

**ROY G. PERRY COLLEGE OF ENGINEERING
CHEMICAL ENGINEERING DEPARTMENT
PRAIRIE VIEW A&M UNIVERSITY**

ASSESSMENT REPORT COVER PAGE

**CHEG 4104 CHEMICAL ENGINEERING
LABORATORY III**

SPRING 2022 SEMESTER

NAME OF INSTRUCTOR: Dr. Jorge Gabitto

TABLE OF CONTENTS

- 1. Report Cover Page**
- 2. Detailed Course Syllabus (ABET + Additional Information)**
- 3. End of Semester Outcomes Assessment Report (New Format)**
- 4. Grade Sheet Showing Student and Class Performance in Outcomes**
- 5. Supporting Outcomes Specific Assignments (Minimum of 2 per outcome except for Project Reports where one is enough)**
 - 5.1 Assignments assessing students' ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factor. (outcome "2")
 - 5.2 Assignments assessing students' ability to identify, formulate, and solve complex engineering problems (CEP) by applying principles of engineering, science, and mathematics.
(Outcome 1)
 - 5.3 Assignments assessing students' ability to communicate effectively with a range of audiences (Oral & Written)

Detailed Course Syllabus
(Distributed to Students at the beginning of the Semester)

Course Description in ABET Format

CHEG 4104 P01

1.	Course number and name:	CHEG 4104 Chemical Engineering Laboratory III
2.	Credits and contact hours:	1 credit hours; 3 contact hours *Engineering topic
3.	Instructor's or course coordinator's name:	Dr. Jorge Gabitto
4.	Text book: Title:	NA
	Author:	NA
	Publisher, Year & Edition:	NA
	a. Other Supplemental material	1. Holman, J. P., Experimental Methods for Engineers, 4 th Ed., McGraw-Hill, New York, 1986.
5.	Specific course information	
	a. Brief description of the content of the course (catalog description)	Chemical Engineering Lab. III (0-3) Credit 1 semester hours Chemical engineering laboratory with emphasis on reactive and control systems. Measurement of reaction conversion, determination of reaction order and rate in a tubular reactor. Analysis of the dynamic responses of stirred tanks in series. Experimental study of the use of analog and digital controller for heat exchanger and flow and level control systems.
	b. Prerequisites or Co-requisites	SPCH 1003, ENGL 1033 or ENGL 1043, CHEG 3063 and CHEG 4033
	c. Indicate whether a required, elective, or selected elective (as per definition provided) course in the program	Required
6.	a. Specific goals for the course specific outcomes of instruction (e.g. The student will be able to explain the significance of current research about a particular topic.) <i>Students will be able to :</i>	b. Explicitly indicate which of the student outcomes listed in Criterion 3 or any other outcomes are addressed by the course. <i>The specific goals for the course specific outcomes listed on the left column will address the following student learning outcomes:</i>
	1. Demonstrate ability to perform quantitative physical measurements, operate, laboratory scale equipment.	Outcome 3 An ability to communicate effectively with a range of audiences Outcome 5
	2. Demonstrate ability to plan, design, and evaluate experiments.	

		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.
	3. Demonstrate ability to communicate effectively in oral and written formats.	
	4. Demonstrate ability to work in teams.	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 Quiz
	Topic 2	Design of Experiments Quiz
	Topic 3	Effect of the PID Controller Parameters on Level Control (Exp. No 1)
	Topic 4	Conversion Determination in a Tank Reactor (Expt. No. 2)
	Topic 5	Simulator Behavior for Operator Training (Expt. No. 3)
	Topic 6	Conversion Determination in a Tubular Reactor (Expt. No. 4)
	Topic 7	Dynamic Behavior of Stirred Tanks (Expt. No. 5)
	Topic 8	Design of Experiments (Assignment project).

Additional Course Syllabus Information

Course Title: Chemical Engineering Laboratory III

Course Prefix: CHEG

Course No.: 4104

Section No.: P01

Department of | Chemical Engineering |

College of | Engineering

Instructor Name:

[Dr. Jorge Gabitto](#)

Office Location:

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U.S. Postal Service Address:

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P.O. Box | 519
Mail Stop | 2505
Prairie View, TX 77446-0519

Office Hours: | M 10:00 AM - 4:50 PM, TR 10:00 AM - 12:50 PM,

Virtual Office Hours: | F 9:00 – 12:00 AM

Course Location: | *[Chem. Eng. Lab. Room 106A Gilchrist bldg.](#)*

Class Meeting Days & Times: | M 5:30 – 8:20 PM

Catalog Description: | (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.

Prerequisite: Senior standing
Co-requisites: CHEG 4303

Required Text: None

Recommended Text/Readings:

1. Holman, J. P., *Experimental Methods for Engineers*, 4th Ed., McGraw-Hill, New York, 1986.
2. Fahien, R. W., *Fundamentals of Transport Phenomena*, McGraw-Hill, New York, 1993.

Access to Learning Resources:

PVAMU Library:
phone: (936) 261-1500;
web: <http://www.tamu.edu/pvamu/library/>

University Bookstore:
phone: (936) 261-1990;
web: <https://www.bkstr.com/Home/10001-10734-1?demoKey=d>

Course Goals or Overview:

The goal of this course is to teach students laboratory skills on the areas of fluid-mechanics and chemical separations.

Course Outcomes/Objectives

At the end of this course, the student will have achieved and demonstrated the following outcomes.

- 1 Demonstrate ability to perform quantitative physical measurements, operate, laboratory scale equipment.
- 2 Demonstrate ability to plan, design, and evaluate experiments.
- 3 Demonstrate ability to communicate effectively in oral and written formats.
- 4 Demonstrate familiarity with commercial scale equipment.

Course Requirements & Evaluation Methods

This course will utilize the following instruments to determine student grades and proficiency of the learning outcomes for the course. The course has been designed to ensure that students acquire a solid grounding in ABET 2000 outcomes b, d and g.

Laboratory reports – written descriptions of lab. experiments including result calculations and conclusions.

Laboratory Oral Presentations – one or more oral assignments, often groups, designed to supplement and reinforce course material

Quizzes – announced or surprise in-class assignments to promote student accountability.

Design of One Experiment – one proposed experiment on the lab. subject areas. It will be evaluated through an oral presentation and a written report.

Grading Matrix

Instrument	Total
Quizzes	20%
Lab. Reports	40%
Final presentation on design of experiments	40%
Total	100%

Grade Determination:

A = 100 – 89 pts;

B = 88 – 79 pts;

C = 78 – 60 pts;

D = 60 – 50 pts;

F = 49 pts or below

Course Procedures**Textbook Policy**

Students must acquire the textbook that is listed as “required” on the course syllabus. The textbook must be acquired by the 10th class day. Students are not allowed to share textbooks with other students who are currently registered in the same class. Failure to acquire (or show proof of purchase) the required textbook by the 10th class day will result in the student being administratively dropped from the course. The University will assess financial obligations for the course to the student as with any other dropped class according to the fee schedule. In addition, your financial aid may be affected by the subsequent registration action(s).

Go to <http://www.pvamu.edu/pages/195.asp> for the Roy G. Perry College of Engineering Textbook Policy.

Conduct:

1. Students will conduct themselves in a manner that is respectful to their fellow classmates and the instructor at all times.
2. **Cell phones MUST** be turned off during class time. Students are **NOT** allowed to leave class to answer cell phones.
3. Students are **NOT** allowed to wear caps/hats in class
4. Arrive to class prepared to discuss lesson.
5. Always bring essential tools: Textbook, paper, calculator.

Submission of Assignments:

- All assignments are due by default one week after being given, unless otherwise stated.

All written assignments are due directly to the Instructor, prior to the start of class or the assignment will not be accepted. All assignments should be written on one side of the page only, and should use the appropriate cover sheet, with the name, assignment title and date. All pages should be numbered. Failure to use the correct format will result in the assignment grade being reduced by 20%.

Exam Policy

Reports are due as scheduled. No makeup examinations will be allowed except under documented emergencies (See Student Handbook).

TOPICS

Topic 1	Laboratory Safety and Loss Prevention (Video Presentation)
Topic 2	Design of experiments (Lecture)
Topic 3	Kinetic determinations in batch reactor (Expt. No. 1)
Topic 4	Plug flow reactor (Expt. No. 2)
Topic 5	Dynamic behavior stirred tanks (Expt. No. 3)
Topic 6	Level (Expt. No. 4)
Topic 7	Simulating behavior of a PID controller (Expt. No. 5)
Topic 8	Design of Experiments (Assignment project)
Topic 9	Writing lab. reports (Lecture)

University Rules and Procedures

Disability statement (See Student Handbook):

Students with disabilities, including learning disabilities, who wish to request accommodations in class should register with the Services for Students with Disabilities (SSD) early in the semester so that appropriate arrangements may be made. In accordance with federal laws, a student requesting special accommodations must provide documentation of their disability to the SSD coordinator.

Academic misconduct (See Student Handbook):

You are expected to practice academic honesty in every aspect of this course and all other courses. Make sure you are familiar with your Student Handbook, especially the section on academic misconduct. Students who engage in academic misconduct are subject to university disciplinary procedures.

Forms of academic dishonesty:

1. Cheating: deception in which a student misrepresents that he/she has mastered information on an academic exercise that he/she has not mastered; giving or receiving aid unauthorized by the instructor on assignments or examinations.
2. Academic misconduct: tampering with grades or taking part in obtaining or distributing any part of a scheduled test.
3. Fabrication: use of invented information or falsified research.
4. Plagiarism: unacknowledged quotation and/or paraphrase of someone else's words, ideas, or data as one's own in work submitted for credit. Failure to identify information or essays from the Internet and submitting them as one's own work also constitutes plagiarism.

Nonacademic misconduct (See Student Handbook)

The university respects the rights of instructors to teach and students to learn. Maintenance of these rights requires campus conditions that do not impede their exercise. Campus behavior that interferes with either (1) the instructor's ability to conduct the class, (2) the inability of other students to profit from the instructional program, or (3) campus behavior that interferes with the rights of others will not be tolerated. An individual engaging in such disruptive behavior may be subject to disciplinary action. Such incidents will be adjudicated by the Dean of Students under nonacademic procedures.

Sexual misconduct (See Student Handbook):

Sexual harassment of students and employers at Prairie View A&M University is unacceptable and will not be tolerated. Any member of the university community violating this policy will be subject to disciplinary action.

Attendance Policy:

Prairie View A&M University requires regular class attendance. Excessive absences will result in lowered grades. Excessive absenteeism, whether excused or unexcused, may result in a student's course grade being reduced or in assignment of a grade of "F". Absences are accumulated beginning with the first day of class.

Student Academic Appeals Process

Authority and responsibility for assigning grades to students rests with the faculty. However, in those instances where students believe that miscommunication, errors, or unfairness of any kind may have adversely affected the instructor's assessment of their academic performance, the student has a right to appeal by the procedure listed in the Undergraduate Catalog and by doing so within thirty days of receiving the grade or experiencing any other problematic academic event that prompted the complaint.

End of Semester Course Assessment Report

This 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. **You cannot use any number of your choice**
- 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.

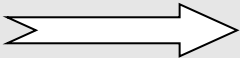
5. Were Expectations Met?

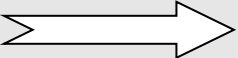
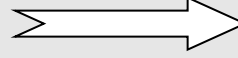
- Answer **YES** if the **class average was above the expected average** and the **stated percentage of students** scored at or above the expected average, else answer NO.

Table 2.1. END OF SEMESTER COURSE OUTCOME ASSESSMENT REPORT
CHEG4104-P01 Chemical Engineering Laboratory III
Spring 2022 SEMESTER

Report Prepared by: Dr. Jorge Gabitto

Report Date: May 20, 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	12	75	72.8	41.2	75	75.3	75.3	75	72.4	41.2
Spring 2021	Direct	15	75	69.5	33.3	75	65.9	0.0	75	65.9	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 decreased significantly over last semester. More work is needed. Extra data are needed to figure it out if it is due to the pandemic or a trend.	The class average has decreased significantly over last semester. More work is needed. Extra data are needed to figure it out if it is due to the pandemic or a trend.	The class average has decreased significantly over last semester. More work is needed. Extra data are needed to figure it out if it is due to the pandemic or a trend.

**Grade Sheet Showing
Student and Class Performance in Outcomes**

**CHEG 4104-P01
SPRING 2022 SEMESTER**

Outcome 5 Ability to design and conduct experiments. Reports 1 & 3	Outcome 6 Ability to function on multi-disciplinary teams. Report 2 & Final Pres	Outcome 3 Oral & Written Communication Report 4 & Final Pres
7.85	7.85	7.05
7.05	7.95	7.7
7.85	7.85	7.05
7.05	7.95	7.7
7.05	7.95	7.7
7.85	7.85	7.05
7.05	7.95	7.7
6.65	6.45	6.95
6.65	6.45	6.95
7.85	7.85	7.05
6.65	6.45	6.95
7.85	7.85	7.05
Av.= 7.283	Av.= 7.533	Av.= 7.242
5 (41.2%)	8 (75%)	5 (41.2%)

	Report I	Report II	Report III	Report IV	Pres
Student 1	8.9	8.1	6.80	6.5	7.6
Student 2	7.1	8.5	7.00	8	7.4
Student 3	8.9	8.1	6.80	6.5	7.6

Student 4	7.1	8.5	7.00	8	7.4
Student 5	7.1	8.5	7.00	8	7.4
Student 6	8.9	8.1	6.80	6.5	7.6
Student 7	7.1	8.5	7.00	8	7.4
Student 8	5.3	7.5	8.00	8.5	5.4
Student 9	5.3	7.5	8.00	8.5	5.4
Student 10	8.9	8.1	6.80	6.5	7.6
Student 11	5.3	7.5	8.00	8.5	5.4
Student 12	8.9	8.1	6.80	6.5	7.6

**OUTCOME SPECIFIC ASSIGNMENTS
USED TO ASSESS OUTCOMES**

ASSIGNMENTS FOR OUTCOME 3

An ability to an ability to communicate effectively with a range of audiences.

**CHEMICAL ENGINEERING DEPARTMENT
OUTCOMES SPECIFIC ASSIGNMENT COVER SHEET
Chemical Engineering Laboratory III
SPRING 2022**

Instructor: Dr. Jorge F. Gabitto

Title of Assignment

Report 4

Outcome Measured Using this Assignment

Outcome 3

An ability to an ability to communicate effectively with a range of audiences.

Brief justification of why this assignment is suitable for this outcome

The rubric used for grading this assignment measures the students' ability to express themselves using written communication. Organization and professional language are also measured.

Roy G. Perry
College of Engineering



CHEG 4104 - Chemical Engineering Lab III

Experiment 4:
Level Control using PID Controller

Group #2

Due Date: April 13, 2022

Submitted by:

Chad Gardner

Anh Nguyen

Meredith Meyer

Franck Nangomoko

Submitted to:

Dr. Jorge Gabitto

Table of Contents

Abstract.....	2
Theory.....	2
Procedures.....	4
Results and Discussion	4
Conclusion	6
References.....	7

Table 1: Controller Constant Values

Figure 1: Schematic of the UPCN Equipment
Figure 2: General Control Loop Components and Setup
Figure 3: Proportional (P) Setting Results
Figure 4: Proportional-Integral (PI) Setting Results
Figure 5: Proportional-Integral-Derivative (PID) Setting Results

Abstract

PID Control is a fundamental aspect of chemical engineering that serves as significant importance in industrial control applications to regulate flow, pressure, temperature, and other process variables. In a proportional-integral-derivative (PID) control, three essential terms are used, to be controlled with precision, i.e., P, I and D, where each term produces an output value that is proportional to current value, integral with past value and estimated future value, respectively. For this experiment, we utilized the Edibon UCPCNCV software model to analyze the behavior of a PID control settings for level control of two tanks of water. The behavioral changes were observed by inputting a variation of proportional, integral, and derivative constants in three settings: P, PI, and PID. The behavior changes of all three control system settings are direct and converged. However, the oscillatory or monotonic behavior is varied. It is determined that the behavior of the PID controller is examined to develop an understanding of parameters set by the control mechanism.

Theory

Process Control is an engineering discipline and statistic that deals with architectures, algorithms, and mechanisms for maintaining the output of a specific process within desired parameters. This is done to achieve a production level of consistency, economy, and safety which cannot be achieved purely by human control. Figure 1 is the EDIBON UPCN, equipment used for analyzing the effect of Proportional-Integral-Derivative controller.

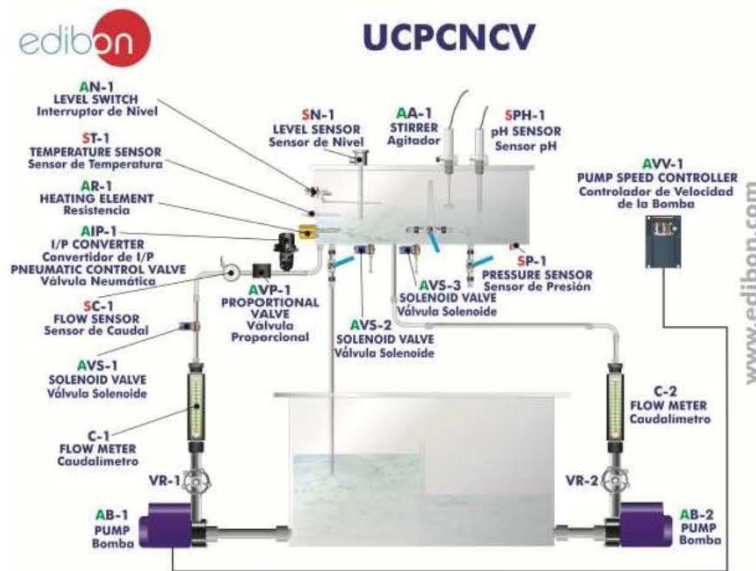


Figure 1: Schematic of the UPCN Equipment

Within this discipline and on an industrial scale, PID controllers serve as receptive and accurate measures to regulate safe and stable operations of a specific processing unit. These systems assist engineers in developing a line of communication of feedback within a control mechanism to identify the occurrence of an error and provide an action in place to mitigate a responsive solution in a safe manner. Figure 2 displays the general components of a control loop.

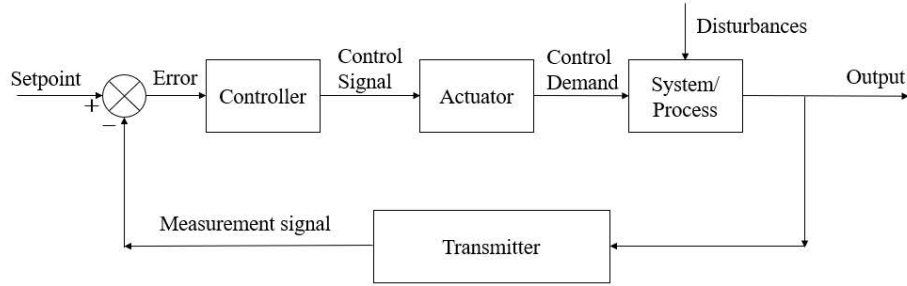


Figure 2: General Control Loop Components and Setup

Within a PID controller, a closed-loop feedback system is used to generate an error signal by evaluating the difference between the feedback variable and the given setpoint, resulting in altering the system output. The process starts by sending an error signal to a controller, which sends a control signal to an actuator. The actuator then sends a control demand to the system to alter the output variables. The output is measured by a transmitter and the measurement signal is sent back to the summing point, where the error signal is generated by the difference of setpoint and measured value. This procedure will continue until the error reaches zero, else the value of the feedback variable becomes equivalent to the specified setpoint.

The PID controller uses the three terms of proportional, integral, and derivative influence on the controller output. The proportional component depends only on the current difference between the set point and the process variable. The integral component accounts for past values of the setpoint-variable error and integrates them over time. Lastly, the derivative component estimates the future trend of setpoint-variable error and effectively controls the output by generating the control influence using the rate of error change. The output variable value $u(t)$ is given by:

$$u(t) = K_p e(t) + K_i \int_0^t e(\tau) d\tau + K_d \frac{de(t)}{dt} \quad (1)$$

where K_p , K_i , and K_d are the proportional, integral, and derivative constants, respectively; $e(t)$ is the error of setpoint and measured value; t is the instantaneous time; τ is the variable of integration.

The transfer function in the Laplace domain of the PID controller is derived from equation (1) is:

$$G(s) = k_p + \frac{k_i}{s} + k_d s \quad (2)$$

where s is the complex frequency.

Different settings can be used for PID control system, includes P, I, D, PI, PD, and PID. The PID mode is considered as providing the most efficient control output as it accounts for past, present, and future changes in that system.

Procedures

This lab experiment was carried out virtually. The equipment was already set up and connected. The experiment would be carried out as follows:

1. Press Start in the top left corner of the Edison UCPCNCV software
2. Add the name of the file to the dialog box that pops up, where the data was recorded
3. Input the set values for P, I, and D parameters for the PID1 controller as shown in Table 1 for run 1 and setpoint value of 120mm

Table 1: Controller Constant Values

Controller	Run (action)	Setpoint (mm)	K_p	K_i	K_d
P	1	100	1	0	0
	2	80	2	0	0
	3	60	5	0	0
PI	1	100	1	5	0
	2	80	1	2	0
	3	60	1	0.5	0
PID	1	100	1	5	0.2
	2	80	1	5	0.5
	3	60	1	5	1

4. Press record and change the interval for the measured data to seconds
5. Change the set point listed in Table 1
6. Run the experiment until steady state was reached
7. Change the value of K_p , K_i , K_d for other two values
8. After the third set, press STOP and retrieve the data file
9. Repeat the whole procedure for the other two types of controllers (PI and PID)

Results and Discussion

The result for each type of controller P, PI, and PID output was obtained and graphed, shown in Figure 3, Figure 4, and Figure 5. Three graphs share a similar trend of output variables. For the first set point changes from 120mm to 100mm, the change in water level slowly decreases. For the second setpoint (100mm to 80mm) and third setpoint (80mm to 60mm), there are oscillatory behaviors. Particularly, for the third setpoint, the water flow rate increases dramatically from almost 0 L/min at 450s to about 2.4 L/min at 610s and then decreases to 0 L/min at 800s. All

changes in water level are converged to the given setpoint, except the first change in Proportional Setting Control is higher than the setpoint of 100mm.

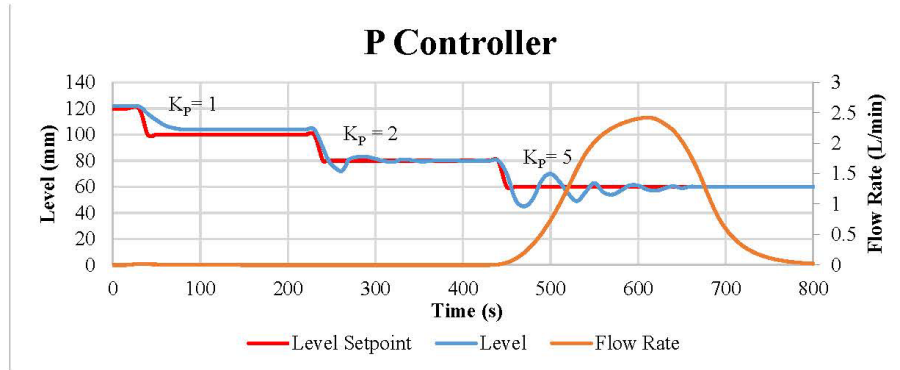


Figure 3: Proportional (P) Setting Results

Figure 3 shows the level readings and flow rate versus the recording time for the proportional setting. The chosen proportional constants K_p are 1, 2, and 5. When $K_p = 1$, the behavior is direct, monotonic, and converged. However, there is still an offset for this K_p . For $K_p = 2$, the behavior is direct, slightly oscillatory, and converged. For $K_p = 5$, the behavior is direct, highly oscillatory, and still converged. The high oscillatory behavior can be spotted as the water flow rate increases dramatically.

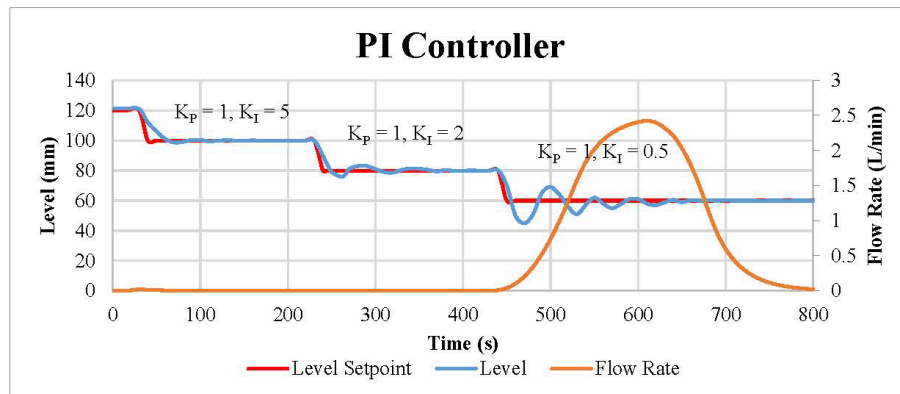


Figure 4: Proportional-Integral (PI) Setting Results

Figure 4 shows the level readings and flow rate versus the time for the effect of the proportional-integral (PI) setting on the system. The proportional constant K_p is kept constant at 1 while the integral constant K_i are 5, 2, and 0.5, respectively. When $K_i = 5$, the behavior is direct, slightly oscillatory, and converged. When $K_i = 2$, the behavior is direct, moderately oscillatory, and converged. When $K_i = 0.5$, the behavior is direct, highly oscillatory, and again converged.

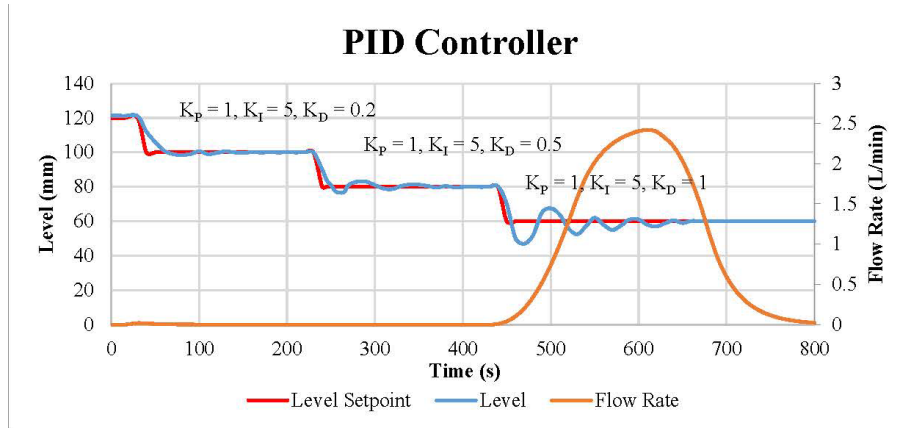


Figure 5: Proportional-Integral-Derivative (PID) Setting Results

Figure 5 shows the effect of the proportional-integral-derivative (PID) setting for the level readings and flow rate vs time. The values for K_I and K_P remain constant at 1 and 5, respectively while the derivative constant K_D increases from 0.2, 0.5, and 1, respectively. For $K_D = 0.2$, the behavior is direct, slightly oscillatory, and converged. For $K_D = 0.5$, the behavior is direct, moderately oscillatory, and converged. For $K_D = 1$, the behavior is direct, highly oscillatory and converged.

Based on the direct behavior we obtained from all the runs, this proves that the roots of the numerator of equation (2) are less than zero. Since the behavior of majority of the results are oscillatory, this means that the roots of the denominator of equation (2) are complex or imaginary numbers. And since the denominator roots are complex, the roots will be converged if the real part of the roots are negative.

Conclusion

PID Controls is an important element in any industries because of its function of regulating flow, pressure, temperature, and other process variables. With the software EDIBON UCPCNCV, the behavior of a P, PI, and PID control settings for level control of the upper tank of water. All control settings show direct and converged behavior. The oscillatory or monotonic behavior is varied depend on the proportional, integral, and derivative constants. With the given K_P , K_I , and K_D , the PI and PID control systems provide a similar efficiency in term of time and oscillation for water level to be converged. Even though the experiment brought in an insight into PID control settings and helped determine the best constants for future use, it should be reconducted with different set of K_P , K_I , and K_D to verify the most efficiency of PID control system.

References

Virtual Lab: Effect of PID Controller Parameters on Level Control. Roy G Perry, Chemical Engineering Department. Accessed 2022.

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

PID Controller. Wikipedia. Accessed 2022.
https://en.wikipedia.org/wiki/PID_controller#Control_damping

**CHEMICAL ENGINEERING DEPARTMENT
OUTCOMES SPECIFIC ASSIGNMENT COVER SHEET
Chemical Engineering Laboratory III
SPRING 2022**

Instructor: Dr. Jorge F. Gabitto

Title of Assignment

Final Presentation

Outcome Measured Using this Assignment

Outcome 3

An ability to an ability to communicate effectively with a range of audiences.

Brief justification of why this assignment is suitable for this outcome

The rubric used for grading this assignment measures the students' ability to express themselves using oral communication. Presentation organization and professional language are also measured.



Level Control Using PID Controller

CHEG 4014-P01

DR. GABITTO

GROUP 1

OLUWATOYOSI IDOWU, CHIEBUKA EJIMADU, CHINENYE IHE, TYREE MADISON



Table of Contents

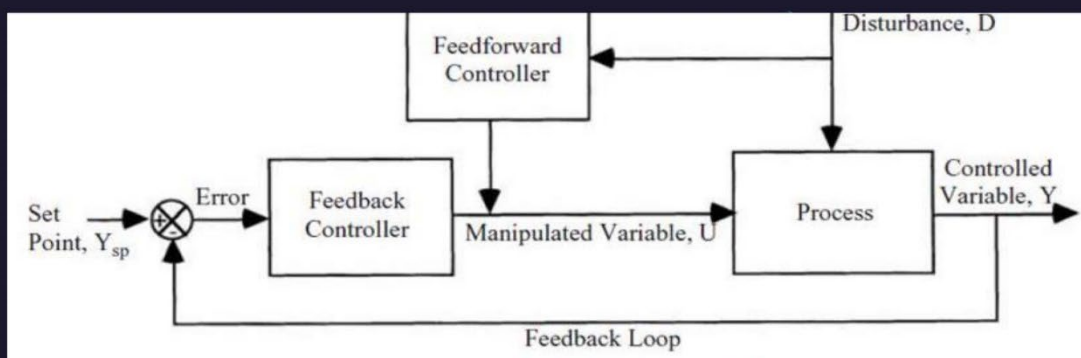
- Abstract
- Theory
- Procedures
- Results
- Discussion
- Conclusion

By Dorinda

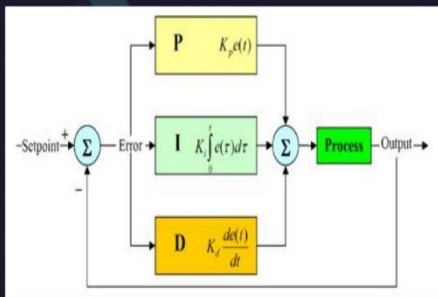
ABSTRACT

The goal of this lab is to perform a qualitative review of the effect of proportional, integral, and derivative (PID) settings on the level control for the UCPN. Taking into consideration the P, PI and PID methods, we determined which method gives the best control and why. We also regulated the set point or level by using a

PID controller which operates the control valve. Furthermore, determined what happened when we decreased or increased the gain, was able to compare time to the measurement signal, and finally the set point against the process variable.



THEORY



- Proportional-integral-derivative controller (PID controller)
 - generic control loop feedback mechanism widely used in industrial control systems.
- PID controller attempts to continuously correct the error ($e(t)$)
 - measure process variable (PV) and,
 - a desired setpoint (SP)
- By calculating, then outputting a corrective action based on
 - proportional,
 - integral, and
 - derivative that can adjust the process consequently.

By Juste

PROCEDURE



By Jae

This experiment was done using a Computer Controlled Process Control System.

- Open the software and hit start.
- After selecting the PID control option, select the element that is being used. Enter a set point, as well as a PID constant.
- Turn on data save and select graph configuration for the program to record.

RESULTS & DISCUSSION

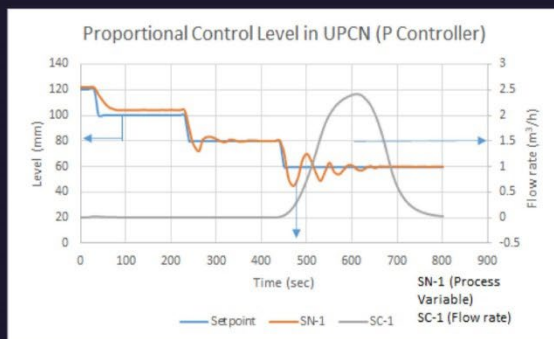


Figure 1: Proportional Control Level in UPCN (P Controller)

Figure 1 is a graph plotted to analyze the time dependence of two variables.

That is the flowrate and the fluid level in the superior tank.

The result is analyzed as both the flowrate and the level approaches the set value.

Fluid level and flowrate data is plotted against time for a P controller.

RESULTS & DISCUSSION

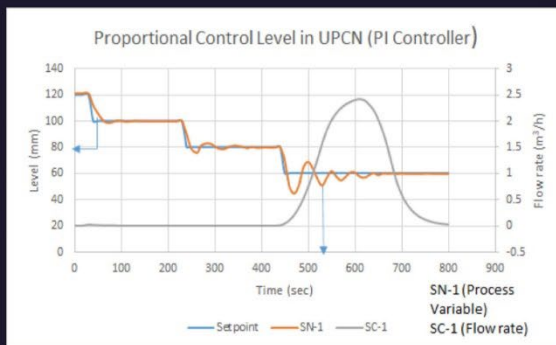


Figure 2: Proportional Control Level in UPCN (PI Controller)

- Figure 2 is also a graph plotted to analyze the time dependence of two variables as well.
- That is the flowrate and the fluid level in the superior tank.
- The result is analyzed as both the flowrate and the level approaches the set value.
- Fluid level and flowrate data is plotted against time for a PI controller.

By Pat

RESULTS & DISCUSSION

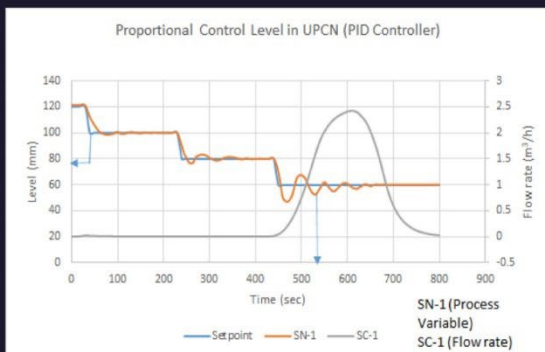


Figure 3: Proportional Control Level in UPCN (PID Controller)

- Figure 3 is a graph plotted to analyze the time dependence of two variables.
- That is the flowrate and the fluid level in the superior tank.
- The result is analyzed as both the flowrate and the level approaches the set value.
- Fluid level and flowrate data is plotted against time for a PID controller.

CONCLUSION



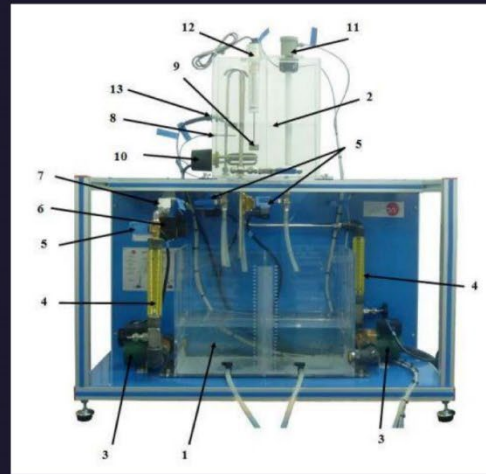
By Jae

- From the goal to perform a qualitative review of the effect of proportional, integral, and derivative (PID) settings on the level control for the UCPN, we have concluded that:
- Regulation of the set point controls the flow rate from the data received
- The application of all three (proportional, integral, and derivative) are the best method of control.
 - All three controllers have their individual strengths and weaknesses.
 - They are mostly combined to maximize their strengths while minimizing their weaknesses.
 - Increasing the systems gain decreases the steady-state error.



Schematic of the Equipment Setup

- 1. A main tank and collector with an orifice in the central dividing wall ($2 \times 25 \text{ dm}^3$), and drainage in both compartments (made of methacrylate).
- 2. A dual process tank ($2 \times 10 \text{ dm}^3$), interconnected through an orifice and a ball valve and an overflow in the dividing wall (methacrylate); a graduate scale and a threaded drain of adjustable level with bypass (metallic).
- 3. AB-1 and AB-2: Two centrifugal pumps.
- 4. C-1 and C-2: Two variable area flowmeters ($0.2\text{-}2 \text{ l/min}$, and $0.2\text{-}10 \text{ l/min}$), and with manual valve (VR-1 and VR-2).



- 5. Line of on/off regulation valves (solenoid). There is one normally opened (AVS-1) and two normally closed with different Cv (AVS-2 and AVS-3); and manual drainage valves of the upper tank.

- 6. AVP-1: A motorized control valve (piston type) with rotation indicator.

- 7. SC-1: A flow sensor, fixed, turbine type.

- 8. ST-1: A temperature sensor.

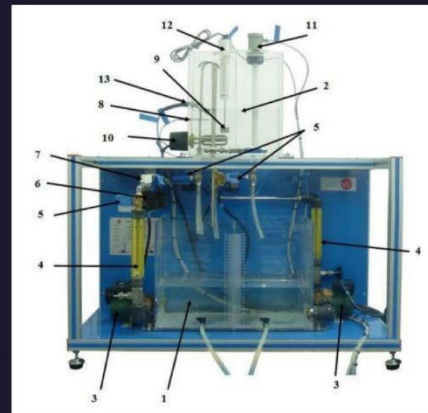
- 9. AA-1: A helix agitator.

- 10. AR-1: An electric heating element (0.5 KW), fixed.

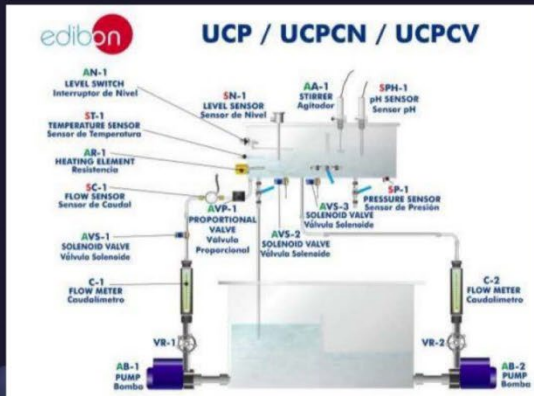
- 11. SN-1: Level sensor 0-300 mm (capacitive and immersion level sensor, 4-20 mA); it can be dismantled.

- 12. SPH-1: pH sensor (glass electrode, ddp (V)), removable (tank/effluent).

- 13. AN-1: On/off level switch. This sensor determines the performance of the immersion heating element.



Process Description



- This unit consists of a hydraulic circuit with a bottom tank (1) and an upper process tank (2), both dual, two centrifugal pumps (3), two flowmeters with manual control valve (4), three on/off solenoid valves (5), and a motorized proportional valve (infinitely variable) (6). Of course, it includes the appropriate tubes, elbows, connections, bulkheads, stopcocks and drains for the circuit operation. All the above[1] mentioned is set on a support frame designed to be placed on a work bench. Additional fixed elements include a flow sensor that is installed in one of the upward lines of flow (7), and a temperature sensor located in the process tank (8) together with an electric heating coil (10). The interchangeable additional elements in the unit are a stirrer (9), the immersion level sensor located in the process tank (11), and the pH sensor (electrode) which can be placed in the process tank or in the bottom tank (12) to study the effect of the time out.

ASSIGNMENTS FOR 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.

**CHEMICAL ENGINEERING DEPARTMENT
OUTCOMES SPECIFIC ASSIGNMENT COVER SHEET
Chemical Engineering Laboratory III
SPRING 2022**

Instructor: Dr. Jorge F. Gabitto

Title of Assignment

Report 1

Outcome Measured Using this Assignment

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.

Brief justification of why this assignment is suitable for this outcome

The rubric used to grade the report assesses the students planning, organization, and collaborative environment. Student participation is also assessed by private communication related to the activity.

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

Submitted by:
Chad Gardner
Anh Nguyen
Meredith Meyer
Franck Nangomoko

Submitted to:
Dr. Jorge Gabitto

Table of Contents

Abstract.....	2
Theory.....	2
Procedures.....	5
Results and Discussion	5
Conclusion	7
References.....	7

Figures

- Figure 1: Schematic Diagram of CSTR
- Figure 2: CEP-MkII Stirred Tank Reactors in Series
- 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.

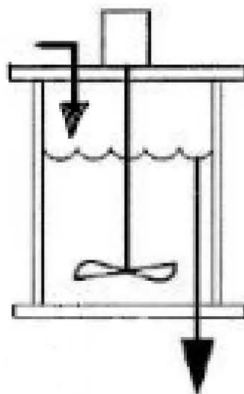


Figure 1: Schematic Diagram of CSTR

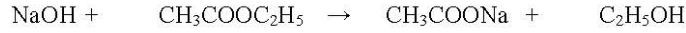
CSTR can be connected in series or in parallel. In this experiment, CEP-MkII Stirred Tank Reactors in Series is used to analyze the steady-state fractional conversion of a limiting reactant in saponification reaction, shown in Figure 2.



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.

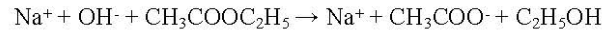


Sodium Hydroxide (A) + Ethyl Acetate (B) $\rightarrow$ Sodium Acetate (C) + Ethyl Alcohol (D)

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^- ($C_{\text{OH}^-}^o$), initial volume of the reactant ($\dot{V}^o$), and conversion (X), equation (1) is equivalent to:

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

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

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

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:

$$-r_A = k_A C_{A0}^2 (1-X)^2 \quad (5)$$

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

$$F_{A0} - F_A + V_R (r_A) = 0$$

Since the volumetric flow rate is constant ($\dot{V} = \dot{V}^o$), $C_A = F_A / \dot{V}^o$, and $C_A = C_{A0} (1-X)$, the mass balance equation can be written in combining with equation (5) as:

$$\dot{V}^o C_{A0} - \dot{V}^o C_{A0} (1-X) + V_R k_A C_{A0}^2 (1-X)^2 = 0 \quad (6)$$

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:

$$\tau = \frac{V_R}{\dot{V}^o} = \frac{X}{k_A C_{A0} (1-X)^2} \quad (7)$$

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.

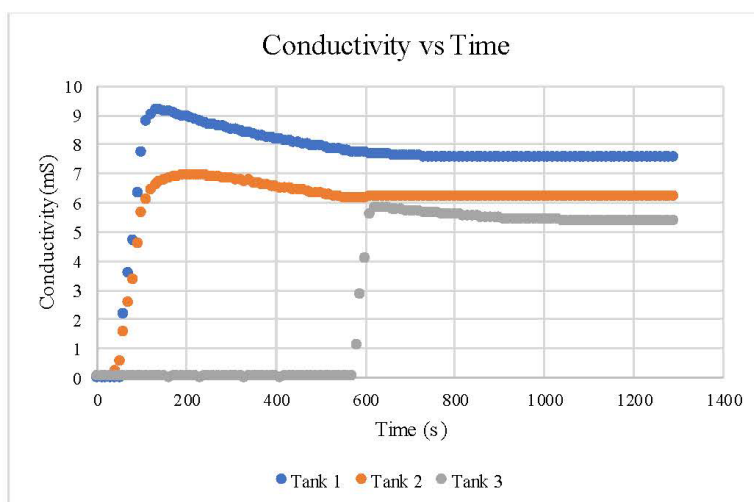


Figure 3: Conductivity of 3 CSTRs over Time

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.

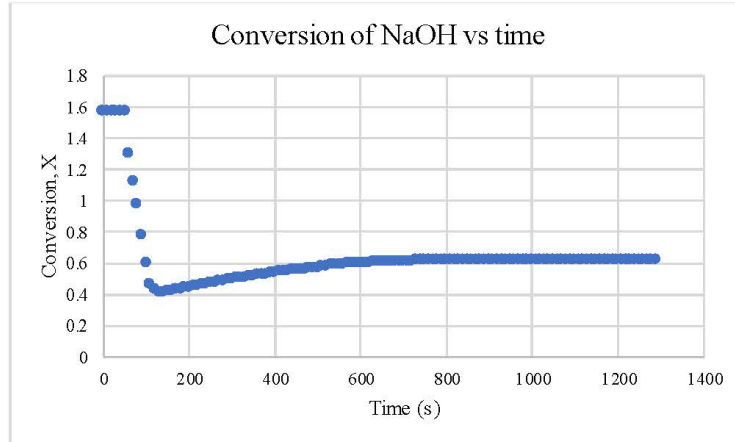


Figure 4: Conversion of NaOH in Tank 1 over Time

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).

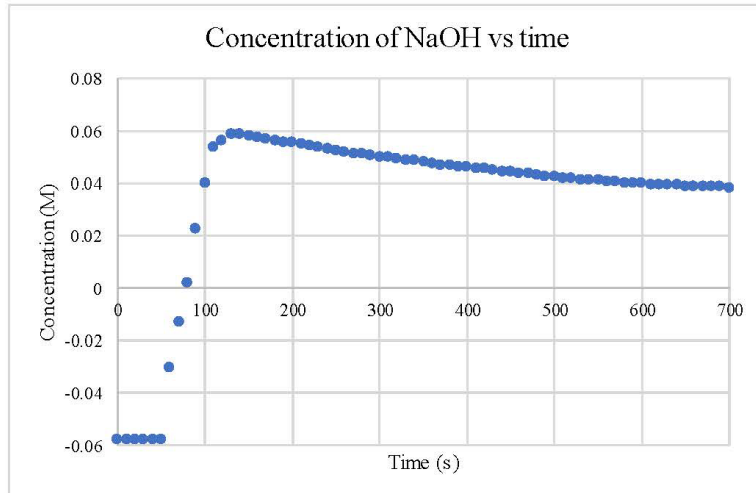


Figure 5: Concentration of NaOH vs Time approaching Steady State Condition

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.

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**CHEMICAL ENGINEERING DEPARTMENT
OUTCOMES SPECIFIC ASSIGNMENT COVER SHEET
Chemical Engineering Laboratory III
SPRING 2022**

Instructor: Dr. Jorge F. Gabitto

Title of Assignment

Report 2

Outcome Measured Using this Assignment

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.

Brief justification of why this assignment is suitable for this outcome

The rubric used to grade the report assesses the students planning, organization, and collaborative environment. Student participation is also assessed by private communication related to the activity.

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

Table of Contents

List of Figures	2
List of Tables	2
Abstract	3
Theory	3
Procedure	5
Results and Discussions	7
Conclusion	11
References	12

List of Figures

Figure 1. List of Equations	5
Figure 2. Conversion of NaOH as Function of Time.	8
Figure 3. Concentration of NaOH as Function of Time	8
Figure 4. Conductivity Calibration Curve	10

List of Tables

Table 1. CSTR Steady State at Given Percentage.	9
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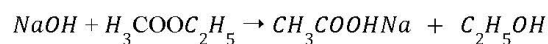
I. Abstract

The continuous stirred tank reactor (CSTR) is the ideal representation of complete mixing in reactor design. A CSTR often refers to a model used to estimate the key unit operation variables when using a continuous agitated-tank reactor to reach a specified output. It is important to consider that there is no CSTR reactor in real life.

This experiment involves a CEP-MkII Stirred Tank Reactor in series. The concentration is kept uniform for each reactor; however a change in concentration is observed as fluid flows from one reactor to the other reactor. This experiment is carried out to determine the conversion of a second order reaction in the tank as well as compare the operation between a real tank reactor and a CSTR (ideal) reactor. Finally, it was concluded that the real tank had a lower conversion rate compared to the ideal CSTR, but there was only a 0.07 difference making the actual experiment feasible.

II. Theory

The reaction taking place in this experiment is the saponification of Ethyl Acetate with Sodium Hydroxide.



This reaction can be considered as equi-molar and first order with respect both to sodium hydroxide and ethyl acetate, and second order overall, within the limits of concentration (0-0.1M) and temperatures between 20°C to 40°C.

The equation above shows that one mole of ethyl acetate reacts with one mole of sodium hydroxide.

The fractional conversion of sodium hydroxide in terms of feed flows can be expressed as:

$$X_A = \frac{A \text{ consumed in reactor}}{A \text{ fed to reactor}} = \frac{A \text{ fed to reactor} - A \text{ leaving reactor}}{A \text{ fed to reactor}} \quad (\text{eq 1})$$

Or can be expressed in terms of concentration as:

$$X_A(t) = \frac{C_{Ai} - C_A(t)}{C_{Ai}} \quad (\text{eq 2})$$

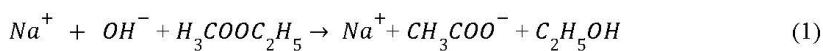
The reaction was carried out in three 0.7 litre tanks connected in series. The tanks eventually reached steady state when a certain conversion of the starting reagents was achieved. The steady state condition of the reaction was observed by observing the changes in the specific electrical conductance or conductivity denoted by the symbol (κ).

It was assumed that the flattening of the conductivity of the conductivity curve of " $\kappa(t)$ vs t " in a tank reactor indicates that the tank has achieved a steady state conversion, X_A^{SS} .

Specific conductivity decreases with a decrease in concentration. Since the

To understand the connection between and, we must first recognize $\kappa(t)$ and $X_A(t)$ that this saponification reaction occurs in a partially electrolytic solution.

Rewriting in terms of its reacting ions, the reaction can be expressed in its charge-balanced form:



The reacting mixture featured a measurable specific conductance due to the presence of the ionic species Na^+ , OH^- , COO^- . and the conductivity, $\kappa(t)$, of the reacting mixture was linearly dependent on the concentration of these ionic species in the solution.

$\kappa(t)$ can be expressed as a sum of the contributions of Na^+ , OH^- , COO^- based on their

respective concentrations and molar conductivity as follows:

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

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

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

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

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

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

Figure 1. List of Equations

III. Procedure

The procedure carried out on this experiment is intended to determine the conversion of a second order reaction using a tank reactor; in addition, it compares the operation of a real tank reactor with that of a CSTR reactor. The equipment used in this experiment is the CEP armfield which has a series of stirred tank reactors. The process consists of two feed vessels of which one contains 0.1M of ethyl acetate while the other has the same concentration of sodium hydroxide; both vessels have a volume of 5 liters.

The feed vessels supply into tank reactor 1, which is connected to tank 2 and both are filled at the same rate. Two pumps are used parallel to each other and are connected into the same header that feeds tank 1 and 2. Once these two tanks are completely full, they overflow into tank 3. Samples of the product are taken from tank 1 once steady state is reached. The process is said to be at steady state once the conductivity is no longer increasing or decreasing, if applicable, and the measurement of conductivity is observed from the CEP armfield display. Below is the systematic sequential steps to performed the experiment:

1. Prepare a solution of 0.1M of ethyl acetate, approximately 5 liters
2. Prepare another solution of 0.1M of sodium hydroxide, approximately 5 liters
3. Remove the lid of one of the two feed vessels
4. Fill the vessel with 0.1M solution up to 50mm from the top
5. Put the lid back securely on the vessel
6. For the second feed vessel (empty at this time), use 0.1M solution of sodium hydroxide and repeat steps 3-5
7. Turn on the pump on vessel 1
8. Set the pump's speed to 10 (~ 80ml/min)
9. Set the agitator speed in tank 1 to 10 (~84% its max)
10. Turn on the other pump from the second vessel and respect steps 8-9
11. Observe tank reactors 1 and 2 being filled and watch overflow into tank reactor 3
12. Allow the process to run for approximately 20-30 minutes until it reaches state state (conductivity is stable)
13. Collect the product sample from tank reactor #1
14. Data collection may begin at this point if no computer is used

IV. Results and Discussions

1. A reaction between a strong base such as sodium hydroxide with a weak acid like ethyl acetate produces sodium acetate and ethyl alcohol. The reaction is a partially electrolytic solution because of the free ions such as Na^+ , OH^- , and COO^- (which represents the acetate). Each ion has its own molar conductivity and its own molar concentration. By multiplying the molar conductivity and concentration of each type of ions and adding them up, the conductivity of the solution can be determined.

The equation, $\kappa(t) = C_{Na^+}(t) \cdot \Lambda_{Na^+} + C_{OH^-}(t) \cdot \Lambda_{OH^-} + C_{COO^-}(t) \cdot \Lambda_{COO^-}$, is supported by references like (Lower, 2021) and (Weedmark, 2018).

2. In this experiment, it was asked to plot a graph of the fraction conversion of the NaOH as a function of time. Using the concentration of NaOH and the conductivities of the ions given in the solution. The plot can be then developed after the conversion of NaOH is computed for each time.

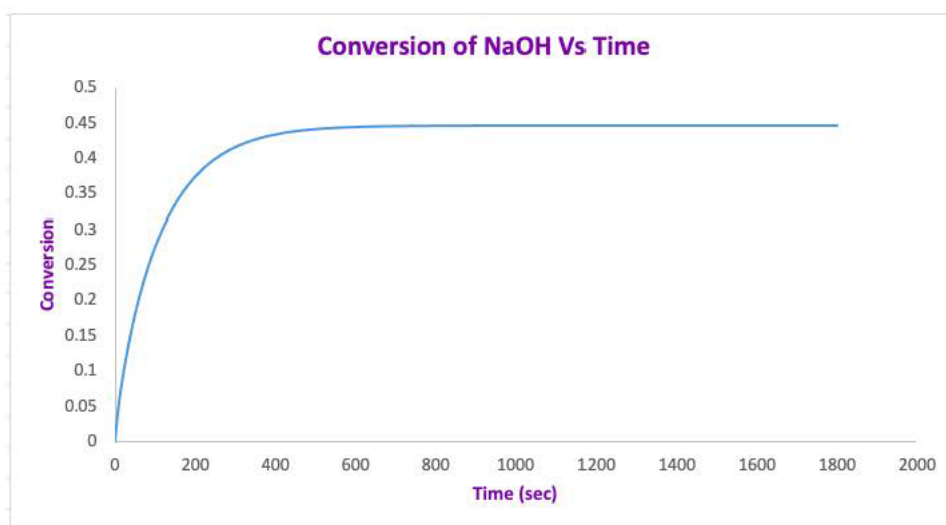


Figure 2. Conversion of NaOH as Function of Time.

As you can observe from the graph above, the conversion rate seems to increase as the time also increases. At a certain conversion rate and time which can be determined to be at 460 sec and 0.439, the rest of the reaction remains the same. At that point, we can consider the reaction reaching steady states and can be indicated by the flattening of the conductivity curves achieved by the tank.

3. The concentration was calculated using the equation provided in the lab manual. The graph below represents the concentration curve developed.

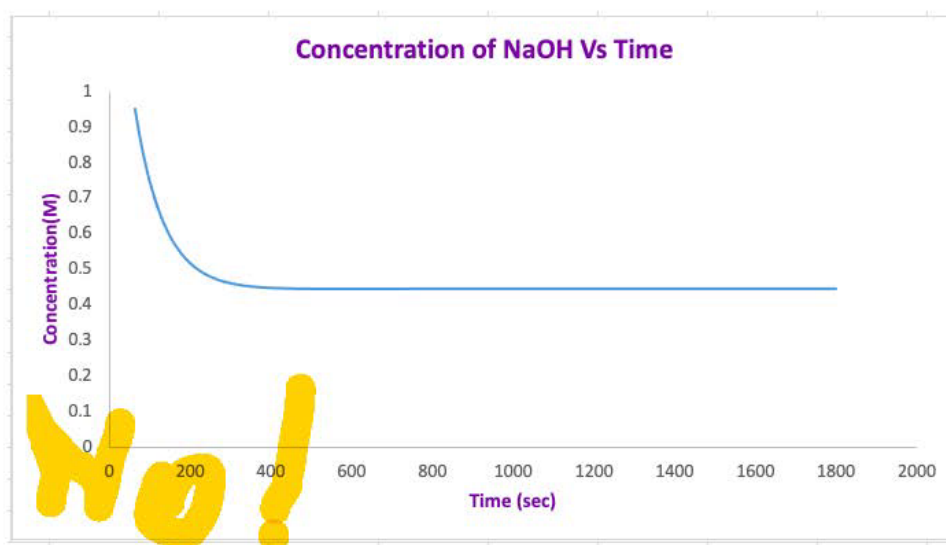


Figure 3. Concentration of NaOH as Function of Time

In this plot, we notice that the concentration decreases as it is being consumed in the first reactor. The reaction does not reach steady state until the curve starts flattening .

4. Below is an analysis based on the configuration and conditions of the experiment that confirms the equation $C_{A,i} = \frac{C_A^\circ}{2}$ where $C_{A,i}$ is the feed concentration of A to the first CSTR and C_A° is the concentration of A in feed tank A.

C_A° is given to be 0.1M. Using the equation, $C_{A,i}$ would be 0.05 M.

In the experiment, the concentration of NaOH in the feed tank (C_A°) and the concentration of ethyl acetate in the feed tank (C_B°) are both given to be 0.1M. An equimolar solution of NaOH (A) and ethyl acetate (B) is fed to the CSTR. Since A and B have the same molar concentration, A and B need to have the same volume to create an equimolar solution. Thus, for a 5.0 L batch, 2.5 L of 0.1 M NaOH and 2.5 L of 0.1 M ethyl acetate will create an equimolar solution that would be fed to the CSTR.

Since there is 2.5 L of 0.1 M NaOH, the moles of NaOH is 0.25. In order to calculate the concentration of NaOH in the 5.0 L solution, 0.25 moles of NaOH is divided by the solution volume, giving 0.05M of NaOH.

The equation $C_{A,i} = \frac{C_A^\circ}{2}$ can be used in this experiment because NaOH and ethyl acetate have the same initial molar concentration that was used to create an equimolar solution.

5. By using equation (7) listed in the lab manual, the conversion was computed and was used to plot a graph. From the graph, we noticed that the steady state is reached at a certain time when the curve starts flattening. The table below represents the steady state conversion given at 25%, 50%, and 75%.

Percentage steady state (%)	Elapsed time (sec)	Conversion	Measured Conductivity (mS/L)	Theoretical Conductivity (mS/L)
-----------------------------	--------------------	------------	------------------------------	---------------------------------

25	297.3	0.426	6.187	6.236
50	594.6	0.446	6.269	6.267
75	891.9	0.446	6.267	6.267

Table 1. CSTR Steady State at Given Percentage.

6. From the values provided in the lab manual, conductivities and the percentage of steady state achieved by the system will be developed by a plot shown below.

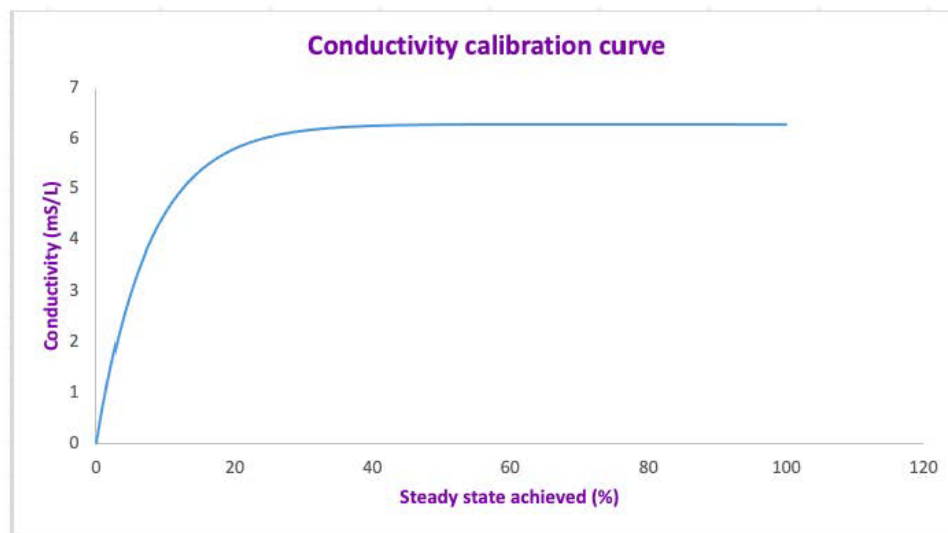


Figure 4. Conductivity Calibration Curve

The plot above demonstrates the curve developed after calibrating the value of the conductivity which starts reaching the steady state at 20%.

7. The mean residence time (τ) of the first reactor can be calculated using the equation:

$$\tau = \frac{\text{Total reactor Volume}}{\text{Total volumetric Flow Rate}}$$

There are 3, 0.7L CSTR tanks connected in series. The volumetric flow rate is 80 mL/min which can be written as 0.0013 L/s.

Using the equation given, the mean residence time for the first reactor is 525 seconds.

V. Conclusion

The main goal of the experiment was to determine the conversion of NaOH in a tank reactor. An equimolar solution of NaOH and ethyl acetate was added into the CEP-MkII Stirred Tank Reactors in Series unit which was compared to a 3-series 0.7L CSTR configuration. The conductivity of the solution was determined using the concentrations of ions and the molar conductivities. The solution's conductivity was then used to determine the conversion of NaOH in the real tank reactor where the conversion was at 0.439. The conversion of NaOH in the ideal CSTR was determined to be around 0.446. In conclusion, the real tank had a lower conversion rate compared to the ideal CSTR, but there was only a 0.07 difference making the actual experiment feasible. Possible ways to increase the conversion of NaOH is to have a higher concentration of NaOH, add an enzyme, larger tank volume, more residence time (if it does not reach equilibrium), and/or have a higher stirring rate.

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<https://sciencing.com/calculate-conductivity-due-concentration-2691.html>

ASSIGNMENTS FOR OUTCOME 6

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

**CHEMICAL ENGINEERING DEPARTMENT
OUTCOMES SPECIFIC ASSIGNMENT COVER SHEET
Chemical Engineering Laboratory III
SPRING 2021**

Instructor: Dr. Jorge F. Gabitto

Title of Assignment

Report 3

Outcome Measured Using this Assignment

Outcome 6

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

Brief justification of why this assignment is suitable for this outcome

The rubric used to grade the report assesses the students' data gathering, data processing, and interpretation of the experimental results. Student understanding of the experiment goals and drawing of appropriate conclusions is also measured.

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

Table of Contents

<i>1. Abstract</i>	<i>2</i>
<i>2. Theory</i>	<i>2</i>
<i>3. Procedure</i>	<i>4</i>
<i>4. Results and Discussion</i>	<i>6</i>
<i>6. Conclusion</i>	<i>9</i>
<i>7. References</i>	<i>10</i>

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;

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

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

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

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

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

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

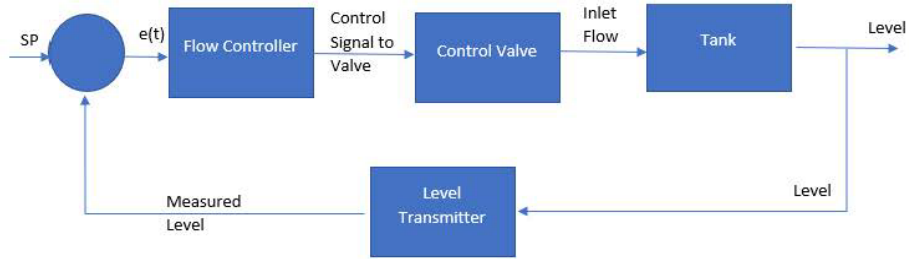


Figure 1. In a closed loop system is an automatic control system in which an operation process is regulated by feedback

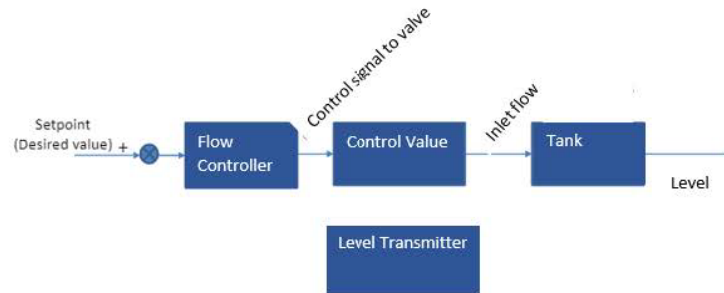


Figure 2. In an open loop system the output signal or condition is neither measured nor fed back for comparison with the input signal or system set point.

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.

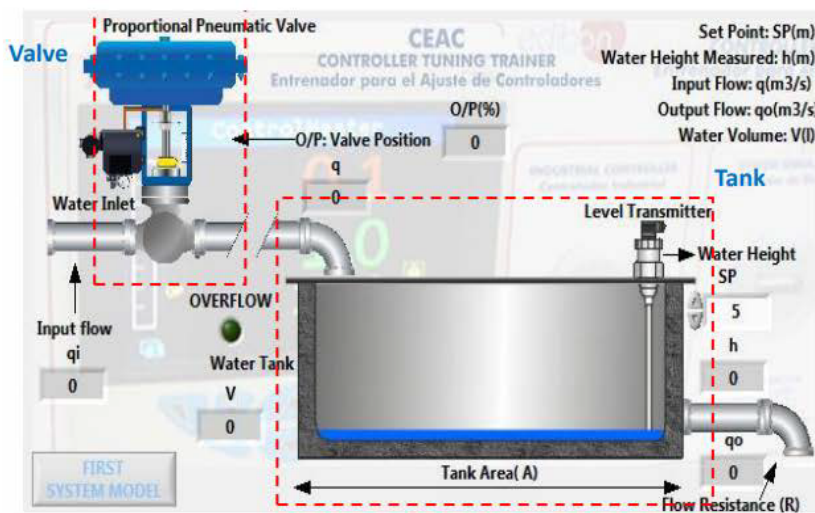


Figure 3 . A schematic of the Edibon CEAC Control Simulator

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.

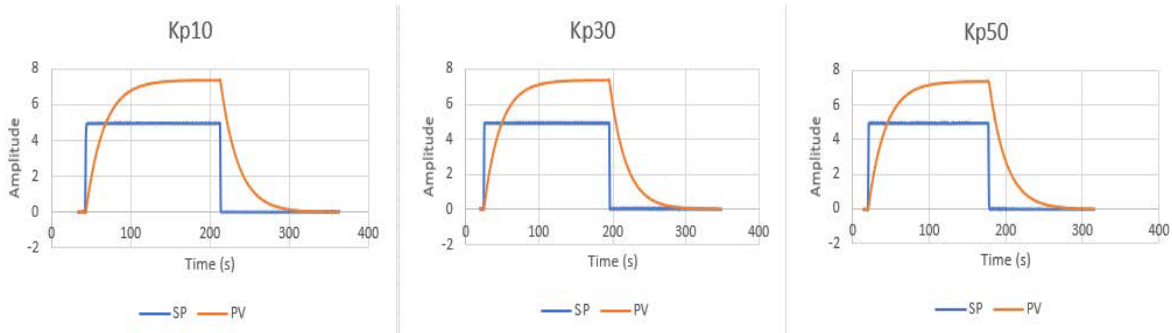


Figure 4. Comparison of open loop control system with different K_p values

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)

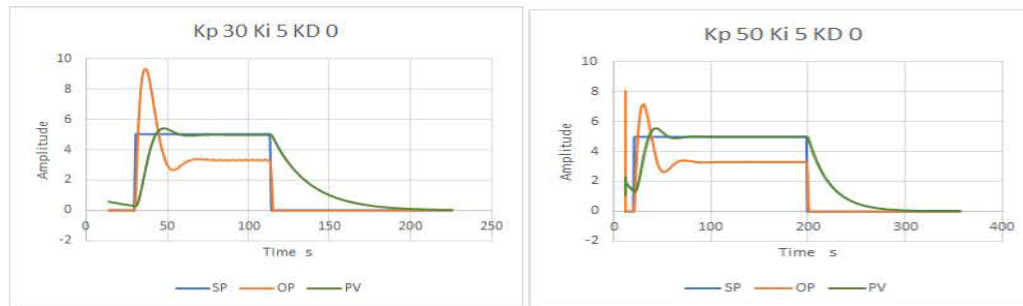


Figure 5. Comparison of PI control for closed loop system with different K_p values

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 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.

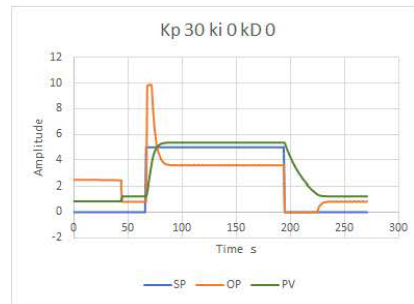


Figure 6 P- only closed loop system

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 that 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

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**CHEMICAL ENGINEERING DEPARTMENT
OUTCOMES SPECIFIC ASSIGNMENT COVER SHEET
Chemical Engineering Laboratory III
SPRING 2021**

Instructor: Dr. Jorge F. Gabitto

Title of Assignment

Final Presentation

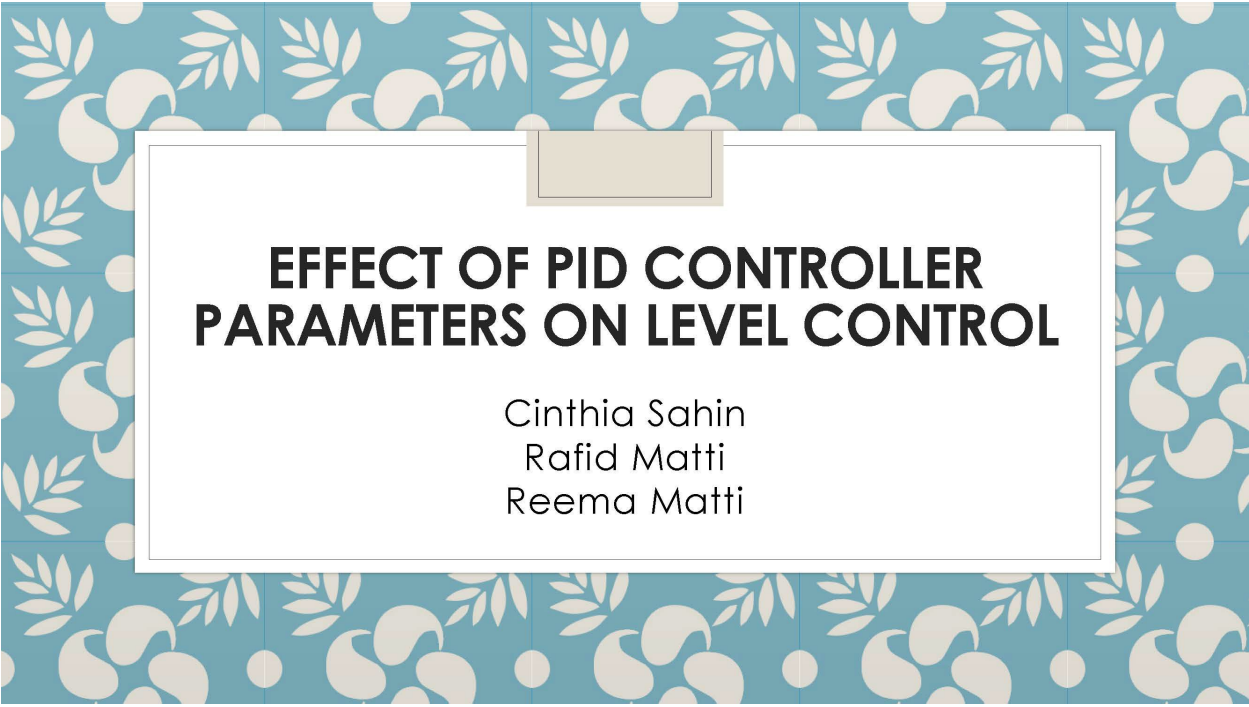
Outcome Measured Using this Assignment

Outcome 6

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

Brief justification of why this assignment is suitable for this outcome

The rubric used to grade the final presentation assesses how the students analyze, process, interpret data, and draw appropriate engineering conclusions. Understanding of proper experimental procedures is also assessed.

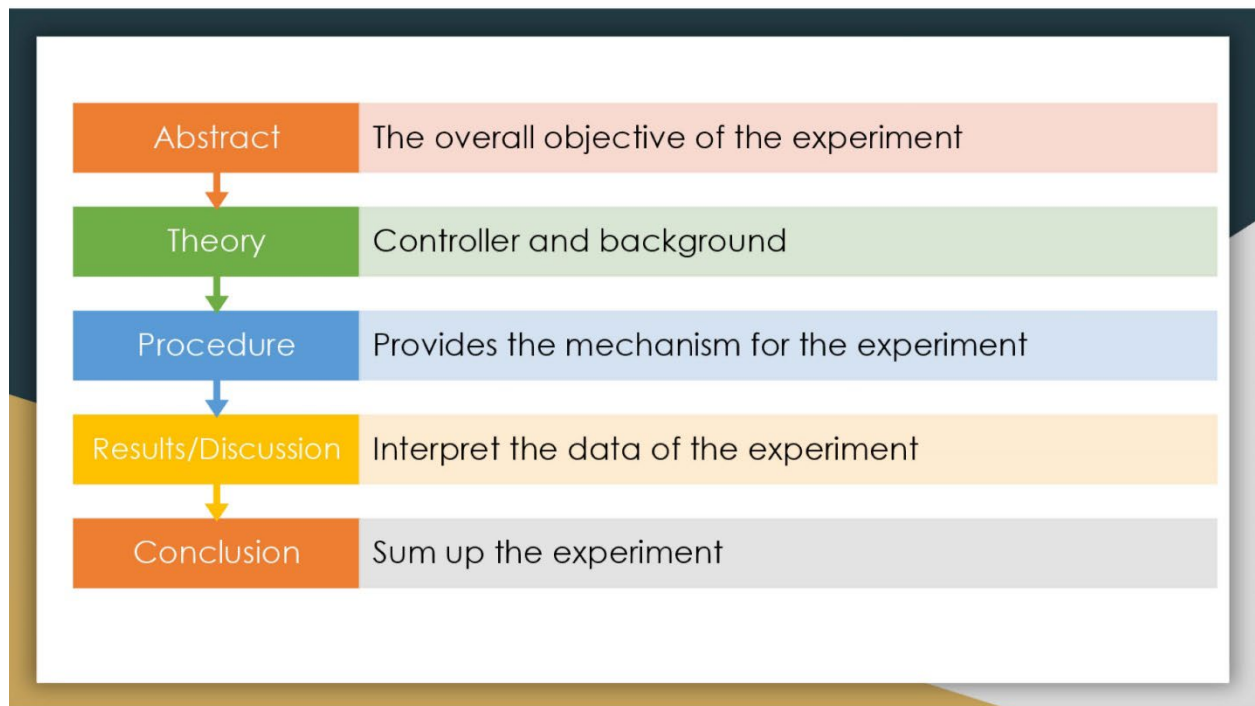


EFFECT OF PID CONTROLLER PARAMETERS ON LEVEL CONTROL

Cinthia Sahin
Rafid Matti
Reema Matti



Outline



An abstract graphic featuring a large gold rectangle. In the top-left corner of the rectangle, there are three parallel dark blue diagonal lines. In the bottom-right corner, outside the rectangle, there are three parallel gold diagonal lines.

Abstract

Abstract

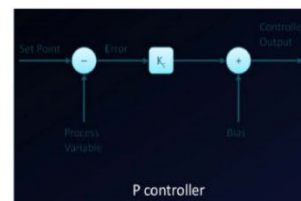
- Controllers used in industrial control applications to adjust the temperature, flow, pressure, speed, and other process variables
- Performed a qualitative analysis of the proportional, integral, and derivative settings' effect on level control for UCPN
- Showed the difference between proportional, integral, and derivative control
- Explanation of which one of them gave the best control
- The experiment confirmed what the literature reviews affirm, the PID was the best controller.



Theory

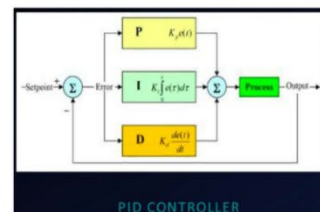
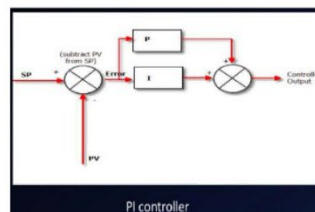
Controllers

A controller is a device that receives the error from a comparator, interprets it, and acts on the final element of control.



There are three basic types of controllers:

- Proportional controller (P controller)
- Integral controller (I controller)
- Derivative controller (D controller)



Figures 1-3: Different types of controllers

PID controllers

- PID stands for Proportional-Integral-Derivative
- Feedback control loop mechanism used in a variety of applications
- Continuously calculates an error value " $e(t)$ "

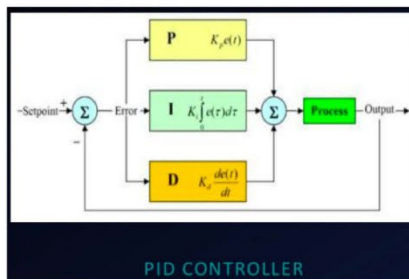


Figure 3: Block diagram of PID controller in a feedback loop

Mathematical form

- The overall control function can be denoted as:

$$u(t) = K_p e(t) + K_i \int_0^t e(t') dt' + K_d \frac{de(t)}{dt},$$

Where K_p , K_i , and K_d denote the coefficients for the proportional, integral and derivative terms (Bequette, 2002).

- In standard form, K_i and K_d are respectively replaced by K_p/T_i and $K_p T_d$ (Bequette, 2002)

$$u(t) = K_p \left(e(t) + \frac{1}{T_i} \int_0^t e(t') dt' + T_d \frac{de(t)}{dt} \right)$$

Advantage and Disadvantage

	<u>Advantages</u>	<u>Disadvantages</u>
<u>P controller</u>	Very stable control process	Steady-state error when disturbances occur
<u>PI controller</u>	Provides better stability	Takes longer to stabilize
<u>PID controller</u>	Improve the stability of the system	Action is instantaneous (as soon as error is produced, control action is taken)



Procedure

Procedure Key Notes

- Planned to regulate the setpoint level of the upper tank.
- Used a PID controller that automatically operates the control valve (final element of the control loop in the unit).
- After setting the values of the controller, a step signal in the setpoint produces changes in the setpoint value from the initial value.
- The output level values are recorded and analysed in plot characteristics
 - Show the influence of different values on the output response.

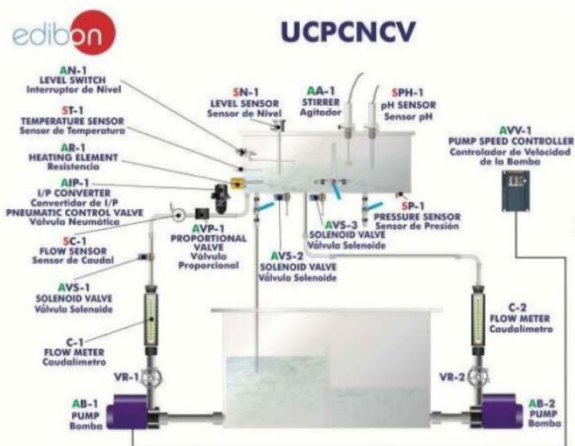


Figure 4: Schematic of the UPCN equipment

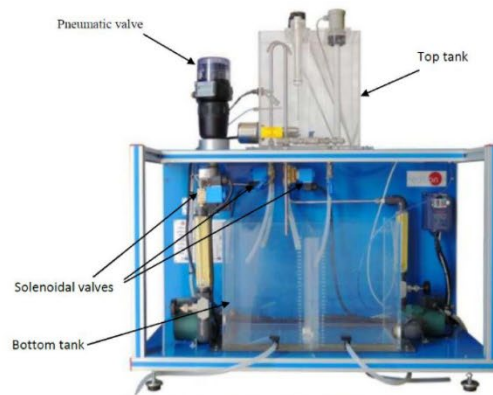


Figure 5: Actual of the UPCN equipment

Procedure Sequential Steps:

1. Press the START button.
2. Add the file name where the measured data will be recorded.
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 setpoint to the value listed in Table 1 (in the next slide).
6. Run the experiment for 5 minutes (300 seconds) or until steady-state is reached.
7. Repeat for **3 times** 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.

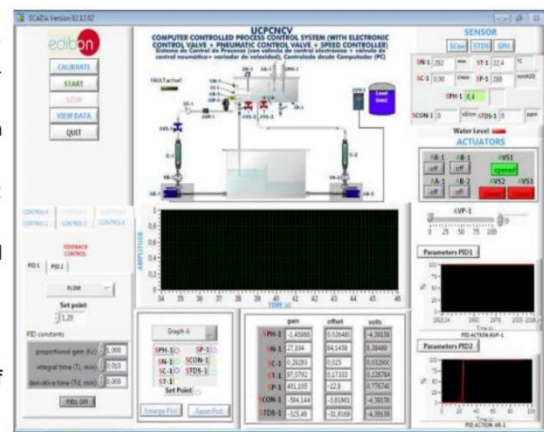


Figure 6: Main Screen

Table I. Controller constants values

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 and Discussion

P Controller Output

P controller output is directly proportional to the error signal

- At a set point of 100, the control response has not reach steady state
- At a set point of 80, the control response has a fast settling time and reach steady state
- At a set point of 60, the control response has a slow settling time with an overshoot before reaching steady state.

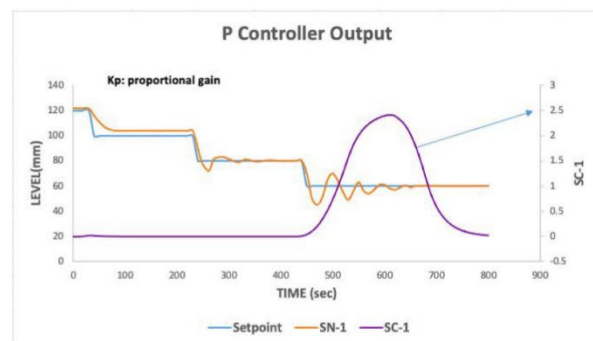


Figure 6: P controller output

PI Controller Output

P and PI controller output is directly proportional to the summation of proportional of the error and integration of the error signal

- At a set point of 100, the control response has a fast settling time and reach steady state
- At a set point of 80, the control response has a fast settling time with a small overshoot before reaching steady state
- At a set point of 60, the control response has a slow settling time with a big overshoot before reaching steady state

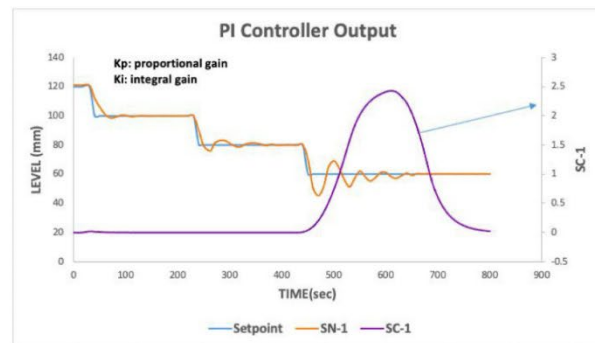


Figure 7: PI controller output

PID Controller Output

P, PI, PID controller output is directly proportional to the summation of proportional, integration, and derivative of the error signal.

- The PID controller produced nearly identical values at given setpoints
- The PID controller produces very slightly smaller oscillations compared to the PI controller

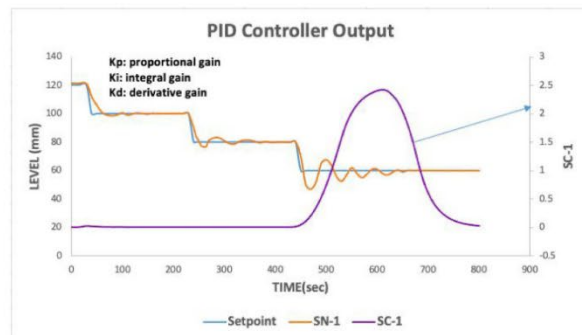


Figure 8: PID controller output



Conclusion

Conclusion

Types of Controllers:

- P controller
- PI controller
- PID controller

PI and PID controller had **near identical** results

PID controller was the **BEST** choice

- P, PI, PID controller output were directly proportional to the summation of proportional, integration, and derivative of the error signal.
 - Provided a more accurate reading

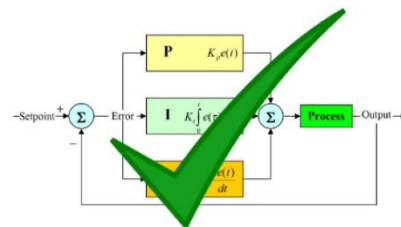


Figure 3: Block diagram of PID controller in a feedback loop

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