Department of Chemical Engineering

18CHC309L - Chemical Engineering Lab III

Name : _____

Register Number : _____

Year/ Sem /Branch : _____

Academic Year :_____

SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

SRM NAGAR, KATTANKULATHUR - 603 203

CHENGALPET DISTRICT

SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

SRM NAGAR, KATTANKULATHUR - 603 203

CHENGALPET DISTRICT

BONAFIDE CERTIFICATE

Register No. _____

Certified to be the bonafide record of work done by _____

of III year B. Tech. Degree course in the Practical **18CHC309L - Chemical Engineering LabIII**

in ***SRMIST, Kattankulathur*** *during the academic year* ***20 – 20*** .

Lab In-charge

Head of the Department

*Submitted for University Examination held on*_____*at* ***SRMIST, Kattankulathur.***

Examiner 1 **Examiner 2**

CONTENT

Department of Chemical Engineering
College of Engineering and Technology
SRM Institute of Science and Technology

B.Tech. in Chemical Engineering

Vision of the Department

To utilize Chemical Engineering and Technology and ensure overall socio-economic growth, welfare, and progress of Indian society and the World-at-large by supporting Academia, Industries through Research and Development, Consultancy and graduating high-quality Chemical Engineers

Mission of the Department

Mission Stmt - 1	To facilitate high quality education, well grounded in the fundamental and applied areas of engineering necessary for learners to contribute effectively to chemical and allied industries
Mission Stmt - 2	To educate, prepare, inspire and mentor learners with the technical and professional skill-set necessary to excel as professionals, grow in their careers and contribute to chemical engineering science and technology
Mission Stmt - 3	To inculcate social-responsibility in learners and train them to contribute effectively to science and society

Program Educational Objectives (PEO)

Within a few years of graduation, the students of the program will be able to attain the following:

PEO - 1	Utilizing their strong fundamental knowledge from the program be able to solve technical problems and contribute to chemical and allied industries
PEO - 2	Pursuing higher studies and/or continuously upgrading their skill-sets with technological advances leading to personal and professional growth and successful careers
PEO - 3	Establishing themselves with successful careers in industry, academia and/or as entrepreneurs that will enable them to address social, economic and environmental challenges and contribute to science and society

Mission of the Department to Program Educational Objectives (PEO) Mapping

	Mission Stmt. - 1	Mission Stmt. - 2	Mission Stmt. - 3
PEO - 1	3	2	1
PEO - 2	2	3	1
PEO - 3	2	1	3

3 – High Correlation, 2 – Medium Correlation, 1 – Low Correlation

Mapping Program Educational Objectives (PEO) to Program Learning Outcomes (PO)

	Program Outcomes (PO)														
	Graduate Attributes (GA)												Program Specific Outcomes (PSO)		
	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
PEO - 1	*3*	*3*	*3*	*3*	*2*				*2*	*2*	*2*		*3*	*3*	*2*
PEO - 2	*3*	*3*	*3*	*3*	*2*		*2*	*2*				*2*	*3*	*2*	*2*
PEO - 3	*2*	*2*	*2*	*2*		*3*	*2*	*2*	*3*	*3*	*3*	*2*	*3*	*2*	*3*

3 – High Correlation, 2 – Medium Correlation, 1 – Low Correlation

PSO – Program Specific Outcomes (PSO)

PSO - 1	*Ability to understand and differentiate processes*
PSO - 2	*Apply the fundamentals to perform equipment design and process design*
PSO - 3	*Evaluate the process plants from Energy, Environment and Safety related aspects*

SYLLABUS

Course Code	18CHC309L	Course Name	CHEMICAL ENGINEERING LABORATORY - III	Course Category	C	Professional Core	L	T	P	C
							0	0	4	2

Pre-requisite Courses	*Nil*	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Chemical Engineering*		Data Book / Codes/Standards	*Nil*	

Course Rationale (CR):	*The purpose of learning this course is to:*	Learning
CR-1:	*Develop the skills in conducting experiments and to verify the theoretical concepts learnt in Chemical Reaction Engineering and Reactor analysis & catalysis courses by evaluating the performance of single ideal reactors.*	1
CR-2:	*Evaluate the performance of multiple reactors*	
CR-3:	*Understand the behavior of non-ideal flow reactors*	
CR-4:	*Develop the skills in conducting experiments and to verify the theoretical concepts learnt in process dynamics, control & instrumentation course*	
CR-5:	*Understand the process control concepts while performing the experiments and analyze the response for different forcing functions for different mode of controllers*	

Course Outcomes (CO):	*At the end of this course, learners will be able to:*	Blooms level (1-6)	Program Outcomes (PO)														
			1 Engineering Knowledge	2 Problem Analysis	3 Design & Development	4 Analysis, Design, Research	5 Modern Tool Usage	6 Society & Culture	7 Environment & Sustainability	8 Ethics	9 Individual & Team Work	10 Communication	11 Project Mgt. & Finance	12 Life Long Learning	PSO - 1 Ability to understand and differentiate processes	PSO - 2 Apply the fundamentals to perform equipment design and process design	PSO - 3 Evaluate the process plants from Energy, Environment and Safety related aspects
CO-1 :	*Demonstrate the working of batch and continuous reactors and analyze the output*	4	2	3	-	-	-	-	-	-	-	-	-	-	3	-	-
CO-2 :	*Analyze the performance of combined reactor system*	4	2	3	-	-	-	-	-	-	-	-	-	-	3	-	-
CO-3 :	*Demonstrate the reason for non-ideal behavior in flow reactors.*	4	2	3	-	-	-	-	-	-	-	-	-	-	3	-	-
CO-4 :	*Analyze flapper- nozzle system and valve characteristics used for control system*	4	2	3	-	-	-	-	-	-	-	-	-	-	3	-	-
CO-5 :	*Analyze the response of different controllers such as P, PI, PD, PID, and their tuning process*	4	2	3	-	-	-	-	-	-	-	-	-	-	3	-	-

Duration (hour)		12	12	12	12	12
S 1-4	SLO-1	*Kinetic study in a batch reactor*	*Performance study of a plug flow reactor.*	*Performance study of a mixed flow reactor.*	*Performance study of (i)a plug flow reactor followed by a mixed flow Reactor (ii) a mixed flow reactor followed by a plug flow reactor*	*Study of effect of temperature in an adiabatic reactor.*
	SLO-2					
S 5-8	SLO-1	*Performance study of a semi batch reactor*	*RTD studies in a plug flow reactor.*	*RTD studies in a mixed flow reactor.*	*Study on Flapper nozzle arrangement, Current to pressure and pressure to current converter*	*Verifying step response of first order system for a given tank*
	SLO-2					
S 9-12	SLO-1	*Study of interacting and non-interacting system*	*Study on control valve characteristics*	*Study on level process controller*	*Study on pressure process controller*	*Optimum controller tuning on level controller*
	SLO-2					

Learning Resources	1. *Laboratory Manual* 2. *Octave Levenspiel, "Chemical Reaction Engineering", 3rd edition, John Wiley & Sons India edition, 2011.* 3. *George Stephanopoulos, "Chemical Process Control: An Introduction to Theory and Practice", Prentice Hall, New Delhi, 1984.*

Learning Assessment											
	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	-	10 %	-	10 %	-	10 %	-	10 %	-	10 %
Level 2	Understand	-	20 %	-	20 %	-	20 %	-	20 %	-	20 %
Level 3	Apply	-	40 %	-	40 %	-	40 %	-	40 %	-	40 %
Level 4	Analyze	-	30 %	-	30 %	-	30 %	-	30 %	-	30 %
Level 5	Evaluate	-	-	-	-	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-	-	-	-	-
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Mr. A. Subramaniam, PESCO Beam Environmental Solutions Pvt. Ltd.,*	1. *Dr. Lima Rose Miranda, Anna University, email: limamiranda2007@gmail.com*	1. *Dr. K. Sofiya, SRMIS*
2. *Mr. S. T. Kalaimani, CPCL, Chennai*	2. *Dr. T. R. Sundararaman, Rajalakshmi Engineering College*	2. *Dr.P. Muthamilselvi , SRMIST*

COURSE ARTICULATION MATRIX

Course Outcomes (CO):	At the end of this course, learners will be able to:	Program Outcomes (PO)														
		1	2	3	4	5	6	7	8	9	10	11	12	PSO - 1	PSO - 2	PSO - 3
CO-1 :	Demonstrate the working of batch and continuous reactors and analyze the output	2	3	-	-	-	-	-	-	-	-	-	-	3	-	-
CO-2 :	Analyze the performance of combined reactor system	2	3	-	-	-	-	-	-	-	-	-	-	3	-	-
CO-3 :	Demonstrate the reason for non-ideal behavior in flow reactors.	2	3	-	-	-	-	-	-	-	-	-	-	3	-	-
CO-4 :	Analyze flapper- nozzle system and valve characteristics used for control system	2	3	-	-	-	-	-	-	-	-	-	-	3	-	-
CO-5 :	Analyze the response of different controllers such as P, PI, PD, PID, and their tuning process	2	3	-	-	-	-	-	-	-	-	-	-	3	-	-

LIST OF EXPERIMENTS

1. KINETIC STUDY IN A BATCH REACTOR
2. PERFORMANCE STUDY OF A SEMI BATCH REACTOR
3. PERFORMANCE STUDY OF A PLUG FLOWREACTOR
4. STUDY OF RTD IN A MIXED FLOW REACTOR
5. STUDY OF A PLUG FLOW REACTOR FOLLOWED BY A MIXED FLOW REACTOR
6. STUDY ON FLAPPER NOZZLE ARRANGEMENT, CURRENT TO PRESSURE AND PRESSURE TO CURRENT CONVERTER
7. VERIFYING STEP RESPONSE OF FIRST ORDER SYSTEM FOR A GIVEN TANK
8. STUDY ON CONTROL VALVE CHARACTERISTICS
9. STUDY ON LEVEL PROCESS CONTROLLER
10. STUDY ON DIFFERENT MODE OF CONTROLLERS P, PD, PI, PID

MAPPING OF COURSE OUTCOMES AND PROGRAM OUTCOMES WITH EXPERIMENTS

Course Outcomes (CO)	Program Outcomes (PO)/ Program specific Outcomes (PSO)	Experiment Details
CO 1 : Demonstrate the working of batch and continuous reactors and analyze the output	PO 1: Engineering Knowledge PO 2: Problem Analysis PSO 1: Ability to understand and differentiate processes	1.Kinetic study in a batch reactor 2.Performance study of a semi batchreactor 3. Performance study of a plug flow reactor.
CO 2 : Analyze the performance of combined reactor system	PO 1: Engineering Knowledge PO 2: Problem Analysis PSO 1: Ability to understand and differentiate processes	5.Study of a plug flow reactor followed by a mixed flow reactor
CO 3 : Demonstrate the reason for non-ideal behavior in flow reactors.	PO 1: Engineering Knowledge PO 2: Problem Analysis PSO 1: Ability to understand and differentiate processes	4.Study of RTD in a mixed flow reactor
CO 4 : Analyze flapper- nozzle system and valve characteristics used for control system	PO 1: Engineering Knowledge PO 2: Problem Analysis PSO 1: Ability to understand and differentiate processes	6. Study on Flapper nozzle arrangement, current to pressure and pressure to current converter 8. Study on control valve characteristics
CO 5 : Analyze the response of different controllers such as P, PI, PD, PID, and their tuning process	PO 1: Engineering Knowledge PO 2: Problem Analysis PSO 1: Ability to understand and differentiate processes	7. Verifying step response of first order system for a given tank 9. Study on level process controller 10.Study on different mode of controllers P, PD, PI, PID

RUBRICS

Course Outcomes	Allocated Marks	High	Medium	Low
Pre-Lab	5	Thorough study and all the questions have been answered correctly	Adequate study and more than half of the questions have been answered correctly	No understanding of any experimental concepts
		5	3	0
Post-Lab	5	Objectives of experiment are fully grasped Developed theoretical understanding of concept	Objectives of experiment are fully grasped	No idea is built from experiment
		5	3	0
Experiment Performance (Observation and Result Analysis)	5	Proper data is collected from experiment	Inconsistency in data	Wrong Observation made
		5	3	0
	5	Accurate and reproducible results Analysis of data	Accurate and reproducible results and absence of analysis of data	No results Calculated No idea has been built from data and results
		5	3	0

EVALUATION CRITERIA

Particulars	Max. Marks
Pre-Lab	5
Post-Lab	5
Experiment Performance	10

SAFETY PRECAUTIONS

Lab Safety Do's and Don'ts for Students

Use this handy checklist to acquaint students with safety dos and don'ts in the laboratory.

Conduct

- Never run in the laboratory.
- The use of personal audio or video equipment is prohibited in the laboratory.
- Do not engage in practical jokes or boisterous conduct in the laboratory.
- Do not sit on laboratory benches.

General Work Procedure

- Know emergency procedures.
- Never work in the laboratory without the supervision of an instructor.
- Immediately report any spills, accidents, or injuries to your instructor.
- Never leave experiments while in progress.
- Do not remove any equipment or chemicals from the laboratory.
- Store coats, bags, and other personal items in designated areas.
- Keep the floor clear of all objects (e.g., ice, small objects, spilled liquids).

Housekeeping

- Keep work area neat and free of any unnecessary objects.
- Thoroughly clean your laboratory work space at the end of the laboratory session.
- Do not block the sink drains with debris.
- Never block access to exits or emergency equipment.
- Properly dispose of broken glassware and other sharp objects (e.g., syringe needles)immediately in designated containers.
- Properly dispose of weigh boats, gloves, filter paper, and paper towels in thelaboratory.

Apparel in the Laboratory

- Always wear personal protective equipment like goggles, gloves when handlinghazardous materials.
- Wear a full-length, long-sleeved laboratory coat or chemical-resistant apron.
- Wear shoes that adequately cover the whole foot.

- Secure long hair and loose clothing (especially loose long sleeves, neck ties, orscarves).

Emergency Procedure

- Know the location of all the exits in the laboratory and building.
- Know the location of the emergency phone.
- Know the location of and know how to operate the following:Fire extinguishers, Eye washes, First aid kits

Chemical Handling

- Check the label to verify it is the correct substance before using it.
- Always use a spatula to remove a solid reagent from a container.
- Do not directly touch any chemical with your hands.
- Hold containers away from the body when transferring a chemical or solution fromone container to another.
- Use a hot water bath to heat flammable liquids. Never heat directly with a flame.
- Clean up all spills properly and promptly.
- Dispose of chemicals as instructed.

CHEMICAL ENGINEERING LAB III

OBSERVATION

Volume of sample solution taken for titration: 10 mL

S.No.	Time	Volume of NaOH used for titration	Volume of CH_3COOH unreacted	Volume of CH_3COOH reacted	Volume of NaOH unreacted	Concentration of NaOH at time t	Fractional conversion for reactant A	$\frac{X_A}{C_{AO}(1-X_A)}$	Rate constant
	t min	V_1 mL	V_2 mL	V_3 mL	V_4 mL	C_A mol/ L	X_A	L / mol	k $\frac{L}{mol\ min}$
1.									
2.									
3.									
4.									
5.									
6.									
7.									
8.									
9.									
10.									
								k_{avg} =	

Experiment No: 1 **Date:**

KINETIC STUDY IN A BATCH REACTOR

AIM

To determine the rate constant for the given second order irreversible esterification reaction using batch reactor.

APPARATUS REQUIRED

Batch reactor set up, Burette, Pipette, Beakers, Conical flasks, Stop watch.

CHEMICALS REQUIRED

Ethyl Acetate ($CH_3COOC_2H_5$), Sodium Hydroxide (NaOH), Acetic acid (CH_3COOH), Phenolphthalein indicator.

THEORY

In a batch reactor, the reactants are initially charged in the container and are well mixed and allowed to react for a certain period. This is an unsteady state operation, where composition changes with time. However, at a specified time, the concentration is same throughout the reactor.

Ethyl Acetate + Sodium Hydroxide → Sodium Acetate + Ethyl alcohol

$CH_3COOC_2H_5 + NaOH \rightarrow CH_3COONa + C_2H_5OH$

The rate expression, for this second order, irreversible reaction is given by,

$-r_A = dC_A/dt = kC_A^2$ Where $C_A = C_{Ao}(1- X_A)$--------- (1)

If concentration vs time data is available, the rate constant can be obtained either by the integral method of analysis or by the differential method of analysis. If the order is known integral method is more accurate. If both order and rate constants are to be evaluated, differential method is preferable.

In the integral analysis, the order is assumed, the rate equation is integrated and the value of the constant is estimated. For different set of values, if the value of the rate constant is same, the assumed order is right and the value of the rate constant is the required one. If the values of the rate constant differ, different order is assumed and the procedure is repeated till the correct order is found.

CALCULATIONS

Initial Volume of NaOH taken (V_{AO}) = 250 mL

Initial Volume of Ethylacetate taken (V_{BO}) = 250 mL

Initial Total Volume present in the Reactor (V_o) = $V_{AO} + V_{BO}$ = 500 mL

Volume of CH_3COOH added for arresting the reaction (V)= 10 mL

Volume of sample solution taken for titration = 10 mL

Volume of NaOH used for titration (V_1) =-------ml (Titre value of NaOH**)**

Normality of NaOH (N_1) = 0.1 N

Normality of CH_3COOH (N_2) = 0.1 N

Volume of CH_3COOH unreacted (V_2) $= \frac{\text{Volume of NaOH used for titration X Normality of NaOH}}{\text{Normality of } CH_3COOH}$

$$V_2 = \frac{V_1 X N_1}{N_2} =$$

Volume of CH_3COOH reacted(V_3) = Volume of CH_3COOH added for arresting the reaction - Volume of CH_3COOH unreacted

= V- V_2 =

Volume of NaOH unreacted (V_4) $= \frac{\text{Volume of } CH_3COOH \text{ reacted X Normality of } CH_3COOH}{\text{Normality of NaOH}}$

$$= \frac{V_3 X N_2}{N_1} =$$

For a second order reaction and for equimolar concentrations of the reactants the integrated form of rate equation from eqn. (1) is If concentration vs time data is available, the rate constant can be obtained either by the integral method of analysis or by the differential method of analysis. If the order is known integral method is more accurate. If both order and rate constants are to be evaluated, differential method is preferable.

In the integral analysis, the order is assumed, the rate equation is integrated and the value of the constant is estimated. For different set of values, if the value of the rate constant is same, the assumed order is right and the value of the rate constant is the required one. If the values of the rate constant differ, different order is assumed and the procedure is repeated till the correct order is found. For a second order reaction and for equimolar concentrations of the reactants the integrated form of rate equation from eqn. (1) is

$$t = \frac{X_A}{kC_{AO}(1- X_A)}$$

t - time (min)

X_A - fractional conversion for reactant A

k - second order rate constant (L / mol .min)

C_{Ao} - initial concentration of reactant A (mol /L)

C_A - concentration of the reactant A at time t (mol / L)

In the differential analysis, the concentration of reactant A is plotted against time. For selected values of concentrations, the corresponding values of the slopes (dC_A / dt) are obtained. A plot of ln (dC_A / dt)vsln C_A will yield a straight line with a slope n, where n is the order of the reaction. The value of the intercept is ln k, where k is the rate constant.

Concentration of NaOH at time t (C_A) = $\frac{\text{Volume of NaOH unreacted X Normality of NaOH}}{\text{Volume of sample solution taken for titration}}$

$$= \frac{V_4 \text{ X } N_1}{10}$$

Initial Concentration of NaOH (C_{Ao}) = $\frac{\text{Initial Volume of NaOH taken X Normality of NaOH}}{\text{Initial Total Volume in the reactor}}$

$$= \frac{V_{AO} \text{ X } N_1}{V_O} = \frac{250 \text{ X } 0.1}{500} = 0.05 \text{ mol / L}$$

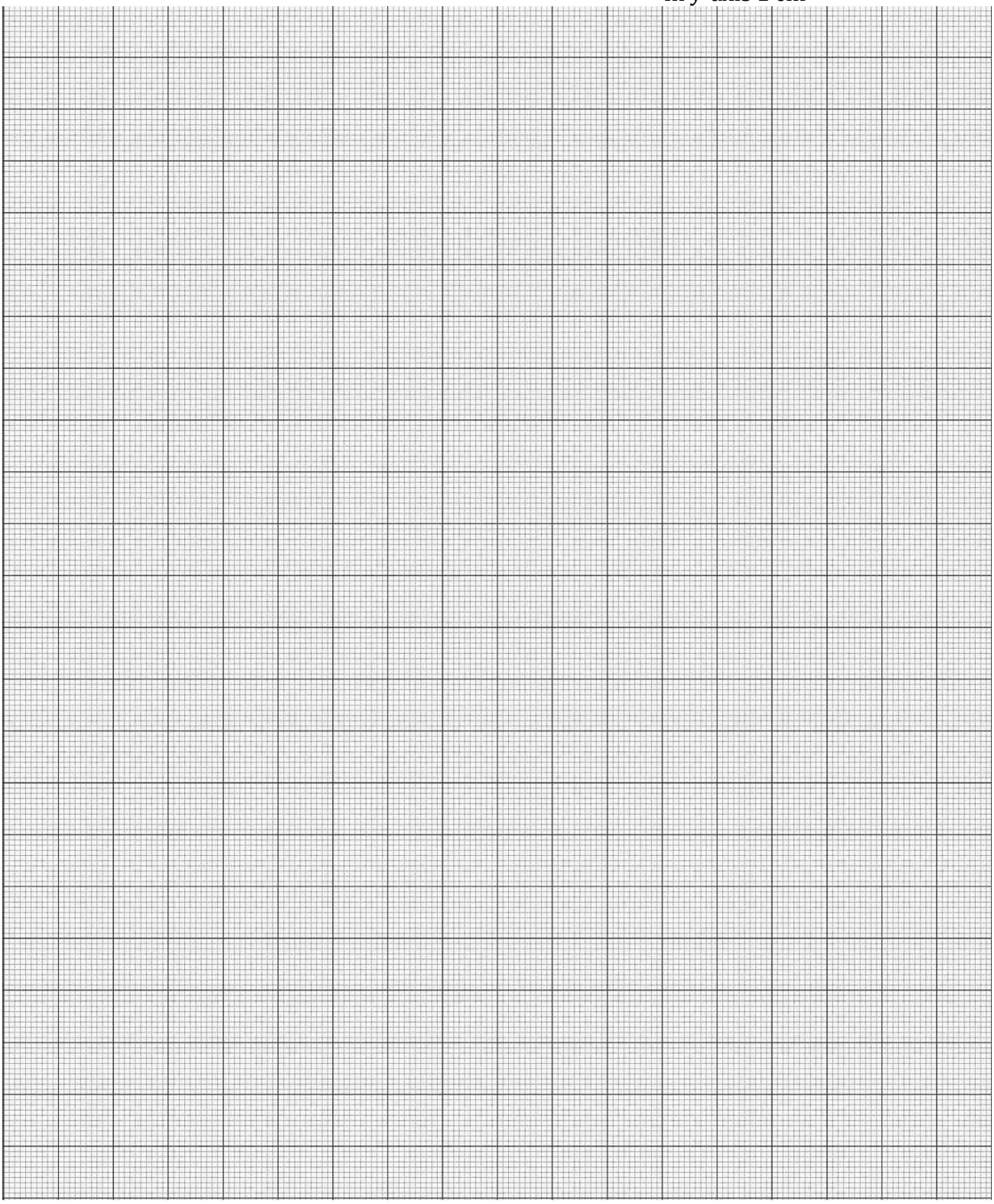
Fractional conversion for reactant A (X_A) = $1 - \frac{C_A}{C_{AO}}$ =

Rate Constant k = $\frac{X_A}{t\, C_{AO} (1 - X_A)}$

PROCEDURE

1. Transfer 250 ml of 0.1 N NaOH into the reactor and switch on the stirrer.
2. Add 250 mL of 0.1N ethyl acetate into the reactor and simultaneously start the stop watch.
3. Pipette out 10 mL reaction mixture at the end of every one minute and transfer into the flask containing 10 L of acetic acid.
4. Titrate the contents with 0.1 N NaOH using phenolphthalein indicator and the end point is appearance of permanent pale pink colour.
5. The volume of NaOH consumed was noted for each solution collected in a conical flask.

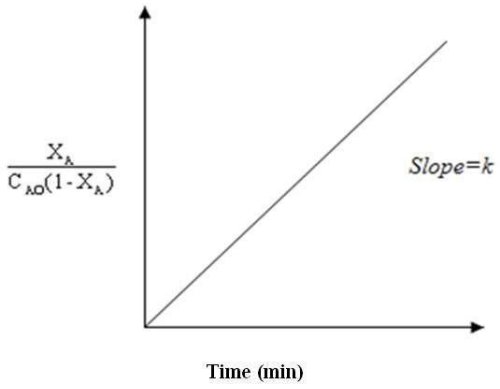
Scale
In x-axis 1cm =
In y-axis 1 cm =



Pre-Lab Questions	Post Lab Questions
1. Define chemical process. 2. Define rate of a chemical reaction. 3. Mention the factors affecting rate of reaction. 4. Define the order of a reaction.	1. Define batch process. 2. Mention the conditions under which the batch process is used. 3. Mention the advantages of batch process. 4. Mention the significance of rate constant with general units. 5. Compare differential method of analysis and integral method of analysis.

MODEL GRAPH

Integral method of analysis $\frac{X_A}{C_{AO}(1- X_A)}$ *Vs time*



Experiment Report

Particulars	Max. Marks	Marks Obtained
Pre-Lab	5	
Post-Lab	5	
Experiment Performance	10	

RESULT

Second order rate constant for esterification reaction between ethyl acetate and sodium hydroxide was found to be

k =_____ L/mol.min (Analytical method)

k =_____ L/mol.min (Graphical method)

OBSERVATION

Volumetric flow rate of Sodium hydroxide V_{Ao} = -------- L/hr =---------- mL/min

Volumetric flow rate of Ethyl acetate V_{Bo} = -------- L/hr = -------- mL/min

S.No.	Time	Volume of NaOH used for titration	Total Volume of mixture	Volume of acetic acid unreacted	Volume of acetic acid reacted	Initial moles of NaOH	Moles of NaOH unreacted	Moles of NaOH reacted at time "t"	Conversion of NaOH
	t min	V_1 mL	V_0 mL	V_2 mL	V_3 mL	mol	mol	mol	X_A %
1.									
2.									
3.									
4.									
5.									
6.									
7.									
8.									
9.									
10.									

Experiment No: 2 **Date:**

PERFORMANCE STUDY OF A SEMI-BATCH REACTOR

AIM

To study the performance of semi batch reactor in which two reactants are added continuously and the product is collected as a batch.

APPARATUS REQUIRED

Semi-batch reactor set up, Burette, Pipette, Beakers, Conical flasks, Stop watch.

CHEMICALS REQUIRED

Ethyl Acetate ($CH_3COOC_2H_5$), Sodium Hydroxide (NaOH), Acetic acid (CH_3COOH), Phenolphthalein indicator.

THEORY

The homogeneous reactions are generally carried out using the following three types of reactor; the batch, the steady-state flow, and semi-batch reactor.

The semi-batch reactor is one of the important types of reactor in the chemical industry particularly in the fine chemical sector and in bioprocesses.

Motivations for Using Semi-Batch Reactors:

1. Control of concentration of reactants to improve the rate of a reaction and hence a better conversion attained.
2. Addition of reactants in small increments to control the better product distribution (e.g polymerization).
3. Offers an advantage of flexibility in making different products.
4. Control heat production of reaction (exothermic reactions).
5. Avoid toxicity of substrates for producing organisms or isolated enzymes.
6. Avoid accumulation of reactants prone to thermal decomposition.
7. Simulate continuous production especially for small scale.

CALCULATIONS

Volume of CH_3COOH added for arresting the reaction (V) = 10mL

Volume of sample solution taken for titration = 10mL

Normality of NaOH (N_1) = 0.1 N

Normality of CH_3COOH (N_2) = 0.1 N

Total Volume of mixture(V_0) = $(V_{Ao} + V_{Bo})\ t$, mL

=

=

Volume of CH_3COOH unreacted (V_2) = $\frac{\text{Volume of NaOH used for titration X Normality of NaOH}}{\text{Normality of } CH_3COOH}$

= $\frac{V_1 \text{ X } N_1}{N_2}$ =

Volume of CH_3COOH reacted(V_3) = Volume of CH_3COOH added for arresting the reaction - Volume of CH_3COOH unreacted

= V- V_2 =

Initial moles of NaOH = Normality of NaOH x Volumetric flow rate of NaOH x time

$= N_1 \, x \, V_{Ao} \, x \, t$

=

Moles of NaOH unreacted

$= \frac{\text{Volume of aceticacid reacted X Total volume of mixture x Normality of aceticacid}}{\text{Volume of aceticacid added for arresting}}$

$= \frac{V_3 \text{ X } V_0 \text{ X } N_2}{V}$

=

Moles of NaOHreacted = Initial moles of NaOH - Moles of NaOH unreacted

=

Conversion for reactant A (X_A) = $\frac{\text{Moles of NaOH reacted}}{\text{Initial moles of NaOH}}$ x 100 =

LIMITATIONS:

The major reason for the limited use of Semi-batch reactor is

1. Due to the difficulty in getting analytical solutions of the differential equations describing the reactor performance.
2. In addition to this in semi-batch reactors concentrations, temperature and volume are getting varied.

PROCEDURE

1. Fill the overhead tanks with 0.1N of sodium hydroxide and 0.1N of ethyl acetate.
2. Equal flow rate of each stream are added to the reactor and wait until steady flow rate is attained.
3. Collect 10 mL reaction mixture for every 2 min intervals, and transfer into the conical flask containing 10 ml of acetic acid.
4. Titrate the contents with NaOH using phenolphthalein indicator and the end point is appearance of permanent pale pink colour.
5. The volume of NaOH consumed was noted for each solution collected in a conical flask.

Pre-Lab Questions	Post Lab Questions
1. Define semi batch process. 2. Does semi batch process occur at steady state? Explain.	1. Mention the conditions under which semi batch process is used. 2. Compare batch process and semi batch process. 3. Mention the applications of semi batch reactor. 4. Mention the advantages of semi batch reactor.

Experiment Report

Particulars	Max. Marks	Marks Obtained
Pre-Lab	5	
Post-Lab	5	
Experiment Performance	10	

RESULT

The effect of addition of the reactant in the alkali hydrolysis of ethyl acetate is studied by a semi batch reactor.

OBSERVATION

S.No.	Volumetric flow rate			Space time	Vol. of NaOH used for titration	Vol. of CH_3COOH unreacted	Vol. of CH_3COOH reacted	Vol. of NaOH unreacted	Conc. of NaOH C_A mol/L		Conversion for reactant A	
	NaOH	EA	Total									
	V_{AO} L/hr	V_{BO} L/hr	V_o L/hr	τ min	V_1 mL	V_2 mL	V_3 mL	V_4 mL	Theo.	Exptl.	$X_{A\ theo}$	$X_{A\ exptl}$
1.												
2.												
3.												

Experiment No: 3 **Date:**

PERFORMANCE STUDY OF A PLUG FLOWREACTOR

AIM

To experimentally determine the conversion, of a given chemical reaction (k-reaction rate constant & n- order of the reaction are known), in a plug flow reactor for a given space time (τ), and compare with the theoretical value.

APPARATUS REQUIRED

Plug Flow Reactor (PFR) set up, Burette, Pipette, Beakers, Conical flasks, Stop watch.

CHEMICALS REQUIRED

Ethyl Acetate ($CH_3COOC_2H_5$), Sodium Hydroxide (NaOH), Acetic acid (CH_3COOH), Phenolphthalein indicator.

THEORY

Tubular Flow Reactor is characterized by the flow of liquid through the reactor with no elements of fluid overtaking or mixing with other elements ahead or behind. Actually, there may be lateral mixing. However, there must be no mixing or diffusion along the flow path. The necessary and sufficient condition for Tubular Flow is the Residence Time in the reactor is to be same for all elements of fluid.

The steady state flow reactor is ideal for industrial purpose when large quantities of material are to be processed. However extremely good product quality control can be obtained by the Tubular Flow Reactor.

$$CH_3COOC_2H_5 + NaOH \rightarrow CH_3COONa + C_2H_5OH$$

The rate expression, for this second order, irreversible reaction is given by,

$-r_A = dC_A/dt = kC_A^2$ Where $C_A = C_{Ao}(1- X_A)$

For a second order reaction with both reactants being equimolar in concentration, the performance equation for the Tubular Flow Reactor is

$$\tau = \frac{X_A}{kC_{AO}(1- X_A)}$$

CALCULATIONS

The Rate constant for this second order reaction is (k) =…….L / mol .min

Diameter of Reactor (D) =

Length of Reactor (L) =

Volume of Reactor (V) $= \frac{\pi}{4} D^2 L$

Space time, $\tau = \frac{\text{Volume of the reactor}}{\text{Total Volumetric flow rate from the reactor}} = \frac{V}{V_o} =$

Normality of NaOH (N_1) =0.1 N

Initial Concentration of NaOH (C_{Ao})

$$= \frac{\text{Volumetric flow rate of NaOH X Normality of NaOH}}{\text{Total Volumetric flow rate from the reactor}}$$

$$= \frac{V_{AO} X N_1}{V_o} =$$

Fractional conversion for reactant A (Theoretical Conversion) $X_A = \frac{k \tau C_{AO}}{1 + k \tau C_{AO}}$

$$k \tau C_{AO} = \frac{X_A}{(1 - X_A)}$$

$$X_A = \frac{k \tau C_{AO}}{1 + k \tau C_{AO}}$$

τ - space time (min)

X_A - fractional conversion for reactant A

k - second order rate constant (L / mol .min)

C_{Ao} - initial concentration of reactant A (mol /L)

C_A - concentration of the reactant A at time t (mol / L)

PROCEDURE

1. Known concentration of NaOH (0.1N) and ethyl acetate (0.1N) were allowed to enter into the reactor at a constant flow rate.
2. After the steady state condition is attained, 10 ml of the sample solution from the outlet point was collected.
3. 10 ml of 0.1N acetic acid was added with the collected sample solution to arrest further reaction.
4. This sample was titrated against 0.1 N NaOH using phenolphthalein indicator.

Pre-Lab Questions	Post Lab Questions
1. Define continuous process. 2. Mention the other names of tubular flow reactor. 3. Define tubular flow reactor. 4. Define space time and space velocity.	1. Mention the performance equation of tubular flow reactor. 2. When the feed conditions are same and volume of tubular flow reactor and MFR are also same, which reactor will give more conversion? Why? 3. How does the flow rate of the reactants influence on the conversion?

Volume of CH_3COOH added for arresting the reaction (V) = 10mL

Volume of sample solution taken for titration = 10mL

Volume of NaOH used for titration (V_1) = ------ mL

Normality of CH_3COOH (N_2) =0.1 N

Volume of CH_3COOH unreacted (V_2) $= \frac{\text{Volume of NaOH used for titrat ion X Normality of NaOH}}{\text{Normality of } CH_3COOH}$

$= \frac{V_1 X N_1}{N_2} =$

Volume of CH_3COOH reacted(V_3) = Volume of CH_3COOH added for arresting the reaction -Volume of CH_3COOH unreacted

$= V - V_2 =$

Volume of NaOH unreacted (V_4) $= \frac{\text{Volume of } CH_3COOH \text{ reacted X Normality of } CH_3COOH}{\text{Normality of NaOH}}$

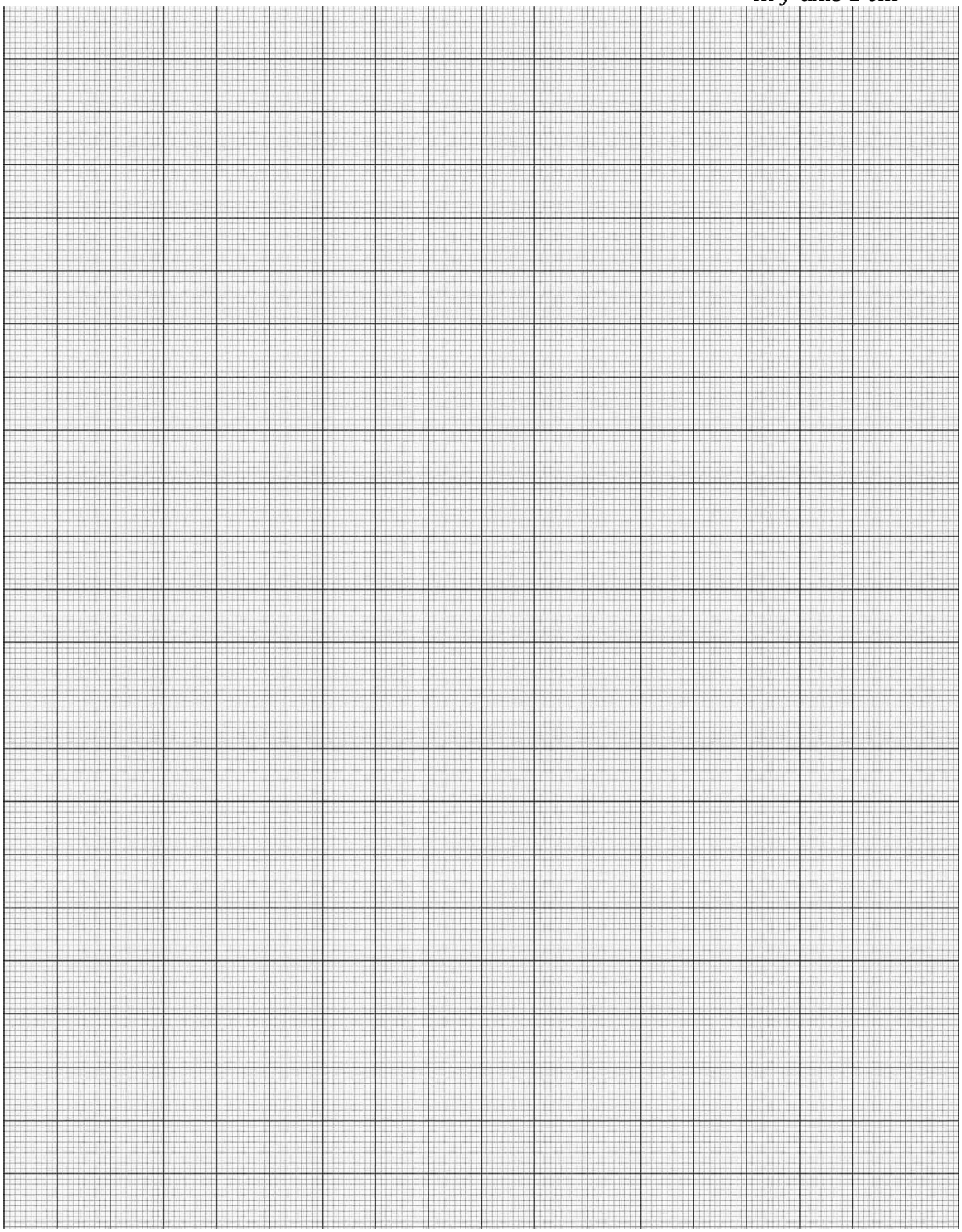
$= \frac{V_3 X N_2}{N_1} =$

Concentration of NaOH (C_A) $= \frac{\text{Volume of NaOH unreacted X Normality of NaOH}}{\text{Volume of sample solution t aken for titration}}$

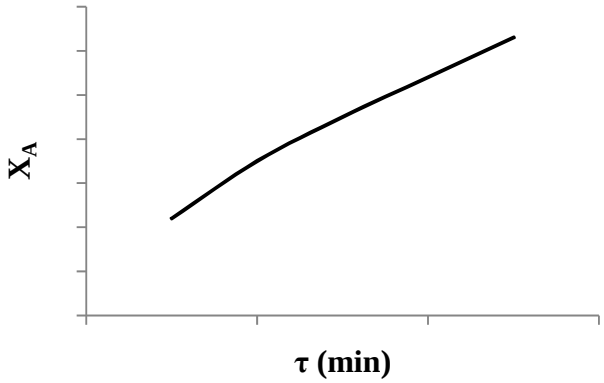
$= \frac{V_4 X N_1}{10} =$

Fractional conversion for reactant A (Experimental Conversion) $X_A = 1 - \frac{C_A}{C_{AO}} =$

Scale
In x-axis 1cm =
In y-axis 1 cm =



MODEL GRAPH



Experiment Report

Particulars	Max. Marks	Marks Obtained
Pre-Lab	5	
Post-Lab	5	
Experiment Performance	10	

RESULT

The experimentally determined conversion =

The theoretically calculated conversion =

The experimentally determined conversion is found to be in agreement with the theoretically calculated conversion within the experimental error.

OBSERVATION

Volumetric flow rate of water V_o = ---------- L/hr

S.No.	Time	Volume of CH_3COOH used for titration	Volume of NaOH in 10ml of sample solution	Conc. of Tracer	Δt	CΔt	t CΔt	t^2 CΔt	E=C /A
	t min	V_2 mL	V_1 mL	C mol/L	s	(mol /L) s	(mol/L) s^2	(mol/L) s^3	s^{-1}
1.									
2.									
3.									
4.									
5.									
6.									
7.									
8.									
9.									
10.									
11.									
12.									
13.									
						$\mathbf{Q}=\sum C_i \Delta t_i$	$\sum t_i C_i \Delta t_i$	$\sum t_i^2 C_i \Delta t_i$	$E =$

Experiment No: 4 **Date:**

STUDY OF RTD IN A MIXED FLOW REACTOR

AIM

To study the residence time distribution (RTD) in a non ideal Mixed Flow Reactor and to estimate the non ideal parameters of the non ideal flow models.

APPARATUS REQUIRED

Mixed Flow Reactor (MFR) set up, Burette, Pipette, Beakers, Conical flasks, Stop watch, and standard measuring jar.

CHEMICALS REQUIRED

Sodium Hydroxide (NaOH), Water (H_2O), Acetic Acid (CH_3COOH), Phenolphthalein indicator.

THEORY

In a non ideal reactor due to stagnation, creation of dead zone, channeling, recycling of fluid etc., the residence time will not be the same for all elements of fluid. Therefore the Residence Time Distribution (RTD) study is very important for design of a recator. This is a study by means of introducing a tracer into the system either as a pulse input or as a step input. The E curve obtained using the pulse input gives the Exit Age Distribution or the Residence Time Distribution for the elements of fluid leaving the reactor. The area under the normalized E curve is unity. The E curve is a measure of how many elements of fluid are in the reactor for a time, less than‘t’. The tracer added should not react with the fluid and should be easily detectable. The steady state flow of an incompressible fluid (i.e.) a constant density fluid without chemical reaction is considered here. Since, the flow considered is at steady state, the Exit Age Distribution for any batch is the same, as the C curve of the batch under consideration, therefore E=C. (i.e.) E = C/Q, where C is the conc. of the tracer at the exit at time “t”; Q is the area under the C curve.

The residence time distribution is obtaining by conducting tracer tests. A pulse input is given at the entrance of the reactor. The concentration of the tracer is obtained at

CALCULATIONS

The C curve is drawn (C vs t).

Area under the C curve

from (i) table $Q = \sum C_i \Delta t_i$ =_____

(ii) Graph = _____

The E curve is drawn (E vs t).

Area under the E curve

from (i) table $\sum E$ = =_____x Δt = _____

(ii) Graph =_____(mol. s)/L

Volume of Reactor (V) =

Volumetric flow rate of liquid from the Reactor (V_o) =

Space Time, $\tau = \frac{\text{Volume of the reactor}}{\text{Volumetric flow rate of liquid from the reactor}} = \frac{V}{V_o} =$

Volume of sample solution taken for titration = 10 mL

Normality of NaOH (N_1) =2 N

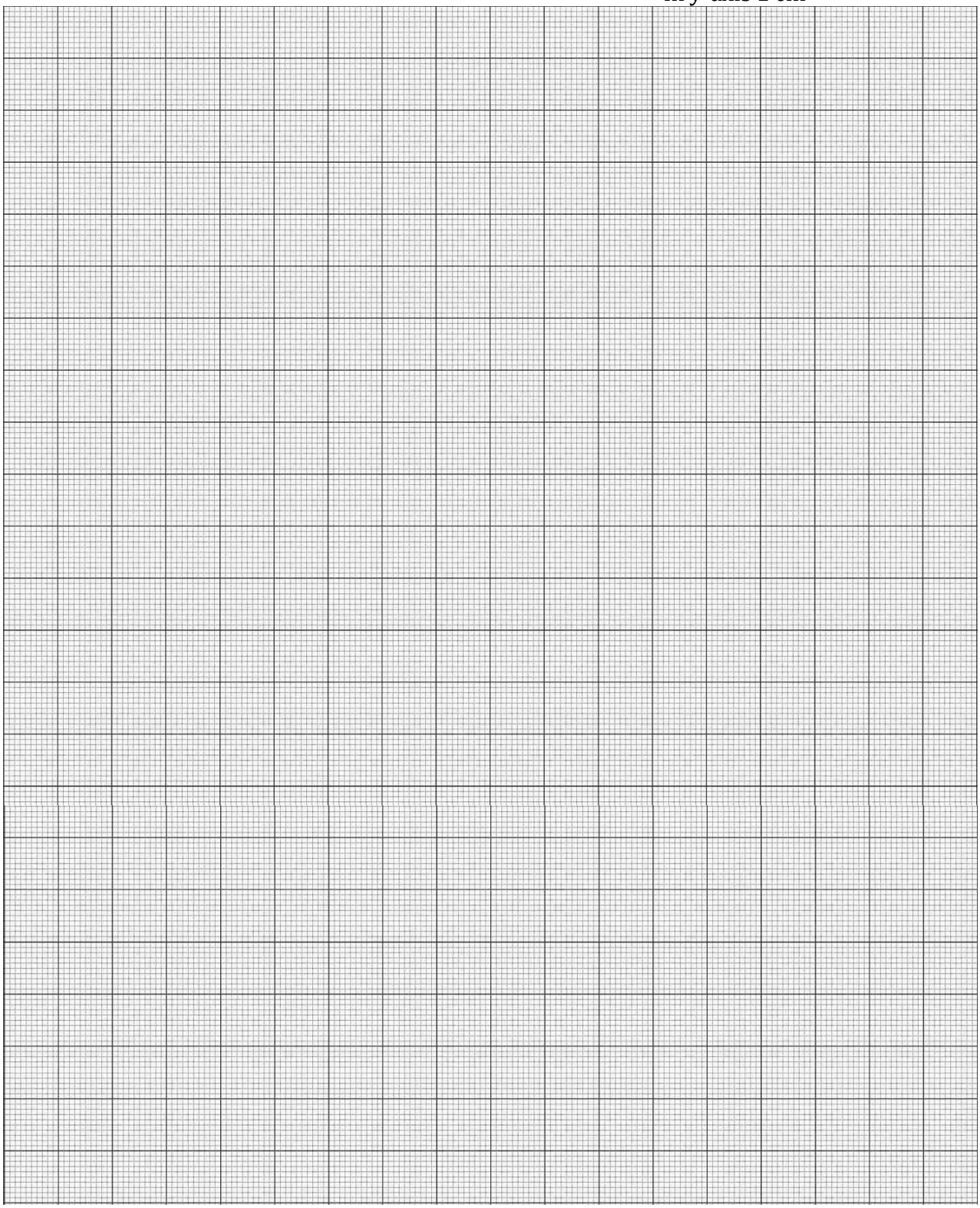
Normality of CH_3COOH (N_2) = 0.1 N

Volume of NaOH in 10ml of sample solution (V_1)

$= \frac{\text{Volume of } CH_3COOH \text{ used for titration X Normality of } CH_3COOH}{\text{Normality of NaOH}}$

$= \frac{V_2 \text{ X } N_2}{N_1} =$

Scale
In x-axis 1cm =
In y-axis 1 cm =



Concentration of NaOH in 10 ml of sample solution (C) =

$$\frac{\text{Volume of NaOH in 10ml of sample solution X Normality of NaOH}}{\text{Volume of sample solution taken for titration}} = \frac{V_1 \text{ X } N_1}{10} =$$

Mean residence time = $\bar{t} = \frac{\sum t_i C_i \Delta t_i}{\sum C_i \Delta t_i}$

Variance = $\sigma^2 = \frac{\sum t_i^2 C_i \Delta t_i - \bar{t}^2}{\sum C_i \Delta t_i}$

Dimensionless variance= $\sigma_\theta^2 = \frac{\sigma^2}{\bar{t}^2}$

Tanks in series model

Number of tanks in series, N = $\frac{1}{\sigma_\theta^2}$

Dispersion model (Assumption: small extents of dispersion)

Vessel Dispersion No. , $\frac{D}{uL} = \frac{\sigma_\theta^2}{2}$

the exit of the reactor at different time intervals. A plot of the concentration of the tracer vs time represents the Exit Age Distribution of the Tracer.

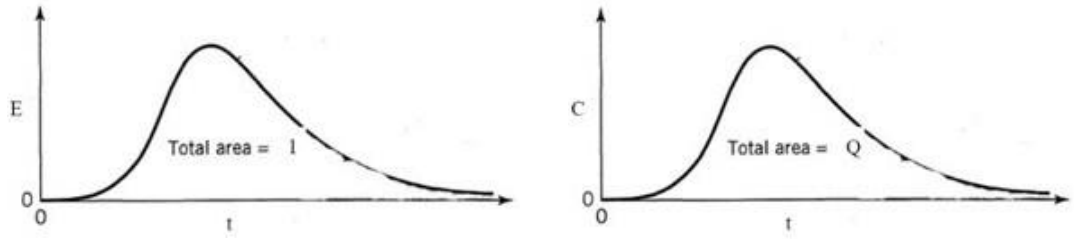
As C(t) dt is the Area under the C curve which is A and E(t) dt is the area under theE curve which is one .Therefore E(t) = C(t) / Q. The Mean Residence Time is same as the Space Time for constant density fluids, since the denominator term becomes unity,

[C(t) dt = 1].

PROCEDURE

1. Water from the overhead tank is allowed to enter into the MFR at constant flow rate using a rotameter.
2. When the steady state condition is reached the 2 N NaOH (5 mL) tracer is injected at the entrance of the MFR as a pulse input and simultaneously the stop watch is started.
3. 10 mL of the sample solution is collected with every 30 seconds time interval continuously.
4. These samples are titrated against 0.1N acetic acid using Phenolphthalein indicator. The end point is disappearance of pale pink colour

GRAPH



Pre-Lab Questions	Post Lab Questions
1. Define RTD 2. What are the various ways of studying the flow pattern in vessels? 3. Differentiate closed vessel and open vessel. 4. Mention the limitations of the parameters of the models. 5. Relation between E, C and F curve.	1. What are the reasons for non-ideality behaviour in reactors? 2. What is stimulus response technique? 3. Mention the models used to study the non ideality 4. Define Dispersion model 5. Define tanks in series model.

Experiment Report

Particulars	Max. Marks	Marks Obtained
Pre-Lab	5	
Post-Lab	5	
Experiment Performance	10	

RESULT

The Residence Time Distribution in a non ideal Mixed Flow Reactor was studied and the non ideal parameters were estimated to be

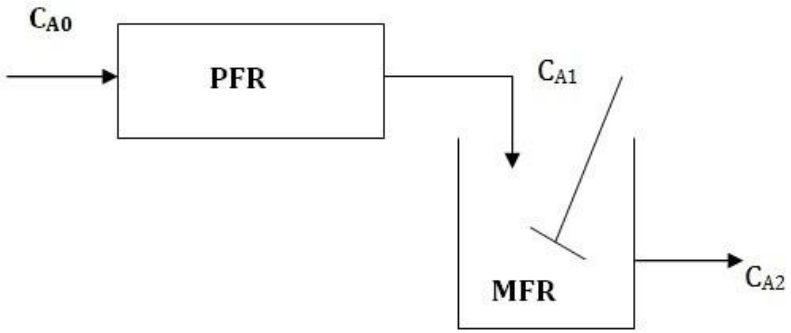
1. Number of tanks in series , N =
2. Vessel Dispersion No. , $\frac{D}{uL}$ =

OBSERVATION

Volume of PFR = ---------- L

Volume of MFR = ----------L

S.No.	Volumetric flow rate			Vol. of NaOH used for titration		Conc. of NaOH		Conversion for reactant A		
	NaOH	EA	Total							
	V_{AO} L/hr	V_{BO} L/hr	V_o L/hr	PFR V_1 (mL)	MFR V_2 (mL)	C_{A1} mol/L	C_{A2} mol/L	X_{A1}	X_{A2}	X_{AF}
1.										
2.										
3.										



Experiment No: 5 **Date:**

STUDY OF A PLUG FLOW REACTOR FOLLOWED BY A MIXED FLOW REACTOR

AIM

To study the performance of combined reactors (PFR followed by MFR) and to calculate the conversion achieved by this multiple reactor system.

APPARATUS REQUIRED

Tubular Flow Reactor (PFR) set up, Mixed Flow Reactor (MFR) set up, Burette, Pipette, Beakers, Conical flasks, Stop watch, and standard measuring jar.

CHEMICALS REQUIRED

Sodium Hydroxide (NaOH), Ethyl acetate (EA)), Acetic acid (CH_3COOH), Phenolphthalein indicator.

THEORY

For a single reaction, total size of multiple reactors connected in series is usually less than the size of single reactor. In other words, for a given size of reactor the conversion in a multiple reactor system is more than in a single reactor. But in PFR connected in series will give the same performance as single PFR. Sometimes different types of flow reactors can be connected in series. For the most effective use of a given set of ideal reactors we have the following general rules:

For a reaction whose rate-concentration curve rises monotonically (any nth-order reaction, $n > 0$) the reactors should be connected in series. They should be ordered so as to keep the concentration of reactant as high as possible if the rate-concentration curve is concave ($n > 1$), and as low as possible if the curve is convex ($n < 1$). As an example, the ordering of units should be plug, small mixed, large mixed, for $n > 1$; the reverse order should be used when $n < 1$.

For reactions where the rate-concentration curve passes through a maximum or minimum the arrangement of units depends on the actual shape of curve, the conversion level desired, and the units available. No simple rules can be suggested. Whatever may be the kinetics and the reactor system, an examination of the $1/(-r_A)$ vs. C_A curve is a good way to find the best arrangement of units.

CALCULATIONS

Normality of NaOH (N_1) = 0.1 N

Normality of CH_3COOH (N_2) = 0.1 N

Initial Concentration of NaOH (C_{Ao})

$$= \frac{\text{Normality of NaOH X Volumetric flow rate of NaOH}}{\text{Total Volumetric flow rate}} = \frac{N_1 \times V_{AO}}{V_{AO} + V_{BO}} = 0.05 \text{ mol / L}$$

Volume of CH_3COOH added for arresting the reaction (V)= 10 mL

Volume of sample solution taken for titration = 10 mL

Unreacted concentration of NaOH after reaction in PFR = $C_{A1} = (V - \ )_1 \frac{N_1}{10} =$

Unreacted concentration of NaOH after reaction in MFR= $C_{A2} = (V - \ )_2 \frac{N_1}{10} =$

Fractional conversion of reactant A NaOH in PFR (X_{A1}) = 1 - $\frac{C_{A1}}{C_{AO}}$ =

Fractional conversion of reactant A NaOH in MFR (X_{A2}) = 1 - $\frac{C_{A2}}{C_{A1}}$ =

Fractional conversion of reactant A NaOH in PFR and MFR (X_{AF}) = 1 - $\frac{C_{A2}}{C_{AO}}$ =

PROCEDURE

1. Transfer 0.1 N NaOH and 0.1 N ethyl acetate solutions into the feed tank.
2. Allow NaOH and ethyl acetate at a constant flow rate into the PFR.
3. Wait until the reactor reaches steady state. Collect about 10 mL of sample from the exit of the PFR and transfer into the flask containing 10 ml of acetic acid.
4. Allow the exit mixture to enter into the MFR.
5. Wait until the reactor reaches steady state. Collect about 10 mL of sample from the exit of the MFR and transfer into the flask containing 10 ml of acetic acid.
6. Titrate the contents with 0.1N NaOH using phenolphthalein indicator and the end point is appearance of permanent pale pink colour.
7. Repeat the experiment for different flow rate.

Pre-Lab Questions	Post Lab Questions
1. Define space time and space velocity. 2. Compare the behaviour of the N equal size MFR in series and single PFR of same total volume. 3. Find the best arrangement of a set of ideal reactors for n>1 4. Find the best arrangement of a set of ideal reactors for n<1	1. When the feed conditions are same and volume of tubular flow reactor and MFR are also same, which reactor will give more conversion? Why? 2. How does the flow rate of the reactants influence on the conversion? 3. When the feed conditions are same and same conversion is expected in both tubular flow reactor and MFR, which reactor volume is less?

Experiment Report

Particulars	Max. Marks	Marks Obtained
Pre-Lab	5	
Post-Lab	5	
Experiment Performance	10	

RESULT

Performance of combined reactors (PFR followed by MFR) was studied and the conversion achieved by this multiple reactor system was calculated at different flow rates.

OBSERVATION

Regularly open and close HV_2 to ensure excess air removal.

	Current to Pressure Converter		Pressure to Current Converter	
S.No	Input Current (mA)	I/P Converter Output G_2(psi)	Input Pressure G3 (psi)	Output Current (mA)
1	4		3	
2	8		6	
3	12		9	
4	16		12	
5	20		15	

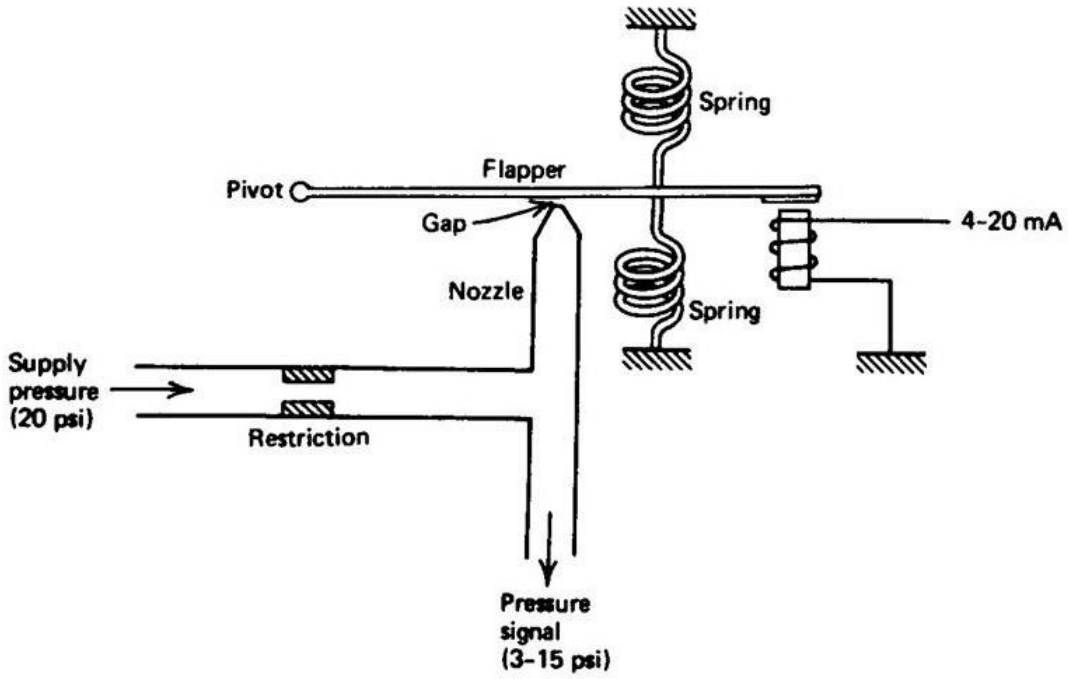


Fig 6.1 Principles of current to pressure converter (flapper nozzle arrangement)

Experiment No: 6 **Date:**

STUDY ON FLAPPER NOZZLE ARRANGEMENT, CURRENT TO PRESSURE AND PRESSURE TO CURRENT CONVERTER

AIM

To study the characteristics of current to pressure (I/P) and pressure to current (P/I) converter and to understand the principle of flapper nozzle system.

HARDWARE REQUIRED

1. Compressor
2. VPI – 01

THEORY

Flapper nozzle method is used for the current to pressure conversion. The schematic arrangement of the system is shown in figure 6. 1. When the flapper moves to the left about its pivot, less air will leak out and a larger pressure will be developed between the fixed restriction and nozzle. Regulated air supply enters through restriction and comes out through the nozzle. In front of the nozzle, a flapper is placed. The midpoint of the flapper is fixed on a pivot. So that the flapper is placed to move freely to and fro. One end of the flapper is placed near the nozzle and the other end is placed near the current carrying coil. This operating coil energized by current flowing through it. As the current in the coil is increased, one of the flapper moves towards the coil and hence the other end moves towards the nozzle.

When the flapper moves towards the nozzle, there is increase in back pressure. When the flapper moves away, there will be a decrease back pressure (see in fig 6.2). So, the back pressure is directly proportional to the distance (X) between the nozzle and the flapper. This relation is given by

$$P_o = \frac{P_s}{1+16\left(\frac{x}{d}\right)^2}$$

Where P_0 = Back Pressure, psi

P_s = Supply Pressure, psi

x = Distance between nozzle and flapper, mm

d = Diameter of the restriction

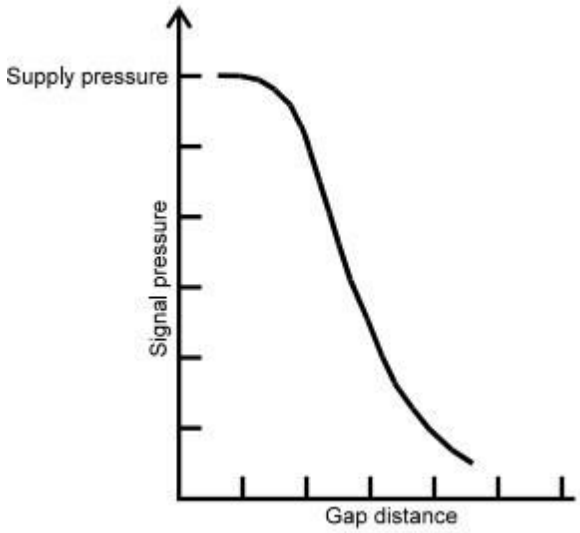


Fig 6.2 Signal pressure versus gap distance

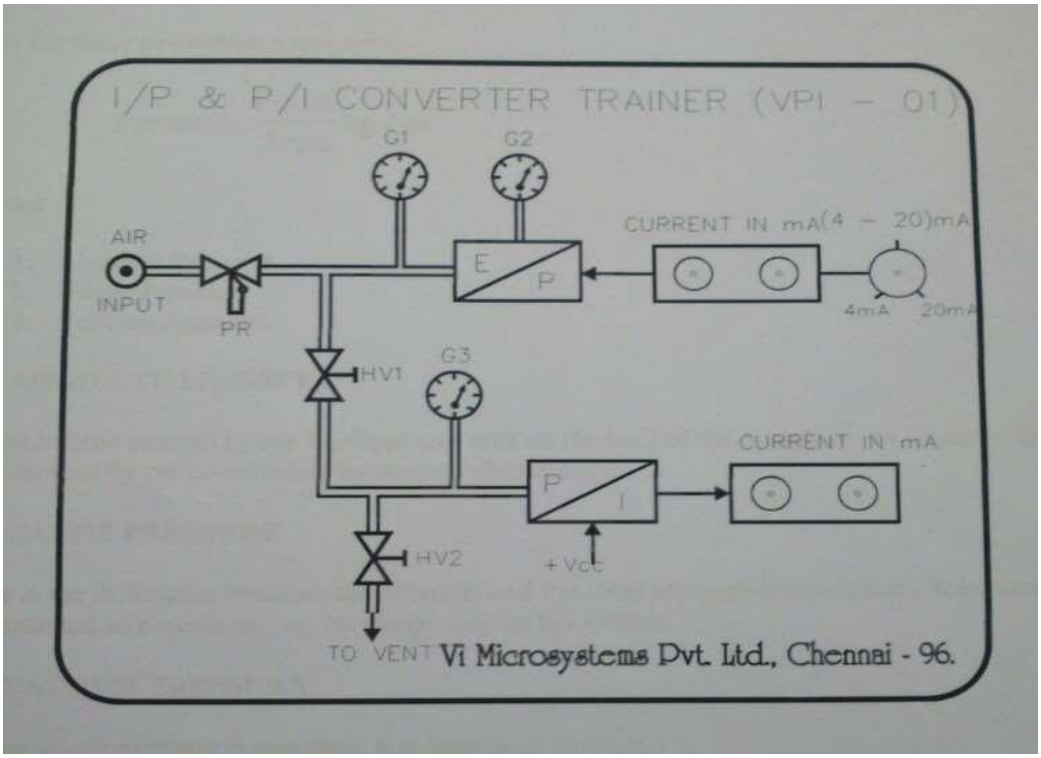


Fig 6.3. Panel diagram

PRESSURE MEASUREMENT

Pressure to be measured is applied to the pressure cell. Diaphragm is used as a seal and pressure gathering number. Due to this applied pressure, there will be change in resistance of the strain gauge. This change in resistance is very small. For measuring this resistance, strain gauge are fixed on the diaphragm to form wheat stone bridge.

This change in resistance causes the unbalance in the wheat stone bridge. This gives voltage output. This output voltage is proportional to the change in resistance. The change in resistance is proportional to the pressure applied. So, the output voltage is proportional to the pressure applied. This voltage is converted into the current using voltage to current converter.When the pressure is applied, the resistance of the strain gauge changed from R to R±ΔR, then

$$V_0 = \left(\frac{\Delta R}{4R} + 2.\Delta R\right).V_i$$

but 4R >> 2.ΔR

$$V_0 = \left(\frac{\Delta R}{4R}\right)_i$$

Hence, the change in resistance is directly proportional to the pressure applied.

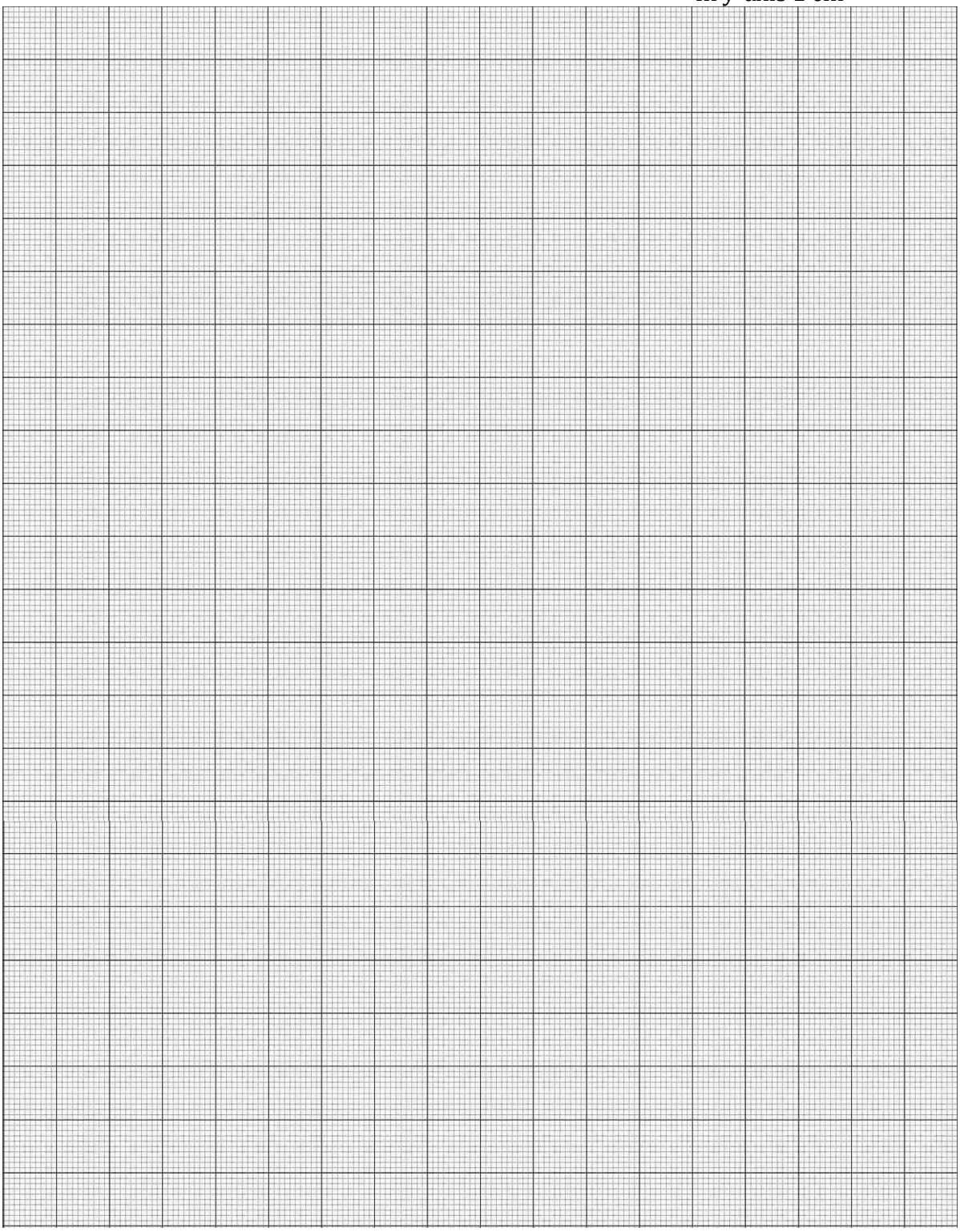
This output voltage is converted into current signal for transmitting over long distance.

PROCEDURE

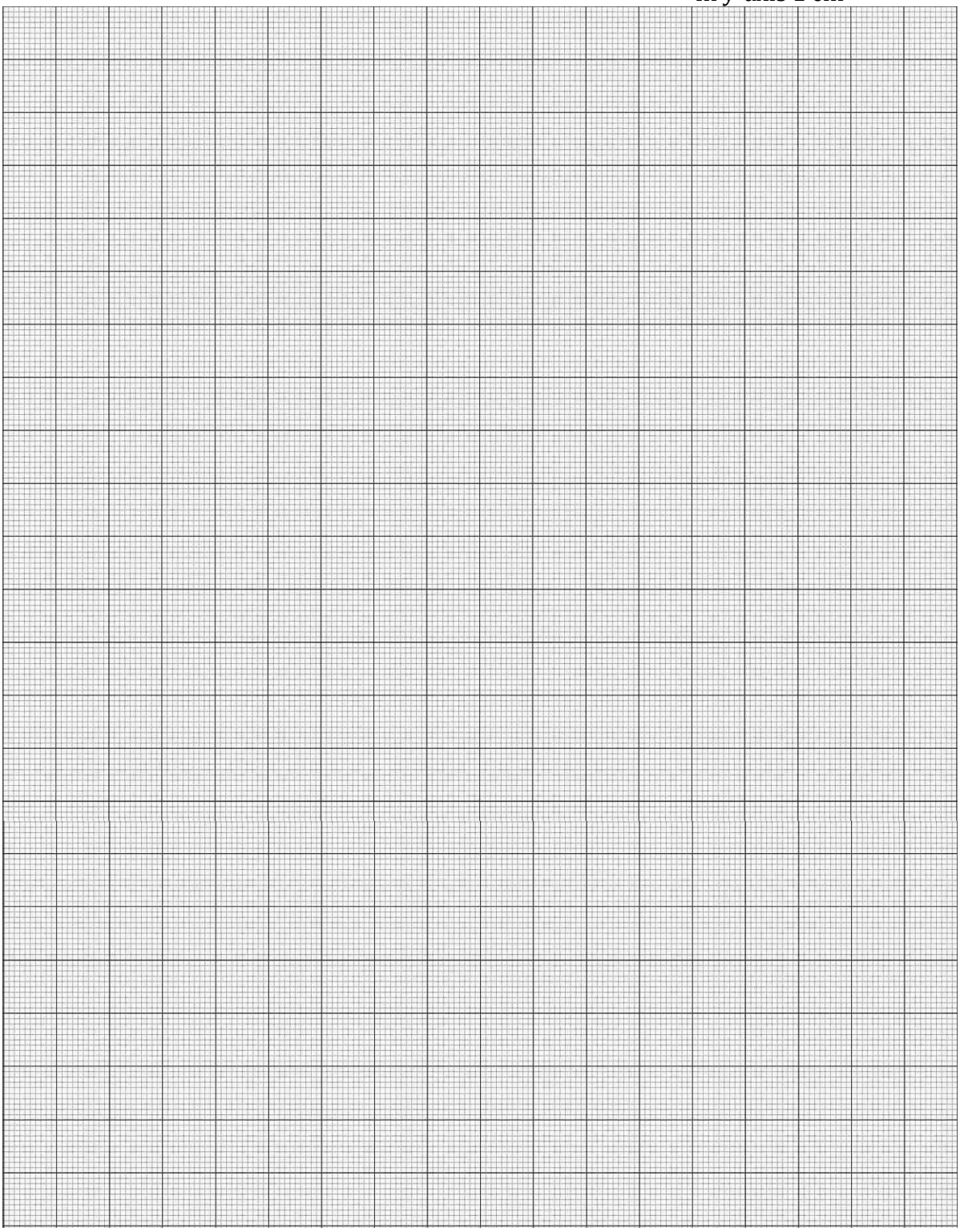
Current to pressure

1. Switch ‘ON’ the compressor.
2. Set ‘G1’ to 20psi by adjusting air regulator.
3. Switch ON the unit.
4. Connect multi meter (in mA mode) to the I to P input terminals.
5. Gradually, increase the current (4 to 20mA) by adjusting knob and note down the corresponding pressure readings (G2).
6. Tabulate the readings.

Scale
In x-axis 1cm =
In y-axis 1 cm =



Scale
In x-axis 1cm =
In y-axis 1 cm =



Pressure to current

1. Switch 'ON' the compressor.
2. Set 'G1' to 20psi by adjusting air regulator.
3. Switch ON the unit.
4. Connect multimeter (in mA mode) to the P to I output terminals.
5. Gradually, increase the pressure (G3) from 0 to 20psi by opening HV1.
6. Measure the output current (mA) for different pressures and tabulate them.

Pre-lab Questions	Post Lab Questions
1. Name some pressure transducer. 2. What is the range of pressure if the current is 4-20 mA? 3. What is LVDT? 4. Why span adjustment is needed? 5. What is the need of P /I converter?	1. What is flapper and nozzle? 2. What are the standard ranges of current and pressure? 3. Where will you use I/P and P/I converters? 4. What is the principle of Bourdon gauge? 5. What is live zero and dead zero?

Experiment Report

Particulars	Max. Marks	Marks Obtained
Pre-Lab	5	
Post-Lab	5	
Experiment Performance	10	

RESULT

Thus, the characteristic of Current to Pressure and pressure to current Converter is studied.

OBSERVATION

Steady state Value: _____ Area of the tank: _____

S.No	Time (sec)	Height of the tank (cm)	First order response C(t)
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			

Experiment No: 7 **Date:**

VERIFYING STEP RESPONSE OF FIRST ORDER SYSTEM FOR A GIVEN TANK

AIM

To study the step response of first order system using liquid level tank process.

HARDWARE REQUIRED

1. Liquid level setup
2. Stop watch

THEORY

A first order system is one in which highest power of S in denominator if transfer function defines order of the system.

$$\frac{C(S)}{R(S)} = \frac{1}{\tau s + 1}$$

$$C(S) = \frac{1}{\tau s + 1} R(S) \quad \ldots\ldots (1)$$

Since the Laplace transform of the unit step function is 1/s, substituting R(s) =M/s in equation

$$C(S) = \frac{1}{\tau s + 1} * \frac{M}{S} \quad \ldots\ldots (2)$$

Where M-Magnitude of step input

τ=A*R (A-Area of the tank, R-Resistance)

Solving the equation by partial fraction and Laplace inverse method, the following solution obtained.

$$C(t) = M\,(1 - e^{\frac{-t}{\tau}}), \quad t > 0 \quad \ldots\ldots (3)$$

Equation (3) shows the step response of equation of first order system

Time constant

(τ) The time required for a changing quantity, to rise or fall approximately 0.632 of the diffe rence betweenits old and new value.

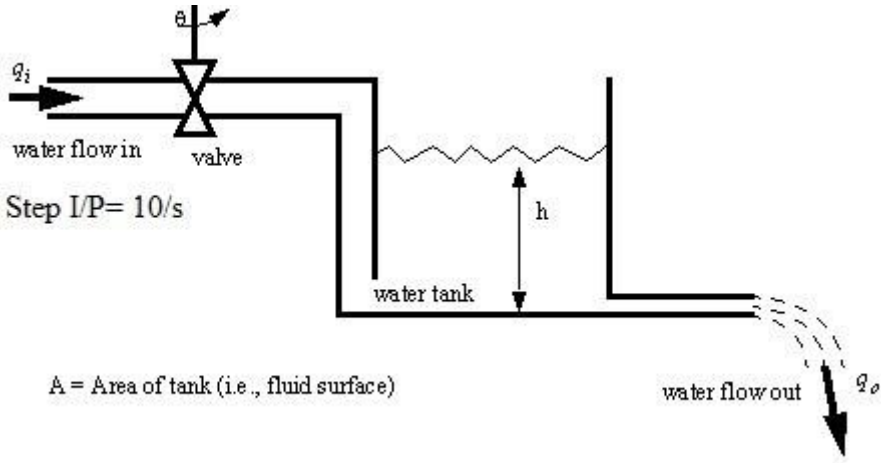
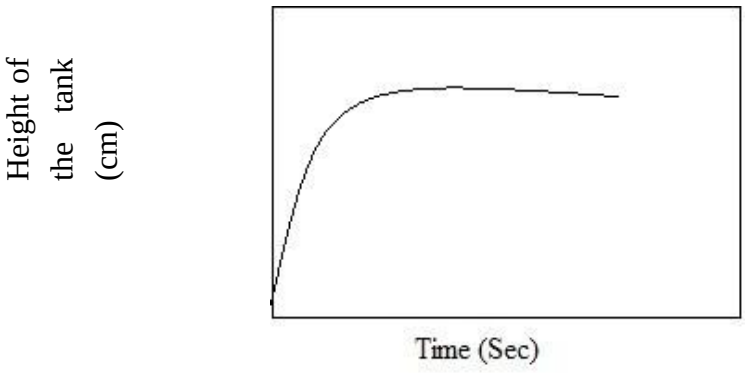


Fig 7.1 First order liquid level tank process

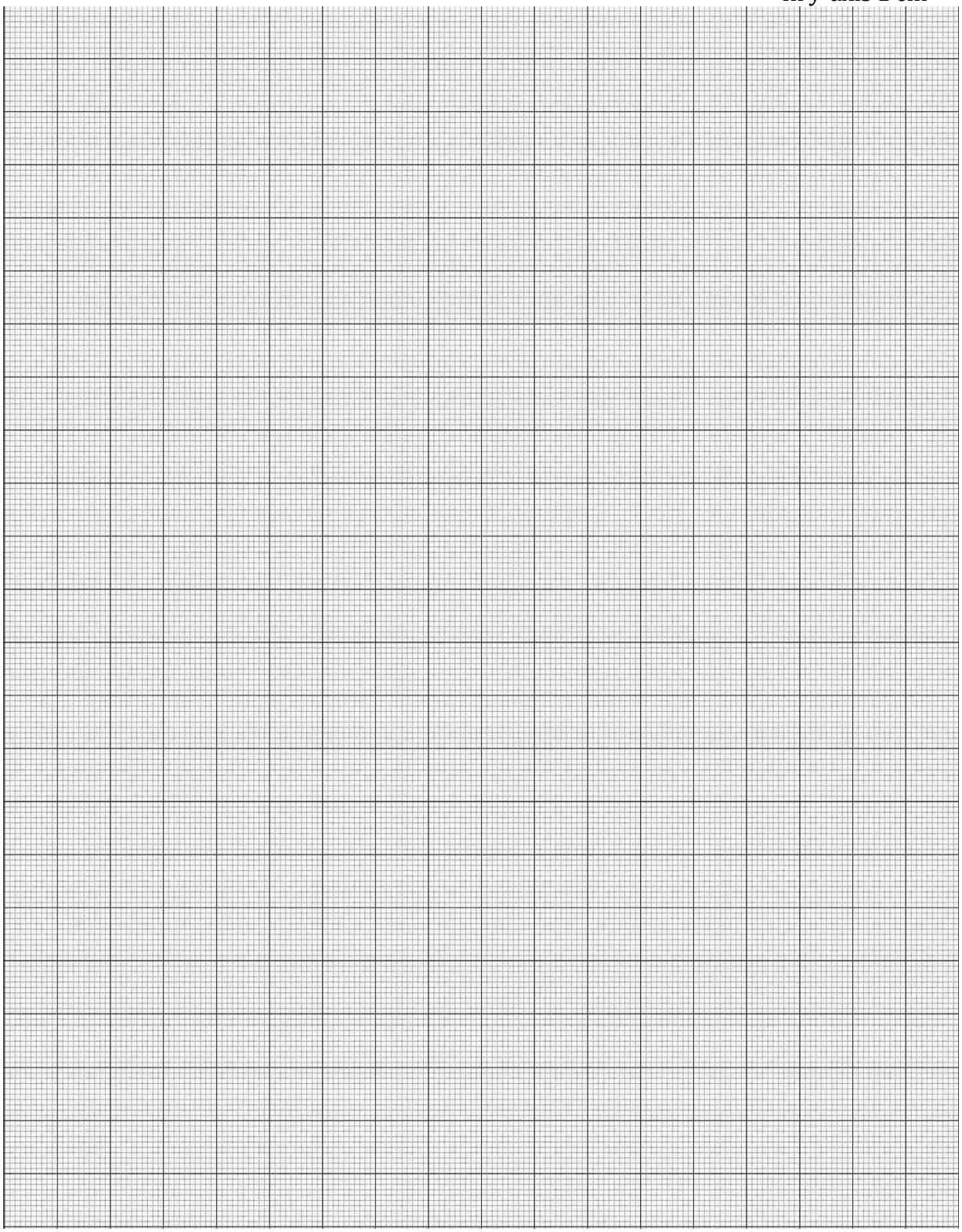
MODEL GRAPH



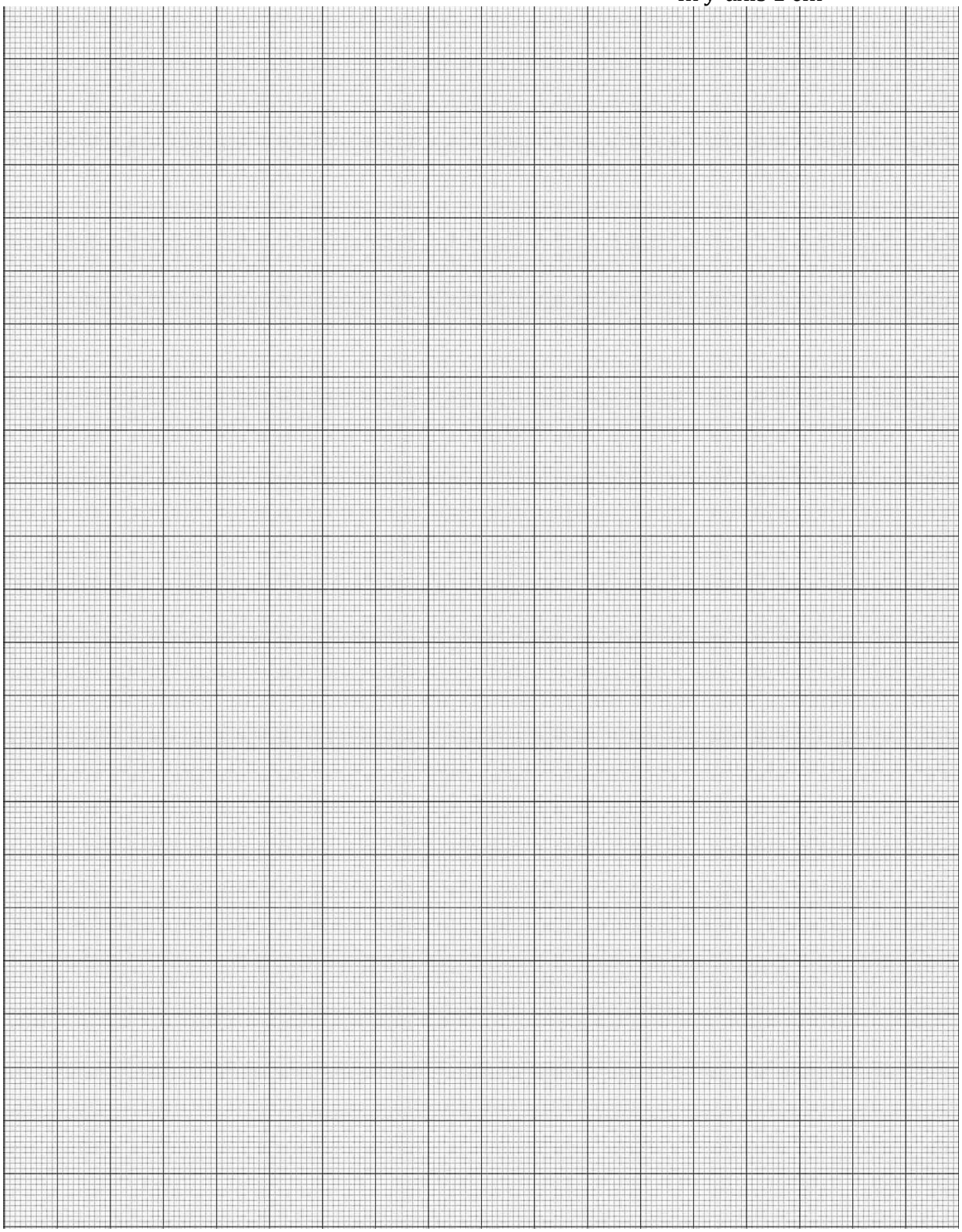
Scale

In x-axis 1cm =

In y-axis 1 cm =



Scale
In x-axis 1cm =
In y-axis 1 cm =



PROCEDURE (Liquid level tank)

1. Start the setup, switch on the pump.
2. Insert the flexible pipe of the rotameter outlet into the cover of top tank-1, keep the outlet valve (R2) and discharge valve (R1) in slightly closed condition.
3. Adjust the flow rate of 10LPH. Allow the level of the two parts to reach the steady state and record the initial flow and steady state level of both the tanks.
4. Apply a step change by increasing the rotameter flow rate by 10LPH.
5. Record the final flow and steady state level of both tanks.
6. Carry out calculations and compare the predicted and observed valves of the tank level.

Pre-lab Questions:	Post Lab Questions
1. What are all the different types of inputs? 2. Define time constant. 3. What are the assumptions made in mathematical modelling of liquid process? 4. Define transfer function. 5. Give the transfer function of first order process?	1. Differentiate between disturbance and response. 2. Give some physical examples of first order system. 3. Define set point. 4. Write the response equation for impulse input. 5. Define second order system.

Experiment Report

Particulars	Max. Marks	Marks Obtained
Pre-Lab	5	
Post-Lab	5	
Experiment Performance	10	

RESULT: The step response of first system has been studied.

Observation:

S.No.	Inlet Pressure	Flow Rate		Change in pressure ΔP		Cv
		LPH	m^3/hr	mm of H_2O	bar	

S.No.	Inlet Pressure	Flow Rate		Change in pressure ΔP		Cv
		LPH	m^3/hr	mm of H_2O	bar	

S.No.	Inlet Pressure	Flow Rate		Change in pressure ΔP		Cv
		LPH	m^3/hr	mm of H_2O	bar	

Experiment No: 8 **Date:**

STUDY ON CONTROL VALVE CHARACTERISTICS

AIM

To obtain the characteristics of control valve.

HARDWARE REQUIRED: control valve set up

THEORY :

The setup is designed to understand the control valve operation and its flow characteristics. It consists of pneumatic control valves of linear, equal % (&quick opening for product 318B) type, stainless steel water tank with pump for continuous water circulation and rotameter for flow measurement. An arrangement is made to measure pressure at the valve inlet in terms of mm of water. An air regulator and pressure gauge is provided for the control valve actuation. In case of additional optional requirement a valve positioned is fitted on linear valve. The setup is stand-alone type.

Types of control valves: -

Valve is essentially a variable orifice. Control valve is a valve with a pneumatic, hydraulic, electric (excluding solenoids) or other externally powered actuator that automatically, fully or partially opens or closes the valve to a position dictated by signals transmitted from controlling instruments. Control valves are used primarily to throttle energy in a fluid system and not for shut off purpose. The figure shows basic elements and internal parts of typical pneumatic control valve. Depending upon the valve plug design the control valves can be classified as quick opening, linear and equal percent type.

Linear: -

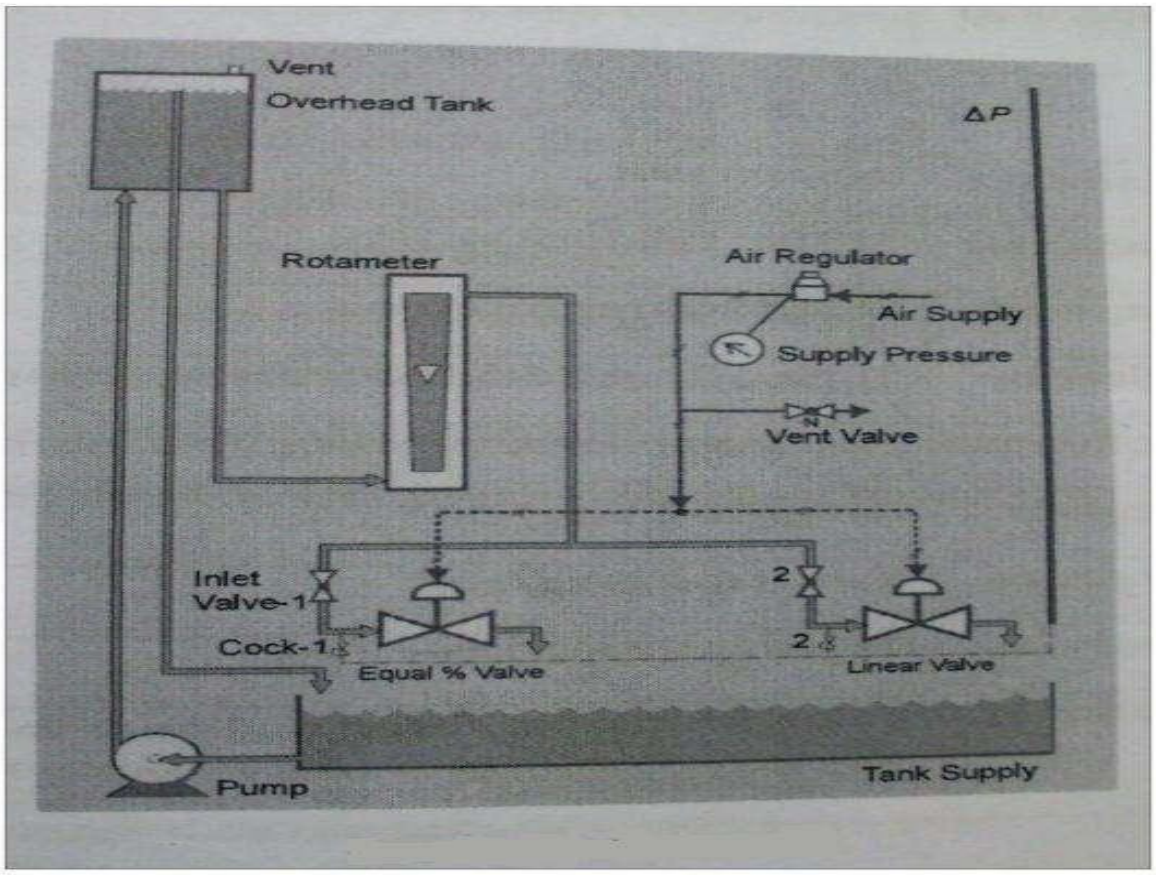
Flow is directly proportional to valve lift.

$$Q = ky$$

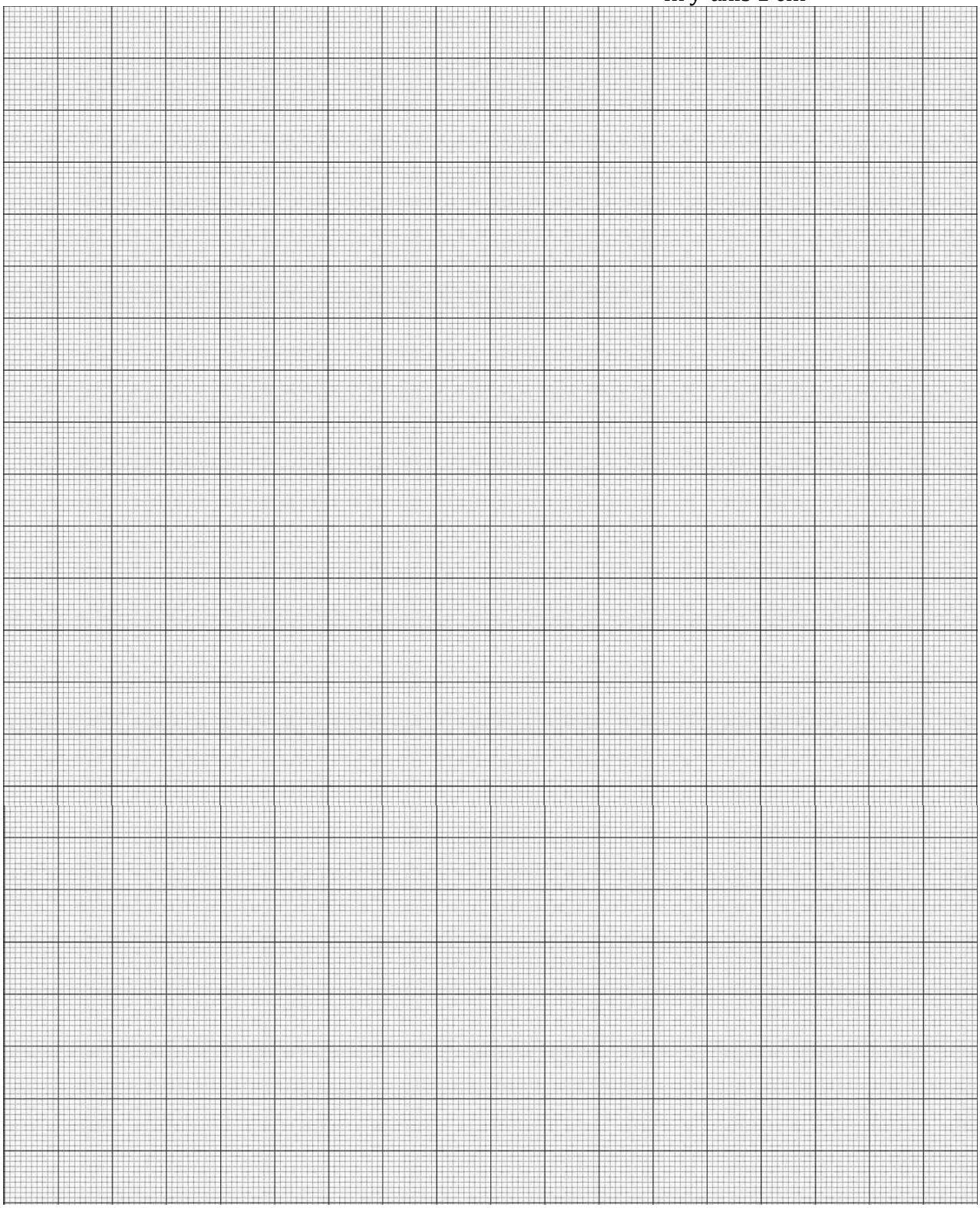
Where

Q = flow at constant pressure drop
y = valve opening
k = constant

Circuit diagram:



Scale
In x-axis 1cm =
In y-axis 1 cm =



Equal%:-

Flow changes by a constant percentage of its instantaneous value for each unit of valve lift

$$\mathbf{Q = b \times } e^{ay}$$

Where

Q = flow at constant pressure drop
y = valve opening
e = base of natural logarithms
a and b = constants

Constants a and b can be evaluated to give more convenient form

$$Q = Q_0 X e^{\{(\log R / y \max) xy\}}$$

Where

Qo = flow at constant drop at zero stroke
R = flow range of valve, maximum to minimum at constant drop.
y max = maximum rated valve opening

Quick opening: -

Flow increases rapidly with initial travel reaching near its maximum at a low lift. It is generally not defined mathematically.

Valve actions and actuator mechanism:

Different types of actuators are used to control the stem travel of the valve, like electrical actuators, pneumatic actuators, hydraulic actuators etc.In this product pneumatic actuators are used for control valves. Spring opposed diaphragm actuator positions the valve plug in response to the controller signals.Mostly the controller signals are in the range of 3-15 psig.

Direct acting actuator (air to close):

Direct acting actuators basically consist of a pressure tight housing sealed by a flexible fabric reinforced elastomer diaphragm. A diaphragm plate is held against the diaphragm by a heavy compression spring. Signal air pressure is applied to upper diaphragm case that exerts force on the diaphragm and the actuator assembly. By selecting proper spring rate or stiffness, load carrying capacity, an initial compression, desired stem displacement can be obtained for any given input signal.

Reverse acting actuator (air to open)

In case of reverse acting actuators the stem gets retracted with increase in pressure.

Control valve flow coefficient:

A control valve regulates the flow rate in a fluid delivery system. In general a close relation exists between the pressure along the pipe and the flow rate so that if pressure is changed, then the flow rate is also changed. A control valve changes the flow rate by changing the pressure in the flow system because it introduces the constriction in the delivery system so we can say that the flow rate through the constriction is given by

$$Q = K\sqrt{\Delta P}$$

The correction factor K in the above equation allows selection of proper size of valve to accommodate the rate of flow that the system must support. This correction factor is called as valve coefficient and is used in valve sizing.

Valve coefficient:

$$C_V = 1.16 * Q * \sqrt{G / \Delta P}$$

Where G is specific gravity of liquid, Q flow in m^3 /h , ΔP pressure drop in bar.

Valve characteristics:

The amount of fluid passing through a valve at any time depends upon the opening between the plug and seat. Hence there is relationship between stem position, plug position and the rate of flow, which is described in terms of flow characteristics of a valve.

Inherent and install are two types of valve characteristics.

Inherent characteristics:

The inherent flow characteristic of control valve is the relation between the flow and the valve travel at constant pressure drop across the valve. Following are the inherent characteristics for different types of valves.

Procedure:

1) Start up the setup. Open the flow regulating valve of the control valve to be studied (linear / equal% / quick opening). Open the respective hose cock for pressure indication. (Close the flow regulating valves and hose cocks of other control valves).

2) Ensure that pressure regulator outlet is connected to the valve actuator of the control valve under study. Keep the control valve fully open by adjusting air regulator.

3) Adjust the regulating valve and set the flow rate. (Set 400 LPH flow for linear / equal% valve or 600 LPH for quick opening valve). Note for measuring flow rates below rotameter minimum range use measuring jar.

Pre-Lab Questions	Post Lab Questions
1. What is FCE? 2. What is control valve? 3. What are the types of control valve? 4. Define valve coefficient. 5. What are the classification of manually operated valves?	1. What is air to close and air to open? 2. What is quick opening? 3. What is direct acting and reverse acting? 4. What are inherent characteristics? 5. What types of valves are used in equal percentage characteristics?

Experiment Report

Particulars	Max. Marks	Marks Obtained
Pre-Lab	5	
Post-Lab	5	
Experiment Performance	10	

Result:

The characteristics of control valve were studied.

OBSERVATION 1

Set point_____

	ON-OFF Controller		P- Controller	
S.No	**Time (s)**	**PV(level) cm**	**Time(s)**	**PV(level) cm**
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
11.				
12.				
13.				
14.				
15.				

Experiment No: 9 **Date:**

STUDY ON LEVEL PROCESS CONTROLLER

AIM

To study the performance of ON-OFF/P/PI/PD/PID controllers on level process

HARDWARE REQUIRED

1. VLPA-101-CE.
2. Data Acquisition card and loop cable.
3. Ammeter (0-200) mA
4. Process control software with PC

THEORY

The level process controller is used to perform the control action of level process and study the characteristics of I/P converter. The RF capacitance level transmitter is used to measure the level of the process tank. In level control action, a pump sucks the air from reservoir and gives it to control valve. Every internal transaction is in voltage. Here, IBM-PC acts as error detector and controller. According to error signal, corresponding control signal is given to the I/P converter. It controls the flow of the liquid in pipeline by varying stem position of the control valve. For maintaining the level of the process tank, flow is manipulated level signal is given to the data acquisition card. By pass line is provided to avoid the pump overloading. From this controller also study the characteristics of the level transmitter, I/P converter, control valve and justify the various control actions.Data Acquisition card has ADC and DAC, so that it acts an effective link between the process and the controller.

TYPES OF CONTROL

ON/OFF Control

One of the most widely used type of control is the ON/OFF control. ON/OFF control is also referred as “TWO POSITION” control or “OPEN AND CLOSE “control. Two position control is a position type of controller action in which the manipulated variable is quickly

OBSERVATION 2

S.No	PD controller		PI- Controller		PID-Controller	
	Time (s)	PV(level)cm	Time (s)	PV(level)cm	Time (s)	PV(level)cm
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						
9.						
10.						
11.						
12.						
13.						
14.						
15.						

changed to either a maximum or minimum value depending on the control variable is greater than or less than the set point. If the control variable is below the set point, the controller is 100 percent (i.e. control valve is fully closed).If the control variable is above the set point, the controller output is 0 percent (i.e. control valve is fully opened), when the differential gap is zero. The turning parameters for ON/OFF control are differential gap and time delay.

DIFFERENTIAL GAP

Differential gap is the region in which the control causes the manipulated variable to maintain its previous value until the controlled variable has moved slightly beyond the set point. Small differential gap is not preferred. Because, it introduces oscillations and reduces the life of the final control element.

ON-OFF CONTROL

Two position control applied to a process results in a continuous oscillation in the quantity to be controlled.This drawback was overcome by a continuous control action which could maintain a continuous balance of the input and output.A mode of control which will accomplish this is known as "PROPORTIONAL CONTROL".

PROPORTIONAL CONTROL

"It is a controller action in which there is a continuous linear relationship between value of the controlled variable and position of the final control element within the proportional band". The tuning parameters for proportional control are, Proportional Gain $K_{p,}$ Time Delay T_d

PROPORTIONAL BAND P_b

Proportional band is defined as the percent deviation in measurement of its full scale required to give 100%valve deviation. Narrow band proportional control gives a comparatively large corrective action to the value for the small change in the measurement. For wide band proportional the corrective action to the valve is small land therefore the offset will be large. Usually, narrow proportional band is preferred. If proportional band is zero, the controller behaves as two position control.

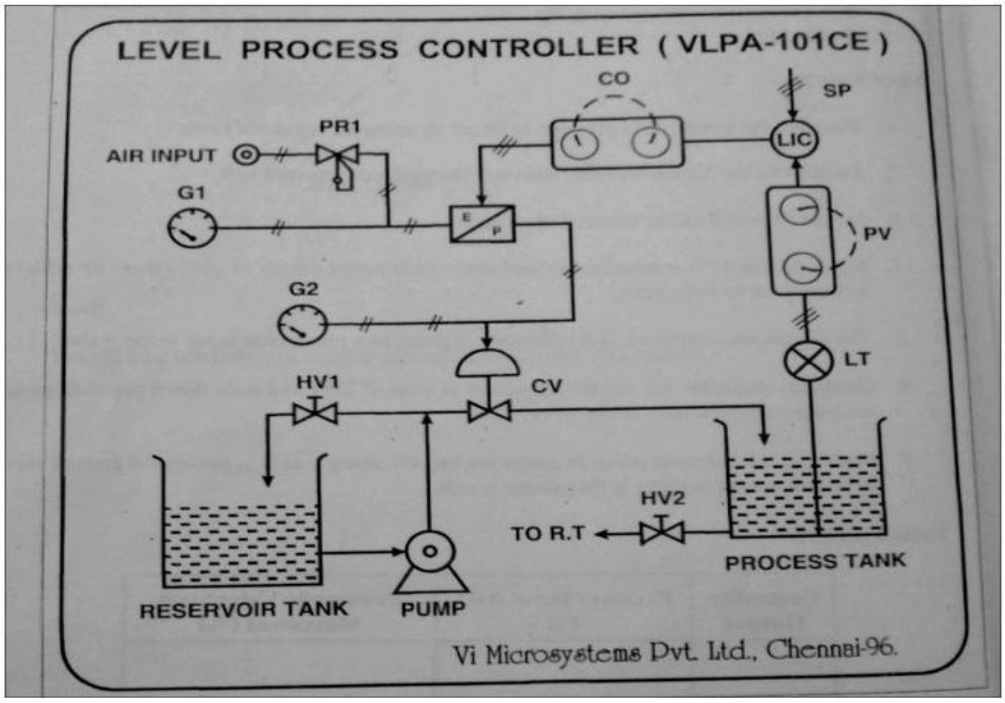


Fig 9.1.Panel Diagram

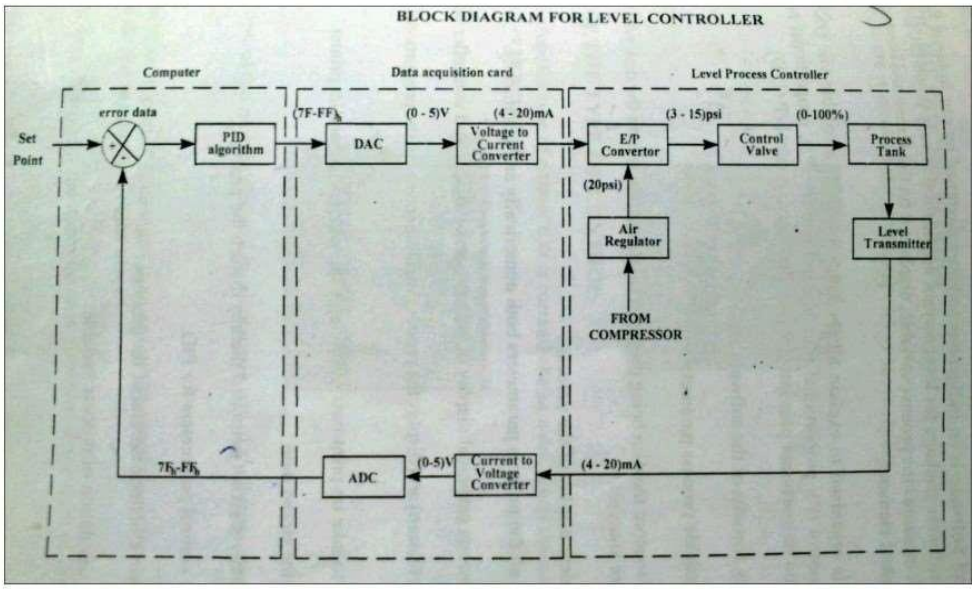


Fig 9.2.Circuit diagram

TIME DELAY

Time required taking the successive sample of process variable.

PROPORTIONAL +INTEGRAL (P+I)

The proportional control mode provides a stabilizing influence while the integral mode will help to overcome OFFSET. Integral controller will provide corrective action as long as there is a deviation in the controlled variable from the set point value.

Integral control has a phase lag of 90 degree over proportional control. This lagging feature of reset will result in a slow response and oscillation will come into picture.

This is suitable for flow control and pressure control where the process has little lag. But require a wide proportional band for stability. The small process lag permits the use of large amounts of integral action.

PROPORTIONAL + DERIVATIVE (P+D)

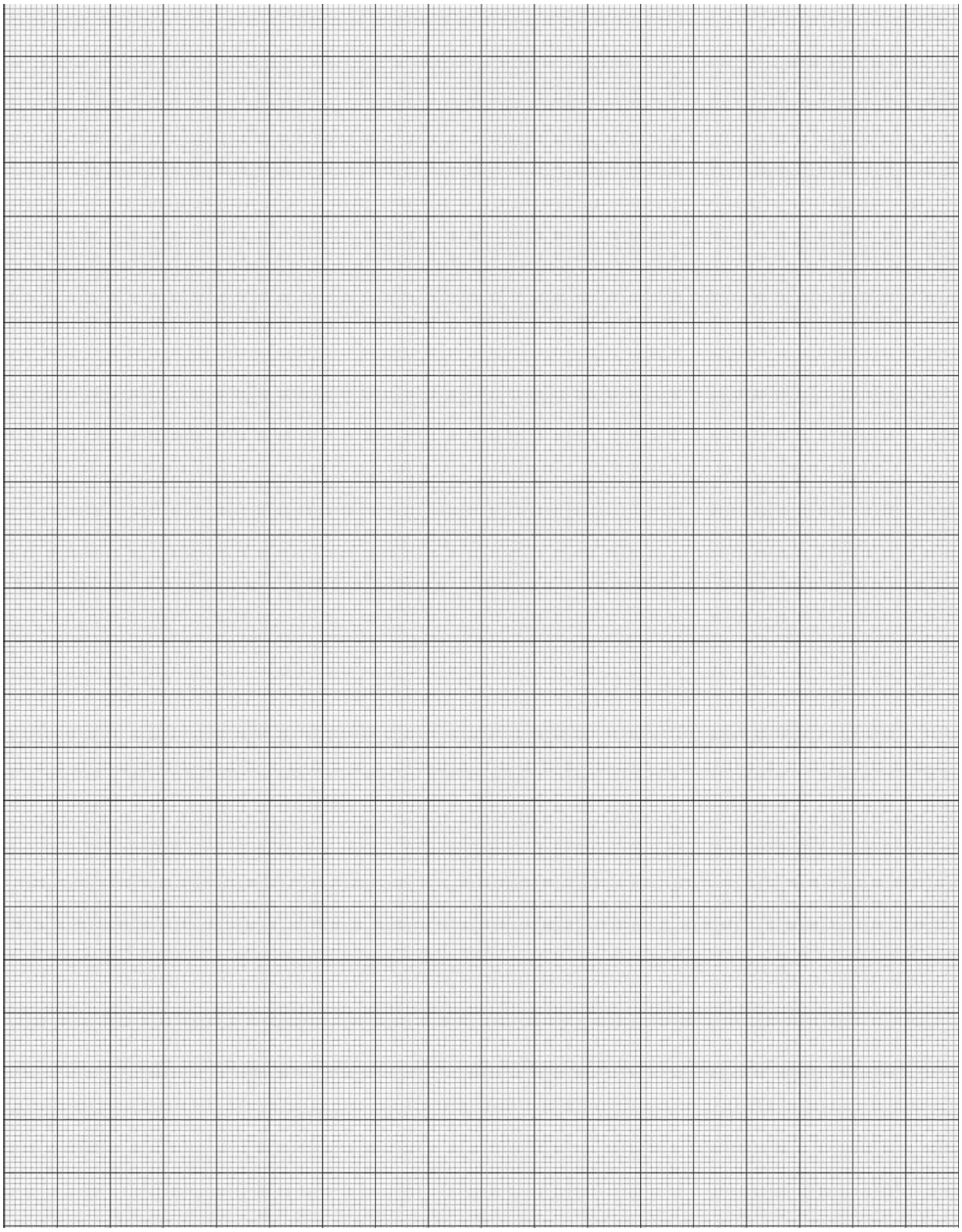
Derivative control action combined with proportional gives a controller which is good on process containing appreciable lag. Because the process lab can be compensated by the anticipatory nature of derivative (i.e) derivative action provides the boost necessary to counteract the time delay associated by 90 degree.

Since this controller combination is most affected where the system lags are high, lit could be used on most multi capacity process applications. Where the process lag is short, this combination could not be used. This controller combination does not eliminate OFFSET after a sustained load disturbance. It does reduce the magnitude of the OFFSET. Because of narrow proportional band. A proportional plus derivative controller properly fitted and adjusted to a process acts to prevent the controlled variable from deviating excessively and reduces the time required to stabilize.

PROPORTIONAL +INTEGRAL DERIVATIVE (P+I+D)

This controller offers the benefit of each control action and moreover the effect duplicates the action of a good human operator on the process. A three mode controller contains the “stability” of proportional control and the ability to eliminate the offset. Because of reset control and the ability to provide an immediate correction for the magnitude of disturbance because of rate control.

Scale
In x-axis 1cm =
In y-axis 1 cm =



PROCEDURE

1. Air pressure regulator input should be more than 25psi and maintain the air regulator output pressure (G1) to 20psi by varying the air regulator knob, which supplies a constant pneumatic input to the electro-pneumatic converter.
2. Keep hand valve HV_1, HV_2 partially open.
3. Invoke "Level process control" software in PC.
4. Select "Control>>ON-OFF/P/PI/PD/PID".
5. Select "settings>>parameters" and enter values for each parameter (i.eK_p, K_i,K_d,dead band).
6. Switch ON the pump and to run the pump in desired speed by using variable speed control knob
7. For getting a desired response, tune the process parameter to optimum values.
8. Now, study the response of ON-OFF/P/PI/PD/PID control action for various values of set point, K_p,K_i,K_d.

Pre-Lab Questions	Post Lab Questions
1. Name some level transducer. 2. Define ON-OFF controller. 3. Write the transfer function for PD controller. 4. Differentiate open loop and closed loop system. 5. Define the term error in process control.	1. Mention the advantages of derivative mode. 2. Mention the drawback of internal mode. 3. Write the transfer function for PID controller. 4. Which controller mode is most advantageous? 5. Define the term set point

Experiment Report

Particulars	Max. Marks	Marks Obtained
Pre-Lab	5	
Post-Lab	5	
Experiment Performance	10	

RESULT

Thus, the performance of ON-OFF P/PI/PD/PID controllers on Level Process was studied.

Observation: 1

Sl.No	Time (sec)	PV(pressure)	Controller o/p in %

Experiment No: 10 **Date:**

STUDY ON DIFFERENT MODE OF CONTROLLERS P, PD, PI, PID

AIM:

To study the performance of ON-OFF/P/PI/PD/PID controllers on Pressure process..

HARDWARE REQUIRED:

1. VPPA-401CE
2. Data Acquisition card with cable.
3. PC with process control software.
4. Patch chords

THEORY:

Types of control

Proportional control:

Two position control applied to a process results in a continuous oscillation in the quantity to be controlled. This drawback was overcome by a continuous control action which could maintain a continuous balance of the input and output. A mode of control which will accomplish this is known as 'PROPORTIONAL CONTROL".

Proportional + Integral (P + I):

The proportional control mode provides a stabilizing influence while the integral mode will help to overcome OFFSET. Integral controller will provide corrective action as long as there is a deviation in the controlled variable from the set point value.

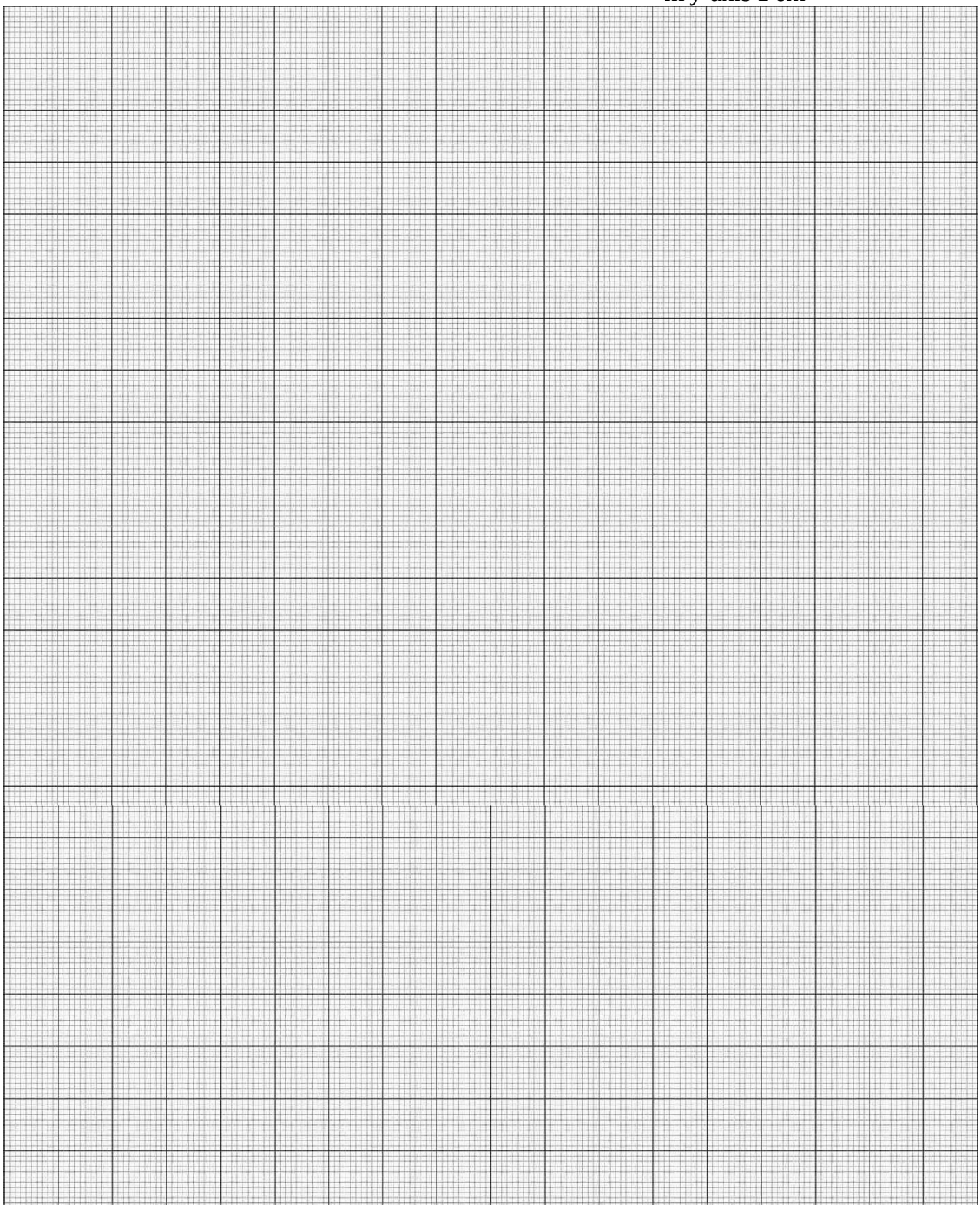
Proportional + Derivative (P + D):

Derivative control action combined with proportional gives a controller which is good on process containing appreciable lag. Because the process lag can be compensated be the anticipatory nature of derivative action (i.e.) derivative action provides the boost necessary to counter act the time delay associated with such control by 90°.

Observation: 2

Sl.No	Time (sec)	PV(pressure)	Controller o/p in %

Scale
In x-axis 1cm =
In y-axis 1 cm =



Observation: 3

Sl.No	Time (sec)	PV(pressure)	Controller o/p in %

Proportional + integral + Derivative (P + I + D):

This controller offers the benefit of each control action and moreover the effect duplicated the action of a good human operator on the process. A three mode controller contains the "stability" of proportional control and the ability to eliminate offset. Because the reset control has the ability to provide an immediate correction for the magnitude of a disturbance.

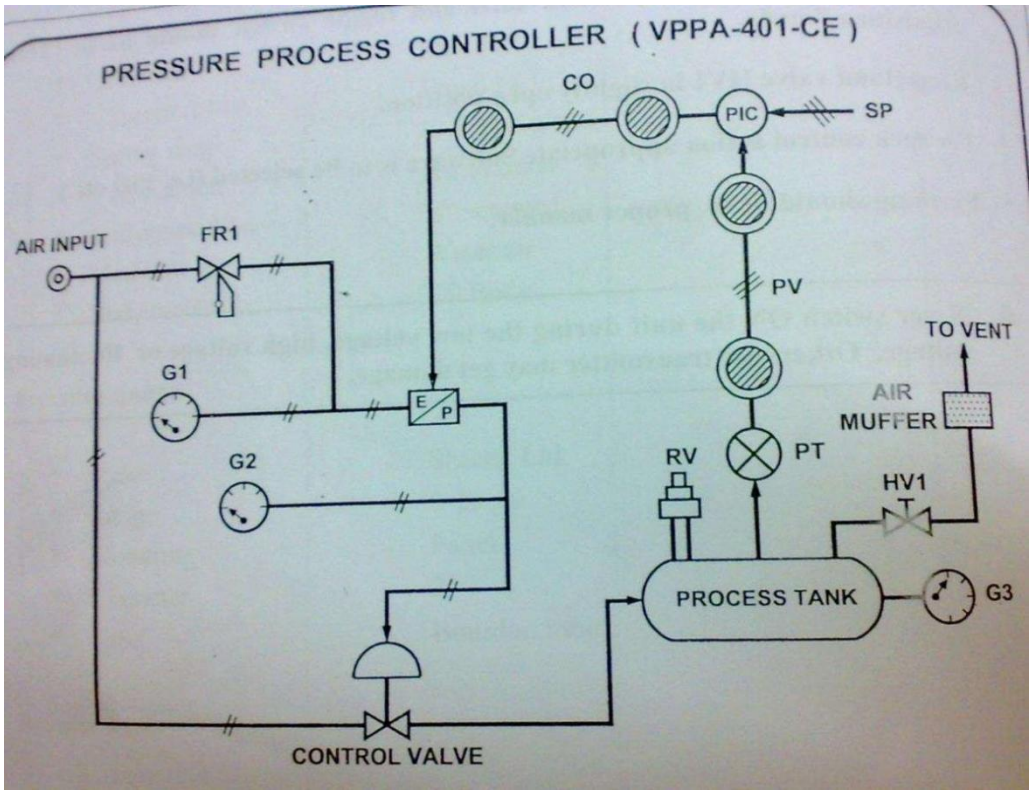
Working principle:

Pressure process controller is used to perform the control action on pressure process. In this unit pressure is the process variable and is sensed and given to controller. A Piezo electric pressure transmitter is used to measure and transmit the pressure developed in the process tank.In thus unit, pressure is developed from a compressor and is given to the unit. Every internal transaction is in voltages. Here a PC acts as error detector and controller. According to the error signal, computer develops a control signal This control signal is given to I/P converter which operates the control valve. Control valve acts here as final control element which controls the pressure inside the process tank by varying its plug opening according to controller output.Data acquisition card has ADC and DAC, so that it acts an effective link between the process and the controller.Relief valve is being used for safety purpose by which excess pressure developed in the process tank can be removed.

Procedure:

1. Ensure the availability of Air.
2. Interface the PC with processes and Data acquisition card.
3. Maintain Gauge(G1) pressure at 20 PSI by using air regulator knob.
4. Position the Hand Valve HV1 in slightly open position.
5. Patch CO and PV terminals using patch chords.
6. Switch ON the Unit and Data Acquisition card with PC.
7. Invoke Process control software.
8. Select "pressure >> control >> ON-OFF/P/PI/PD/PID".
9. Enter the parameters and observe the responses of various controllers.
10. Save the response and conclude the behavior of pressure process.

Panel Diagram:



Pre-Lab Questions	Post Lab Questions
1. Name some pressure transducer. 2. Define PB. 3. What is two position controls? 4. Define offset. 5. What is integral windup?	1 Why derivative mode is not used alone? 2 What are the advantages of PI controller? 3 What are the drawbacks of P controller? 4 Comment on the response of P, PI and PID controllers. 5 What is differential gap?

Experiment Report

Particulars	Max. Marks	Marks Obtained
Pre-Lab	5	
Post-Lab	5	
Experiment Performance	10	

Result:

Thus the performance of ON-OFF/P/PI/PD/PID controllers on pressure process was studied.