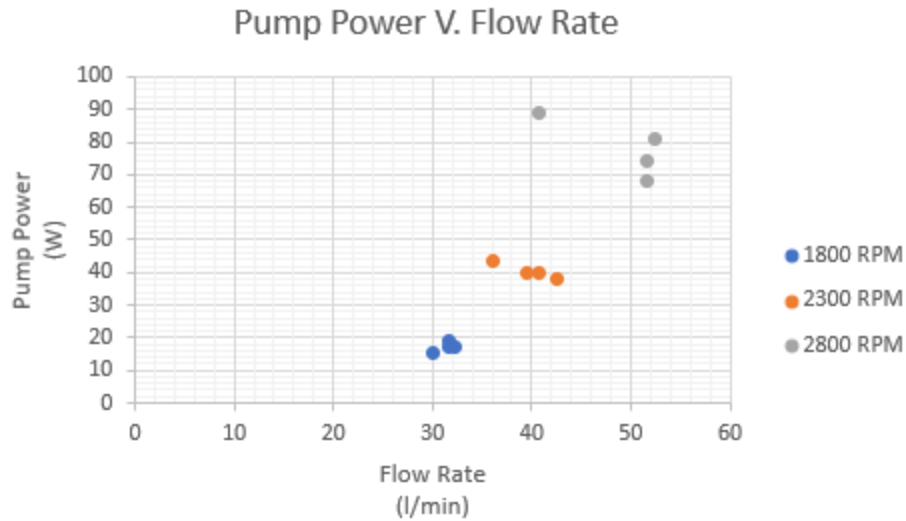
Graph 2.



For Graph 2, you can observe that higher flow rates can create more efficient pumps. This is also shown

using equations from the theory,

Graph 3.



From Graph 3 above the relationship between flow rate and the power of the pump is linear as the pump flow rate is increased so does the pump power. This equation is also described in the theory.

Conclusion 4/10

The pump performed more efficiently when the RPM was higher, simultaneously as the valve performed during the experiment. One recommendation would be to keep the revolutions for the valve constants while changing RPM'S to collect data.