

**COLLEGE OF ENGINEERING
CHEMICAL ENGINEERING DEPARTMENT
PRAIRIE VIEW A&M UNIVERSITY**

BINDER REPORT COVER PAGE

**CHEG 4104 – P02
Chemical Engineering Laboratory III**

SPRING 2022 SEMESTER

NAME OF INSTRUCTOR: Dr. Jorge Gabitto

**PRAIRIE VIEW A&M UNIVERSITY
ROY G. PERRY COLLEGE OF ENGINEERING
DEPARTMENT OF CHEMICAL ENGINEERING
CHEG 4104 P02 - Chemical Engineering Lab. III
SPRING 2022**

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Course Description in ABET Format

CHEMICAL ENGINEERING DEPARTMENT CHEG 4104 CHEMICAL ENGINEERING LAB. III

1.	Course number and name:	CHEG 4031 CHEMICAL ENGINEERING LAB. III
2.	Credits and contact hours:	1 credit hour; 3 contact hours
3.	Instructor's or course coordinator's name:	Dr. Jorge F. Gabitto
4.	Text book: Title:	NA
	Author:	NA
	Publisher, Year & Edition:	NA
	a. Other Supplemental material	Holman, J. P., <i>Experimental Methods for Engineers</i> , 4 th Ed., or newer, McGraw-Hill, New York, 1986.
5.	Specific course information	
	a. Brief description of the content of the course (catalog description)	CHEG 4104. (0-3) Credit 1 semester hours. Continuation of CHEG 3011, but directed to sensors, reaction engineering and control systems. Study of reaction rates and equilibria in simple chemical systems. Emphasis is placed upon experimental data required for the scale-up to commercial scale equipment.
	b. Prerequisites or Co-requisites	Senior standing. CHEG 4303.
	c. *Indicate whether a required, elective, or selected elective (as per definition provided) course in the program	Required
6.	Specific goals for the course	Students will be able to :
	a. Specific learning outcomes	1. Demonstrate ability to perform quantitative physical measurements and operate laboratory scale equipment. 2. Design, plan, and operate experiments. 3. Communicate proficiently in oral and written formats.
	b. Explicitly indicate which of the student outcomes listed in Criterion 3 or any other outcomes are addressed by the course.	This course addresses: Outcome 3 An ability to communicate effectively with a range of audiences. Outcome 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.

		Outcome 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	Topic 1 Laboratory Safety and Loss Prevention (Video Presentation) Topic 2 Design of experiments (Lecture) Topic 3 Writing lab. reports (Lecture) Topic 3 Conversion in a Tank Reactor (Expt. No. 1) Topic 4 Conversion in a Plug Flow Reactor (Expt. No. 2) Topic 5 Simulating behavior of one and two tanks in series system (Expt. No. 3) Topic 6 Level Control by a PID Controller (Expt. No. 4) Topic 7 Design of Experiments (Assignment project)

***Required** courses are required of all students in the program, **elective** courses (often referred to as open or free electives) are optional for students, and **selected elective** courses are those for which students must take one or more courses from a specified group.

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.

Outcome 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.

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 Outcomes Averages

Outcomes	3	5	6
Semester	Semester Class Average (%)	Semester Class Average (%)	Semester Class Average (%)
Spring 2022	72.4	72.8	75.3
Spring 2021	69.5	65.9	65.9
Spring 2020	82.5	79.5	87.1
Comments on Trend of Data (Improving or deteriorating)	The class average has decreased significantly over last semester. Most students did not fulfill minimum requirements. This behavior may have been produced by the emergency that significantly changed the teaching procedures. More data points are needed to determine whether it is an anomaly or reflect a trend.	The class average has decreased significantly over last semester. Most students did not fulfill minimum requirements. This behavior may have been produced by the emergency that significantly changed the teaching procedures. More data points are needed to determine whether it is an anomaly or reflect a trend.	The class average has decreased significantly over last semester. Students did not fulfill minimum requirements. This behavior may have been produced by the emergency that significantly changed the teaching procedures. More data points are needed to determine whether it is an anomaly or reflect a trend.

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

End of Semester Course Assessment Reports Spring 2022 and Last Two 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.

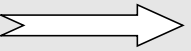
5. Were Expectations Met?

- 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
CHEG4104-P02 Chemical Engineering Laboratory III
Spring 2022 SEMESTER

Report Prepared by: Dr. Jorge Gabitto

Report Date: May 23, 2022

Semester	Analysis Type	Number of Students	Outcome 5 Ability to design and conduct experiments.			Outcome 6 Ability to function on multi-disciplinary teams.			Outcome 3 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	13	75	79.3	100.0	75	79.7	100	75	78.2	69.2
Spring 2021	Direct	15	75	67.7	33.3	75	67.5	33.3	75	67.5	33.3
Spring 2020	Direct	20	75	80.0	85.0	75	75.0	70.0	75	82.1	100.0
Implementation Summary			Practice sessions in laboratory describing procedures for data acquisition and analysis. Design of experiments lecture.			Evaluation of student participation in and out of the laboratory.			Lab report format distributed to students and discussed. A class on how to prepare reports/presentations added.		
Perceived Problems			Students perform well the data acquisition part of the experiment but fail in data analysis. This issue leads to wrong conclusions.			Uneven participation in conducting the laboratory experiments and preparing the corresponding Lab. Report.			Students could not write logical conclusions and could not adequately comment on the results.		
Plans for Addressing Problems			The following is recommended for implementation next course offering: 1. Draft data analysis will be required during lab. class. 2. Quizzes will be administered to stress the need for proper data analysis. 3. Students will be encouraged to check their lab. Reports before turning them in.			The instructor proposes: 1. Assign every group a group leader. The leader is responsible for even student participation. The leader evaluates student participation in every report/presentation. 2. The instructor evaluates student participation by direct observation plus given individual quizzes when appropriate.			The instructor did: 1. Samples of conclusions on research report can be given to students. 2. Instructor discussed the reports with the students in class, and privately. 3. The students should be encouraged to discuss their reports/presentations with the instructor BEFORE turning them in. .		
Overall Trend over Periods			The class average has increased significantly over last semester. Extra data are needed to figure it out if it is due to the pandemic or a trend.			The class average has increased significantly over last semester. Extra data are needed to figure it out if it is due to the pandemic or a trend.			The class average has increased significantly over last semester. Extra data are needed to figure it out if it is due to the pandemic or a trend.		

Grades Sheet Showing Student and Class Performance in Outcomes

Grade Sheet Showing Student and Class Performance in Course Outcomes

CHEG 4104-P02 SPRING 2021 SEMESTER

	Outcome 5 Ability to design and conduct experiments.	Outcome 6 Ability to function on multi- disciplinary teams.	Outcome 3 Oral & Written Communication
Student 1	5.95	7.25	7.35
Student 2	7.25	8.25	7.8
Student 3	9	8.35	8.3
Student 4	5.95	7.25	7.35
Student 5	7.25	8.25	7.8
Student 6	5.95	7.25	7.35
Student 7	9	8.35	8.3
Student 8	9	8.35	8.3
Student 9	9	8.35	8.3
Student 10	7.25	8.25	7.8
Student 11	7.25	8.25	7.8
Student 12	5.95	7.25	7.35
Student 13	7.25	8.25	7.8
	7.39 (100.0%)	7.97 (100.0%)	7.82 (69.2%)

	Report I	Report II	Report III	Report IV	Pres
Student 1	5.4	6.8	6.5	7	7.7
Student 2	7.5	8.7	7	7.8	7.8
Student 3	9.5	8.6	8.5	8.5	8.1
Student 4	5.4	6.8	6.5	7	7.7
Student 5	7.5	8.7	7	7.8	7.8

Student 6	5.4	6.8	6.5	7	7.7
Student 7	9.5	8.6	8.5	8.5	8.1
Student 8	9.5	8.6	8.5	8.5	8.1
Student 9	9.5	8.6	8.5	8.5	8.1
Student 10	7.5	8.7	7	7.8	7.8
Student 11	7.5	8.7	7	7.8	7.8
Student 12	5.4	6.8	6.5	7	7.7
Student 13	7.5	8.7	7	7.8	7.8

**CHEMICAL ENGINEERING LAB. III
SPRING 2022**

Title of Assignment: Quiz 1

TOPICS COVERED IN QUIZ 1

1. Laboratory and Industrial Safety

**CHEMICAL ENGINEERING LAB. III
SPRING 2022**

SAMPLE QUIZ QUESTIONS and SOLUTION FOR QUIZ 1

Laboratory and Industrial Safety Quiz

Question 1

1 / 1 pts

1). Write out what PPE and SDS stand for:

☐

Personal protective equipment and Safety data solutions

☐

Personal protective equipment and Security data sheets

☒

Personal protective equipment and Safety data sheets

☐

Protective personal equipment and Safety data sheets

Question 2

1 / 1 pts

2). What does an SDS contain?

☐

Contains no information if a mixture

☐

Describes only product usage

☒

Contains safety and toxicological information

☐

Contains manufacturer's label information only

Question 3

1 / 1 pts

3) How long do you rinse off in a shower or eyewash station if you get a chemical spilled on you?

☐

10 minutes

☒

15 minutes

☐

25 minutes

☐

5 minutes

Question 4

1 / 1 pts

4) A graduate student was working with concentrated sulfuric acid. She splashed some of the acid onto her latex gloves and it quickly burned a hole through the gloves and caused a second-degree burn. Why did the student suffer a second degree burn to her hand?

☒

The glove that she was wearing was the wrong type for that chemical

☐

She was not paying attention when she was using the chemical

☐

She was using the chemical in an unsafe way

☐

The area where the chemical splashed was not covered by the gloves

Question 5

1 / 1 pts

5) Proper chemical storage includes all except:

☒

Storing flammables in a household refrigerator and/or freezer

☐

Dating the chemicals when they are received and opened

☐

Storing alphabetically within their hazard classes

☐

Keeping away from heat and sunlight

Question 6

1 / 1 pts

6) What is the one thing you should not do with safety goggles?

☐

Wear them with glasses

☐

Clean them. It removes the protective coating.

☐

Try different sizes to obtain the correct fit.

☒

Remove the vent.

Question 7

1 / 1 pts

7) Prescription glasses can replace the use of goggles

☐

Yes

☐

Yes if nobody else is around

☒

No

☐

Depends

Question 8

1 / 1 pts

8) It is fine to store glass and metallic objects together.

☐

Sometimes

☐

Yes

☒

No

☐

If the drawer is seldom opened.

Question 9

1 / 1 pts

9) Flammable reagents should be stored

☒

In the flammable cabinet

☐

In the fume hood

☐

In a household refrigerator or freezer

☐

On the floor

Question 10

1 / 1 pts

10) Good housekeeping in the laboratory environment (select all that apply)

☒

Includes keeping a neat and tidy bench space.

☒

Allows easy access to emergency equipment



Eliminates fire hazards



Includes keeping empty boxes in the laboratory in the corner.

Quiz Score: 10 out of 10

CHEMICAL ENGINEERING LAB. III – P02
SPRING 2022

Laboratory and Safety Quiz Grade Distribution

The course was administered online; therefore, there are not copies of the individual assignments. The statistics for the course are:

Above average ($> 9/10$) = 12 students.

Average ($> 8/10$) = 2 students.

Below average ($< 8/10$) = 1 students.

Note: Students with grades below 8/10 had to retake the quiz.

**CHEMICAL ENGINEERING LAB. III
SPRING 2022**

Title of Assignment: Quiz 2

TOPICS COVERED IN QUIZ 2

1. Design of Experiments

**CHEMICAL ENGINEERING LAB. III – Y03
SPRING 2021**

SAMPLE QUIZ QUESTIONS and SOLUTION FOR QUIZ 2

Design of Experiments Quiz

Question 1

1 / 1 pts

1. List two requirements to select an acceptable experiment.

☒

Suitable subject and acceptable cost

☐

Suitable subject and no matter the cost

☐

Any subject matter and acceptable cost

☐

Suitable subject and no matter safety conditions

Question 2

1 / 1 pts

2. How far you should go on your theoretical search?

☒

Far enough.

☐

It does not matter.

☐

As far as possible.

☐

Copy and paste everything you can.

Question 3

1 / 1 pts

3. If you have a problem with one dependent variable and two independent ones, how many experimental variables you should try to measure?

☒

2

☐

As many as you can.

☐

1

☐

It is not clear.

Question 4

1 / 1 pts

4. If you have a problem with one dependent variable and two independent ones, the range of the independent variables will determine what kind of domain?



Rectangle



Cube



Straight line



Triangle

Question 5

1 / 1 pts

5. If you have a problem with one dependent variable and two independent ones, show how the errors in the independent variables will impact the dependent one.



$$dy = dy/dx_1 dx_1 + dy/dx_2 dx_2$$



$$dy = A_1 dx_1 + A_2 dx_2$$



$$dy = A_1 dx_1 + A_2 (dx_1)^2$$



$$dy = dy/dx_1 dx_1$$

Question 6

1 / 1 pts

6. If you propose to measure a physical property list the two steps to generate credible experimental data.



Pick real value. Add and subtract experimental error



Pick any value. Add and subtract experimental error



Pick real value. Add experimental error



Pick real value. Subtract experimental error

Question 7

1 / 1 pts

7. If you are verifying a physical principle list the two steps to generate credible experimental data.

☒

Pick the equation representing the principle. Add and subtract experimental errors.

☐

Pick the equation representing the principle. Report several values.

☐

Pick the equation representing the principle. Add experimental errors.

☐

Make-up some values. Add and subtract experimental errors.

Question 8

1 / 1 pts

8. Which are the two kinds of experimental errors.

☒

Random and deterministic.

☐

Random and made-up.

☐

There are not two kinds.

☐

Calculated and measured.

Question 9

1 / 1 pts

9. Should you consider more than one alternative to achieve your proposed goal?

☒

Yes

☐

No

☐

Maybe

☐

As many as you can

Question 10

1 / 1 pts

10. Should you consider cost?

☒

Yes



No



Maybe



I do not know.

Quiz Score: 10 out of 10

CHEMICAL ENGINEERING LAB. III – P02
SPRING 2022

Design of Experiments Quiz Grade Distribution

The course was administered online; therefore, there are not copies of the individual assignments. The statistics for the course are:

Above average ($> 8/10$) = 9 students.

Average ($< 8/10$ & $> 7/10$) = 2 students.

Below average ($< 7/10$) = 2 students.

Title of Assignment: Quiz 3

TOPICS COVERED IN QUIZ 3

1. Writing Reports

**CHEMICAL ENGINEERING LAB. III
SPRING 2022**

SAMPLE QUIZ QUESTIONS and SOLUTION FOR QUIZ 3

Writing Reports Quiz

Question 1

1 / 1 pts

Figure captions and Table captions are placed:

Correct!



Below the Figure and above the Table



Above the Figure and Table



Below the Figure and Table



Above the Figure and Below the Table

Question 2

1 / 1 pts

Figure captions and Table captions are labeled:

Correct!



Sequentially and in ascending order



If required, in any order



If desired, in any order

Question 3

1 / 1 pts

Choose all the appropriate responses.

Theory section:

Correct!



Contains equations that are used to treat raw data



Contains inferences about the experiment

Correct!



Contains citations

Correct!



Must refer to pertinent background information for the experiment being reported

Question 4

0 / 1 pts

Abstract and Conclusions sections are similar except that:



Abstract contains a high-level summary of the experiment objective

Correct Answer



Conclusions contain forward-looking statements

You Answered



Conclusions contain a high-level summary of the results



Abstract contains forward-looking statements

Question 5

1 / 1 pts

Data acquired using data acquisition software are typically:

Correct!



Timed data



Current vs. voltage



Response vs. rate



Dependent on length

Question 6

1 / 1 pts

It is better to represent raw data (dependent variable vs. independent variable) as a:



Table

Correct!



Graph

Question 7

1 / 1 pts

Apart from the data points, a graph must contain the following elements:

☐

Figure caption, axes labels with units and appropriate scale only

☐

Axes labels, legend or key and appropriate scale only

Correct!

☒

Figure caption, axes labels with units, legend or key, appropriate scale

☐

Axes labels with units and legend or key only

Question 8

1 / 1 pts

Which chart type should you use in Excel for plotting series data (dependent variable vs. independent variable)

☐

Bubble

☐

Bar

☐

Line

Correct!

☒

Scatter

Question 9

1 / 1 pts

The purpose of the Discussion in the Results & Discussion section is to:

☐

Discuss what's wrong with the results

Correct!

☒

Explain, analyze and interpret the results

☐

Show the results

☐

Explain and analyze the results

Question 10

1 / 1 pts

The Discussion in the Results & Discussion section must be linked to:



Procedure

Correct!



Theory



Conclusions



Abstract

Quiz Score: 9 out of 10

CHEMICAL ENGINEERING LAB. III – P02
SPRING 2022

Writing Laboratory Reports Quiz Grade Distribution

The course was administered online; therefore, there are not copies of the individual assignments. The statistics for the course are:

Above average ($> 8/10$) = 7 students.

Average ($< 8/10$ and $> 7/10$) = 4 students.

Below average ($< 7/10$) = 2 students.

**CHEMICAL ENGINEERING LAB. III
SPRING 2022**

Title of Assignment: REPORT 1

TOPICS COVERED IN REPORT 1

Report 2 covered the following topic:

1. Kinetic determinations in a tank reactor (Expt. No. 1)

Objective:

Determination of the conversion of a chemical reaction in a batch reactor. A saponification reaction carried out with excess ethyl acetate is studied. Final concentration of the limiting reactant (NaOH) is determined by titration.

**CHEMICAL ENGINEERING LAB. III
SPRING 2022**

RUBRIC AND GRADING SCHEME FOR LAB. REPORTS

**Laboratory Grading Sheet
Reports**

Technical Content	Maximum Grade
--------------------------	----------------------

2. Abstract/Objective	5 points
3. Theory	5 points
4. Results	5 points
5. Conclusions	5 points

Writing Content

6. Organization	5 points
7. Language	5 points
8. Write-up	5 points
9. Appearance	5 points

Every report will be graded according to the items described in this grade sheet.

Technical Content	Maximum	Grade
Abstract/Objective	5	
Theory	5	
Results	5	
Conclusions	5	
Total =	20	
Writing Content		
Organization	5	
Language	5	
Professional content	5	
Appearance	5	
Total =	20	

ABOVE AVERAGE

Roy G. Perry
College of Engineering



CHEG 4104 - Chemical Engineering Lab III

Experiment 1:
Conversion of NaOH in Saponification Reaction in a 3-Series CSTR
Group #2

Due Date: March 30, 2022

Commented [JG1]: Very good report. Grade= 9.4/10

Submitted by:
Chad Gardner
Anh Nguyen
Meredith Meyer
Franck Nangomoko

Submitted to:
Dr. Jorge Gabitto

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- Figure 3: Conductivity of 3 CSTRs over Time
- Figure 4: Conversion of NaOH in Tank 1 over Time
- Figure 5: Concentration of NaOH vs Time approaching Steady State Condition

Abstract

A continuous-stirred tank reactor is a common model for the estimation of key unit operation variables with specified output. For this experiment, the Armfield CEP-MkII stirred tank reactors model was used to observe the second-order reaction of 0.1M EtOAc and 0.1M NaOH. The aims of the experiment were to investigate and determine the conversion of a second order reaction in a tank reactor as well as to determine the reaction rate of the reaction. The parameters considered for analysis were conductivity, concentration of NaOH, and residence time. The steady state conversion was obtained as 0.62 at 25°C with the residence time of 264 seconds. The constant rate of reaction was calculated as 0.162L/mol.s. The results were helpful in determining the condition of operating variables to achieve a desirable conversion of the saponification reaction in CSTRs on an industrial scale.

Theory

Reactor is an important equipment in every chemical process. Continuous stirred tank reactors (CSTRs) have proven to be more energy efficient than batch reactors. Since the reaction is continuous, there is no need to go through an empty-fill and heat up cycles. Despite being under further investigations for various processes, these reactor vessels serve as great importance to the chemical industry. A CSTR consists of a tank and an impeller to provide efficient mixing.

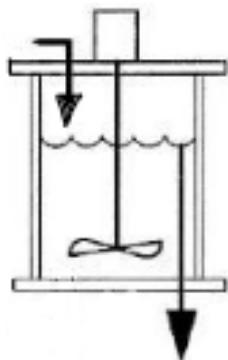


Figure 1: Schematic Diagram of CSTR

CSTR can be connected in series or in parallel. In this experiment, CEP-MkII Stirred Tank Reactors in Series is used to analyze the steady-state fractional conversion of a limiting reactant in saponification reaction, shown in Figure 2.

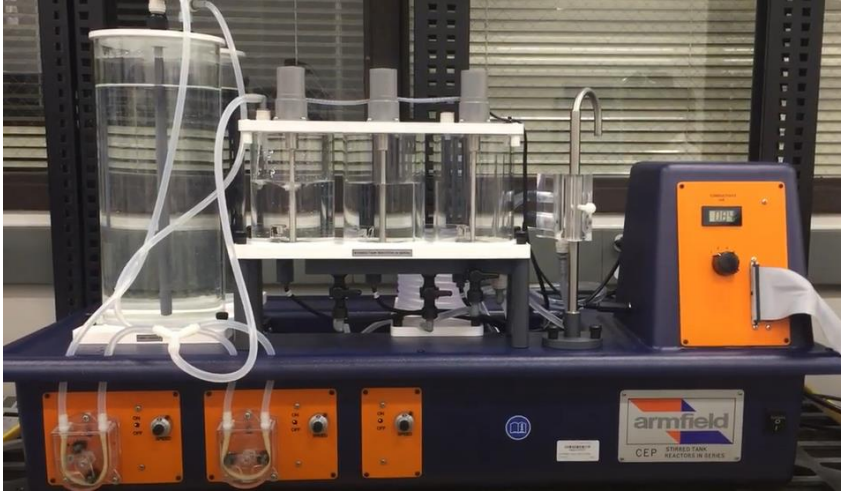
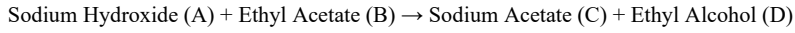
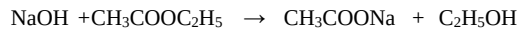


Figure 2: CEP-MkII Stirred Tank Reactors in Series

The reactants used in the experiment are sodium hydroxide and ethyl acetate. The reaction is called saponification reaction which its products are used in different fields, such as petroleum, cosmetics, and textile industry.

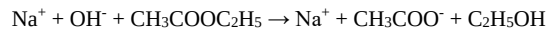
The reaction is shown below.



Sodium hydroxide (NaOH) and ethyl acetate (EtOAc) are fed in equimolar. Each reactant has a concentration of 0.1M. The fraction conversion of limiting reactant is expressed by the change in flow rate of NaOH (component A).

$$X_A(t) = \frac{A \text{ fed to reactor} - A \text{ leaving reactor}}{A \text{ fed to reactor}} = \frac{C_{A,i} - C_A(t)}{C_{A,i}}$$

The saponification reaction occurs in a partially electrolytic solutions, the conversion can be obtained by monitoring the changes in conductivity (κ) of the reacting mixture in steady-state condition, including ionic species Na^+ , OH^- , and CH_3COO^- . The reaction is expressed in ion form:



Since the conductivity $\kappa(t)$ is linearly dependent on the concentration of these three ions, it can be expressed as the sum of ions' concentrations (C_{Na^+} , C_{OH^-} , C_{COO^-}) with their molar conductivities (Λ_{Na^+} , Λ_{OH^-} , Λ_{COO^-}) which COO^- represents acetate ion.

$$\kappa(t) = C_{\text{Na}^+}(t) \cdot \Lambda_{\text{Na}^+} + C_{\text{OH}^-}(t) \cdot \Lambda_{\text{OH}^-} + C_{\text{COO}^-}(t) \cdot \Lambda_{\text{COO}^-} \quad (1)$$

The concentration of each ion can be expressed in terms of initial concentration of OH^- ($C_{\text{OH}^-}^0$), initial volume of

the reactant ($\dot{V}^o$), and conversion (X), equation (1) is equivalent to:

$$\kappa(t) = \frac{\dot{V}^o C_{OH}^o}{2\dot{V}^o} \cdot \Lambda_{Na^+} + \frac{\dot{V}^o C_{OH}^o (1-X)}{2\dot{V}^o} (t) \cdot \Lambda_{OH^-} + \frac{\dot{V}^o C_{OH}^o X}{2\dot{V}^o} (t) \cdot \Lambda_{COO^-} \quad (2)$$

The relationship between conductivity $\kappa(t)$ and conversion (X) is then expressed in equation (3):

$$X = \frac{2\kappa(t) - C_{OH}^o (\Lambda_{Na^+} + \Lambda_{OH^-})}{C_{OH}^o (\Lambda_{COO^-} - \Lambda_{OH^-})} \quad (3)$$

where Λ_{Na^+} is 50.1 S.cm²/mol, Λ_{OH^-} is 198.6 S.cm²/mol, and Λ_{COO^-} is 40.9 S.cm²/mol [2].

To determine the steady state conversion of the reactor, we look at the conductivity curve in the software. A “flattening” of the curve indicates the steady-state conversion of the reactor.

Additionally, we analyzed the mean residence time (τ) which is the average time that a reactant or product will spend in the reactor.

$$\tau = \frac{\text{Total reactor volume}}{\text{Total volumetric flow rate}} = \frac{V_R}{\dot{V}^o} \quad (4)$$

Rate of saponification reaction (r_A) can then be determined by

$$r_A = k_A C_A C_B$$

where A is NaOH, and B is EtOAc; k_A is the rate constant with respect to A and C is the concentration. Since NaOH and EtOAc are fed in equimolar, the rate of equation can be expressed in terms of initial concentration of NaOH as:

$$-r_A = k_A C_{Ao}^2 (1-X)^2 \quad (5)$$

Assuming the reaction is elementary, the component mass balance equation is:

$$F_{Ao} - F_A + V_R (r_A) = 0$$

Since the volumetric flow rate is constant ($\dot{V} = \dot{V}^o$), $C_A = F_A/\dot{V}^o$, and $C_A = C_{Ao}(1-X)$, the mass balance equation can be written in combining with equation (5) as:

$$\dot{V}^o C_{Ao} - \dot{V}^o C_{Ao} (1-X) + V_R k_A C_{Ao}^2 (1-X)^2 = 0 \quad (6)$$

The reaction rate constant as a function of fractional conversion and the residence time can be written in combining equation (6) with equation (4) as:

$$\tau = \frac{V_R}{\dot{V}^o} = \frac{X}{k_A C_{Ao} (1-X)^2} \quad (7)$$

Procedures

As the equipment was already set up, the experiment proceeded in the following steps:

1. Start the Armfield software for CSTR in series
2. Collect conductivity data until all 3 reactors in steady state conditions (“flat” conductivity curve) in approximately 25 minutes
3. Make sure the pump speed controls to give 80mL/min flowrate and the agitator speed controller to 84% max capacity
4. Switch on both feed pumps and agitator motor and click “Go” on the screen to record the data. The data were obtained in a 10-second interval.

Results and Discussion

Feed flow rate of 80 mL/min 0.1M NaOH and 80 mL/min 0.1M EtOAc were used in the experiment. The reaction was carried out at a constant temperature of 25°C and stirrer speed at 54% (6.43 rpm). Ten (10) minutes after the start of the experiment, the steady state conditions were reached. Figure 3 shows the conductivity of CSTRs as time elapses. The conductivity of the reaction mixture decreases as reaction takes place in all three tanks. It is because as the reaction proceeds, the concentration of NaOH reduces resulting in a drop in conductivity values.

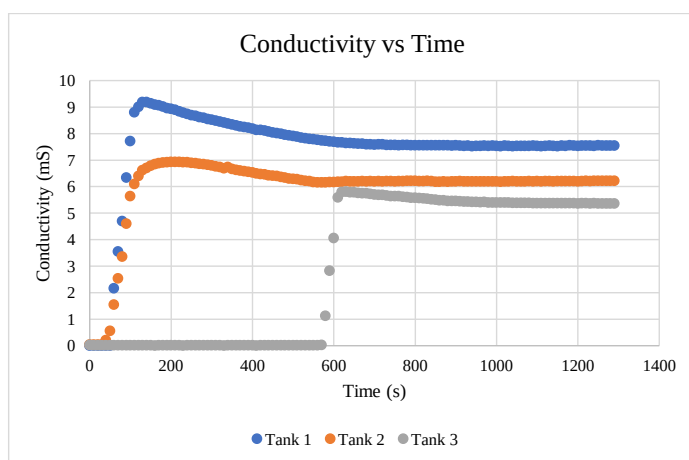


Figure 3: Conductivity of 3 CSTRs over Time

Figure 4 shows the trend of conversion of NaOH in Tank 1 over time as it approaches steady state (starting from 140s). It is determined that the conversion of NaOH at steady state is 0.62. According to Figure 4, it takes 230s (almost 6 minutes) for the CSTR to get 75% of its steady-state conversion.

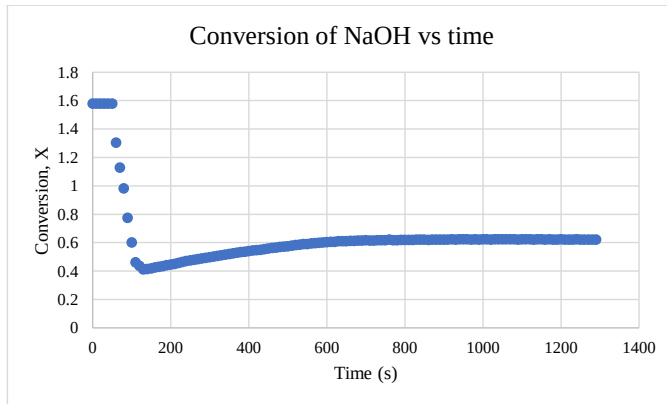


Figure 4: Conversion of NaOH in Tank 1 over Time

Figure 5 shows the dynamically change of the concentration of NaOH $C_A(t)$ as the 1st CSTR approaches a steady state. The concentration reaches a peak of 0.059M (at $t = 130s$) and gradually decreases to a steady state value of 0.038M in 540s (9 minutes).

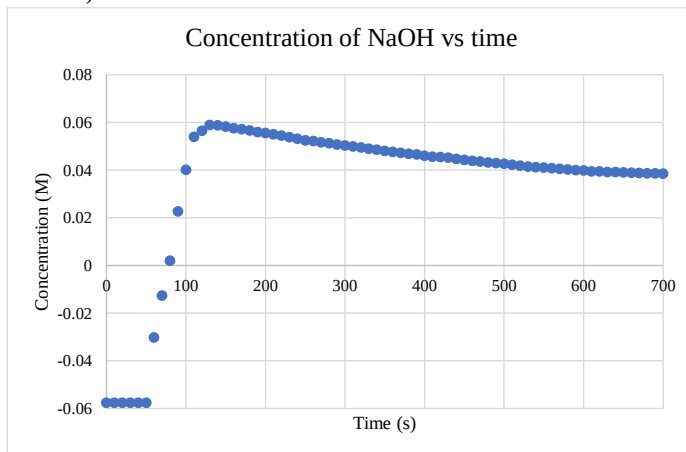


Figure 5: Concentration of NaOH vs Time approaching Steady State Condition

From Figure 3, 4 and 5, it clearly shows that as the reaction proceeds, the conductivity of the solution decreases, the concentration of NaOH decreases, and the conversion of NaOH increases. The three variables, however, will eventually achieve their own steady state value. Those values are important in any chemical processes as it determines the efficiency of the process and desired rate of production.

The mean residence time of the first tank was then calculated using equation (4) to be 4.4 minutes (264 seconds) in which the reactor volume was 0.7L and the total flow rate was 0.16L/min. The reaction rate constant k_A at

steady state was found to be 0.162 L/mol.s using equation (7). The reaction rate constant for the saponification reaction would not change over time because the CSTR could be consider as a batch reactor. Therefore, the volumetric flow rate is constant, and the reaction rate constant is constant under this experiment's conditions.

Conclusion

Understanding the conversion of a second-order reaction in a CSTR is crucial in the estimation of unit operation variables with specified output. The steady state conversion of NaOH was 0.62 after about 10 minutes of the experiment running. The steady state concentration of NaOH leaving the 1st reactor was 0.38M. The result showed that as the reaction proceeded the concentration of NaOH reduced resulting in a dropping of the conductivity values; and the conductivity of the reaction mixture decreased as the reaction took place. The overall time to reach steady state conditions was approximately 18 minutes. With different conditions (feed's flow rates, feed's concentration, and temperature), the steady state conversion, the residence time, and the rate constant of the reaction can be varied. Therefore, this experiment can be reconducted at different temperatures and/or the feed stream's conditions to determine the conversion of NaOH.

References

Roy G Perry. Chemical Engineering Department. *Reaction Kinetics in a 3-Series CSTR*. Accessed 2022.

Electrical Conductivity of Aqueous Solutions. Accessed 2022.

<https://www.colby.edu/chemistry/CH141/CH141L/CH141Lab4Fall2009.pdf>

AVERAGE

**Prairie View A&M University
Chemical Engineering Department**



Lab #3: Reaction Kinetics in a 3-Series CSTR

Shimere Gregory, Cherish Vaughn, Alexis Lovelace, Irene Atatah

Due Date: 04/13/22

Date Conducted: 04/06/22

Commented [JG2]: Fair report. Grade= 7/10

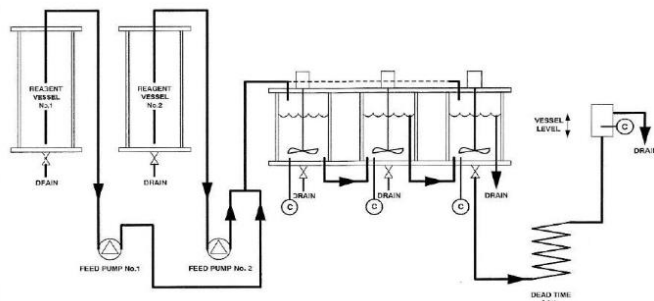


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Abstract

- [Purpose](#)
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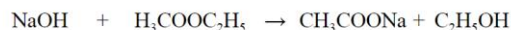
Appendix

Abstract

In chemical plants today, reaction processes are essential to produce products at a specific rate using known reactants. To accomplish that, there are various kinds of reactors that can produce the products under these circumstances. The purpose of this experiment is to be able to determine the conversion of a second order reaction in a tank reactor. We are to identify the comparisons between operations of a real tank reactor and an CSTR which is the ideal reactor. The CEP-MKII stirred tank reactor in series unit will be used to find out the conversion of reactant in a second-order reaction carried out in a 3-series CSTR configuration to study the fluid dynamics in tanks. The purpose of the first two tanks in the reactor is to store and distribute the reactants. The variable that we are measuring in this experiment is conductivity. In this experiment, we are to find the conversion of the limiting reactant in a tank reactor by measuring conductivity.

Theory

To perform the experiment, the following reaction is used.



Sodium Hydroxide (A) + Ethyl Acetate (B) → Sodium Acetate (C) + Ethyl Alcohol (D)

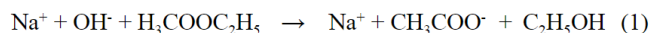
The Reactants Sodium Hydroxide and Ethyl Acetate are used to produce Sodium Acetate and Ethyl Alcohol through the stir tank reactor. Understanding that each reactant must have a particular set of conditions for us to properly operate the series of reactors. Those conditions were set so that the two input streams have the same molar flow, volumetric flow, and concentration. In terms of the two-molar feed flow the fractional conversion of Sodium Hydroxide can be calculated.

The fractional conversion of Component A (sodium hydroxide) is given by:

$$X_A = \frac{A \text{ consumed in reactor}}{A \text{ fed to reactor}} = \frac{A \text{ fed to reactor} - A \text{ leaving reactor}}{A \text{ fed to reactor}}$$

When a certain conversion is reached the tanks come to a point of steady state. This process can be observed by monitoring the changes on the screen that shows you the conductivity of the effluent. This is caused by the changes of the ions present. You may see on a graph the line starting to flatten indicating that the reaction is reacting steady state.

To better understand the ions and the approach to steady state the following formula is written in terms of its reacting ions.



They are four ions in this reaction present in the output stream. Knowing the chemicals and how they react is a major component in this experiment. Initially, understanding that ethyl acetate is not completely dissociated in ions, but sodium hydroxide is. In this experiment you will see that the concentration is linear to the conductivity

of the reacting mixture.

The objectives of this experiment are listed below

- Determine conversion of a second order reaction in a tank reactor
- Study the dynamic behavior of a reaction proceeding in a stirred tank as it approaches steady state
- Study the effect that the conversion and residence time have on the overall reaction kinetics in tank
- Understand the limiting reactant
- Measure the Conductivity and Conductivity of the output solution.

Procedure

To perform this experiment, we are using the CEP-MkII Stirred tank reactors equipment in series unit.

1. Make up 2.0-liter batches of 0.1M sodium hydroxide and 0.1M ethyl acetate solutions.
2. Remove the lids of the reagent vessels and carefully fill them with a level approximately 50mm from the top. Refit the lids.
3. Conductivity data will be collected until a steady state condition is reached in the reactor and this takes approximately 25 minutes. It is advisable to set the data collection period to, say, 30 minutes.
4. Using the calibration graph for each of the feed pumps, set the pump speed controls to give 80 ml/min flowrate (from each feed tank.)
5. Set the agitator speed controller to 10.0 (84% max. capacity.)
6. Switch on both feed pumps and agitator motor and initiate the data logger program (or begin taking readings if no computer is being used).
7. It has been determined that the degree of conversion of the reagents affects the conductivity of the reactor contents so that recording the conductivity with respect to time using the Armfield data logger can be used to calculate

Results & Discussion

The experiment is conducted to determine the reaction constant and to determine the effect of residence time on the conversion in continuous stirred tank reactor (CSTR). Continuous stirred tank reactors are used in this experiment to predict the behavior of chemical reactors; thus, the dimensions of the reactor can be estimated. Figure 1 shows the conductivity of series of CSTRs as time elapses. The conductivity of the CTSR is reaching

steady state at different **eslap** times.

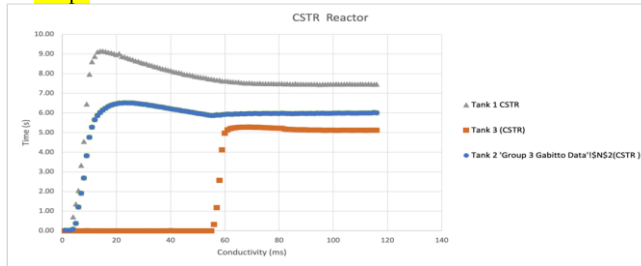


Figure 1: CSTR Reactor vs Time

Figure 2 shows conversion vs time trend at tank 1 and expressing reactor reaching steady state. Figure 2 shows directly proportional to the residence time which is value of conversion increases as the time increases. The results show from the experiment a 0.14L/min value of conversion and residence time of 6 minutes to reach steady state.

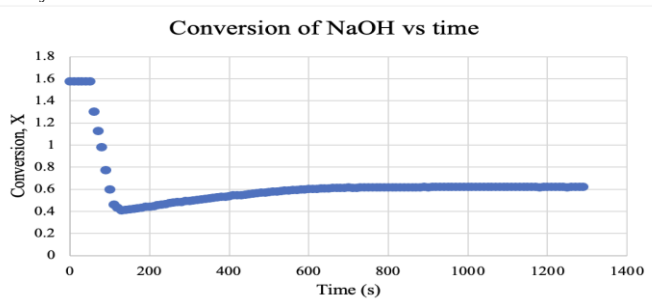


Figure 2: Conversion vs Time

Conclusion

For this experiment, their series continuous **tan** reactor is used. The main objective is determining the reaction rate and the effect of residence time on the conversion. The results show reactions proceeded the concentration of NaOH reducing resulting in dropping of the conductivity values. The overall time to reach steady state conditions was 15 minutes. This experiment can be reconducted at different temperatures / feed streams conditions to determine the conversion of NaOH.

References

Roy G Perry. Chemical Engineering Department. *Reaction Kinetics in a 3-Series CSTR*. Accessed 2022.

Electrical Conductivity of Aqueous Solutions. Accessed 2022.

<https://www.colby.edu/chemistry/CH141/CH141L/CH141Lab4Fall2009.pdf>

BELOW AVERAGE



Reaction Kinetics in a 3-series CSTR

CHEG 4104-PO1

Submit to: Dr.Gabitto

Submitted by : Cinthia Sahin , Rafid Matti , Reema Matti

Commented [JG3]: Poor report. Grade = 5.6/10

Abstract

The goal of this project is to determine a conversion of a second order reaction in a tank (real) reactor. Another goal is to seek out the comparisons between a real and CSTR, or ideal, reactor. ~~It is relevant because, with a second order reaction, there must be multiple tanks to store and distribute the reactants.~~ Tank reactors help acquire overall efficiency and are the most widely used and preferred reactors in the industry. Conductivity is the only variable measured in the experiment, in the output stream. ~~There are 2 input streams and one output stream for the equipment.~~ In this lab, we were to make up 5-liter batches of 0.1M sodium hydroxide and 0.1 m ethyl acetate solution. After the reagent vessel lids are removed, they are filled with the reagents until 50mm from top is remaining. Conductivity data ~~is~~ collected until steady state is reached. The agitator is set and both feed inlet pumps are on as the data begins to be read and is documented.

For the results, as time increases, the conductivity increases until about 250 seconds and AFTER THIS TIME the conductivity ~~curve~~ remains constant ~~throughout~~. Steady state was achieved at 6.2 μ S/L. ~~When it came to the~~ NaOH Conversion vs Time, ~~NaOH also increases~~ with time before it, too, flattens out for the remaining time. Steady state here was achieved at 600 seconds. Overall, to determine the conversion of a second order reaction of a tank reactor, an experiment was done, and as time increases, ~~both the conductivity and NaOH conversion increase for a set period of time before entering steady state and remaining constant.~~

Theory:

Reactors are an important equipment to the overall efficiency of an industrial plant and the product to produce. There are a variety of reactors to choose from depending upon what is being asked to produce. Common reactors used in industrial plants are batch, continuously stirred tank reactor (CSTR), plug flow reactor (PFR), and packed bed reactor (PBR).

Batch reactors are used for a variety of situations such as small-scale operations, testing of new products, and for processes where it is hard to convert to a continuous operation (Fogler, 2016). Advantages of a batch reactor is that there is a high conversion rate since the reactants can be left in the reactor for an extended period of time (Fogler, 2016). Some disadvantages are that the labor costs are through the roof, there isn't a wide variety of products that can be made using this type of reactor, and it is difficult to go from pilot to industrial scale (Fogler, 2016). A CSTR is used for liquid-phase reactions. The CSTR operates at steady state and is assumed to be perfectly mixed unless stated. The CSTR reactor can either be ideal or nonideal (Fogler, 2016). Advantages of a CSTR reactor is that it is a continuous reactor which leads to good temperature control (Fogler, 2016). A disadvantage is that conversion is small in comparison to the volume of other flow reactors. A PFR or a tubular

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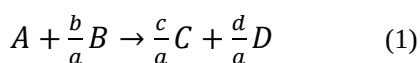
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reactor operates a steady state similarly to the CSTR, but the phase that the reactor can accommodate are gases. In this particular reactor, reactants are consumed as they flow down the reactor (Fogler, 2016). A PBR is unique in comparison to the other reactors previously mentioned. This reactor is based on the mass of the catalyst used in the product. The reaction occurs on the surface of the catalyst.

In this particular experiment, an ideal CSTR reactor was used. The basic equation used for a CSTR to find various aspects needed for reactors such as: conversion, stoichiometric coefficients is:



$$F_A = F_{A_0}(1 - X) \quad (2)$$

$$F_{A_0} = C_{A_0}v_0 \quad (3)$$

This equation is based upon the limiting reactant which is given the letter A. Manipulating this equation based on the location of the other variables used in the location results in the consequential equations to be formed.

Industrial safety is a critical component to the success of an industrial plant. Industry safety is based upon operations management of an event that can occur within the industry. The safety measures are put into place to ensure the employees are protected to minimize hazards and risks that are associated when proper safety precautions are not taken. Daily tips that are needed in any manufacturing plant are letting supervisors know when the conditions are deemed unsafe, wearing proper PPE, prevent slips and trips, keeping work areas and emergency exits clear, and to eliminate any potential fire hazard.

Procedures

1. Make up 5.0-liter batches of 0.1M sodium hydroxide and 0.1M ethyl acetate solutions.
2. Remove the lids of the reagent vessels and carefully fill with the reagents to a level approximately 50mm from the top. Refit the lids.
3. Conductivity data will be collected until a steady state condition is reached in the reactor and this takes approximately 25 minutes. It is advisable to set the data collection period to, say, 30 minutes.
4. Using the calibration graph for each of the feed pumps, set the pump speed controls to give 80 ml/min flowrate (from each feed tank.)
5. Set the agitator speed controller to 10.0 (84% max. capacity.)
6. Switch on both feed pumps and agitator motor and initiate the data logger program (or begin taking readings if no computer is being used).
7. It has been determined that the degree of conversion of the reagents affects the conductivity of the reactor

Commented [GJ10]: You do not need to compare all reactors. Just talk about the CSTR. Half page wasted.

Commented [GJ11]: Wrong. A tank reactor (real) was used.

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contents so that recording the conductivity with respect to time using the Armfield data logger can be used to calculate the amount of conversion.

Results & Discussion

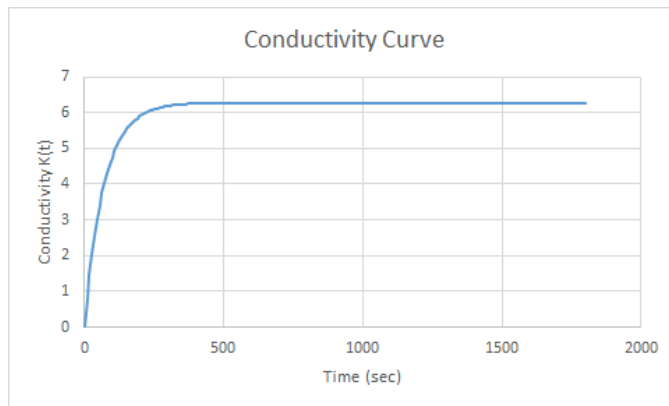


Figure 1 : Conductivity Curve

According to figure 1 the tank has achieved steady state conversion when the curve has reached a flattening point, X^{ss}_A . The steady state conversion is obtained at a value of $6.2\mu S/L$.

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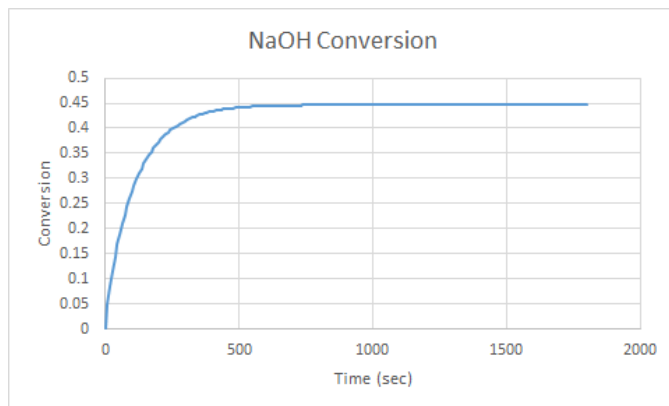


Figure 2: NaOH Conversion vs Time

The graph demonstrates the relationship between NaOH conversion and time, as shown above. NaOH CONVERSION increases with time until reaching a steady state at a time interval of 600 seconds. Once the steady state is reached it is maintained there for the rest of the time interval therefore one knows that for the

Commented [GJ16]: Say what Figure 2 is!!!

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Commented [GJ18]: Where did you get this graph from? You were NOT given these data!!! This is NOT the plot I showed you!!!

steady state conversion of NaOH in the first tank is 45% when $t \geq 600 \text{ secs}$.

Percentage	Conductivity ($\mu\text{S/L}$)
25%	5.30
50%	6.15
75%	6.23

Commented [GJ19]: What the percentage means? What are the conversions values? Very poor (2) results section. Cheating and copying is also suspected.

Conclusion

In closing statements, the group conducted an experiment to determine a conversion of a second order reaction in a tank (real) reactor as well as seeking out the comparisons between batch reactor, CSTR, or ideal reactor. The relevance of this experiment is because, with a second order reaction, there must be multiple tanks to store and distribute reactants. Resulting from this experiment, we can conclude that as time increases, the conductivity increases until about 250 second and the curve remains constant. We achieved steady state at 6.2 of conductivity in the tanked reactor based on figure 1 shown above. From figure 2 expresses the relationship between the conversion of NaOH and time. As NaOH increases, we reach steady state at 600 seconds therefore one knows that for the steady state conversion of NaOH in the first tank is 45% when time is greater than 600 seconds. From there we can determine the concentration, conversion, and conductivity all changed with time, until the reaction reached steady state, and residence time was determined. During the analysis of this procedure, different linear relationships were found to aid in collecting, calculating, and confirming data. The linear relationship between conductivity and conversion is inversely correlated and shows that with one, the other can be calculated.

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Commented [GJ21]: This statement is true , BUT does NOT agree with the plots you presented. This is a copied report and done very poorly!! I am not going to fail you, but you really deserved it.

Commented [GJ22]: Contradicts the previous statement! Poor writing too.

References

Fogler, H. Scott. *Essentials of Chemical Reaction Engineering: Essenti Chemica Reactio Engi*. Pearson Education, 2010.

**CHEMICAL ENGINEERING LAB. III
SPRING 2022**

Title of Assignment: REPORT 2

TOPICS COVERED IN REPORT 2

Virtual Report 2 covered the following topic:

1. Determine the conversion of a 2nd order reaction in a tubular reactor.

Objective:

To determine the conversion factor X for a given set of condition of the tubular reactor

ABOVE AVERAGE



Experiment # 2: Tubular Reactor

CHEG 4104-PO1

Submit to: Dr. Gabitto

Submitted by : Cinthia Sahin , Rafid Matti , Reema Matti

Due Date:04/13/2022

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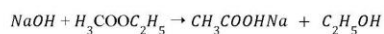
I. Abstract

A tubular reactor is a vessel through which the flow is continuous, usually at a steady state, and configured so that conversion of the chemicals and other dependent variables are functions of position within the reactor rather than time. Typical industrial uses of tubular reactors are in gasoline production, oil cracking, synthesis of ammonia from its elements, and the oxidation of sulfur dioxide to sulfur trioxide; tubular reactors can also be used as bioreactors or for small scale production.

This experiment is carried out to study and determine the conversion factor X of the solution for a given set of conditions in a tubular reactor, the effect of the reaction rate constant, and the conductivity and conversion of NaOH. The two samples (sodium hydroxide and ethyl acetate) had less contact time, resulting in a reduction in the conversion of the products (ethanol and sodium acetate). In the results session of this report, three graphs represent the experimental finding. The first graph, which is a plot of time versus conductivity, depicts that the plug flow reactor is close to the ideal behavior of an ideal reactor. The second graph shows a plot of position versus concentration A at a given time, which represents that as the fluid moves in the plug flow reactor, the concentration increases. Finally, the third graph represents a plot of the position versus the concentration of substance A , which shows that the plug flow reactor is not far from an ideal reactor. In sum, the experimental step is shown to be close to its ideal step thus suggesting that the real plug flow reactor produces near ideal behavior.

II. Theory

The reaction:



can be considered equi-molar and first-order with respect to both sodium hydroxide and ethyl acetate – and second-order overall, within the limits of concentration (0 - 0.1M) and temperature (20 - 40°C) studied. It is known that 1 mol of ethyl acetate reacts with 1mol of NaOH.

A mass balance can be conducted over the reactor (at steady state), in terms of the two molar feed flows (F_A and F_B), resulting in an expression for the fractional conversion of NaOH (component A), X_A , is as follows:

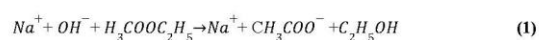
$$X_A = \frac{A \text{ consumed in reactor}}{A \text{ fed to reactor}} = \frac{A \text{ fed to reactor} - A \text{ leaving reactor}}{A \text{ fed to reactor}}$$

Or,

$$X_A = \frac{A \text{ consumed in reactor}}{A \text{ fed to reactor}} = \frac{A \text{ fed to reactor} - A \text{ leaving reactor}}{A \text{ fed to reactor}}$$

The reaction is carried out in the tubular reactor which will eventually reach steady state when a certain conversion of the starting reagents is achieved. A steady-state condition for this saponification reaction can be observed by continuously monitoring changes in the specific electrical conductance or conductivity (κ) of the effluent that are caused by changes in the concentrations of ions present in the effluent. It is assumed that a "flattening" of the conductivity curve - $\kappa(t)$ vs. t - in a tank reactor indicates that the tank has achieved its steady state conversion, X_A^{ss} .

To understand the connection between $\kappa(t)$ and $X_A(t)$, we must first recognize that this saponification reaction occurs in a partially electrolytic solution. Rewritten in terms of its reacting ions, the reaction can be expressed in its charge balanced form:



The reacting mixture features a measurable specific conductance due to the presence of the ionic species Na^+ , OH^- , and COO^- (representing acetate.) And the conductivity, $\kappa(t)$, of the reacting mixture is linearly dependent on the concentration of these ionic species in solution, and additive. As such, $\kappa(t)$ can be expressed as a sum of the contributions of Na^+ , OH^- , and COO^-

based on their respective concentrations (C_{Na^+} , C_{OH^-} , and C_{COO^-}) and molar conductivities (

Λ_{Na^+} , Λ_{OH^-} , and Λ_{COO^-}) as follows:

$$\kappa(t) = C_{Na^+}(t) \cdot \Lambda_{Na^+} + C_{OH^-}(t) \cdot \Lambda_{OH^-} + C_{COO^-}(t) \cdot \Lambda_{COO^-} \quad (2)$$

$$\kappa(t) = \frac{F_{Na^+}}{V} \Lambda_{Na^+} + \frac{F_{OH^-}}{V} (t) \cdot \Lambda_{OH^-} + \frac{F_{COO^-}}{V} (t) \cdot \Lambda_{COO^-} \quad (3)$$

$$\kappa(t) = \frac{\dot{V}^o C_{OH^-}^0}{2 \dot{V}^o} \Lambda_{Na^+} + \frac{\dot{V}^o C_{OH^-}^0 (1-X)}{2 \dot{V}^o} (t) \cdot \Lambda_{OH^-} + \frac{\dot{V}^o C_{OH^-}^0 X}{2 \dot{V}^o} (t) \cdot \Lambda_{COO^-} \quad (4)$$

$$\kappa(t) = \frac{C_{OH^-}^0}{2} \Lambda_{Na^+} + \frac{C_{OH^-}^0 (1-X)}{2} (t) \cdot \Lambda_{OH^-} + \frac{C_{OH^-}^0 X}{2} (t) \cdot \Lambda_{COO^-} \quad (5)$$

$$\kappa(t) - \frac{C_{OH^-}^0}{2} \Lambda_{Na^+} - \frac{C_{OH^-}^0}{2} (t) \cdot \Lambda_{OH^-} = - \frac{C_{OH^-}^0 X}{2} (t) \cdot \Lambda_{OH^-} + \frac{C_{OH^-}^0 X}{2} (t) \cdot \Lambda_{COO^-} \quad (6)$$

$$X = \frac{\kappa(t) - \frac{C_{OH^-}^0}{2} \Lambda_{Na^+} - \frac{C_{OH^-}^0}{2} (t) \Lambda_{OH^-}}{\frac{C_{OH^-}^0}{2} (\Lambda_{COO^-} - \Lambda_{OH^-})} = \frac{2 \kappa(t) - C_{OH^-}^0 (\Lambda_{Na^+} + \Lambda_{OH^-})}{C_{OH^-}^0 (\Lambda_{COO^-} - \Lambda_{OH^-})} \quad (7)$$

III. Procedure

1. Make 3 liters of 0.1 M of NaOH and 3 liters of 0.1M of EtOAc.
2. Start the Edibon Software, select QRFT, and input a filename to save your data.
3. Switch on both pumps AB1 and AB2 using the software and adjust (if necessary) the flow rates to ~6 L/Hour for each feed; check that the product discharges into the product bottle.
 - a. Note that for our actual experiment, AB-1 is set at ~50 and AB-2 is set at ~55, approximately pumping fluid at ~5L/Hour.
4. Click on the icon for Take data and change the periodic time to 5 seconds.
5. Let the reaction run for 15-25 minutes or until the reactor has reached a steady state.
 - a. Note the flow rates of NaOH and EtOAc, and the conductivity readings.
6. Write down the steady-state conductivity value and use eq. (7) in the theoretical section to calculate the value of the limiting reactant conversion.

IV. Results and Discussion

In this experiment, we utilized the conductivity and time to develop the plot for the tubular reactor by using the Edibon's QRFT and QRUBI.

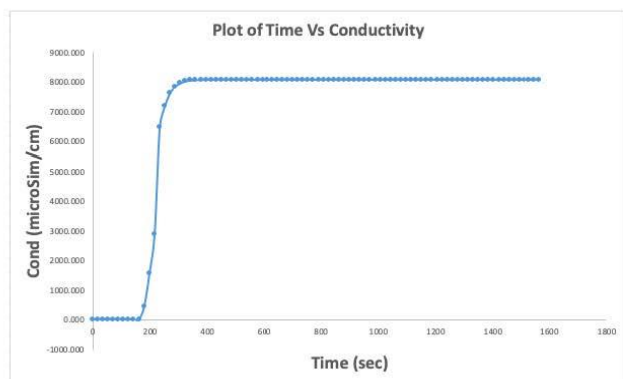


Figure 1. Plot of Time vs Conductivity

The plot above is represented by a curve of conductivity and time. As we can see from the graph, at time zero to about 194 sec, the conductivity is maintained at zero. Then the conductivity increases rapidly before reaching steady state at about 504 sec and 8079.4 microSim/cm with a conversion of 0.5577. This plot can be compared to a representation of a step response but in this case the step response is not ideal because it has an inclination and is not instantaneous. However, the inclination shows that the plug flow reactor is close enough to the ideal behavior of an ideal reactor. Thus, the experimental step is very close to its ideal step.

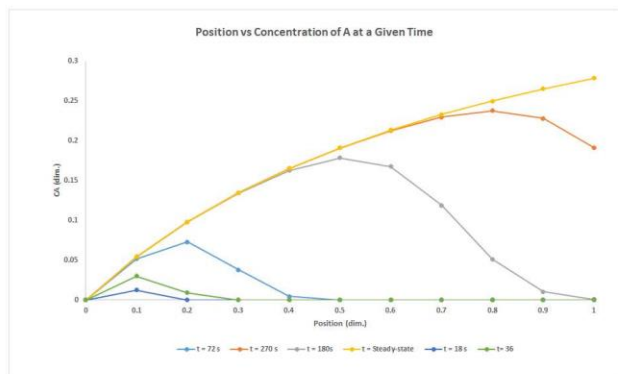


Figure 2. Plot of Position vs Concentration A at a Given Time

In Figure 2., the graph shows that as the concentration moves in the plug flow reactor, the concentration increases. At 72 seconds, the concentration produced was about 0.06M when it reached the position of 0.2 in the plug flow reactor. At position 0.3, the concentration produced was about 0.05M. As the time increases, the position in the plug flow reactor gets closer to its output of the reactor. The yellow line represents the steady-state of the reaction. As the time increases, the reaction follows the steady-state line more closely. For example, at 180 seconds, as the concentration moves further in the plug flow reactor to position 0.5, the concentration increases to about 0.16M. From position 0 to 0.4, the line follows the steady-state curve before deviating.

The next graph below will represent the concentration C_A versus position in the plug flow reactor experiment.

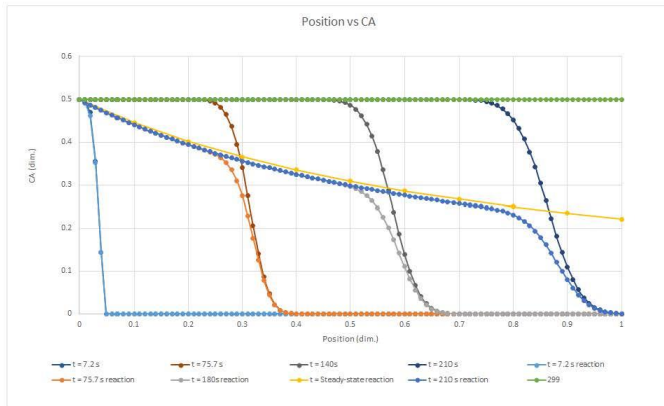


Figure 3. Plot of Position vs C_A

Figure 3. Plot of Position vs C_A shows the concentration and the position change of a plug flow reactor. From position zero to one, we have, respectively, the input and output of the reaction of the reactor. At 7.2 sec, the position of the plug flow reactor has not really changed. At 75.7 sec, the position of the plug flow reactor moved from 0.38. At 140 sec, the position of plug flow reactor keeps moving to the output of the plug flow reactor to reach 0.65. At 210 sec, the position reaches 0.98.

The green line "299" remains at a concentration of 0.5M. This line shows that there is no reaction occurring as the concentration passes through the plug flow reactor. Line $t=7.2$ s, line $t=75.7$ s, line $t=140$ s, and line $t=210$ s represent the concentration moving in the plug flow reactor without reacting. The plug flow reactor is indicated to be a real reactor because these lines have a slope or inclination towards the end of where they stop in the plug flow reactor at their particular times. However, since these lines have a slope near a vertical line, the plug flow reactor is not far from an ideal reactor.

The line labelled as t =steady-state reaction is the curved line that represents the steady state at which a reaction is occurring. Line $t=7.2$ s reaction, line $t=75.7$ s reaction, line $t=140$ s reaction, and line $t=210$ s reaction represent the concentration moving in the plug flow reactor while a reaction is occurring. As the concentrations move through the plug flow reactor, the reactant concentrations decrease since the reaction consumes the reactant to produce the product. The area between the horizontal line (line 299) and curve line (line t =steady state reaction) is the amount of limited reactants consumed. The more the concentration moves through the plug flow reactor, the more of the reactants are consumed.

V. Conclusion

The experiment was carried out using a tubular reactor to study and determine the conversion factor of the solution. 3 liters of 0.1 M of sodium hydroxide and 3 liters of 0.1M of ethyl acetate were used to make sodium acetate and ethanol. The conversion of NaOH was determined to be 0.557 at 504 seconds with a conductivity of 8079.4 microsim/cm. As the concentrations move through the plug flow reactor, the concentrations of the products increase and the concentrations of the reactants decrease. When the two reactants had less contact time in the plug flow reactor, there was a reduction in the conversion. The experimental data shows that the plug flow reactor is not an ideal reactor due to the step response having an inclination instead of being instantaneous. However, the experimental step is shown to be close to its ideal step thus suggesting that the real plug flow reactor produces near ideal behavior.

VI. References

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- Lower, Stephen. "8.10.9B: The nature of ions in aqueous solution" Chemistry LibreTexts. Mar. 3, 2021. Web. Accessed 3/31/2021. [https://chem.libretexts.org/Bookshelves/General_Chemistry/Book%3A_Chem1_\(Lower\)/08%3A_Solutions/8.10%3A_Ions_and_Electrolytes/8.10.9B%3A_8.10.9B%3A_The_nature_of_ions_in_aqueous_solution](https://chem.libretexts.org/Bookshelves/General_Chemistry/Book%3A_Chem1_(Lower)/08%3A_Solutions/8.10%3A_Ions_and_Electrolytes/8.10.9B%3A_8.10.9B%3A_The_nature_of_ions_in_aqueous_solution)
- Weedmark, David. "How to Calculate Conductivity Due to Concentration". Sciencing. Mar. 9, 2018. Web. Accessed 3/31/2021. <https://sciencing.com/calculate-conductivity-due-concentration-2691.html>

AVERAGE

Prairie View A&M University
Chemical Engineering Department



Lab #2: Determine the conversion of the Tubular Flow Reactor

Shimere Gregory, Cherish Vaughn, Alexis Lovelace, Irene Attah

Due Date: 04/27/2022

Date Conducted: 04/20/2022



V10

Abstract

The objective of this lab is to figure out the conversion factor (X) for a given set of conditions of the tubular flow reactor. A conversion factor is the glue between different units and is always equal to 1. If the conversion factor is wrong, it will make the conversion incorrect, and that could have grave and unintended consequences in high stakes situations. This is important because a tubular reactor, also known as a plug flow reactor, is usually large scale and used for fast reactions and continuous production. There are high conversions per unit volume, low labor cost and good heat transfer in a PFR, but poor temperature control. When discussing PFRs, there is either one big tube or many short reactors in a tube bank. For the procedure, 3 liters of 0.1 M sodium hydroxide and EtOAc are made and both pumps are switched on using the software. The reaction runs for 20 minutes or until a steady state is gotten. Both flow rates of the compounds are found and recorded. For the results, in the conductivity curve, steady state is achieved at 290s, and steady state conversion is obtained at a total conductivity of 8,000 microS/cm. Between conversion and time, as time increases the conversion rate decreases, coming to a steady state at 290s, same as the previous finding. The calibration curve is a downward slope, showing that as conductivity increases, conversion decreases. In conclusion, we were able to get a conversion factor from using the first and second order reactions and plugging that in with computerized systems and tank reactors. Steady state was achieved.

Theory

The reaction:



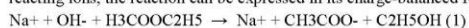
Sodium Hydroxide (A) + EthylAcetate (B) → SodiumAcetate (C) + EthylAlcohol(D)

can be considered equi-molar and first-order with respect to both sodium hydroxide and ethyl acetate –and second-order overall, within the limits of concentration (0 -0.1M) and temperature (20 -40°C) studied. It is known that 1 mol of ethyl acetate reacts with 1mol of NaOH. A mass balance can be conducted over the reactor (at steady state), in terms of the two molar feed flows (FA and FB), resulting in an expression for the fractional conversion of NaOH (component A), X_A , is as follows:

$$X_A = \frac{\text{A consumed in reactor}}{\text{A fed to reactor}} = \frac{(\text{A fed to reactor} - \text{A leaving reactor})}{\text{A fed to reactor}}$$

The reaction is carried out in 3, 0.7 L tanks connected in series. The tanks eventually reach steady state when a certain conversion of the starting reagents is achieved. A steady-state condition for this saponification reaction can be observed by continuously monitoring changes in the specific electrical conductance or conductivity (κ) of the effluent that are caused by changes in the concentrations of ions present in the effluent. It is assumed that a “flattening” of the conductivity curve $-\kappa(t)$ vs. t in a tank reactor indicates that the tank has achieved its steady-state conversion, X .

To understand the connection between $\kappa(t)$ and $X_A(t)$, we must first recognize that this saponification reaction occurs in a partially electrolytic solution. Rewritten in terms of its reacting ions, the reaction can be expressed in its charge-balanced form:



The reacting mixture features a measurable specific conductance due to the presence of the ionic species Na^+ , OH^- , and COO^- (representing acetate.) And the conductivity, $\kappa(t)$, of the reacting mixture is linearly dependent on the concentration of these ionic species in solution, and additive. As such, $\kappa(t)$ can be expressed as a sum of the contributions of Na^+ , OH^- , and COO^- based on their respective concentrations (C_{Na^+} , C_{OH^-} , and C_{COO^-}) and molar conductivities (Λ_{Na^+} , Λ_{OH^-} , and Λ_{COO^-}) as follows:

$$\kappa(t) = C_{\text{Na}^+}(t) \cdot \Lambda_{\text{Na}^+} + C_{\text{OH}^-}(t) \cdot \Lambda_{\text{OH}^-} + C_{\text{COO}^-}(t) \cdot \Lambda_{\text{COO}^-} \quad (2)$$



$$(t) = F_{\text{Na}^+} V_{\text{Na}^+} + F_{\text{OH}^-} V(t) \cdot \Lambda_{\text{OH}^-} + F_{\text{COO}^-} V(t) \cdot \Lambda_{\text{COO}^-} \quad (3)$$

$$(t) = V_0 C_{\text{OH}^-} - 0.2 V_0 \Lambda_{\text{Na}^+} + V_0 C_{\text{OH}^-} - 0(1-X) 2 V_0(t) \cdot \Lambda_{\text{OH}^-} + V_0 C_{\text{OH}^-} - 0 X 2 V_0(t) \cdot \Lambda_{\text{COO}^-} \quad (4)$$

$$(t) = C_{\text{OH}^-} - 0.2 \Lambda_{\text{Na}^+} + C_{\text{OH}^-} (1-X) 2(t) \cdot \Lambda_{\text{OH}^-} + C_{\text{OH}^-} X 2(t) \cdot \Lambda_{\text{COO}^-} \quad (5)$$

$$(t) = C_{\text{OH}^-} - 0.2 \Lambda_{\text{Na}^+} - C_{\text{OH}^-} 0.2(t) \cdot \Lambda_{\text{OH}^-} - C_{\text{OH}^-} X 2(t) \cdot \Lambda_{\text{OH}^-} + C_{\text{OH}^-} X 2(t) \cdot \Lambda_{\text{COO}^-} \quad (6)$$

$$X = (t) = C_{\text{OH}^-} - 0.2 \Lambda_{\text{Na}^+} - C_{\text{OH}^-} 0.2(t) \cdot \Lambda_{\text{OH}^-} - C_{\text{OH}^-} 0.2(\Lambda_{\text{COO}^-} - \Lambda_{\text{OH}^-}) - 2(t) = C_{\text{OH}^-} 0(\Lambda_{\text{Na}^+} + \Lambda_{\text{OH}^-}) - C_{\text{OH}^-} 0(\Lambda_{\text{COO}^-} - \Lambda_{\text{OH}^-}) \quad (7)$$

Procedure

- 1) Make up 3 liters of 0.1 M of NaOH and 3 Liters of 0.1M of EtOAc.
- 2) Open the software, click START and input a file name to save your data.
- 3) Switch on both pumps using the software and adjust (if necessary) the flow rates to ~6 L/Hour for each feed; check that the product discharges into the product bottle.
 - a. Note: for our actual experiment, AB-1 is set at ~50 and AB-2 is set at ~55, approximately pumping fluid at ~5L/Hour.
- 4) Click on the icon for Take data and change the periodic time to 5 seconds.
- 5) Let the reaction run for 15-25 minutes, or until the reactor has reached a steady state.
- 6) Note the following readings: Flow rates of NaOH and EtOAc, and the conductivity readings.
- 7) Write down the steady-state conductivity value and use eq. (7) in the theoretical section to calculate the value of the limiting reactant conversion.

Results & Discussion

The graph obtained in figure 2 shows the relationship between conversion and time. Steady state begins at the start of the reaction and towards the end around 290 seconds. Once achieved it is maintained at steady state for the rest of the time interval.

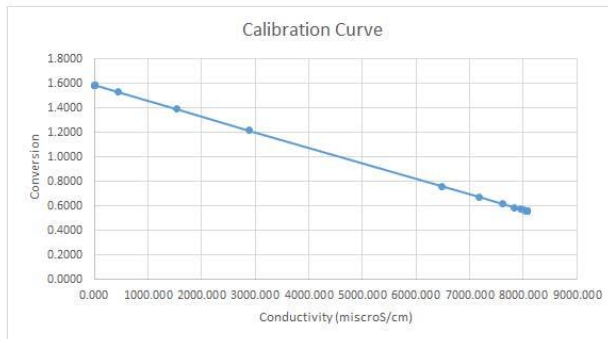


Figure 3 : Conversion vs. Conductivity

The conversion achieved at steady state is obtained in figure 3. As shown as the conductivity is increased the conversion decreases until it is close to reach steady state.

The fluid dynamic resident time t_r is obtained by dividing the volume of the tubular reactor by the volume flow which means it will take more than 4 minutes for the plug to move from the input to the output and has a fast reaction time according to the Da number.

Conclusion

As we conclude the purpose of this lab was to figure out the conversion factor for a given set of conditions of the tubular flow reactor. We learned that a tubular flow reactor or PFR reactor is usually used for a fast and continuous process, which is important if conversion is wrong and could lead to drastic results. As for our results the conductivity curve, steady state is achieved at 290s, and steady state conversion is obtained at a total conductivity of 8,000 microS/cm. Between conversion and time, as time increases the conversion rate decreases, coming to a steady state at 290s, same as the previous finding. The calibration curve is a downward slope, showing that as conductivity increases, conversion decreases. In the figure above we can see the relationship between conversion and conductivity, like figure 1 we can see that we reach steady state and with an conductivity about 8 thousand micro per seconds. Figures 2 and 3 also express

that the value of Λ increases as the conversion factors decrease as time progresses and when Λ remains constant, time versus conversion showing a flat line which expresses there is no conversion and have reached a steady state.



BELOW AVERAGE

Roy G. Perry
College of Engineering



CHEG 4104 - Chemical Engineering Lab III

Experiment 2: Reaction Kinetics in PFR Reactor

Instructor: Dr. Jorge F. Gabitto

Team 1 Members:

Jacquelyn Fuller
Kennedi Henderson
Taylon Owens
Amiya Rogers
Alessia Williams



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ABSTRACT

The goal of this experiment is to determine the conversion factor X for a given set of conditions of a tubular reactor. Sodium hydroxide (C_A) and ethyl acetate (C_B) are used as reagents in this procedure. Here, three equal volumes continuously stirred tank reactors are carried out in series and this takes place in an electrolytic solution. At the end of the procedure, a steady state needs to be achieved by the tanks and this is recorded once the desired conversion of the reagents are achieved, thereby leading to the relationship between conductivity and conversion.



THEORY



Sodium Hydroxide + Ethyl Acetate → Sodium Acetate + Ethyl Alcohol

This reaction can be considered equimolar and first-order with respect to both sodium hydroxide (NaOH) and ethyl acetate ($\text{H}_3\text{COOC}_2\text{H}_5$) and second-order overall, within the limits of concentration from 0-0.1M and temperature from 20-40°C studied. It is known that 1 mol of ethyl acetate reacts with 1 mol of NaOH. A mass balance can be conducted on the reactor (steady state), in terms of two molar feed flows (F_A and F_B) resulting in an expression for the fractional conversion of NaOH (X_A):

$$X_A = \frac{A \text{ consumed in reactor}}{A \text{ fed to reactor}} = \frac{A \text{ fed to reactor} - A \text{ leaving reactor}}{A \text{ fed to reactor}}$$

(2)

Or,

$$X_A(t) = \frac{F_{A,i} - F_{A,t}}{F_{A,i}}$$

(3)

The reaction is carried out in 3, 0.7L tanks connected in series. The tanks eventually reach steady state when a certain conversion of the starting reagents is achieved. A steady-state condition for this saponification reaction can be observed by continuously monitoring changes in the specific electrical conductance or conductivity (k) of the effluent that are caused by changes in the concentrations of ions present in the effluent. It is assumed that a “flattening” of the conductivity curve- $k(t)$ vs t in a tank reactor indicates that the tank has achieved its steady-state conversion, X_A^{ss} .

To understand the relationship between $k(t)$ and $X_A(t)$, we must first recognize that this saponification reaction occurs in a partially electrolytic solution. Rewritten in terms of its reacting ions, the reaction can be expressed in its charge-balanced form:



The reacting mixture features a measurable specific conductance due to the presence of the ionic species Na^+ , OH^- , and COO^- . The conductivity, $k(t)$ of the reacting mixture is linearly dependent on the concentration of these ionic species in solution, and additive. As such, $k(t)$ can be expressed as a sum of the contributions of Na^+ , OH^- , and COO^- based on their respective concentrations (C_{Na^+} , C_{OH^-} , and C_{COO^-}) and molar conductivities (Λ_{Na^+} , Λ_{OH^-} , and Λ_{COO^-}) as follows:

$$\kappa(t) = \frac{F_{\text{Na}^+}}{V} \Lambda_{\text{Na}^+} + \frac{F_{\text{OH}^-}}{V} (t) \cdot \Lambda_{\text{OH}^-} + \frac{F_{\text{COO}^-}}{V} (t) \cdot \Lambda_{\text{COO}^-} \quad 5$$

$$\kappa(t) = \frac{\dot{V}^o C_{\text{OH}^-}^0}{2 \dot{V}^o} \Lambda_{\text{Na}^+} + \frac{\dot{V}^o C_{\text{OH}^-}^0 (1-X)}{2 \dot{V}^o} (t) \cdot \Lambda_{\text{OH}^-} + \frac{\dot{V}^o C_{\text{OH}^-}^0 X}{2 \dot{V}^o} (t) \cdot \Lambda_{\text{COO}^-} \quad 6$$

$$\kappa(t) = \frac{C_{\text{OH}^-}^0}{2} \Lambda_{\text{Na}^+} + \frac{C_{\text{OH}^-}^0 (1-X)}{2} (t) \cdot \Lambda_{\text{OH}^-} + \frac{C_{\text{OH}^-}^0 X}{2} (t) \cdot \Lambda_{\text{COO}^-} \quad 7$$

$$\kappa(t) - \frac{C_{\text{OH}^-}^0}{2} \Lambda_{\text{Na}^+} - \frac{C_{\text{OH}^-}^0}{2} (t) \cdot \Lambda_{\text{OH}^-} = - \frac{C_{\text{OH}^-}^0 X}{2} (t) \cdot \Lambda_{\text{OH}^-} + \frac{C_{\text{OH}^-}^0 X}{2} (t) \cdot \Lambda_{\text{COO}^-} \quad 8$$

$$X = \frac{\kappa(t) - \frac{C_{\text{OH}^-}^0}{2} \Lambda_{\text{Na}^+} - \frac{C_{\text{OH}^-}^0}{2} (t) \cdot \Lambda_{\text{OH}^-}}{\frac{C_{\text{OH}^-}^0}{2} (\Lambda_{\text{COO}^-} - \Lambda_{\text{OH}^-})} = \frac{2 \kappa(t) - C_{\text{OH}^-}^0 (\Lambda_{\text{Na}^+} + \Lambda_{\text{OH}^-})}{C_{\text{OH}^-}^0 (\Lambda_{\text{COO}^-} - \Lambda_{\text{OH}^-})} \quad 9$$

————— { 5 } —————

PROCEDURE

- 1) Make up 3 liters of 0.1 M of NaOH and 3 Liters of 0.1M of EtOAc.
- 2) Open the software, click START and input a file name to save your data.
- 3) Switch on both pumps using the software and adjust (if necessary) the flow rates to ~6 L/Hour for each feed, check that the product discharges into the product bottle. a. Note: for our actual experiment, AB-1 is set at ~ 50 and AB-2 is set at ~55, approximately pumping fluid at ~5L/Hour.
- 4) Click on the icon for Take data and change the periodic time to 5 seconds.
- 5) Let the reaction run for 15-25 minutes, or until the reactor has reached a steady state.
- 6) Note the following readings: Flow rates of NaOH and EtOAc, and the conductivity readings.
- 7) Write down the steady-state conductivity value and use eq. (7) in the theoretical section to calculate the value of the limiting reactant conversion.

RESULTS

From the obtained results, graphs are plotted. The graphs below show plots of conductivity and real tank reactor conversion against and time. In addition, there is a graphical representation of conversion as a of function conductivity to analyze the tank reactor's conversion varies and relates with the conductivity. As shown, time (t) is the independent variable whereas the conductivity and the reactor's conversion are the dependent parameters which vary with time. Below are graphs:

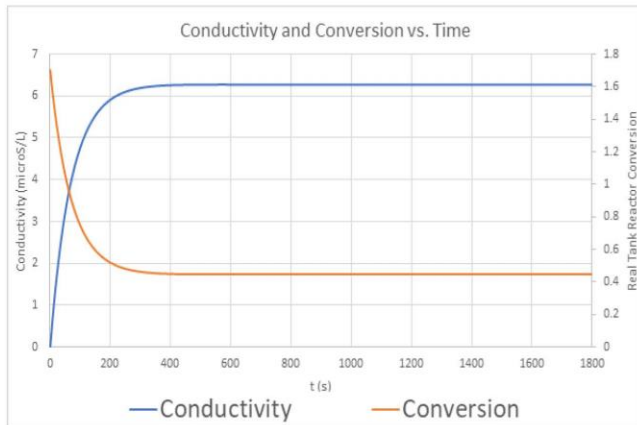


Figure 1: Graph of Conversion and Conductivity against time

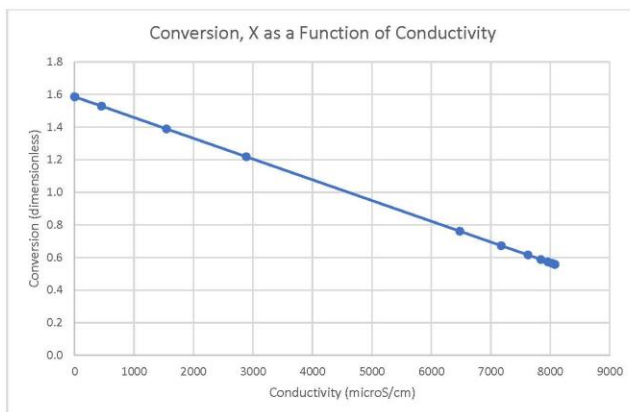


Figure 2: Graph of Reactor's Conversion against Conductivity



DISCUSSION

Based on the two sets of data points recorded, graphs were plotted. The above graphs *Figure 1* and *Figure 2* are graphical representation the results. *Figure 1* shows how the conductivity and real tank reactor conversion against vary with time. *Figure 2* on the other hand, shows a graphical representation of conversion as a function of conductivity to analyze the tank reactor's conversion varies and relates with the conductivity.

In *Figure 1*, the fractional conversion of the NaOH is varied with time. Also, the conductivity of the reaction plotted against time is observed to rise from 0 to about a constant rate of 6.2 microS/L at time 300s. Conversion also is recorded for time 0 to be 0.45 and remains at steady state constants value till time 1600s when it begins to steadily increases to about 1.7 which in actuality is not possible. The highest attainable conversion is 1 which will only happen in a perfectly ideal

system. With all the entropy in this world it is just not possible. This means all the reactants will be consumed at the time 0s to 1700s. The conversion and the conductivity intersect at time 300s.

In *Figure 2*, the conversion can be described as inversely proportional to the conductivity for this particular experiment. The conductivity increases as the conversion decreases. The conversions in both *Figure 1* and *Figure 2* are calculated from equation (7) from the theory. From analyzing the results, it can be inferred that the reactor used in this experiment behaves as a real reactor.

CONCLUSION

The goal of this experiment is to determine the conversion factor X for a given set of conditions of a tubular reactor. Using a Tubular Reactor, two reagents (NaOH and E_tOAc), were fed through the reactor, it was then mixed to let it react with respect to time. Using the collected data recorded by the conductive meter, located at the output we have concluded that the conductivity and the conversion are inversely proportional. We can see in figure 1 that as conductivity increases, conversion decreases with time. Both eventually converges, reaching steady state at approximately 325s. Likewise, in Figure 2 we observed that as the conductivity increases, the conversion decreases. After our observation, we deduced that the reactor used here behaves as a real reactor.

REFERENCES

Virtual Lab 4 Lecture:

https://pypanther.zoom.us/rec/play/SMtriQ1n2jkthMRPsC8ooH4uGBJMiu_aGMFj-8C7Bl_SkLw2-j_0vjhBsLUhYE2gVpTnBqVYvNwotp6g.KfbRLnlf6eRUL6lD?continueMode=true&x_zm_rtaid=6s9s-qH7TDvX8omL08IFvw.1619711424432.d5468ba994f68db9458a9ff2b6f7011d&x_zm_rhtaid=866

Virtual Experiment IV, QRFT Introduction to the equipment:

<https://www.youtube.com/watch?v=-OHnTwLN85M>

**CHEMICAL ENGINEERING LAB. III
SPRING 2022**

Title of Assignment: REPORT 3

TOPICS COVERED IN REPORT 3

Report 3 covered the following topic:

1. To investigate Level Response in a Single Tank with a Drain in Open and Closed Loop Systems using the Edibon CEAC Controller Tuning Trainer. (Expt. No. 3)

Objective

1. To make a qualitative comparison of the response of a first order system (a tank with a drain) in:
 - a. An open loop configuration set to different set point values.
 - b. A closed loop system in PID control using an industrial controller.
2. To calculate the values of k_p and $k_p K_{max}$ for the open loop system.

ABOVE AVERAGE



Experiment #: Investigating Level Response in a Single Tank with a Drain in Open
and Closed Loop Systems

CHEG 4104-PO1

Submit to: Dr.Gabitto

Submitted by : Cinthia Sahin , Rafid Matti , Reema Matti

Due Date: May 01, 2022



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Abstract

Industrial processes require specific levels to be maintained to ensure a process is carried out to completion. Level control is also needed to maintain a safe operating environment and ensure equipment is within good working condition. The purpose of this experiment is to analyze the level response in a single tank with a drain, comparing the qualitative results of both the open and closed loop systems. An additional goal of this experiment is to calculate τ_p (time constant) and $\kappa_p K_{max}$ for the open loop system. The experiment was carried out using the Edibon CEAC Controller Tuning Trainer. The experiment involves running an open loop and closed loop simulation, three runs for each, and changing the proportional gain, integral time for different runs. The resulting data was graphed and calculations were made in order to analyze and compare results of each configuration. From the data it can be said that the open loop control system has a larger steady state error than that of the closed loop system. This could be due to the inability to make adjustments automatically from feedback given. The closed system shows slight oscillation in some graphs, but overall has less offset error than that of the open loop control system.

Theory

Proportional-integral-Derivative (PID) is known to be one of the most common control algorithms used in the industry not to mention its been universally accepted in industrial control. PID controllers are simple to use and can function a wide range of operating conditions. CEAC is one of the many software that can help us investigate the level response in a single tank with a drain in an open and closed loop system. The tank consists of an inlet stream, outlet stream, flow resistor, level transmitter, and a proportional pneumatic valve. The proportional pneumatic valve is controlled by compressed air, by applying that pressure it allows how much the valve opens and closes thus regulating the level in the tank. The first order level control system is formed with water in the tank with $15m^3$ and a flow resistance of $1.5Ns/m^5$. These parameters were gathered by the output function. The output response is calculated by the inverse laplace transform. In the industries, control engineers use PID to control input, desired operating values, and current plant process values.

The Valve equation: V is the flow rate, K_{max} is the linear constant, and P is the pressure signaled from the controller:

$$V = K_{max} P \quad (1)$$

τ_p is the time it takes for 63.2% of the steady state value, therefore;

$$\tau_p = 63.2(\text{Steady State})/100 \quad (2)$$

$$\tau_p = K_p A \quad (3)$$

$$Y(s) = \frac{k_p K_{max} \Delta u}{(\tau_p s + 1)s} \quad (4)$$

$$L(t) = k_p K_{max} \Delta u [1 - e^{-t/\tau_p}] \quad (5)$$

$$\lim_{s \rightarrow 0} s Y(s) = k_p K_{max} \Delta u \quad (6)$$

$$TF_{global}(s) = \frac{k_p K_{max}}{\tau_p s + 1} \quad (7)$$

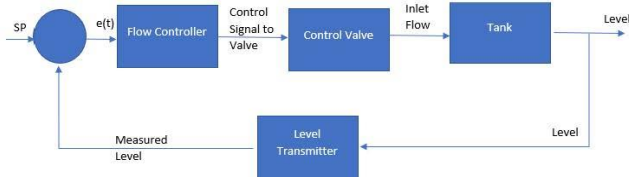


Figure 1. In a closed loop system is an automatic control system in which an operation process is regulated by feedback

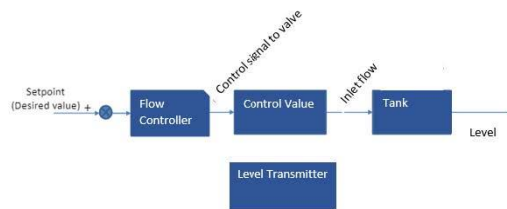


Figure 2. In an open loop system the output signal or condition is neither measured nor fed back for comparison with the input signal or system set point.

Procedure

The CEAC software is used to simulate the controller by first opening the program and selecting start. The level controller will be operated under an open loop configuration which is why the appropriate box must be selected in step 1 as seen in the instructions below. This means that the measurement signal will not be used to send feedback to the controller, rather it will operate in manual mode. The proper parameters are set in steps 2-3 by entering the values into the corresponding box. The area of 15 m^2 is given and refers to the area of the tank while the resistance refers to the flow rate. A proportional term of 30%, an integral time of 0 sec and a derivative time of 0 sec is entered as described in step 6. The initial set point value is set to 0 m and then set to 5 m after introducing a disturbance. After the first order system stabilizes and steady state has been reached, the data must be stopped. This procedure is repeated twice more for the open loop configuration, with a $K_p = 10\%$ and finally, with a $K_p = 50\%$. The values of these terms are changed to investigate the control response while maintaining a level of 5 m.

The open loop box must not be selected for the closed loop portion of the experiment as described in step 1 of the closed loop instructions. The closed loop system allows for feedback control. The control variable is being measured and the measurement signal is being compared to

the set point. The difference is fed to the controller and the controller determines how the flow rate should be changed. The proportional gain is set to 50 %, the integral time is set to 5 sec, and derivative time set to 0 sec as explained in step 6. The set point is changed from 0m to 5m. The valve position, or the percentage that the valve is opened is also measured in this step. The closed loop process is repeated twice. Once with $K_p = 30\%$, integral time = 5 sec, derivative time = 0 sec. Lastly, the process will be set with parameters $K_p = 50\%$, integral time = 5 sec, and derivative time = 0 sec. Changing the values of K_p and integral time allows for the investigation of control response while maintaining a level of 5 m in a closed loop system.

Instructions:

Open Loop

1. Check the "Open Loop" Checkbox in the "Systems" Box.
2. Choose the "first order system" in the "Systems" Box and set a tank area of 15m² with an output flow resistance of 1.5 N*s/m⁵ and delay time (DT) = 0 s. The other parameters, time constant and gain are not accessible.
3. Adjust the period and amplitude of the Time Graph to 200 s/Div. and with 2.5 A/Div, respectively.
4. Click "Load System" to start.
5. Click Save Data. You will notice that the Time Graph displays the SP and PV.
6. Choose a value of PROPORCIONAL BAND (K_p) = 30%. Maintain INTEGRAL TIME(s) and DERIVATIVE TIME (s) at zero.
7. Set the initial Set Point value at 0 m and the final Set Point value at 5 m.
8. Check that the first order system stabilizes. Estimate the (i) time constant, τ_p (ii) the time taken for the system to stabilize and (iii) the offset between amplitudes of the level (PV) and the setpoint (SP).
9. Repeat for $K_p = 10\%$ and 50%

Closed Loop

1. Ensure that the "Open Loop" Checkbox in the "Systems" Box is unchecked.
2. Choose the "first order system" in the "Systems" Box and set a tank area of 15 m² with an output flow resistance of 1.5 N*s/m⁵ and delay time (DT) = 0 s. The other parameters, time constant and gain are not accessible.

3. Adjust the period and amplitude of the Time Graph to 200 s/Div. and with 2.5 A/Div, respectively.
4. Click "Load System" to start.
5. Click Save Data. You will notice that the Time Graph displays the SP, PV and OP – the proportional pneumatic valve position.
6. Choose a value of PROPORCIONAL BAND (KP) = 30%, INTEGRAL TIME(s) = 0 and DERIVATIVE TIME (s) = 0.
7. Set the initial Set Point value at 0 m and the final Set Point value at 5 m.

The Edibon CEAC control system consists of a tank with a drain that allows for water to flow out. The inlet is connected to a proportional pneumatic valve that increases or decreases the flow rate by opening and closing. An overflow sensor and level transmitter, which sends the signal to the controller. A schematic for the Edibon CEAC system can be seen below in Figure 3.

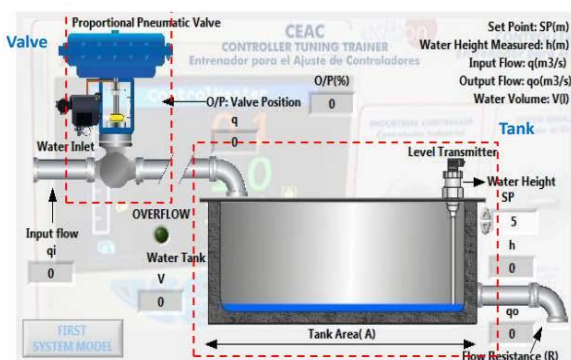


Figure 3 . A schematic of the Edibon CEAC Control Simulator

Results and Discussion

This experiment was carried out for three different proportional open loop systems and three different closed loop systems. Two consisting of proportional and integral control, and one that is proportional only. Figure 4 below shows the graphs for the open loop systems and Figures 5 and 6 are the closed loop systems.

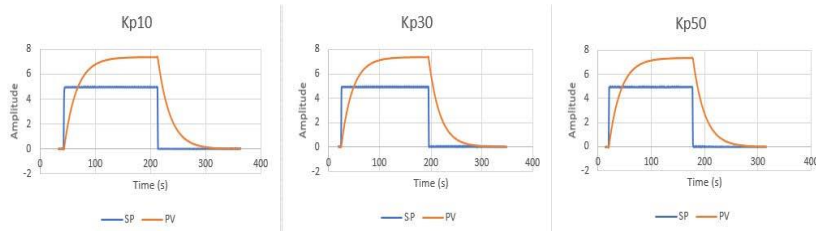


Figure 4. Comparison of open loop control system with different K_p values

For the open loop system, similar behaviors are observed every time the set point is changed. When the set point is increased to 5 meters, an observation in all three graphs is that the process variable overshoots the set point by approximately 2.4 meters to 2.5 meters, before it reaches steady state. All three of the graphs in Figure 4 show direct, monotonic, and stable responses creating an offset from the set point. The set point and process variable then converge as the set point is manipulated to zero.

The time, setpoint, and process variable data were given for the entirety of the experiment. The data for K_p , Proportional band percentage of 10%, 30%, and 50% were analyzed and used for calculating the τ_p (Equation 2), and $K_p K_{max}$ (Equation 6), which were then used to find the Global Transfer Function (Equation 7).

Using the graphs in figure 4, the steady state was approximated. The data in Table 1 shows the calculations that were done.

Table 1: Calculation for finding the Global Transfer functions for the three open loop systems

	$K_p = 10\%$	$K_p = 30\%$	$K_p = 50\%$
Steady State (m)	7.38	7.389	7.383
Time of Stability (s)	187	184	168
$e(t)$ (m)	2.42	2.47	2.42

Taup (s)	66	46	42
Kp (s/m ²)	4.4	3.1	2.8
Kmax	0.33	0.47	0.52
kpkmax	1.452	1.457	1.456
TF Global (s)=	1.452/(66s+1)	1.457/(46s+1)	1.456/42s+1)

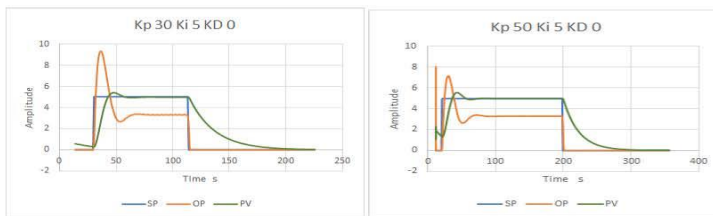


Figure 5. Comparison of PI control for closed loop system with different K_p values

For the closed loop system, different behaviors are observed each time a step or set point is changed in the system. A qualitative observation on Figure 5 shows that when the set point is increased to 5 meters in the tank, the level over shoots the set point before a short oscillation is observed, which quickly steadies. This transformation, or system reaction to the setpoint change, can be summarized as direct, oscillatory and convergent. The inlet flow valve opening, OP, also reacts to the set point change in a direct proportion to achieve steadying of the flow. When the system's setpoint is taken back down to zero, the system reacts successfully because of its direct, monotonic and convergent behavior.

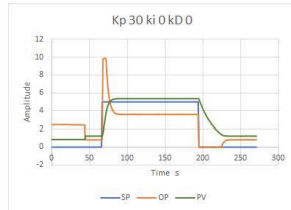


Figure 6 P- only closed loop system

Figure 6, also is also a closed loop system, such as Figure 5, but with the integral and derivative values both set to zero, the system reacts differently. When the level is set to 5 meters, the behavior is direct, monotonic and divergent, which means the system yields an offset or a steady-state error at approximately 0.5 meters. Although the margin of error increases by about 1 meter, the same behaviour is observed when the setpoint is taken back down to zero.

Conclusion

Comparisons of the systems, close and open loops, show that the open loop not only creates a steady-state error when the setpoint is raised, but that it is much bigger compared to that of the closed loop. Not having a feedback response created the opportunity for a much larger offset from the setpoint. Due to this, it is recognizable that all of the graphs look very similar even though the Proportional band percentages were different.

It can be observed in Figures 5 and 6 that the only resulting offset is very close to the size of the step. This indicates that closed loops can better control processes than open loops. The two systems show little to no difference when the system's setpoints are returned to zero which might be because at that point, the two systems allow little to no flow into the tank. If the setpoints were reduced to 1 meter instead of zero, it might have given a better indication of how these systems behave in a step down situation.

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AVERAGE

Prairie View A&M University
Roy G. Perry College of Engineering
Department: Chemical Engineering



CHEG 4104- P01

Chemical Engineering Laboratory III

Lab Experiment #3:

Open and Closed – Loop Control in a Tank

Group #1

Lab Completed: April 11, 2022

Submitted by

Chiebuka Ejimadu
Oluwatoyosi Idowu
Chinenye Ihe
Tyree Madison

Submitted to

Dr. Jorge Gabitto

proportional to the rate of change of the error. The “D element” is sensitive to disturbances. This element is capable of making an estimation of the future error and can decrease or increase the speed of corrections.

Equation (1) below is the equation of the level curve recorded during the experiment. Utilizing the final value theorem, the long-term value is given by,

$$\lim_{s \rightarrow 0} sY(s) = k_p k_{max} \Delta u \quad (1)$$

The result from this equation proves that there is an offset in the open loop response as Δu is multiplied by the factor $K_p K_{max}$.

$$L(t) = k_p K_{max} \Delta u \left[1 - e^{-\frac{t}{\tau_p}} \right] \quad (2)$$

After manipulation we can use it to find τ_p .

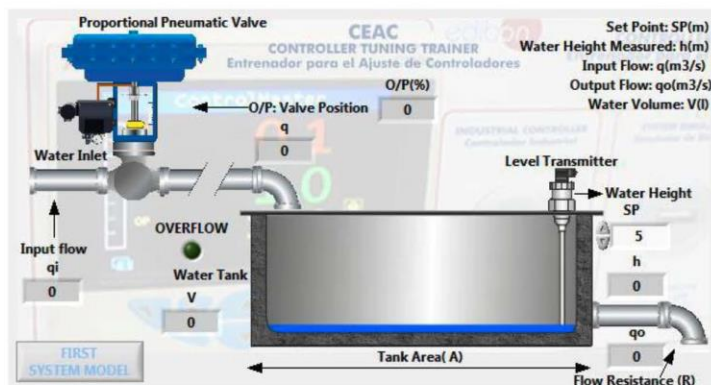
$$TF_{global}(s) = \frac{k_p K_{max}}{\tau_p s + 1} \quad (3)$$

This equation is the product of the transfer functions in the open system. As previously stated, the lab will prove pivotal in analyzing the system to differentiate key aspects of an open and closed system as well as analyzing the set point under different process conditions to investigate how the system is maintained.



Procedure

Equipment



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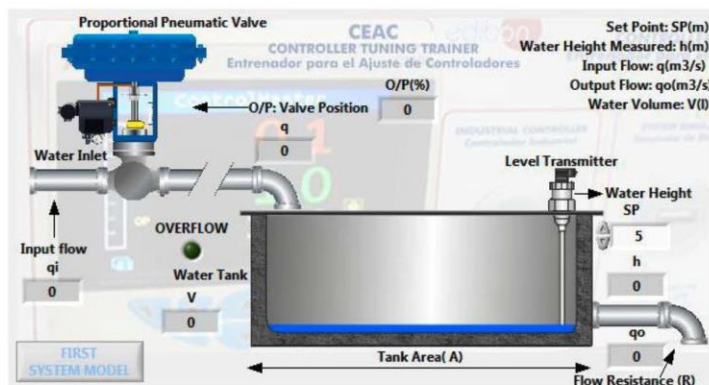
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This equation is the product of the transfer functions in the open system. As previously stated, the lab will prove pivotal in analyzing the system to differentiate key aspects of an open and closed system as well as analyzing the set point under different process conditions to investigate how the system is maintained.



Procedure

Equipment



Open Loop System Method

1. In “Systems” box, check “Open Loop”.
2. In “Systems” box, choose “first order system” and ensure tank area was set to 15 m^2 with output flow resistance set to 1.5 Ns/m^5 with a delay time (DT) of 0s.
3. Adjust period and amplitude graph by setting s/Div to 200 and Amp/Div to 2.5.
4. Click “Load System” to start and save data
5. Set proportional band (K_p) to 30% and maintain integral and derivative time to 0.
6. Set initial set point to 0 m and final set point to 5 m.
7. Repeat for proportional bands (K_p) equating 10% and 50%.

For the three (3) trials with different proportional bands (10%, 30%, & 50%), ensure that the first order system stabilizes. Once stable, estimate the time constant, τ_p , the time taken for the system to stabilize, and the offset between amplitudes of the level (PV) and the setpoint (SP).

Closed Loop System Method

1. In “Systems” box, uncheck “Open Loop”

Figure 1. Schematic diagram of Edibon’s CEAC Controller Tuning Trainer open loop system.

2. In “Systems” box, choose “first order system” and ensure tank area was set to 15 m^2 with output flow resistance set to 1.5 Ns/m^5 with a delay time (DT) of 0s.
3. Adjust period and amplitude graph by setting s/Div to 200 and Amp/Div to 2.5.
4. Click “Load System” to start and save data
5. Set proportional band (K_p) to 30% and maintain integral and derivative time to 0.
6. Set initial set point to 0 m and final set point to 5 m.
7. Repeat for proportional band (K_p) = 30%, integral time(s) = 5, derivative time(s) = 0, and proportional band (K_p) = 50%, integral time(s) = 5, and derivative time (s) = 0.

For the three (3) trials with different proportional bands (10%, 30%, & 50%), ensure that the first order system stabilizes. Once stable, estimate the time constant, τ_p , the time taken for the system to stabilize, and the maximum offset between amplitudes of the level (PV) and the setpoint (SP).

Results and Discussion

Open loop system is a type of process control system where the control variable is independent of the process output variable. The measuring device is not connected to the controller meaning that the controller output is changed manually. This system is also known as manual mode or non-feedback system. Diagram 1 shows the open loop system for our experiment.

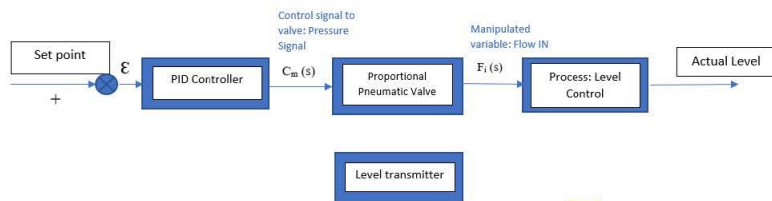


Diagram 1: Open Loop System

In figure 2, the offset is the difference between the amplitude of the level (PV) and the set point (SP). It was expected to be 2.431 m because it was derived from the highest recorded PV = 7.397 m and the highest SP = 4.966 m which was supposed to be 5 m.

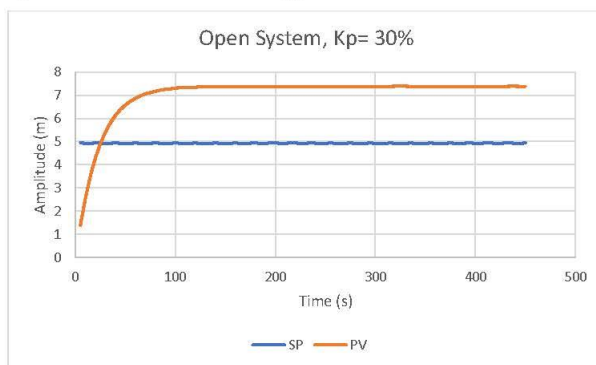


Figure 2: Open Loop System for $K_p = 30\%$

In figure 3, it shows the open loop system for $K_p = 50\%$, which resulted in similar trends when $K_p = 30\%$. The offset was calculated to be 2.434 m as the maximum PV = 7.395 m and maximum SP = 4.961 m. This shows the open system has a wider range for an offset between set point water level and actual level.

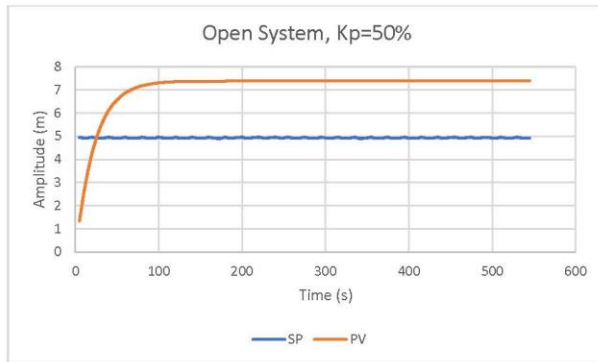


Figure 3: Open Loop System for $K_p = 50\%$

The Closed Loop system is a type of process control system that utilizes feedback signals to adjust itself to make sure it is at the desired set point. The control variable is dependent on the output variable. Diagram 2 shows the closed loop system for our experiment.

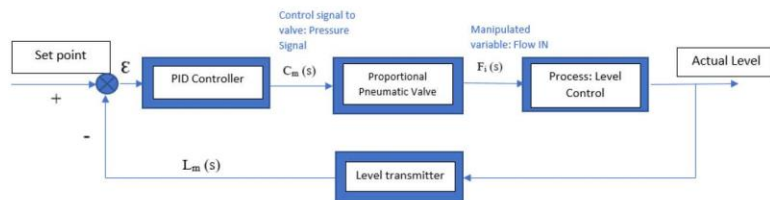


Diagram 2: Closed Loop System

Figure 4 - 7 illustrates the closed loop system for when the K_p is at 30% and 50% with changes to the integral time and derivative time. These graphs recorded the data of PV, SP, and OP, which is the position of the valve and how much of it is open in terms of percentage. 

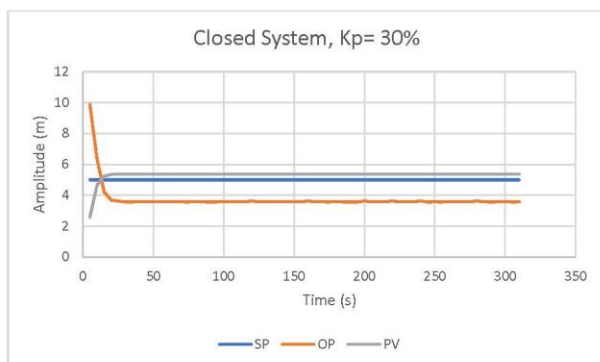


Figure 4: Closed Loop System for $K_p = 30\%$

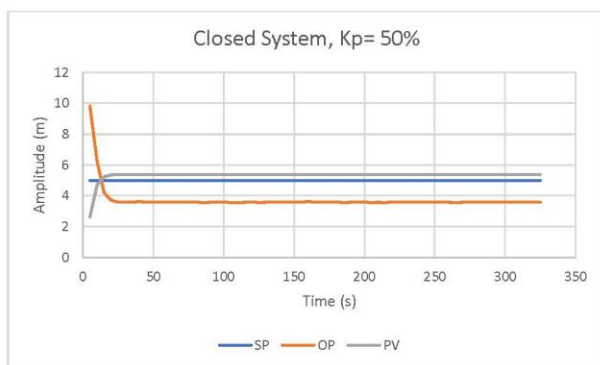


Figure 5: Closed Loop System for $K_p = 50\%$

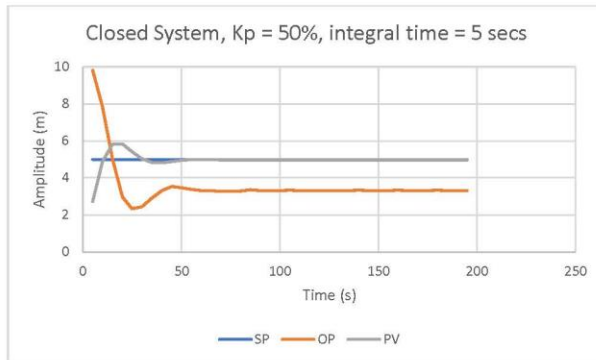


Figure 6: Closed Loop System for $K_p = 50\%$ and Integral Time = 5 secs

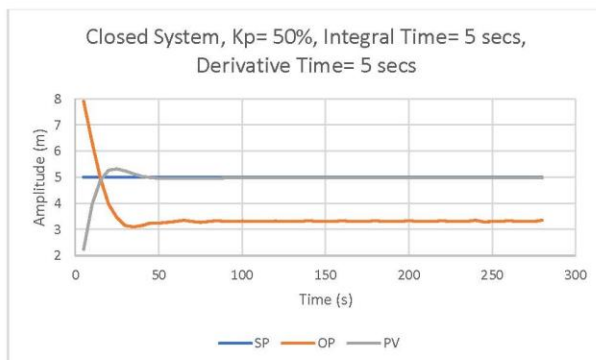


Figure 7: Closed Loop System for $K_p = 50\%$, Integral Time = 5 secs, and Derivative Time = 5 secs

Both types of systems are **significant and used** based on their need in the industry. The outputs of both systems often differ as the data and theory is backed up. Open loop systems have more offset than closed loop systems. For example, the open loop system had a larger offset of 2.434 m at $K_p = 50\%$ while the closed loop system had an offset of 0.374 m showing the difference in error and how the system is efficient in keeping desired conditions.

With the analysis of the data measured, we were able to record the level of the water, $L(t)$, in the tank over time, t . Based on the global transfer function, the open loop response is direct, monotonic, and convergent. With the equation below, we can find that the long-term value will converge to 7.5 m over time.

$$\lim_{s \rightarrow 0} sY(s) = k_p K_{max} \Delta u$$

Knowing that the change in U is 5 m, we can calculate that $k_p K_{max}$ will be 1.5. With the recorded data of $L(t)$ and t , we can find the τ_p using the formula below. At 315 secs, $L(t) = 7.391$ m. By manipulating the formula below and inserting the known values, we can derive that $\tau_p = 74.44$

$$L(t) = k_p K_{max} \Delta u [1 - e^{-t/\tau_p}]$$

To get the TF_{global} , we combined the known values that we calculated, which resulted to be .0199 or approximately 0.02.

$$TF_{global}(s) = \frac{k_p K_{max}}{\tau s + 1}$$

$$TF_{global} = \frac{1.5}{(74.44+1)} = .0199$$

Conclusion

For this experiment we are asked to make a qualitative comparison of the response of a first order system. We focused on two methods, open loop, and closed loop. We also needed to calculate the values of τ_p and $k_p K_{max}$ for the open loop system. For open loop, the response is direct, monotonic, and convergent. The long-term value will converge to 7.5 m over time, and $k_p K_{max}$ will be 1 and $\tau_p = 74.44$. We can conclude that open loop systems tend to have more of an offset than closed loop systems. We can see from the data that the open loop system had a larger offset of 2.434 m at $K_p = 50\%$ while the closed loop system had an offset of 0.374 m. This showed the difference in error and how efficient the system was at maintaining desired conditions.

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Prairie View A&M University
Chemical Engineering Department



Lab #3: Open and Closed-Loop Control in a Tank
CHEG 4104—P01 Chemical Engineering Lab III

Tiarra Rodrigues, Katelyn Inman, Jevaun Christie, Tyecia
Franklin, Abdul Zakir

Date Conducted: 02/28/2022

Submission Date: 03/21/2022

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Abstract

Industrial processes require specific levels to be maintained to ensure a process is carried out to completion. Level control is also needed to maintain a safe operating environment and ensure equipment is within good working condition. The purpose of this experiment is to analyze the level response in a single tank with a drain, comparing the qualitative results of both the open and closed loop systems. An additional goal of this experiment is to calculate τ_p (time constant) and $K_p K_{max}$ for the open loop system. The experiment was carried out using the Edibon CEAC Controller Tuning Trainer. The experiment involves running an open loop and closed loop simulation, three runs for each, and changing the proportional gain, integral time for different runs. The resulting data was graphed and calculations were made in order to analyze and compare results of each configuration. From the data it can be said that the open loop control system has a larger steady state error than that of the closed loop system. This could be due to the inability to make adjustments automatically from feedback given. The closed system shows slight oscillation in some graphs, but overall has less offset error than that of the open loop control system.

Theory

Proportional-integral-Derivative (PID) is known to be one of the most common control algorithms used in the industry not to mention its been universally accepted in industrial control. PID controllers are simple to use and can function a wide range of operating conditions. CEAC is one of the many software that can help us investigate the level response in a single tank with a drain in an open and closed loop system. The tank consists of an inlet stream, outlet stream, flow resistor, level transmitter, and a proportional pneumatic valve. The proportional pneumatic valve is controlled by compressed air, by applying that pressure it allows how much the valve opens and closes thus regulating the level in the tank. The first order level control system is formed with water in the tank with 15m^2 and a flow resistance of 1.5Ns/m^5 . These parameters were gathered by the output function. The output response is calculated by the inverse laplace transform. In the industries, control engineers use PID to control input, desired operating values, and current plant process values.

The Valve equation: V is the flow rate, K_{max} is the linear constant, and P is the pressure signaled from the controller.

$$V = K_{max}P \quad (1)$$

τ_p is the time it takes for 63.2% of the steady state value, therefore;

$$\tau_p = 63.2(\text{Steady State})/100 \quad (2)$$

$$\tau_p = K_p A \quad (3)$$

$$Y(s) = \frac{k_p K_{max} \Delta u}{(\tau_p s + 1)s} \quad (4)$$

$$L(t) = k_p K_{max} \Delta u [1 - e^{-t/\tau_p}] \quad (5)$$

$$\lim_{s \rightarrow 0} s Y(s) = k_p K_{max} \Delta u \quad (6)$$

$$TF_{global}(s) = \frac{k_p K_{max}}{\tau_p s + 1} \quad (7)$$

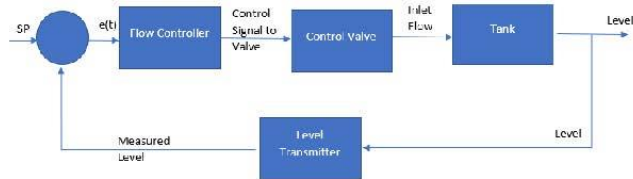


Figure 1. In a closed loop system is an automatic control system in which an operation process is regulated by feedback

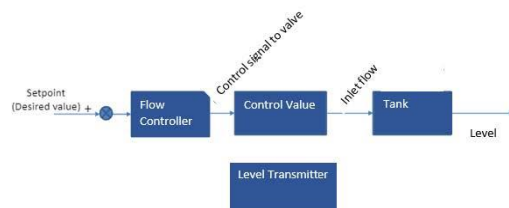


Figure 2. In an open loop system the output signal or condition is neither measured nor fed back for comparison with the input signal or system set point.

Procedure

The CEAC software is used to simulate the controller by first opening the program and selecting start. The level controller will be operated under an open loop configuration which is why the appropriate box must be selected in step 1 as seen in the instructions below. This means that the measurement signal will not be used to send feedback to the controller, rather it will operate in manual mode. The proper parameters are set in steps 2-3 by entering the values into the corresponding box. The area of 15 m^2 is given and refers to the area of the tank while the resistance refers to the flow rate. A proportional term of 30%, an integral time of 0 sec and a derivative time of 0 sec is entered as described in step 6. The initial set point value is set to 0 m and then set to 5 m after introducing a disturbance. After the first order system stabilizes and steady state has been reached, the data must be stopped. This procedure is repeated twice more for the open loop configuration, with a $K_p = 10\%$ and finally, with a $K_p = 50\%$. The values of these terms are changed to investigate the control response while maintaining a level of 5 m.

The open loop box must not be selected for the closed loop portion of the experiment as described in step 1 of the closed loop instructions. The closed loop system allows for feedback control. The control variable is being measured and the measurement signal is being compared to the set point.

The difference is fed to the controller and the controller determines how the flow rate should be changed. The proportional gain is set to 50 %, the integral time is set to 5 sec, and derivative time set to 0 sec as explained in step 6. The set point is changed from 0m to 5m. The valve position, or the percentage that the valve is opened is also measured in this step. The closed loop process is repeated twice. Once with $K_P = 30\%$, integral time = 5 sec, derivative time = 0 sec. Lastly, the process will be set with parameters $K_P = 50\%$, integral time = 5 sec, and derivative time = 0 sec. Changing the values of K_P and integral time allows for the investigation of control response while maintaining a level of 5 m in a closed loop system.

Instructions:

Open Loop

1. Check the "Open Loop" Checkbox in the "Systems" Box.
2. Choose the "first order system" in the "Systems" Box and set a tank area of 15m² with an output flow resistance of 1.5 N*s/m⁵ and delay time (DT) = 0 s. The other parameters, time constant and gain are not accessible.
3. Adjust the period and amplitude of the Time Graph to 200 s/Div. and with 2.5 A/Div, respectively.
4. Click "Load System" to start.
5. Click Save Data. You will notice that the Time Graph displays the SP and PV.
6. Choose a value of PROPORCIONAL BAND (K_P) = 30%. Maintain INTEGRAL TIME(s) and DERIVATIVE TIME (s) at zero.
7. Set the initial Set Point value at 0 m and the final Set Point value at 5 m.
8. Check that the first order system stabilizes. Estimate the (i) time constant, τ_p (ii) the time taken for the system to stabilize and (iii) the offset between amplitudes of the level (PV) and the setpoint (SP).
9. Repeat for $K_P = 10\%$ and 50%

Closed Loop

1. Ensure that the "Open Loop" Checkbox in the "Systems" Box is unchecked.
2. Choose the "first order system" in the "Systems" Box and set a tank area of 15 m² with an output flow resistance of 1.5 N*s/m⁵ and delay time (DT) = 0 s. The other parameters, time constant and gain are not accessible.

3. Adjust the period and amplitude of the Time Graph to 200 s/Div. and with 2.5 A/Div, respectively.
4. Click "Load System" to start.
5. Click Save Data. You will notice that the Time Graph displays the SP, PV and OP – the proportional pneumatic valve position.
6. Choose a value of PROPORTIONAL BAND (KP) = 30%, INTEGRAL TIME(s) = 0 and DERIVATIVE TIME (s) = 0.
7. Set the initial Set Point value at 0 m and the final Set Point value at 5 m.

The Edibon CEAC control system consists of a tank with a drain that allows for water to flow out. The inlet is connected to a proportional pneumatic valve that increases or decreases the flow rate by opening and closing. An overflow sensor and level transmitter, which sends the signal to the controller. A schematic for the Edibon CEAC system can be seen below in Figure 3.

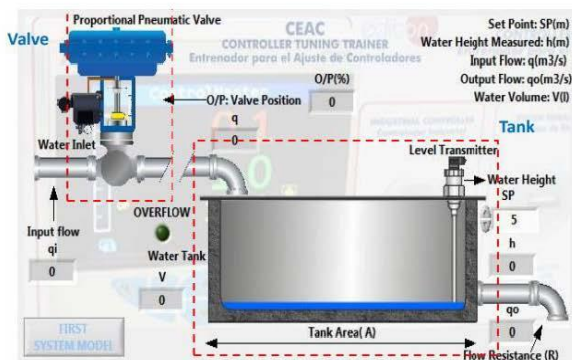


Figure 3 . A schematic of the Edibon CEAC Control Simulator

Results and Discussion

This experiment was carried out for three different proportional open loop systems and three different closed loop systems. Two consisting of proportional and integral control, and one that is proportional only. Figure 4 below shows the graphs for the open loop systems and Figures 5 and 6 are the closed loop systems.

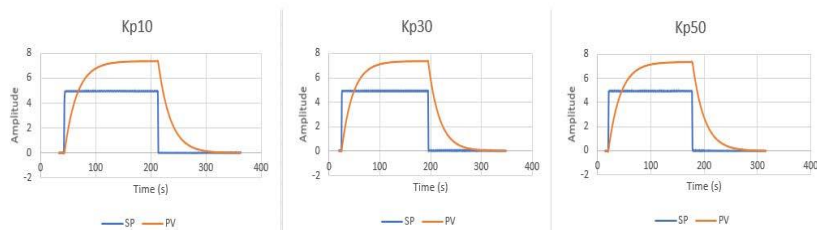


Figure 4. Comparison of open loop control system with different K_p values

For the open loop system, similar behaviors are observed every time the set point is changed. When the set point is increased to 5 meters, an observation in all three graphs is that the process variable overshoots the set point by approximately 2.4 meters to 2.5 meters, before it reaches steady state. All three of the graphs in Figure 4 show direct, monotonic, and stable responses creating an offset from the set point. The set point and process variable then converge as the set point is manipulated to zero.

The time, setpoint, and process variable data were given for the entirety of the experiment. The data for K_p , Proportional band percentage of 10%, 30%, and 50% were analyzed and used for calculating the τ_p (Equation 2), and $K_p K_{max}$ (Equation 6), which were then used to find the Global Transfer Function (Equation 7).

Using the graphs in figure 4, the steady state was approximated. The data in Table 1 shows the calculations that were done.

Table 1: Calculation for finding the Global Transfer functions for the three open loop systems

	$K_p = 10\%$	$K_p = 30\%$	$K_p = 50\%$
Steady State (m)	7.38	7.389	7.383
Time of Stability (s) 187	187	184	168

e(t) (m)	2.42	2.47	2.42
Taup (s)	66	46	42
Kp (s/m ²)	4.4	3.1	2.8
Kmax	0.33	0.47	0.52
kpkmax	1.452	1.457	1.456
TF Global (s)=	1.452/(66s+1)	1.457/(46s+1)	1.456/(42s+1)

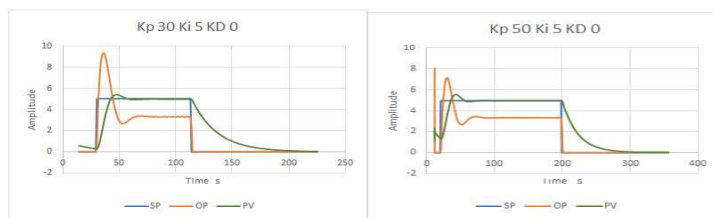


Figure 5. Comparison of PI control for closed loop system with different K_p values

For the closed loop system, different behaviors are observed each time a step or set point is changed in the system. A qualitative observation on Figure 5 shows that when the set point is increased to 5 meters in the tank, the level overshoots the set point before a short oscillation is observed, which quickly steadies. This transformation, or system reaction to the setpoint change, can be summarized as direct, oscillatory and convergent. The inlet flow valve opening, OP, also reacts to the set point change in a direct proportion to achieve steadying of the flow. When the system's setpoint is taken back down to zero, the system reacts successfully because of its direct, monotonic and convergent behavior.

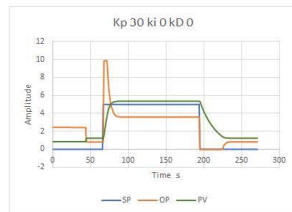


Figure 6 P- only closed loop system

Figure 6, also is also a closed loop system, such as Figure 5, but with the integral and derivative values both set to zero, the system reacts differently. When the level is set to 5 meters, the behavior is direct, monotonic and divergent, which means the system yields an offset or a steady-state error at approximately 0.5 meters. Although the margin of error increases by about 1 meter, the same behaviour is observed when the setpoint is taken back down to zero.

Conclusion

Comparisons of the systems, close and open loops, show that the open loop not only creates a steady-state error when the setpoint is raised, but that it is much bigger compared to that of the closed loop. Not having a feedback response created the opportunity for a much larger offset from the setpoint. Due to this, it is recognizable that all of the graphs look very similar even though the Proportional band percentages were different.

It can be observed in Figures 5 and 6 that the only resulting offset is very close to the size of the step. This indicates that closed loops can better control processes than open loops. The two systems show little to no difference when the system's setpoints are returned to zero which might be because at that point, the two systems allow little to no flow into the tank. If the setpoints were reduced to 1 meter instead of zero, it might have given a better indication of how these systems behave in a step down situation.

Reference

Bequette, Section 4.2: First order+Dead time., W. B. "Process Control: Modelling, Design, and Simulation", Fifth Edition to First edition, Prentice Hall (2002 to present).

<https://www.ni.com/en-us/innovations/white-papers/06/pid-theory-explained.html>

<https://www.comsol.com/blogs/how-to-simulate-control-systems-using-the-pid-controller-add-in/>

**CHEMICAL ENGINEERING LAB. III
SPRING 2022**

Title of Assignment: REPORT 4

TOPICS COVERED IN REPORT 4

Report 1 covered the following topic:

1. Simulating behavior of a PID controller (Expt. No. 4)

Objective:

To show the effect of the Proportional, Integral Derivative settings on the behavior of a three-term PID Controller (proportional-integral-derivative) used for level control.

**CHEMICAL ENGINEERING LAB. III
SPRING 2022**

RUBRIC AND GRADING SCHEME FOR LAB. REPORTS

**Laboratory Grading Sheet
Reports**

Technical Content

Maximum Grade

- | | |
|-----------------------|----------|
| 1. Abstract/Objective | 5points |
| 2. Theory | 5 points |
| 3. Results | 5 points |
| 4. Conclusions | 5 points |

Writing Content

- | | |
|-----------------|----------|
| 5. Organization | 5points |
| 6. Language | 5points |
| 7. Write-up | 5 points |
| 8. Appearance | 5points |

Every report will be graded according to the items described in this grade sheet.

Technical Content	Maximum	Grade
Abstract/Objective	5	
Theory	5	
Results	5	
Conclusions	5	
Total =	20	
Writing Content		
Organization	5	
Language	5	
Professional content	5	
Appearance	5	
Total =	20	

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Prairie View A&M University
Roy G. Perry College of Engineering
Department: Chemical Engineering



CHEG 4104- P01
Chemical Engineering Laboratory III
Virtual Lab Experiment #4:
Effect of PID Controller Parameters on Level Control

Group #2

Date Due: March 16, 2022

Submitted by

Cynthia Sahin
Reema Matti
Rafid Matti

Submitted to

Dr. Jorge Gabitto

Abstract

Process control is a mechanism that is used to monitor the algorithms and operational variables of industrial processes. The information that is gathered via monitoring is used to adjust the operational variables to achieve the desired product output specifications. The proportional-integral-derivative controller is deemed to be the most stable and accurate. It uses a control loop feedback mechanism to manipulate the operational variables. The goal of this experiment is to reveal how the behavior of a proportional-integral-derivative controller is influenced by inputting varying proportional, integral, and derivative constants. The EDIBON software is used to generate the results, which simulate the input conditions. By graphing the generated data, the behavior of the proportional-integral-derivative controller is shown to be the most efficient. It brings the level sensor reading to setpoint in the shortest amount of time. By conducting this experiment, an understanding of controller parameters and their effects can be gained.

Theory

Controllers are used for applying the accurate and responsive correction to a control function to allow for the safe and stable operation of a processing unit.¹ A proportional-integral-derivative controller (PID) is a popular control loop mechanism used in industrial control systems. This feedback or backward control mechanism waits for an error to occur before an action enacts. Figure 1 displays the primary elements of a control loop: system, sensor, controller, and actuator (valve).

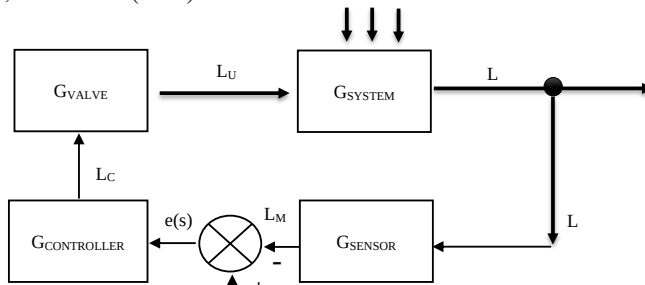


Figure 6. Basic Control Loop Setup and Elements

PID controllers use three control terms (proportional, integral, and derivative) to influence the controller output to achieve optimal control. The controller continuously calculates the error, $e(s)$, by comparing the measured valve with the specified setpoint (SP). The controller also determines a strategy to minimize and eliminate the error. The proportional term acts directly on the error in a linear way. The integral term has a memory and integrates values of the error. The derivative term predicts a short time into the future. The following equations (1 – 4) show the mathematical output of the controller. Equation 1 expresses the output, $(Au(s))$, in a real domain.² Equation 2 through 4 expresses the output in a Laplace domain.

¹ "PID Controller." Wikipedia. Wikimedia Foundation, March 12, 2020.

https://en.wikipedia.org/wiki/PID_controller#Control_damping.

² "Virtual Lab Level Control Lab Manual." CHEG 4031. Prairie View A&M University, n.d. Accessed March 30, 2020.

$$Au(t) = \underbrace{k_P e(t)}_{\text{P - "Present"}} + \underbrace{k_I \int_0^t e(\tau) d\tau}_{\text{I - "Past"}} + \underbrace{k_D \frac{de(t)}{dt}}_{\text{D - "Future"}} \quad (\text{Eq. 1})$$

$$Au(s) = k_P e(s) + k_I \frac{e(s)}{s} + k_D s e(s) \quad (\text{Eq. 2})$$

$$Au(s) = e(s) \left\{ k_P + \frac{k_I}{s} + k_D s \right\} \quad (\text{Eq. 3})$$

$$G(s) = k_P + \frac{k_I}{s} + k_D s = \frac{k_D s^2 + k_P s + k_I}{s} \quad (\text{Eq. 4})$$

Other controllers include P, PI, PD, and PID. PID or full mode controllers are considered to be the most efficient as they typically converge to the true value the fastest if the optimal values for k_P , k_I , and k_D (proportional, integral, and derivative constants).³ The correct selection of the constant parameters for the PID typically yields optimal behavior for the system: direct, monotonic, and convergence.⁴

Procedure

The Edibon UPCN equipment and software is used to show the effect of PID settings on the behavior of a full mode controller used for level control. The experiment involves inputting various sets of values for k_P , k_I , and k_D (the P, I, D constants) of the PID1 controller. After the constant values are set, a step signal in set point is produced by altering the set point value to a higher value.⁵ The output level is documented, and an analysis of the plot characteristics display the influence of different sets of values on the output response.⁶ A detailed, step by step procedure is listed below.

1. Press START in the top left corner.
2. A dialogue box will ask you for a file name. The measured data will be recorded in this file.
3. Input a set of values for the P, I, and D parameters of the PID1 controller. Select CONTROL 1 (Level) in the bottom left side and then input the constants values.
4. Press record and set the time interval (in seconds) between data.
5. Change the set point to the value listed in Table 1.
6. Run the experiment for 5 minutes or until steady state is reached.
7. Repeat the procedure for the three times listed in Table I for each type of controller, P/PI/PID.
8. After the third set press STOP and retrieve the data file.
9. Repeat the whole procedure for the other two types of controllers. After changing the controller type ALWAYS reset the set point to the original value (120 mm)
10. Process the three data files for the three separate controller setups.

Results and Discussion

By following the procedure listed in the prior section, the result for each controller output was obtained. The

³ Bequette, W. B. Process Control. Fifth Edition to First edition. Prentice Hall, 2002.

⁴ Bequette, W. B. Process Control. Fifth Edition to First edition. Prentice Hall, 2002.

⁵ "Virtual Lab Level Control Lab Manual." CHEG 4031. Prairie View A&M University, n.d. Accessed March 30, 2020.

⁶ "Virtual Lab Level Control Lab Manual." CHEG 4031. Prairie View A&M University, n.d. Accessed March 30, 2020.

procedure led to the level sensor reading obtained in each trial. Through plotting the setpoint versus the sensor reading, the behavior of the controller was determined. Figures 2 through 4 show the results of the experiment.

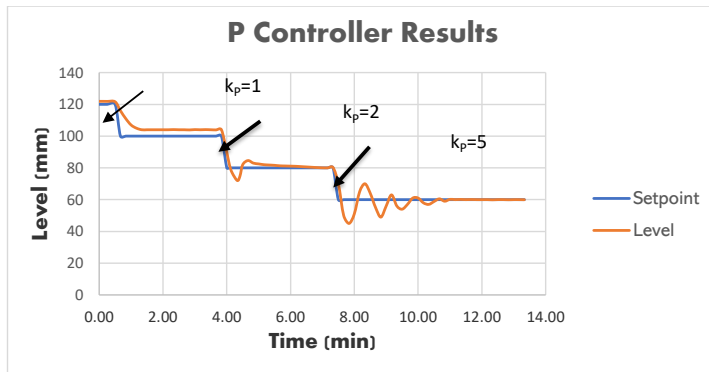


Figure 7. Proportional (P) Setting Results

Figure 2 shows the effect of the proportional setting on the system. The figure shows level readings versus the time. As time increases, the level reduces and the constants for k_p increases. The constants for k_p varied between 1, 2, and 5, respectively. For $k_p=1$, the behavior is direct, monotonic, and it converges. However, there is an offset. For $k_p=2$, the behavior is direct, slightly oscillatory, and converges. For $k_p=5$, the behavior is direct, highly oscillatory, and converges.

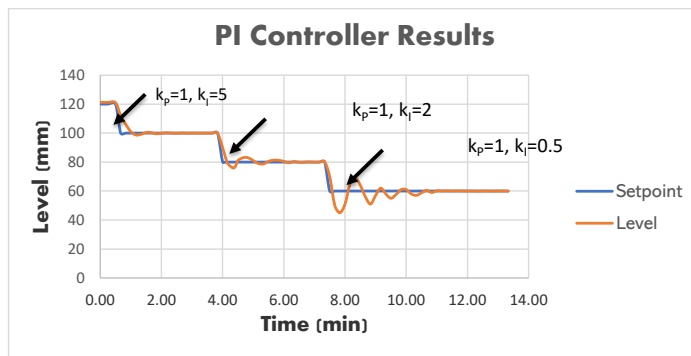


Figure 8. Proportional-Integral (PI) Setting Results

Figure 3 shows the effect of the proportional-integral setting on the system. The figure shows level readings versus the time. As time increases, the level reduces and the value for k_p remains constant. The constants for k_i varied between 5, 2, and 0.5, respectively. For $k_i=5$, the behavior is direct, slightly oscillatory, and converges. For $k_i=2$, the behavior is direct, moderately oscillatory, and converges. For $k_i=0.5$, the behavior is direct, highly oscillatory, and converges.

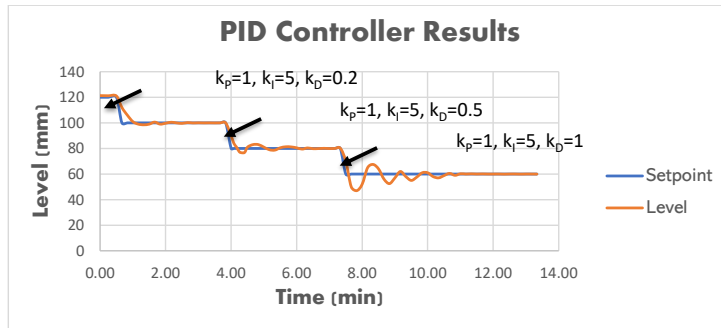


Figure 9. Proportional-Integral-Derivative (PID) Setting Results

Figure 4 shows the effect of the proportional-integral-derivative setting on the system. The figure shows level readings versus the time. As time increases, the level reduces and the value for k_p and k_i remains constant. The constants for k_D varied between 0.2, 0.5, and 2, respectively. For $k_D=0.2$, the behavior is direct, slightly oscillatory, and converges. For $k_D=0.5$, the behavior is direct, moderately oscillatory, and converges. For $k_D=2$, the behavior is direct, highly oscillatory, and converges.

Since the behavior is direct for all the trials, this proves that the sign of k_p must be negative to mirror the decrease of the level, or the root of the numerator is less than zero. The behavior of the majority of the results is oscillatory. This means that the roots of the denominator are complex or imaginary. Since the denominator roots are complex, the roots will only converge if the real part of the roots are negative.

Conclusion

In the experiment, the behavior of a PID controller was analyzed by graphing the data generated from the EDIBON controller software. The system regulated the level by use of the PID controller that automatically operated the element of the loop, which is the control valve.⁷ The results show that in comparison to the proportional and proportional-integral controllers, the PID controller allowed for the sensor level to reach the setpoint in the most efficient manner. Convergence was apparent, and there was minimal oscillation for each of the three PID trials. The first PID trial, with a k_D value of 0.2, achieved the setpoint in approximately two minutes. This was the fastest time of the three PID trials. By decreasing the value of k_D , the setpoint was reached quickly and without significant oscillation. Manipulation of controller parameters was necessary in order to determine the optimum parameter values.

References

Bequette, W. B. *Process Control*. Fifth Edition to First edition. Prentice Hall, 2002.

"PID Controller." Wikipedia. Wikimedia Foundation, March 12, 2022. https://en.wikipedia.org/wiki/PID_controller#Control_damping.

UCP: *Computer Controlled Process Control System (With Electronic Control Valve)*. YouTube. Edibon International, 2013. <https://www.youtube.com/watch?v=UBMPMaJM3Qo>.

⁷ UCP: *Computer Controlled Process Control System (With Electronic Control Valve)*. YouTube. Edibon International, 2013. <https://www.youtube.com/watch?v=UBMPMaJM3Qo>.

“Virtual Lab Level Control Lab Manual.” CHEG 4104. Prairie View A&M University, n.d. Accessed March 30, 2022.

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Roy G. Perry College of Engineering
Department of Chemical
Engineering



CHEG 4104 –P01

Chemical Engineering Laboratory III

Spring 2022

Virtual Lab Report 4: Effect of PID Controller Parameters on Level Control

Submitted By

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Chinenye Ihe
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On May 2nd, 2022

To

Dr. Jorge Gabitto

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Abstract

This experiment is concerning the effect of PID (proportional-integral-derivative) controller parameters on level control. The equipment used is a hydraulic unit with centrifugal pumps and a variety of control valves for the PID controller. The objective of this experiment is to show the effect of the proportional, integral, and derivative settings from the behavior of the PID controller used for level control. P, I, and D constants are set in the PID controller in which it produces a step signal in a set point by changing the set point value from the initial value to one higher. The output levels are recorded and analysis the plot characteristics for different set of values. Results showed the proportional constant values increasing from 1 to 5, the estimated steady state error occurred frequently for set point values 100, 80 and 60 showing over shooted or under shooted values compared the level. For the derivative constant, the level values were between became closer to the set point values (ranges 100-99.9, 79-84, 51-60 for each set point) due to the derivatives characteristic of “anticipating” the error as a result it decreased the magnitude of the error occurring. For the integral constant, the persistent errors that occurred were reduced as the integral constant is decreasing from 5 to 0.5.

Procedures

The experiment consists in inputting different sets of values for the P, I, and D constants of the PID1 controller. How to do this is explained in detail after the procedure. After setting the values of the controller three constants, a step signal in set point is produced by changing the set point value from the initial value to one higher. See the values in Table I below. The output level values are recorded and an analysis of the plot characteristics shows the influence of different sets of values on the output response.

- 1) Press START in the top left corner.
- 2) A dialogue box will ask you for a file name. The measured data will be recorded in this file.
- 3) Input a set of values for the P, I, and D parameters of the PID1 controller.
- 4) Press record and set the time interval (in seconds) between data.
- 5) Change the set point to the value listed in Table 1.
- 6) Run the experiment for 5 minutes or until steady-state is reached.
- 7) Repeat the procedure for the three times listed in Table I for each type of controller, P/PI/PID.
- 8) After the third set press STOP and retrieve the data file.
- 9) Repeat the whole procedure for the other two types of controllers. After changing the controller type ALWAYS reset the set point to the original value (120 mm)

Results & Discussion

The purpose of this experiment was to observe how changing PID controller parameters affect the level control in a tank. PID controllers calculate an error by measuring the difference between a desired set point and a measured process variable. The controller then applies a correction based on proportional, integral, and derivative terms. In this experiment the proportional, integral and derivative parameters were changed and the output variable of the controller was measured. In order to see the impact of changing each control parameter, a graph was plotted.

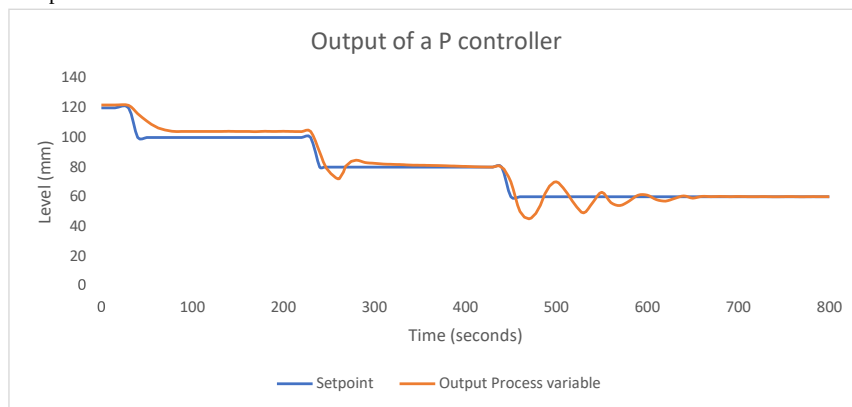


Figure 1: Output of a P controller

The first parameter changed in the experiment is the K_p which represents the proportional gain. From the hypothesis, it's expected to see an increase in the speed of the control system response as the proportional gain is increased. This is shown on the graph by the slope of the output variable. The value of the proportional gain is increased from 1 $\rightarrow$ 2 when the set point decreases to 80mm. That is indicated on the graph by a steeper slope of the output variable at the point the setpoint changes from 100 $\rightarrow$ 80 compared to the slope at the point the setpoint goes from 120 $\rightarrow$ 100. According to the hypothesis, as the value of K_p increases even further the value of the process variable will eventually begin to oscillate. In this experiment when the setpoint decreases to 60mm the K_p value is increased to 7 and oscillation can be observed in Figure 1, thereby confirming the hypothesis.

Next, a graph of the controller including the integral parameter is plotted.

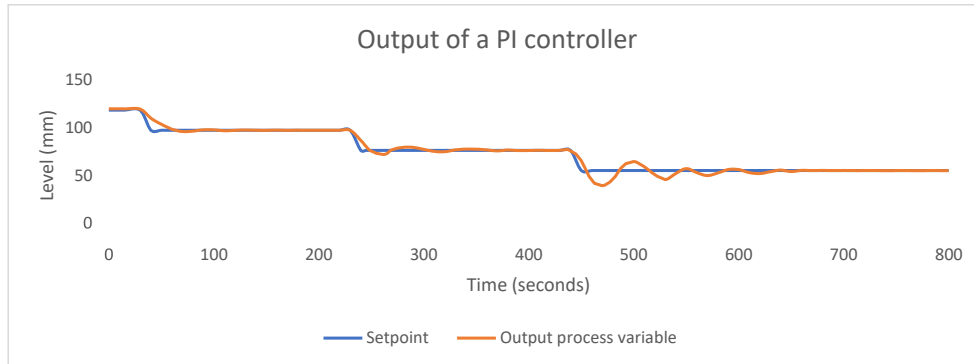


Figure 2: Output of a PI controller

In this graph the integral time parameter T_i is introduced and decreased as the setpoint decreases. According to the hypothesis, increasing the integral time should decrease the steady state error. The graph shows that the output process variable closely follows the level of the setpoint when the setpoint is set to 100. Once the setpoint decreases to 80 and integral time decreases from $5 \rightarrow 1$, some oscillation between the setpoint and output variable can be observed. The setpoint continues to decrease to 60 and integral times goes from $1 \rightarrow 0.2$. At this point, a lot of oscillation or error between the value of the setpoint and output variable can be observed. This confirms the hypothesis is correct as the error or difference between both levels is greater whenever the integral time value is low. Finally, a graph of the controller including the derivative parameter is plotted.

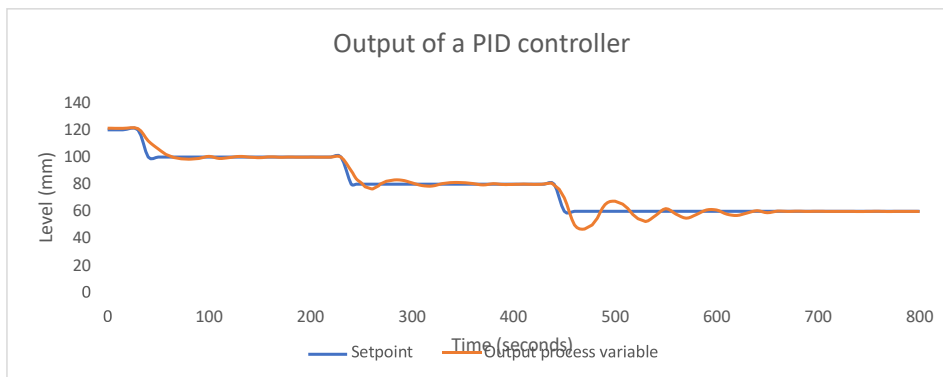


Figure 3: Output of a PID controller

In this graph the derivative time parameter T_d is introduced and changed as the setpoint decreases. According to the hypothesis, increasing the derivative time should increase the speed of the overall control system response. In the graphs we can see the slope of the output process variable is very steep whenever the setpoint is changed. This indicates that the system response is very quick to match the new setpoint. However, a large derivative time also makes the control system sensitive to noise and unstable. When the setpoint decreases to 60 and derivative time increases to 1, the control system becomes unstable and starts oscillating. For this reason, most control systems use a small derivative time to avoid instability.

Conclusion

In this experiment the effects of changing the proportional, integral and derivative parameters in a PID controller were observed. According to the hypothesis increasing the proportional and derivative parameter increases the control system response speed while increasing the integral time parameter decreases the steady state error. After analyzing the data from this experiment, the hypothesis was verified. Graphs were utilized to show how the controller responded to each change by comparing the setpoint values to the values of the output process variable (water level). In the future, it would be interesting to determine the ideal parameter values for optimum operation of a control system.

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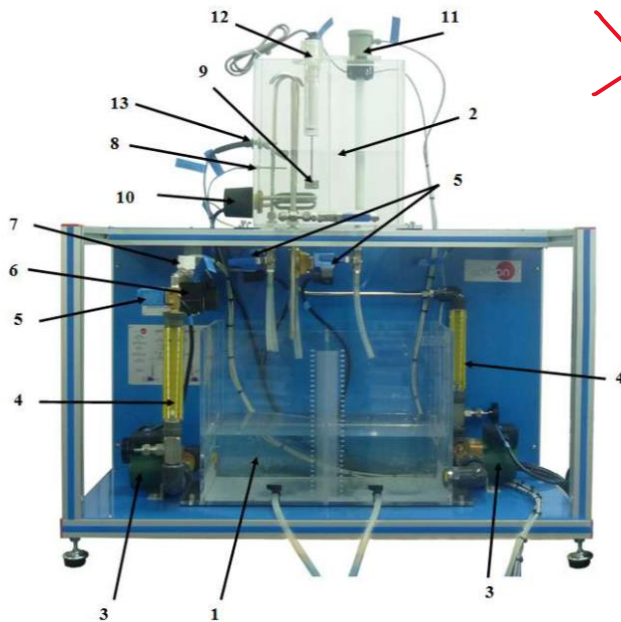


Lab #4: Effect of PID Controller Parameters on Level Control

Shimere Gregory, Cherish Vaughn, Alexis Lovelace, Irene Atatah

Due Date: 03/30/2022

Date Conducted: 03/23/2022



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Appendix

Abstract

Process control is the ability to be able to adjust a process to get a desired output. The variable we will be controlling is the flow rate to keep the level constant by using a controller. We are to compare the set point to the process variable by using a controller that will eliminate the disturbance rejection and to be able to track and maintain a set point. In this experiment we are measuring the proportional control of level by the level sensor within different time frames. The purpose of this experiment is to show the behavior of a proportional-integral derivative controller by inputting selective values for proportional, integral, and derivative constants. From the results we were able to conclude that the PID controller was the most effective because we were able to receive our set point in a short time period.

Commented [JG23]: Good structure. Grade= 4

Theory

In industrial industries the application that is used to control and or adjust the feedback of various temperatures, pressures, flows and many other processes is known as the PID controller. There are 3 levels of control of the application known as the Proportional, Integral, and Derivative hence the name PID. The focus is to force feedback to the related set point that is selected whether that is P, I, D, PD and or PID. Proportional term constitutes the bulk of your control response. It produces and outputs that is proportional to the error value. The given equation for proportional is $P_{out} = K_p \times \varepsilon$ (error) and K_p being your proportional gain. Now, The Integral term is the accumulation of the instant error over time. Which is a sum that offsets the results of proportional control only. When you add the two you can get exceptionally good control and eliminate offset. The Equation is then as follows: $I_{out} = K_i \int_0^t e(\tau) d\tau$. Lastly, The Derivative Term predicts system behavior, achieves stability faster. This term is rarely used in practice. The term is given by:

$$D_{out} = K_D \frac{d\varepsilon(t)}{dt}.$$

Together the output is as follows:

$$Au(t) = K_p e(t) + K_i \int_0^t e(\tau) d(\tau) + K_D \frac{de(t)}{dt}$$

Using the controller in full mode will give the best true value with the fastest values for K_p , K_i ,

and K_d .

The objectives of this experiment are listed below.

- To show the effect of the Proportional, Integral Derivative settings on the behavior of a three-term PID Controller used for level control.
- Perform a qualitative review of the effect of proportional, integral, and derivative settings on level control for UCPN.
- Determine the best control level.

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Grade= 4

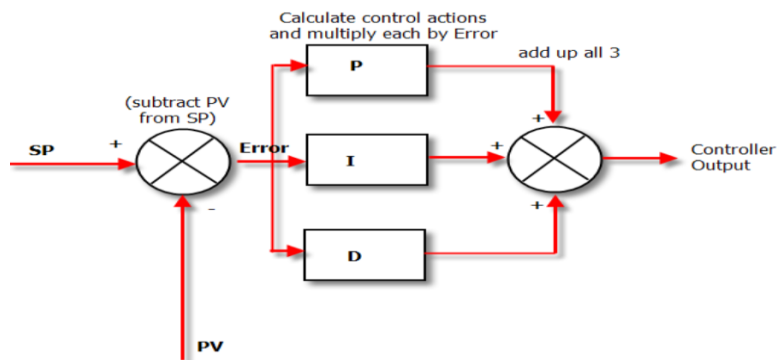


Figure 1 Demonstrates a simple explanation of how a PID controller works. Using the SP and PV to create the error and go into using the P, I, PI, and PID.

Procedure

To perform this experiment, we are using the EBIDON UPC process unit. The equipment that we will be using is a hydraulic circuit with a bottom tank, an upper process tank, both dual, two centrifugal pumps, two flowmeters with manual control valve, three on/off solenoid valves, a motorized proportional valve, and it also includes flow sensors, temperature sensors, and electric heating coil, and PH sensor. This equipment is used to measure level, flow, temperature and PH regulation.

1. Press START in the top left corner.
- 2) A dialogue box will ask you for a file name. The measured data will be recorded in this file.
- 3) Input a set of values for the P, I, and D parameters of the PID1 controller.
- 4) Press record and set the time interval (in seconds) between data.
- 5) Change the set point to the value listed in Table 1.
- 6) Run the experiment for 5 minutes or until steady state is reached.
- 7) Repeat the procedure three times listed in Table I for each type of controller, P/PI/PID.
- 8) After the third set press STOP and retrieve the data file.
- 9) Repeat the whole procedure for the other two types of controllers. After changing the

controller type ALWAYS reset the set point to the original value (120 mm)
 10) 0 mm)
 11) Process the three data files.

Results & Discussion

The figure below shows plots of on/off controls with a set point of 60,80,100 and different K_p values for different process controllers. By investigating P, PI, PID for (figure 1,2,3) were plotted set points versus sensor readings



Figure 1: Proportional (P) Results

Figure 1 shows the time increases, as K_p increases closer output to the set point. The $K_p=1$ is direct, monotonic then converges. The $K_p=2$ is direct and oscillatory and converges. The $K_p=3$ is direct, oscillatory and converges. The oscillations of each K_p value changes with setpoint.

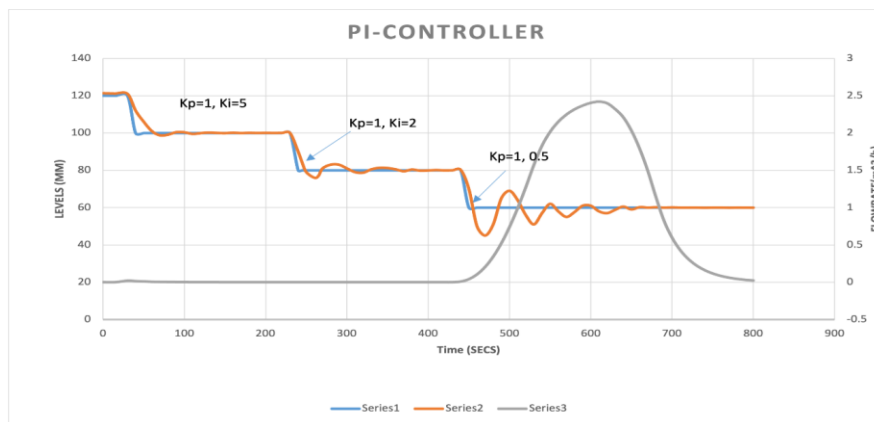


Figure 2: Proportional-Integral (PI) Results

Figure 2 shows the results of the proportional-integral setting in the system. In this graph at the time increases the K_p remains constant. The $K_i=5$ is direct, monotonic and converges. The $K_i=2$ is direct, oscillatory and converges. The $K_i=0.5$ is direct, oscillatory and converges.

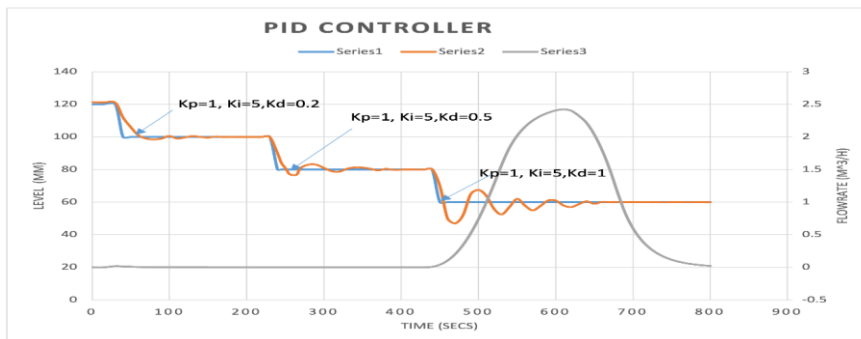


Figure 3: Proportional-Integral-Derivative (PID Results)

Figure 3 shows the results of the proportional-integral derivative setting on the system. In this graph at the time increases the K_p and K_i remain constant. The $K_d=0.2$ is direct, monotonic and converges. The $K_d=0.5$ is direct, oscillatory and converges. The $K_d=1$ is direct, oscillatory and converges.

Conclusion

In conclusion, the purpose of this experiment was to get a clear understanding in the relations of proportional, proportional-integral, and proportional integral derivative constants to also see which method of constant would be the most suitable for our experiment. In this experiment our team used the p, pi, and pid controller to collect data in a process control system. After comparing each graph while using the ebidon upc process unit, pid controller was the most effective level controller, being that we were able to collect the data on it faster than any other controller throughout the system.

References

Sc W. S., Tarun Agarwal says: Hi Capt. Waris Shaheen Thank you for this positive feedback. To know more about electrical concepts please refer the below link <https://www.elprocus.com/category/electrical-2/> Reply, says:, T. A., says:, G. C. J. P., says:, S. A., Says:, D., says:, G. singh, says:, S. K., Says:, K., & *, N. (2021, November 22). *PID controller : Working, types, Advantages & Its Applications*. ElProCus. Retrieved March 30, 2022, from <https://www.elprocus.com/the-working-of-a-pid-controller>

**CHEMICAL ENGINEERING LAB. III
SPRING 2022**

FINAL PRESENTATION

TOPICS COVERED IN FINAL PRESENTATION

Final Presentation covered the following topics:

1. Safety in the lab.
2. Conduct experiments and data analysis.
3. Oral and written communication.

**CHEMICAL ENGINEERING LAB. III
SPRING 2022**

Rubric and Grading Scheme used to grade the final presentation.

CHEG 4104_P01

Experiment:

Group:

Technical Content	Maximum	Grade
Abstract/Objective	5	
Theory	5	
Results	5	
Conclusions	5	
Total =	20	
Writing Content		
Organization	5	
Language	5	
Professional content	5	
Appearance	5	
Total =	20	

ABOVE AVERAGE

EFFECT OF PID CONTROLLER PARAMETERS ON LEVEL CONTROL

Cinthia Sahin
Rafid Matti
Reema Matti



Outline

- Abstract
- Introduction
- Theory
- Procedure
- Results/Discussion
- Conclusion
- Safety

Abstract

- An experiment was conducted to investigate the effect of different parameters of PID controllers on the response to changes in liquid level set-point values in a tank.
- The main objective of the experiment was to observe the effect of proportional gain, integral time and derivative time on the response of the system to steps in set-point values.
- To demonstrate this, three controllers including the P (proportional) control, the PI (Proportional – integral) control, and PID (Proportional Integral Derivative) were used.
- The results showed that when there was an increase in proportional gain, offset decreased but was never eliminated. Oscillatory behavior also increased.
- Integral time will eliminate offset but increasing its value will cause increased oscillatory behavior in the system.
- Increased derivative time will increase the size of oscillations.
- A full PID controller produces a response that is direct, convergent and with minor oscillatory behavior. It also reduces the time to reach steady-state when compared with P and PI controllers.

Introduction

- Most chemical processes require rigorous control of their operational parameters such as temperature, pressure, flow rate and the composition of components.
- The control process involves operating the process equipment within safe limits and that the variables are within a desirable set point.
- A process control loop had four fundamental components including; controller, actuator, the process, and a transmitter or sensor.
- The controller – compares actual signal value with the desired set point to calculate an error and generates appropriate action.
- The actuator - receives an electrical signal that changes manipulated variable to return the control variable back to its set point.
- The sensor – measures the process control variable and sends a signal to the controller.

Theory

- The PID controller participates in feedback control loops in a variety of applications where a continuously modulated control is crucial.
- Control is achieved by continuously calculating an error value $e(t)$.
- The error is the difference between an idealized set point (SP) and the process variable (PV).
- After the error has been determined the controller applies corrective measures by utilizing proportional, integral and derivative terms.
- The output variable for PID controller is therefore given by the following equation.

$$u(t) = K_p e(t) + K_i \int_0^t e(\tau) d\tau + K_d \frac{d e(t)}{dt}$$

Where; K_p is the proportional constant, K_i is the integral constant and K_d is the derivative constant.

The standardized form of the above equation is as follows.

$$u(t) = K_p e(t) + \frac{K_i}{T_i} \int_0^t e(\tau) d\tau + K_d T_d \frac{d e(t)}{dt}$$

Procedure

Initiate	Initiate the collection of data by pressing the start button in the top left corner of the monitor screen.
Input	Input a set of values for P,I.
Press	Press record and input a time interval (in seconds) between the recording of data.
Alter	Alter the set point in accordance with a value provided in the given table (Table
Run	Run the experiment until a steady-state is achieved.
Repeat	Repeat steps 1-6 for each of the three types of controllers.
Press	After data has been collected for the third controller, press STOP on the monitor screen and retrieve the data file.
Reset	Reset the set point to the original value (120 mm) and repeat the whole procedure for the two types of controllers (PID2 and PID3).
Process and analyze	Process and analyze the three final data files that have been retrieved, and D parameters of the PID1 controller.

Results and Discussion – P-controller

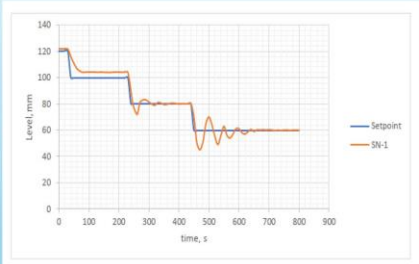


Figure 1: Level control using P-controller

- At a gain value of 1, the system was deviated from set point and there was off-set.
- When value of gain is doubled, the offset is reduced, however, oscillations in the system appear.
- Further increases in the value of the gain to 5 results in reduction in offset but system shows more oscillatory behavior.
- We can conclude that increasing the proportional gain increases oscillatory behavior.

Results and Discussion – PI Controller

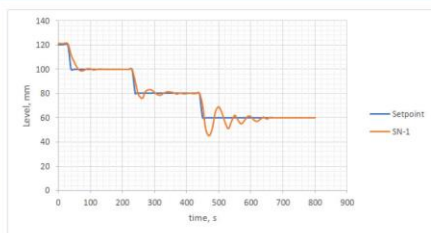


Figure 2: Level control using PI-controller

- For PI-controller, similar procedure is carried out by fixing the controller proportional gain.
- However, the integral time is varied. With an integral time of 5, the offset was eliminated, and system was stable with only minor oscillations.
- However, reducing the value of integral time to 2 produces more oscillations in system.
- Further reduction in the value of integral time to 0.5 results in bigger oscillations, however, system converges to the set point after certain period of time.
- PI controller eliminates offset.
- Increasing integral time reduces oscillatory behavior.

Results and Discussion – PID Controller

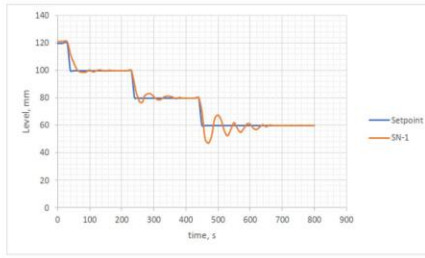


Figure 3: Level control using PID-controller

- For PID controller, the values of proportional gain and integral time are fixed, and the derivative time is varied.
- With a value of integral time of 0.2, the system was stable around set point but increasing to 0.5 results in production of more oscillations.
- Further, increase in derivative time value causes more oscillations in the system.
- PID decreases convergence time.
- Increasing derivative time produces more oscillations.

Conclusions

- The experiment focuses on the demonstration of different types of controller (P, PI and PID) for the control of fluid level in a tank and the effect of the values of different controller parameters (gain, derivative time, integral time) on the behavior of liquid level in a tank.
- Increase in proportional controller gain decreases offset but increases oscillatory behavior.
- By increasing the integral time, offset is eliminated but it produces oscillations which increase with the decrease in integral time value.
- As derivative time increases the amplitude of oscillations increase.
- A PID controller with small proportional gain, high integral time, and small derivative time produces the best response to steps in set-point values.

Safety

Safety considerations for the lab where the following:

Safety goggles

Lab coat

Closed-toe shoes

Thank you

AVERAGE

Level Control Using PID Controller

CHEG 4014-P01
DR. GABITO
GROUP 1

OLUWATOYOSI IDOWU, CHIEBUKA EJIMADU, CHINENYE IHE, TYREE MADISON

Agenda

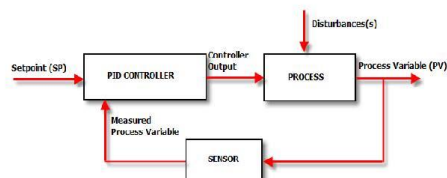
- ▶ Abstract
- ▶ Theory
- ▶ Procedure
- ▶ Results & Discussion
- ▶ Conclusion
- ▶ Questions

Abstract

- ▶ What is a PID controller?
- ▶ What are typical uses of PID controller?
- ▶ What is the Objective of the experiment?
- ▶ Conclusions drawn from experiment

Theory

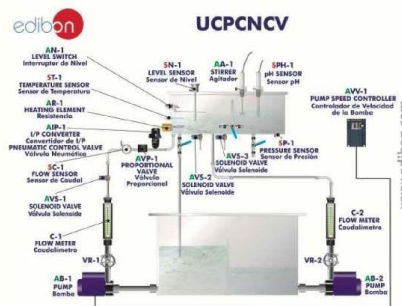
- ▶ Process Controls is an important aspect of industrial processes within as it provides skills to analyze and measure several ways to control different parameters in that specific process
- ▶ Proportional-Integral-Derivative (PID) controllers are used to assist in regulating process variables to a desired set point
- ▶ The objective of the experiment is to analyze these three behavioral settings on the effect of level control
- ▶ Utilizing the equation below, the output responses will be analyzed thus determining best control for the system



$$u(t) = K_p e(t) + K_i \int_0^t e(\tau) d\tau + K_d \frac{d e(t)}{dt},$$

Procedure

- Input different sets of values for the P, I, and D constants
- Change set point value from the initial value of 120 mm to decreasing values of 100 mm, 80 mm, and 60mm
- Repeat the procedure for the P/PI/PID controller variations



Data Table

Run (action)	Setpoint (mm)	K_p	T_i	T_d
1 (P)	100	1	0	0
2 (P)	80	2	0	0
3 (P)	60	5	0	0
1 (PI)	100	1	5	0
2 (PI)	80	1	1	0
3 (PI)	60	1	0.2	0
1 (PID)	100	1	5	0.1
2 (PID)	80	1	5	0.2
3 (PID)	60	1	5	1

Results & Discussion (1 of 3)

- P controller has the most unsteady response compared to the other two.
- Major offsets and overshoots of the system



Results & Discussion (2 of 3)

- PI Controller combines proportional and integral controllers
- Eliminates offset
- Mostly used in pressure control, temperature control and flow control



Results & Discussion (3 of 3)

- Similar effect as like the PI Controller, but also mitigates the overshoots
- Reduce the rate of change of error making it quicker to apply change



Conclusion

- Relevance
- Results
 - Best Controller?
 - What graph trend shows

Questions



References

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- ▶ "PID Controller," Wikipedia https://en.wikipedia.org/wiki/PID_controller#Control_damping
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- ▶ Libretexts. "9.2: P, I, D, PI, PD, and PID Control," Engineering LibreTexts, Libretexts, 4 Dec, 2021, [https://eng.libretexts.org/Bookshelves/Industrial_and_Systems_Engineering/Book%3A_Chemical_Process_Dynamics_and_Controls_\(Wolff\)/09%3A_Proportional-Integral-Derivative_\(PID\)_Control/9.02%3A_P%3C%20I%3C%20D%3C%20PI%3C%20PD%3C%20and_PID_control](https://eng.libretexts.org/Bookshelves/Industrial_and_Systems_Engineering/Book%3A_Chemical_Process_Dynamics_and_Controls_(Wolff)/09%3A_Proportional-Integral-Derivative_(PID)_Control/9.02%3A_P%3C%20I%3C%20D%3C%20PI%3C%20PD%3C%20and_PID_control).

BELOW AVERAGE

Level Control using a PID Controller

Ojevwe Sarah Emedo, Chima Louis, Tysiannah Anderson, Ebuka Louis, Clifton Collins

Presentation Overview

- Abstract
- Theory
- Procedure
- Results and Discussions
- Conclusion

Abstract

- Find PID effect on a level control for a UCPN
- P values vs. PI values vs. PID values
- PID controllers widely used in the industry
- Helps with regulating temperature, flow, pressure, speed
- Many types of control loops

What are controllers?

- Attempt to control the error between a measured process variable and desired setpoint
- 3 controllers used in industry
 - P controller
 - PI controller
 - PID controller

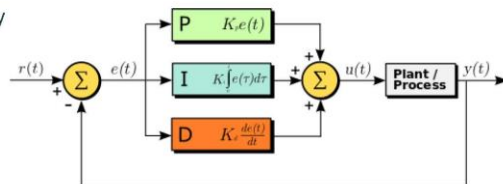


Figure 1: PID Control Loop

Control Loops

- Manual or automatic
- Feedback control and non-feedback control
 - Open loop: control actions are independent of the output
 - Closed loop: control actions are dependent of the desired output
- Types of control loops
 - Feed-forward control
 - Cascade control
 - Feed-forward with feedback

Control Loop used for Experiment

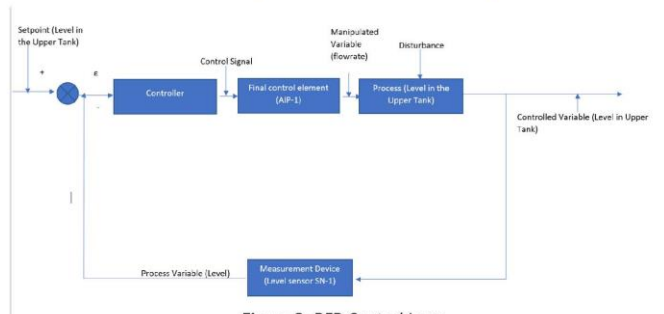


Figure 2: BFD Control Loop

Procedure

1. Select UCP unit equipment
2. Open control and acquisition software
3. Select start in upper left corner of main control scheme on the main screen
4. Dialog box input name of lab and choose location to store the data
5. Control 1 select level in the button left side
6. Input the set values of the controller for the P, I, and D parameters
7. Select take data to record and set the time interval(sec.) between data
8. Change the set point to value listed in Table 1
9. Run the experiment for 5 minutes or until steady state is reached
 - a. Pump AB-1 must be activated and the proportional valve can be operated (by means of control loops) to perform different controls.
 - b. For safety reasons, AR-1 will be always switched off when the type of control is changed, the control is removed, there is not enough water, etc.
10. Repeat steps 6-9 four more times for each controller (P/PI/PID)
 - a. REMEMBER to reset the set point to the original value (120mm) after changing the controller types
11. After the last set is done press STOP and retrieve the data file
12. Process the three data files

Process Description

The experiment consists of inputting different sets values for the P, I, and D constants of the controller. After setting the values of the controller three constants, a step signal in set point is produced by changing the set point value from the initial value to one higher. The output level values are recorded and an analysis of the plot characteristics shows the influence of different sets of values on the output response. The experiment ran until steady state was achieved or 5 minutes, whichever was first shown. This occurred a total of 12 times, broken down into 3 chunks.



Figure 3: UCP Equipment

Results and Discussion

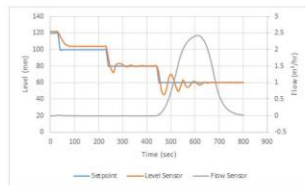


Figure 2: Proportional level control in UCPN

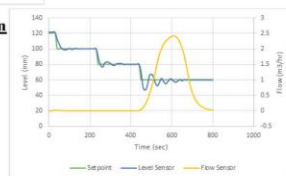


Figure 3: Proportional Integral level control in UCPN

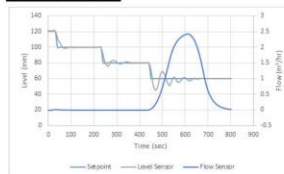


Figure 4: Proportional Integral Derivative level control in UCPN

Conclusion

- We able to analyze the behavior of our PID Controller used for level control
- We were able to locate the values for Proportional, Proportional-Integral , and Proportional-Integral-Derivative
- Having control over the time, temperature, flow, pressure and speed are very vital to any process.
- We can conclude that these fundamentals of Proportional, Integral Derivative settings are vital to any process being designed or created in the industry of engineering.

Questions?