INDIAN INSTITUTE OF TECHNOLOGY

DATE | Group - 4 | SHEET NO.

Sl No	Exp. No.	Experiment Name (Date)	Page No.	Remarks
1.	4	Interacting and Non-interacting System (03/08/23)	1-11 8.5/10	To be evaluated once all concerns are addressed.
2.	5	Study of control valve characteristics (10/08/23)	12-20 8.5/10	
3.	6	Calibration of Thermocouple and Resistance Thermometer (17/8/23)	21-24 8.5/10	Mogani 24/8/23
4.	7	Flapper-Nozzle system (24/8/23)	25-28 8.5/10	Rohit 31/8/23
5	8	Calibration of Differential Pressure Transmitter	29-33 8/10	Rohit 5/10
6	9	1st & 2nd order experiment	14/09/23	9/10 Sajdeep
7	10	Study of P/I & I/P Converter	5/10/23	9/10 Mogani 12/5/23
8	1	Pressure Control Trainer	12/10/23	9/10 no process
9	2	Temperature control trainer	19/10/23	8/10 reaction curve & calc. based on that.

P.R.E.

INDIAN INSTITUTE OF TECHNOLOGY

DATE 03/08/23 | Experiment No- 04 | SHEET NO. 01

TITLE : Interacting and Non-interacting System.

OBJECTIVE : To observe the :

(i.) Step response of single capacity system
(ii) Step response of first order systems arranged in non-interacting mode.
(iii) Impulse response of first order systems arranged in non-interacting mode.
(iv.) Step-response of first order systems arranged in interacting mode.
(v.) Impulse response of first order systems arranged in interacting mode.

THEORY :

(i.) Step response of single capacity

Step function of magnitude A can be expressed as

$$X(t) = A\ u(t)$$

where u(t) is unit step function. , X = step function.

X = ??

To study transient response, consider the system consisting of tank of uniform cross section A and outlet flow resistance R. q_0 volumetric flow rate through resistance is related to h linear relationship.

$$q_0 = h/R \quad \text{—— (1)}$$

P.R.E.

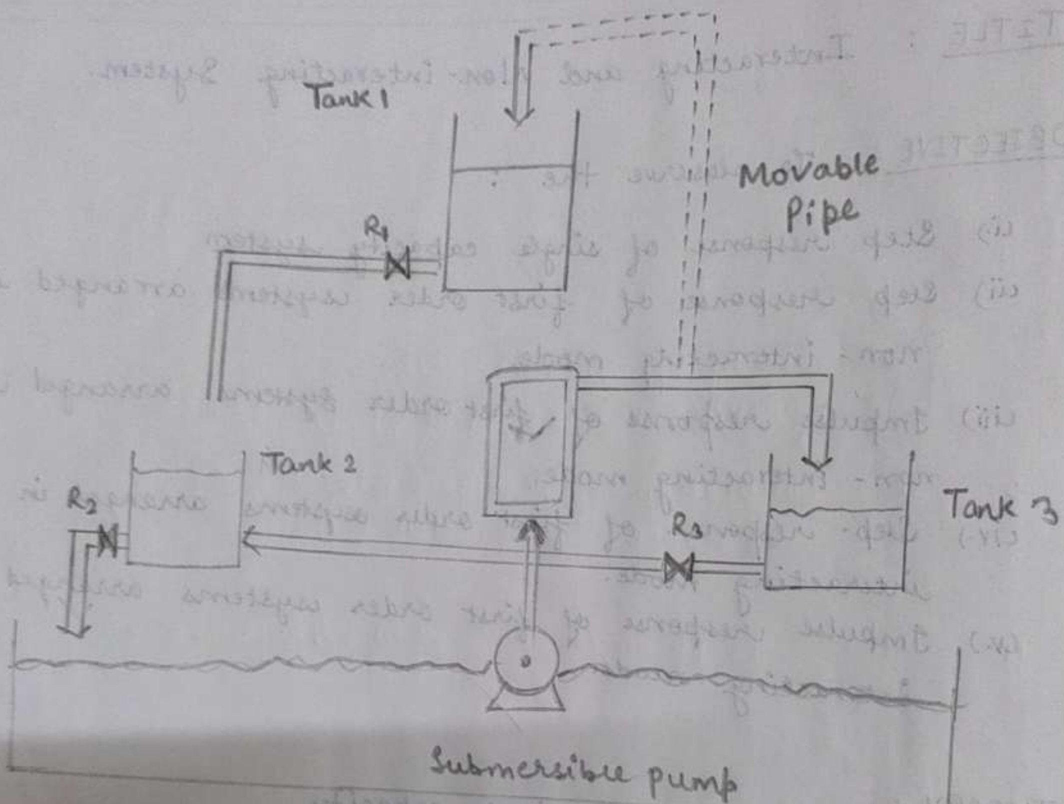


Fig 1 : Experimental Configuration

Fig 1. Title.

Experimental Setup & Apparatus {Fig 1}:

Set up specifications :

Rotameter : 10 - 100 LPH

Process tank : Acrylic Cylinder, ID 92 mm

Supply tank : 55 .

(I.) Step - response of single Capacity System.

Mass Balance about the tank

$$q(t) - q_0(t) = A_1 (dh/dt) \quad \text{—— ①}$$

This gives $H(t) = AR \{ (1 - e^{-t/6}) \}$

Procedure :

① Set up was started.

② Flexible pipe was provided at rotameter outlet. Pipe was inserted in to the cover of the top tank 1 the outlet value (R_1 & R_2) was kept slightly closed.

③ Pump was switched ON. Rotameter flow rate was adjusted in steps of 10 LPH from 50 to 100 LPH & noted steady state. Levels for tank 1 against each flow rate.

④ Suitable band for experimentation was sorted from data.

⑤ Flow rate was adjusted at lower value of selected tank and allowed the level of tank 1 to reach the steady state and recorded the flow & level at steady state.

⑥ Step change was applied by increasing rotameter flow by @ 10 LPH.

Table Title
1) Step response of a first order Single Capacity System

Time(s)	H(t)Observed	H(t)Predicted
0	0	0
15	6	5.05
30	9	8.28
45	10	10.34
60	11	11.66
75	12	12.5
90	13	13.04
105	13	13.39
120	14	13.61
135	14	13.75
150	14	13.84

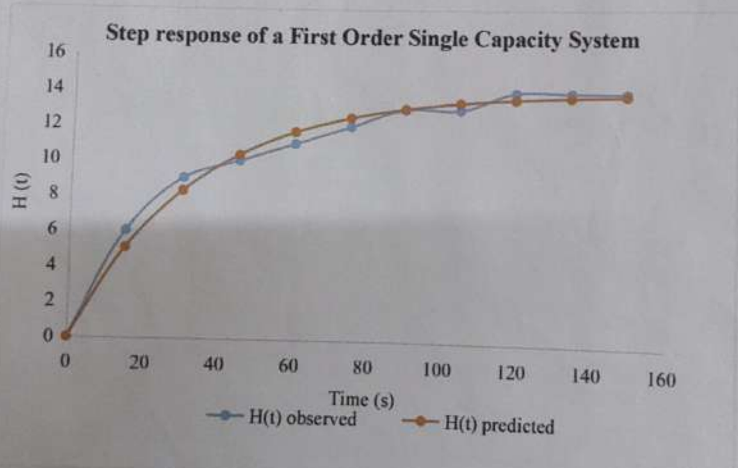


Fig 2- Title.
Transient response of Single Tank System.

(7) Immediately started recording level of tank 1 at interval of 15 sec. until the level reaches at steady state.

(II.) Step response of 1^{st} order systems, we assume the tanks have uniform cross sectional area and flow resistance is linear. To find out the transfer function of system that is related h_2 to q, Applying mass transfer equation, we get →

$$H_2(t) = AR_2\left[1 - \frac{\tau_1\tau_2}{\tau_1-\tau_2}\left\{\frac{1}{\tau_2}e^{-t/\tau_1} - \frac{1}{\tau_1}e^{-t/\tau_2}\right\}\right]$$

Procedure :

1.) Outlet of rotameter was connected to top cover of tank 1. Outlet valve R_1 & R_2 was kept slightly closed R_3 was kept fully closed.

2.) Pump was switched on and flow rate was adjusted.

3.) After system reaches steady state, step change was applied.

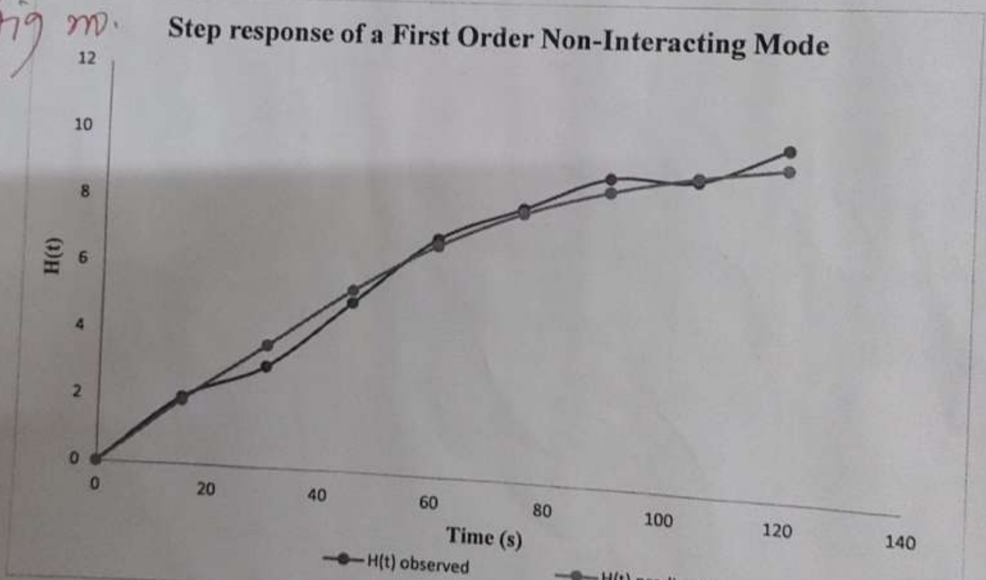
4.) Level of tank 2 was recorded at interval of 30 seconds...

Table no. 1) Step response of a First Order Non-Interacting Mode

Time (s)	H(t) Observed	H(t) predicted
0	0	0
15	2	1.92
30	3	3.63
45	5	5.37
60	7	6.8
75	8	7.86
90	9	8.6
105	9	9.1
120	10	9.43

not followed what is shown in the last class.

Fig no.



INDIAN INSTITUTE OF TECHNOLOGY

DATE

SHEET NO. 04

III) To study impulse response of 1st order systems arranged in non-interacting mode.

Mathematically, the impulse function of magnitude A is defined as $x(t) = A\,TM(t)$

where $TM(t)$ is unit impulse function.

$$H_2(t) = VR_2 \left[\frac{e^{-t/\tau_1} - e^{-t/\tau_2}}{(\tau_1 - \tau_2)} \right]$$

Procedure :

(I.) Outlet of Rotameter was connected to the top cover of tank I. Outlet valves R_1 & R_2 were kept slightly closed. R_3 was kept fully closed.

(II.) Pump was switched ON and flow rate was maintained.

(III) After system reached steady state, an impulse was applied by adding 100 ml water in tank 1.

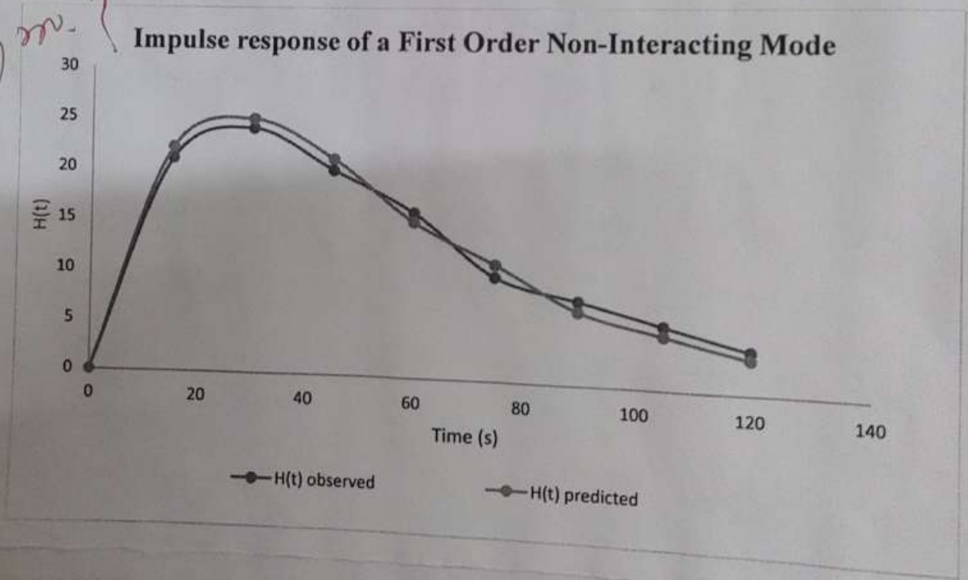
(IV) Level of tank was noted at regular intervals until steady state is obtained.

Table no?

2)Impulse response of a First Order Non-Interacting Mode

Time (s)	H(t) observed	H(t) predicted
0	0	0
15	21	22.12
30	24	24.93
45	20	21.09
60	16	15.08
75	10	11.219
90	8	7.015
105	6	5.08
120	4	3.25

Fig no.?



(IV.) Step Response of 1st order systems arranged in interaction mode. Assuming the tank of uniform cross section area and values with linear flow resistance the transfer function of interacting system can be written as:-

$$\frac{H_2(s)}{Q(s)} = \frac{R_2}{\tau_1\tau_2 s^2 + (\tau_1+\tau_2 + A_1R_2)s + 1}$$

$$H_2(t) = AR_2 \left\{ 1 - \frac{[(1/\alpha)(e^{\alpha t}) - (1/\beta)e^{\beta t}]}{1/\alpha - 1/\beta} \right\}$$

Procedure :

(i.) outlet of rotameter was connected to top cover of tank 3 Outlet valves R_2 & R_3 were kept slightly closed.

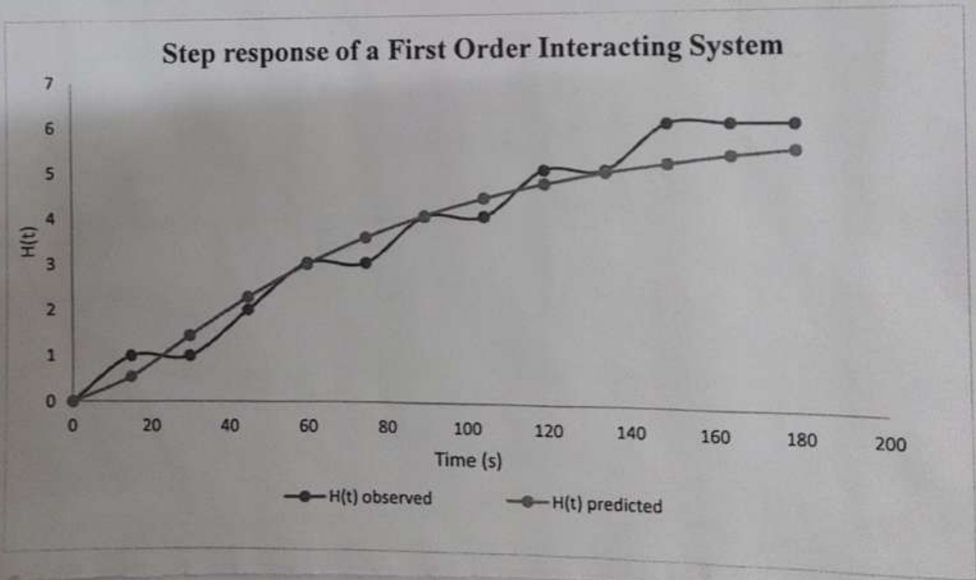
(ii.) Pump was switched ON and flow rate was adjusted.

(iii) After system reached to steady state, a step change was applied increasing the flow by 10 LPH.

(iv.) Level was recorded after regular time intervals.

3)Step response of a First Order Interacting System

Time (s)	H(t) observed	H(t) predicted
0	0	0
15	1	0.545
30	1	1.438
45	2	2.271
60	3	2.973
75	3	3.548
90	4	4.015
105	4	4.393
120	5	4.699
135	5	4.947
150	6	5.14
165	6	5.31
180	6	5.44



(V.) Impulse Response of 1st order systems arranged in interacting mode.

As mentioned in theory part Exp. 3 impulse function described as $x(t) = A \; \delta(t)$

Overall transfer function,

$$\frac{H_2(s)}{Q(s)} = \frac{R_2}{\tau_1 \tau_2 s^2 + (\tau_1 + \tau_2 + A_1 R_2) s + 1}$$

For impulse $Q(t) = V \; \delta(t)$

$$H_2(t) = \frac{V R_2}{\tau_1 \tau_2 (\alpha - \beta)} \left[e^{\alpha t} - e^{\beta t} \right]$$

Procedure:

(i) Outlet valve of tank 2 was slightly closed. The valve between tank 2 & tank 3 was slightly closed.

(ii) The pump was switched ON and level of both tank was allowed to react at steady state.

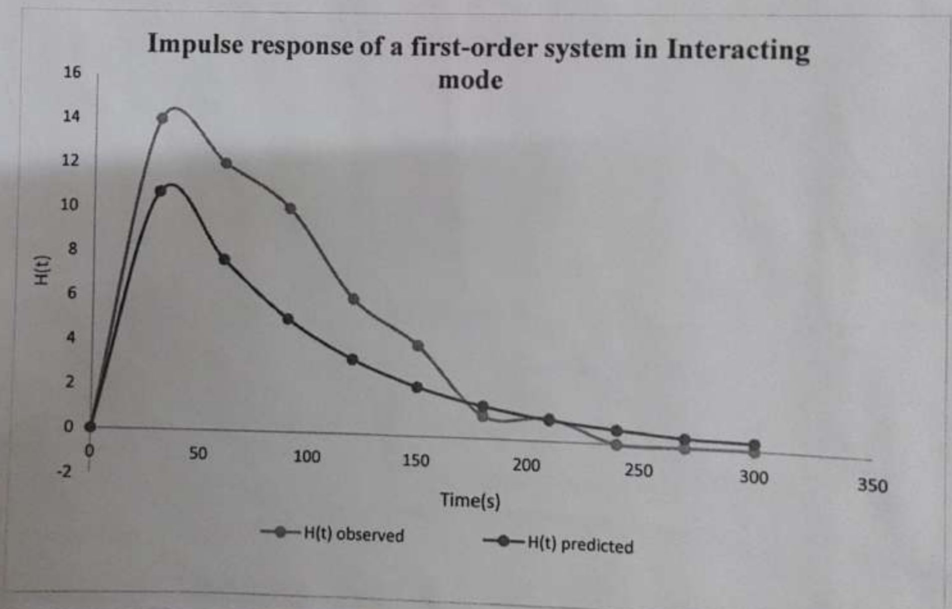
(iii) Impulse input was applied by adding 100 ml of water in each.

(iv) Level of tank 2 at intervals of 30 sec is recorded until level reaches to steady state.

(v.) Final steady state level of tank 3 was reached.

4)Impulse response of a first-order system in Interacting mode

Time	Tank 2 level	H(t) observed	H(t) predicted
0	12	0	0
30	26	14	10.7
60	24	12	7.65
90	22	10	5.05
120	18	6	3.314
150	16	4	2.171
180	13	1	1.422
210	13	1	0.931
240	12	0	0.61
270	12	0	0.41
300	12	0	0.32



INDIAN INSTITUTE OF TECHNOLOGY

DATE

SHEET NO 07

<u>Sample Calculation</u>

(1) R_1 = outlet valve resistance

$$R_1 = \frac{dH_1}{dQ} = \frac{(50-36)\times 10^{-3}}{2.778\times 10^{-6}} = 5040\ s/m^2$$

$$A_1 = \frac{\pi}{4}d^2 = \frac{\pi}{4}(0.092)^2 = 6.647\times 10^{-3}\ m^2$$

$$\tau = A_1 R_1 = 5040 \times 6.647 = 33.5\ s.$$

$$H(t)\ \text{predicted} = AR_1(1-e^{-t/\tau})$$
$$= 2.778\times 10^{-6}\times 5040\ (1-e^{-t/\tau})$$

At $t = 15$ sec

$$H(t) = 14\,(1-e^{-15/33.5})$$
$$= 5.05\ m.$$

Meet all 5 objectives stated in Page 1

P.R.E.

INDIAN INSTITUTE OF TECHNOLOGY

DATE

SHEET NO. 08

(II) $R_1 = \frac{dH_1}{dQ} = \frac{(50-3)\times10^{-3}}{2.778\times10^{-6}} = 4320\ s/m^2$

$R_2 = \frac{dH_2}{dQ} = \frac{(18-8)\times10^{-3}}{2.778\times10^{-6}} = 3600\ s/m^2$

$A_1 = A_2 = \frac{\pi}{4}(0.092)^2\ m^2 = 6.647\times10^{-3}\ m^2$

$\tau_1 = A_1R_1 = 6.647\times10^{-3}\times4320 = 28.7\ sec$

$\tau_2 = A_2R_2 = 6.647\times10^{-3}\times3600 = 23.93\ sec$

$AR_2 = 10\ mm$

$$H(t) = AR_2\left[1 - \frac{\tau_1\tau_2}{\tau_1-\tau_2}\left(\frac{e^{-t/\tau_1}}{\tau_2} - \frac{e^{-t/\tau_2}}{\tau_1}\right)\right]$$

$$= 10\left[1 - 144\left(0.041\,e^{-t/28.7} - 0.035\,e^{-t/23.93}\right)\right]$$

At $t = 15$ sec

$H(t)_{\text{predicted}} = 1.92$ mm

At $t = 30$ sec

$H(t) = 3.63$ mm.

P.R.E.

(III) $$H(t) = VR_2 \left[\frac{e^{-t/\tau_1} - e^{-t/\tau_2}}{\tau_1 - \tau_2} \right]$$

$$V = 0.5\,L = 5\times10^{-4}\ m^3$$

$$\tau_1 = 28.7\,sec \qquad \tau_2 = 23.93\,sec$$

$$R_2 = 3600\ s/m^2$$

$$H(t)_{predicted} = 5\times10^{-4} \times 3600 \left[\frac{e^{-t/28.7} - e^{-t/23.93}}{28.7 - 23.93} \right]$$

At $t = 15$ sec.

$$H(t) = 22.13\ mm$$

At $t = 30$ sec

$$H(t) = 24.93\ mm$$

(IV) $$R_3 = \frac{(98-56)\times10^{-3}}{2.778\times10^{-6}} = 7919.9\ s/m^2$$

$$R_2 = \frac{6\times10^{-3}}{2.778\times10^{-6}} = 459.9\ s/m^2$$

$$A_2 = A_3 = \frac{\pi}{4}(0.092)^2 = 6.647\times10^{-3}\ m^2$$

$$\tau_3 = A_3R_3 = 52.6\,sec \qquad \tau_2 = A_2R_2 = 14.35\,sec$$

$$b = \frac{1}{\tau_3} + \frac{1}{\tau_2} + \frac{A_1R_1}{\tau_1\tau_3} = 0.1077$$

$$\alpha = -\frac{b}{2} + \sqrt{\left(\frac{b}{2}\right)^2 - \frac{1}{Z_2 Z_3}} = -14.1 \times 10^{-3}$$

$$\beta = -\frac{b}{2} + \sqrt{\left(\frac{b}{2}\right)^2 - \frac{1}{Z_2 Z_3}} = -93.5 \times 10^{-3}$$

$$H(t)_{predicted} = AR_2 \left[1 - \frac{1}{\left(\frac{1}{\alpha} - \frac{1}{\beta}\right)} \left\{ \frac{1}{\alpha} e^{\alpha t} - \frac{1}{\beta} e^{\beta t} \right\} \right]$$

$$= 0.545 \text{ mm}$$

(V) $$H(t)_{predicted} = \frac{VR_2}{Z_1 Z_2 (\alpha - \beta)} (e^{\alpha t} - e^{\beta t})$$

$Z_1 = 52.6\,s$ $\quad Z_2 = 14.35\,s$ $\quad V = 0.5\,L = 5 \times 10^{-4}\ m^3$

$\alpha = -0.0141$ $\quad \beta = -0.0935$

$R_2 = 2159.9\ s/m^2$

$$H(t) = \frac{(5 \times 10^{-4} \times 2159.9)}{52.6 \times 14.35\,(0.0794)} \left(e^{-0.014t} - e^{-0.0935t}\right)$$

At $t = 30$ sec
$H(t) = 10.7$ mm

At $t = 60$ sec
$H(t) = 7.65$ mm.

Discussions

① The step response starts at 0 and gradually approaches the steady-state value, over a period proportional to the time constant τ. The steady state gain determines the final value that the output approaches as time goes to infinity.

② Non-interacting system always results in an overdamped or critically damped second order system, for step change. On the other hand, response of interacting system is always over-damped for step input change.

③ From the graph, we can infer that response of interacting and non interacting systems is slower than that of single capacity system. This is because single capacity is first order whereas interacting/ non-interacting system is 2nd order.

④ The deviations present in graph can be due to valve resistance, experimental errors while giving step change etc.

⑤ From the nature of graph, we can conclude that response of interacting system is more sluggish than that of non-interacting system.

Aim: To study control valve characteristics by conducting the following experiments.

1. Study of control valve flow coefficient
2. Study of inherent characteristics of control valve.
3. Study of installed characteristics of control valve.
4. Study of Hysteresis of control valve.

Description:

In this apparatus three control valve with pneumatic actuators are provided. One control valve is with equal % characteristic (air to close type), the second is with linear characteristic (air to open type) and the third one is quick opening type. Water from receiving tank is pump to supply tank flows through control valve. water flow is measured using rotameter in terms of column. The control valve stem travel is adjusted ~~in terms~~ of by air regulator resulting changes in flow through the control valve. As outlet of ~~column~~ control valve is open to atmosphere and pressure at inlet is considered as pressure drop across the valve.

Theory:-

The movement of the valve, whether opening or closing is achieved through its corresponding actuator mechanism. Various types of actuators are employed to regulate the extent of stem travel in valves, including electrical, pneumatic, and hydraulic variants, each catering to specific operational needs. In this particular product, Pneumatic actuators play a pivotle role in controlling valve function. These mechanisms employ spring-opposed diaphragms to accurately position the valve plug in direct response to signals recieved from the controller.

Direct acting actuators

Direct acting actuators features a sealed housing with a flexible diaphragm, reinforced by resilient elastomers. The diaphragm enclosure holds a plate secured by a strong compression spring. Signal air pressure applied to the upper diaphragm section exists force on the diaphragm and actuators assembly. choosing the right spring rate and compression allows the actuator to achieve desired stem displacement in response to the input signal.

Reverse Acting Actuator :-

Reverse Acting actuators the stem gets retracted with increase in pressure.

Types of control valve:-

① Equal- percentage valve:-

The ratio of the change in flow rate to the change in valve opening position is proportional to the flow rate before the change, and is expressed by the following equation. Here, L is the valve opening position, and k is constant.

$$\frac{dC_v}{dL} = kC_v \rightarrow C_v = e^{k(L-1)}$$

C_v ?

② Linear (Characteristic) valve:-

with the linear characteristic, the valve opening position and the flow rate are proportional to each other.

$$C_v = kL$$

③ Quick open valve:-

Also known as the on-off characteristic, this is a characteristic that is efficient when switching the flow rate between a maximum and a minimum such as on-off control.

Valve coefficient:-

This is an index that represents the maximum flow rate that can pass through (a factor that represents the volume of the valve). It is defined as "the flow rate ~~in~~ when fresh water at 60°F flows at the maximum position at a differential pressure of 1Psi". For example, if $C_v = 20$ it represents (4.542 m³/h) of water that can flow at a pressure drop of 1Psi (6.897 kPa) when the valve fully open.

For liquids, the followed equation is used:

$$C_v = 1.16\, Q \sqrt{\frac{G}{\Delta P_v}}$$

Q: Flow Rate (m³/h)

G: specific gravity

ΔP_v: Pressure Drop [kg/cm²]

Valve characteristics :-

The amount of fluid passing through a valve at ~~anytht~~ any time depends upon the opening b/w plug & seat. Hence, there is relationship between stem position and the rate of flow which is delivered in terms of flow characteristics of a valve. Inherent and installed are the two types of valve characteristics.

Inherent Characteristics:-

Inherent flow characteristics is determined under laboratory conditions by testing the valve flow versus valve lift or travel using a constant differential pressure drop across the valve throughout the test. The inherent flow characteristics for each control valve are published by manufactures and they are standardized for a fixed pressure drop as defined by the use of the valve flow coefficient value C_v.

Installed Flow characteristics:-

This could be regarded as the Actual flow characteristics of the control valve because it is determined for each installation by the actual differential Pressure drop across the valve when in service. In operation, the differential Pressure across the control valve varies throughout the valve position due to the system characteristics.

Hysteresis :-

Hysteresis:- Hysteresis is a Predictable error resulting from the differences in the transfer function when a reading is taken from above and below the value to be noted. In case of control valve for some actuator signal different stem travel are obtained depending upon the direction of change in sig

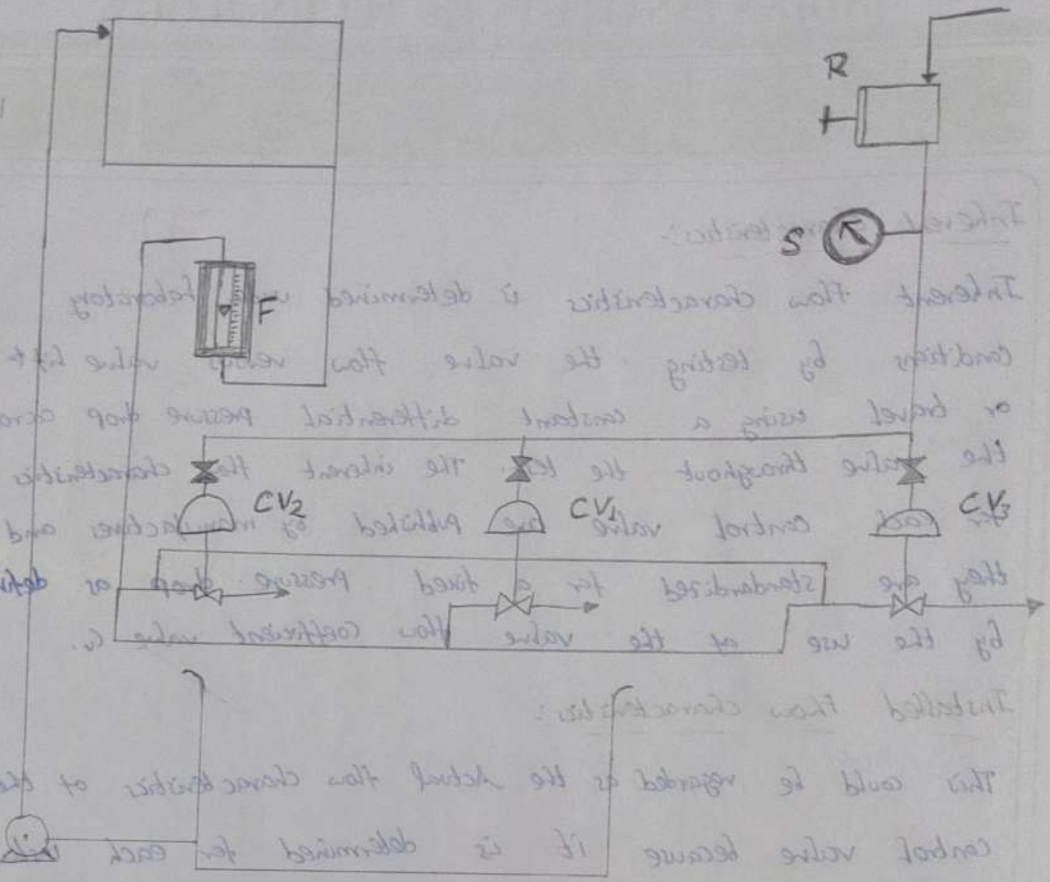


Fig.- Schematic diagram of Control Valve characteristics.

F : Rotameter

CV_1 : Control valve 1, quick opening (pressure to open)

CV_2 : Control valve 2, Equal percentage (Pressure to close)

CV_3 : Control valve 3, linear (Pressure to open)

R : Pressure Regulator

S : Supply Pressure gauge.

INDIAN INSTITUTE OF TECHNOLOGY

DATE | | SHEET NO. 17

Observation:

1. For linear value :-

Lift (mm)	flow rate (LPH)	Cv
1.7	400	10.542
1.6	390	10.278
1.5	370	9.751
1.375	350	9.224
1.25	340	8.960

2. For equal % value

Lift (mm)	flow rate (LPH)	Cv
2	400	10.542
2.1	300	7.906
2.2	290	7.643

3. ~~For~~ quick opening

Lift (mm)	flow rate (LPH)	Cv
0.5	175	4.612
1	195	5.139
1.8	235	6.193
2.5	300	7.906
3	375	9.882

INDIAN INSTITUTE OF TECHNOLOGY

DATE | | SHEET NO. 18

2.

1. For linear valve :-

water flow rate (LPH)	Air pressure (Kg/cm²)	Stem height
270	0.1	2.5
235	0.19	3.5
170	0.3	5.0
120	0.4	6.5
80	0.5	8.5

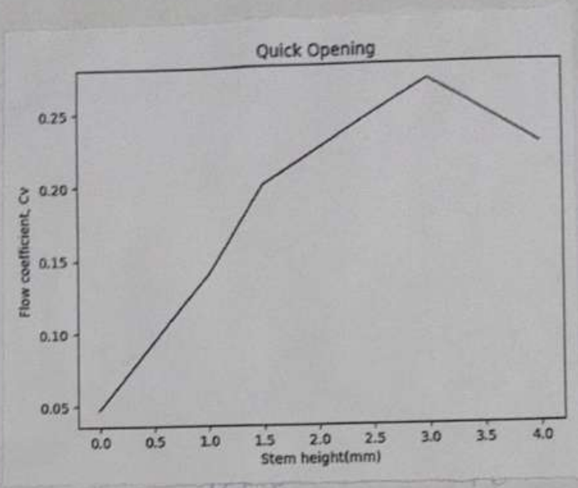
2. For equal % valve :-

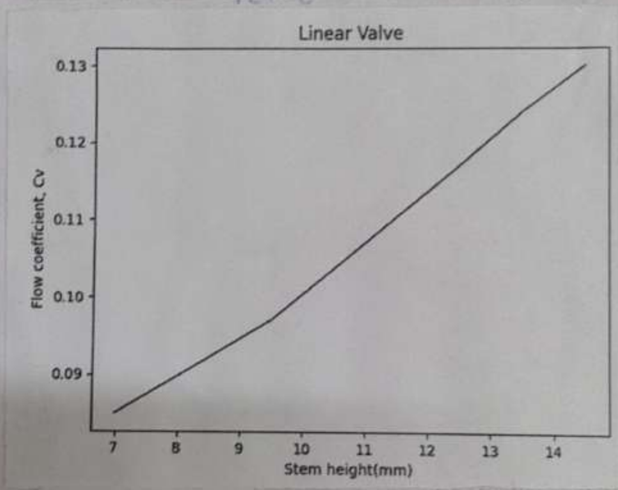
water flow rate (LPH)	Air pressure (Kg/cm²)	stem height
495	19	0.5
460	18.5	1.5
410	14.5	2.5
320	13	5.5
269	11.5	8

3. quick opening

water flow rate (LPH)	Air pressure	stem height
65	2.5	0
	4.5	1.0
255		1.5
430	6	
540	7.5	3.0
550	8	4.0

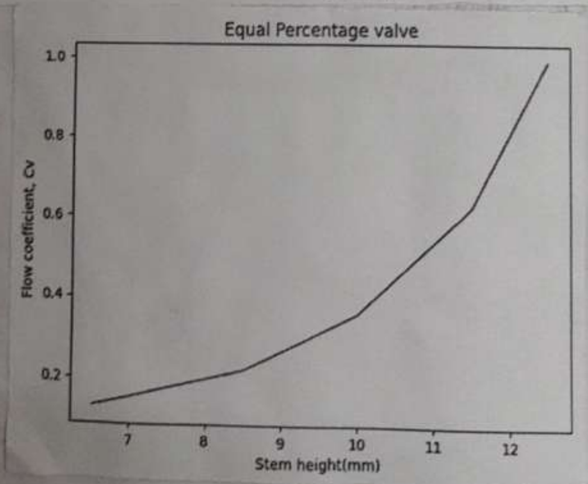
Group 1.





g name.

fig no.: ??



INDIAN INSTITUTE OF TECHNOLOGY

DATE | SHEET NO. 19

DISCUSSION

+ A linear control valve is designed so that the flow capacity increases in a linear manner with the valve's displacement or opening. This means that if you open the valve by a certain percentage, the flow rate will also increase by a proportional percentage. However, despite this theoretical linearity, factors from which deviations can arise due to several reasons.
    - 1) Instrumentation
    - 2) Human Error
    - 3) Cavitation and flashing
    - 4) Frictional and Pressure Drops.

+ An Equal percentage valve is designed with a characteristics such that for each equal percentage change in valve opening, the flow rate increases by the same percentage. This results in an exponential relationship between the valve opening and the flow rate. In ~~order~~ other words as the valve is opened more, the increase in flow rate becomes more significant. This characteristic is chosen because it compensates for the non-linear behavior of other componential growth in flow rate ~~con~~ counteracts the natural decrease in flow caused by these components.

+ Installed characteristics refer to how the control valve behave within a specific system, ~~according~~ accounting for factors like pipe lengths, fitting and pressure conditions. while equal percentage valve are designed to have a specific flow characteristic, the actual installed characteristics might deviate due to factors like incorrect installation, variation in pipe dimensions, and process conditions. These deviations in pipe can affect the valve's responce to changes in control signals.

+ when observing the inherent characteristics of a control valve, it's important to keep the pressure constant to isolate valve behavior. Pressure changes can indeed impact flow rates, and for accurate characteristic of the valve's inherent behavior, it's essential to maintain a consistent pressure throughout the experimentation.

+ control valves play a certain role in regulating flow rates in industrial processes. Understanding their inherent and installed characteristics as well as accounting for deviations introduced by various factors, is essential for accurate and reliable process control.

INDIAN INSTITUTE OF TECHNOLOGY

DATE 17/8/23 | Exp-06 · Calibration of Thermocouple and Resistance Thermometer | SHEET NO 21

Aim

- To calibrate a thermocouple with the help of a mercury filled thermometer.
- To calibrate a resistance thermometer (RTD) with the help of a mercury filled thermometer.

Objective

The objective of this experiment is to calibrate an RTD (Resistance Temperature Detector) and thermocouple using a mercury-filled thermometer as a reference. This involves creating a controlled environment to apply known temperatures, recording resistance or voltage values from RTD and thermocouple and comparing them to readings from the reference thermometer. Deviations need to be identified and necessary adjustment are made to align the measurements.

Apparatus Required

(i) Resistance Thermometer (RTD)
(ii) Mercury-filled thermometer
(iii) Beakers
(iv) Thermocouple
(v) Water Bath

(vi) Stirrer

Theory

The calibration process for an RTD and a thermocouple, utilizing a mercury filled thermometer as reference, is grounded in the principles of accurate temperature measurement. RTDs exploit the linear relationship between electrical resistance and temperature. Thermocouples harness the seebeck effect, generating a voltage proportional to temperature difference across dissimilar metals.

The calibration procedure involves subjecting the RTD and thermocouple to controlled temperature variations while concurrently monitoring the mercury thermometer's readings. Collected data facilitate the creation of calibration curves, mapping the sensor's output signals against the reference thermometer's values.

Procedure

1. The main switch was switched on and the power of heater and stirrer speed were set.
2. Readings of RTD, thermocouple and mercury filled thermometer were noted at intervals of 2 min.

4) The thermocouple and RTD readings were plotted against the temperature of mercury filled thermometer.

Observations

Sl No.	Thermometer Reading (°C)	Thermocouple voltage (mV)	RTD (°C)
1	38	0.2	40
2	41	0.2	42
3	44	0.2	45
4	46	0.2	47
5	49	0.25	49
6	50	0.4	51
7	52	0.4	53
8	55	0.42	55
9	55	0.42	56
10	57	0.5	59
11	59	0.6	60

Table 1

Name of table?

Hysteresis? to be calculated

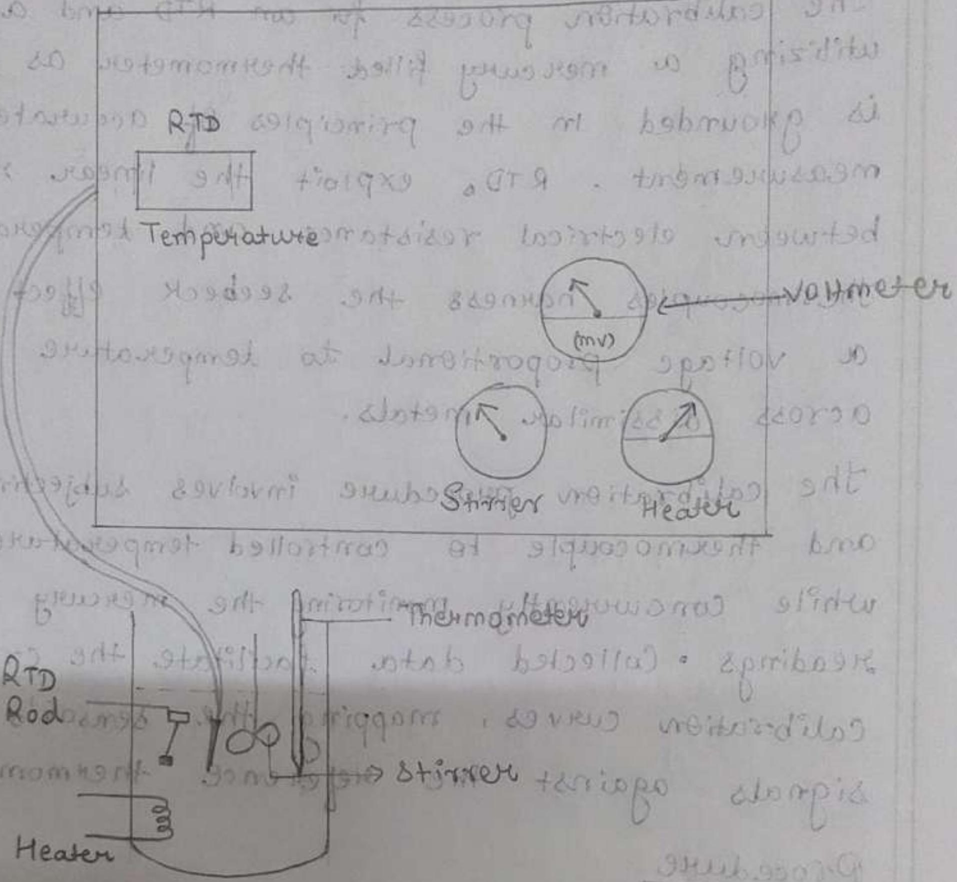


Fig 1: Experimental Setup to calibrate RTD and thermocouple.

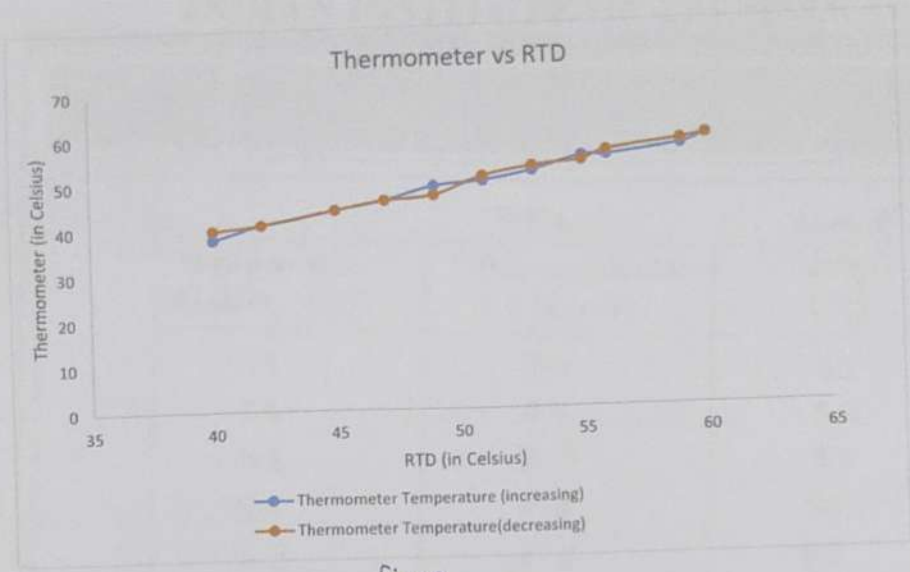


Fig:2

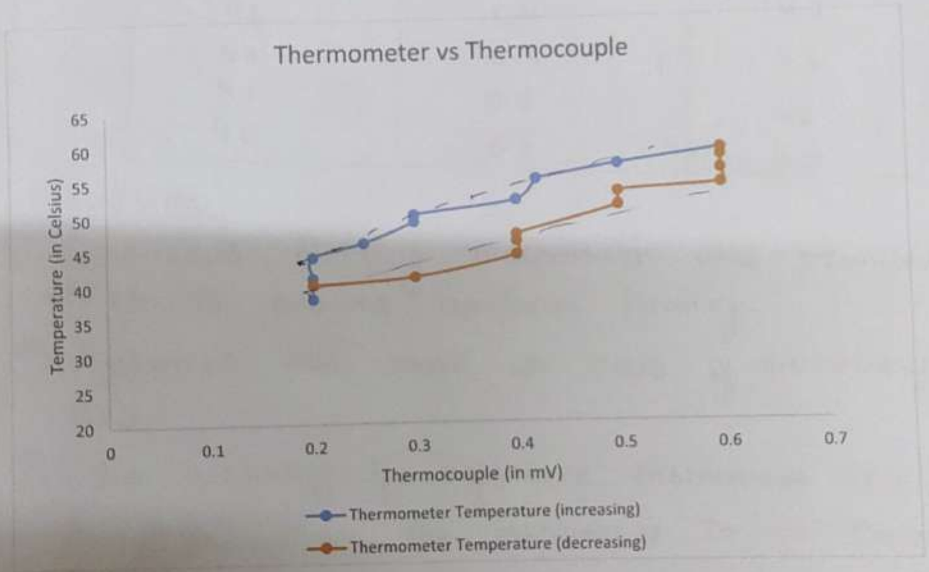


Fig:3

Best fitting curve need to be plotted

Redo plot

INDIAN INSTITUTE OF TECHNOLOGY

DATE

SHEET NO. 24

Table : 2

Name of table?

Thermometer Reading (°C)	Thermocouple (in mV)	RTD (°C)
59	0.6	60
58	0.6	59
56	0.6	56
54	0.5	55
53	0.5	53
51	0.5	41
47	0.4	49
46	0.4	47
44	0.4	45
41	0.3	42
40	0.2	40

Discussion

(1) Continuous stirring mechanism was provided in order to ensure uniform heating.

(2) Hysteresis was more in case of thermocouple than RTD.

(3) The accuracy of reference instrument (thermometer) is higher than the instrument to be calibrated.

(4) One possible source of error is the time lag while noting down the readings of thermometer, RTD and voltmeter.

Group 1.

(5) One needs to account the parallax error while noting down the thermocouple reading.

Conclusion

Our experiment revealed that the thermocouple exhibited more hysteresis compared to RTD. Through our calibration process, we successfully refined the accuracy of both the RTD and thermocouple readings, a critical aspect for a range of application. This precision holds significance in scientific, industrial and technological realms, contributing to better processes, product quality and research outcomes.

8.5/10

Nagani
24/8/23

DATE 24/08/23 | Experiment 07 Flapper - Nozzle System | SHEET NO. 25

Objective: To investigate the characteristics of a flapper nozzle system. The flapper nozzle system is a device commonly used in fluid mechanics to control the flow of fluids through a nozzle using a hinged flapper. The experiment involved analysing the relationship between the flow rate of a fluid and the angle of the flapper, as well as the effects of different pressure differentialy on the system.

Aim: To study the characteristics of flapper nozzle system.

Theory: The setup helps in understanding conversion of mechanical motion ~~of~~ to pressure signal. It consists of flapper - nozzle mechanism, dial guage indicator, pressure gauge and air filter regulator. A regulated supply of pressure, usually over 20 psig, provides a source of air through the restriction. The nozzle is open at the end where the gap exist between the nozzle and flapper and air

Group 1

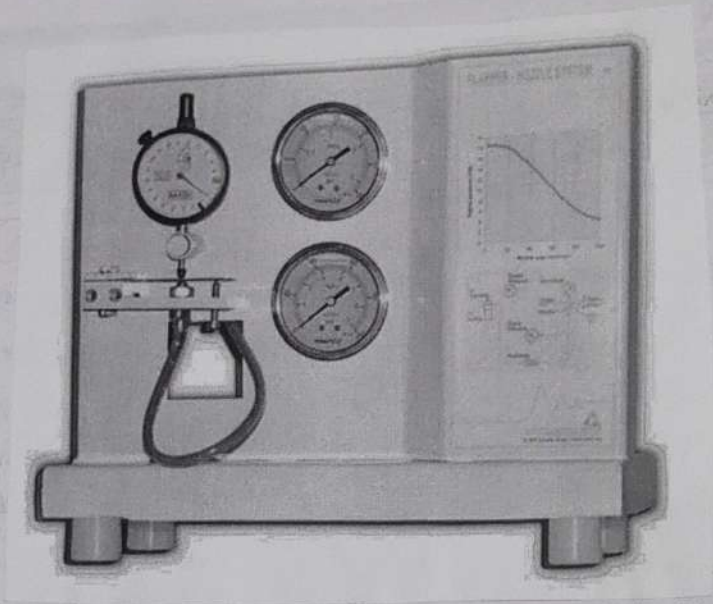
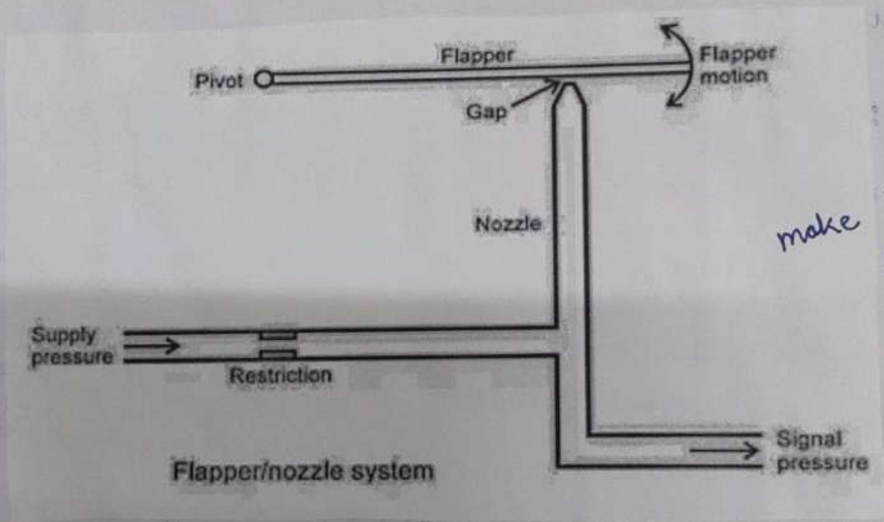


Figure 7.1 Apparatus of Flapper/nozzle system



make your own diagram (Cant copy)

Figure 7.2 Schematic diagram

escapes in this region

Apparatus: The experimental setup consisted of a flapper nozzle system attached to a fluid source, a pressure differential control system, and measure-ments. The key compounds included:

- Flapper nozzle assembly with a hinged flapper.
- Fluid reservoir & pump.
- Flow rate measurement apparatus (Flowmeter)
- Angle measurement device / Gap measurement device.

Procedure:

1. Caliborate the angle measurement device.
2. Set up pressure differential control system to maintain a constant pressure across the nozzle.
3. Gradually adjust the gap of the flapper from fully closed to fully opened.
4. Record signal pressure and nozzle gap and repeat the set of observation till 100 um gap.

INDIAN INSTITUTE OF TECHNOLOGY

DATE

SHEET NO. 27

Observations : $P_{Total} = 1.95\ kg/cm^2 = 27.7\ psig$

S.No	Nozzle Gap (um)	Signal Pressure (psig)
1.	10	27.02
2.	20	24.8
3.	30	19.9
4.	40	12.08
5.	50	12.2
6.	60	7.8
7.	70	6.8
8.	80	5.6
9.	90	5
10.	100	4.5

Table : Flapper-nozzle System

Results :

To calculate gain of flapper nozzle system.

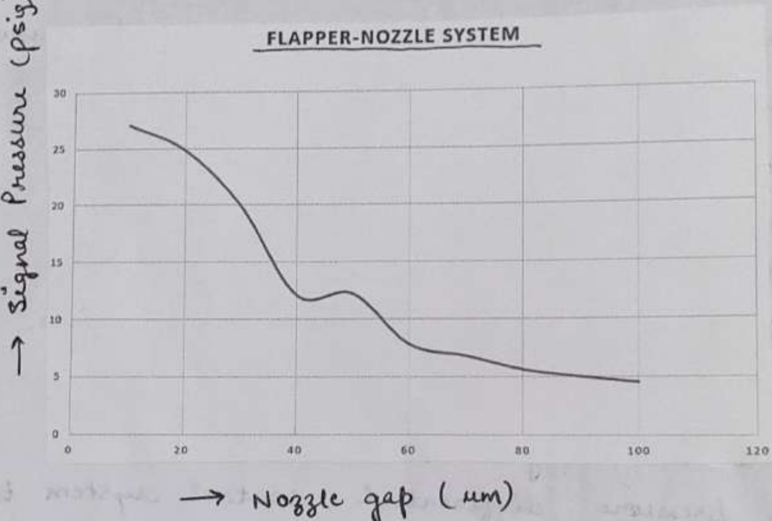
Gain of flapper nozzle system

$$= \frac{\text{change in signal pressure}}{\text{corresponding change in nozzle gap}} \ psig/um$$

$$= \frac{15 - 7.8}{60 - 35} = \frac{7.2}{25} = 0.288\ psig/um$$

P.R.E.

Group 1



title: ?

Graph: 7.1

Discussion: The observed relationship between flapper angle / nozzle gap and flow rate is consistant with theoretical expectations. As the flapper angle increases the effective flow area enlarges, allowing more fluid to pass through the nozzle.

Conclusion: The experiment successfully demonstrated the characteristics of a flapper nozzle system. The relation between nozzle gap and pressure differential was established, highlighting the system's responsiveness to these parameters. This knowledge can be applied to optimize the design and operation of flapper nozzle system in various engineering applications, like

Aim:- study the characteristics of the Differential pressure transmitter.

Theory:- A differential Pressure transmitter is a type of pressure measurement device that employs in capacitive sensors as the sensor element to measure the Pressure difference between two points in a fluid system. This design combines the Principles of capacitive sensing and accurate output signal.

It includes:-

(i) Capacitive sensing element :- It typically consists of 2 parallel Plates seperated by a dielectric material One of these Plates is fixed, while the other is movable and is exposed to Pressure being measured.

(ii) Pressure difference :- It has 2 pores, one for high pressure (P_1) and the other for Low pressure (P_2). The pressure difference b/w these two points affects the position of the movable plate in the capacitive sensor.

3. Dielectric Deformation:- Pressure difference makes the movable plate in the capacitive sensor to undergo deformation due to the force applied by the pressure. Thus pressure increases, distance b/w plates decreases, changing the capacitance b/w the plates.

4. Output signal:- The varying capacitance is considered into a current signal, which can be scaled / calibrated to represent the actual pressure difference in the system.

Procedure :-

1. The Pressure difference can be altered by changing the height of water column, by adjusting the valve.

2. We first reduce the height of water column; altering the pressure and record the current indicated.

3. Then we increase the height of water column, and record the current indicated again. This accounts for the hysteresis in the relationship b/w capacitance change indicator by current and the differential pressure.

Group 1.

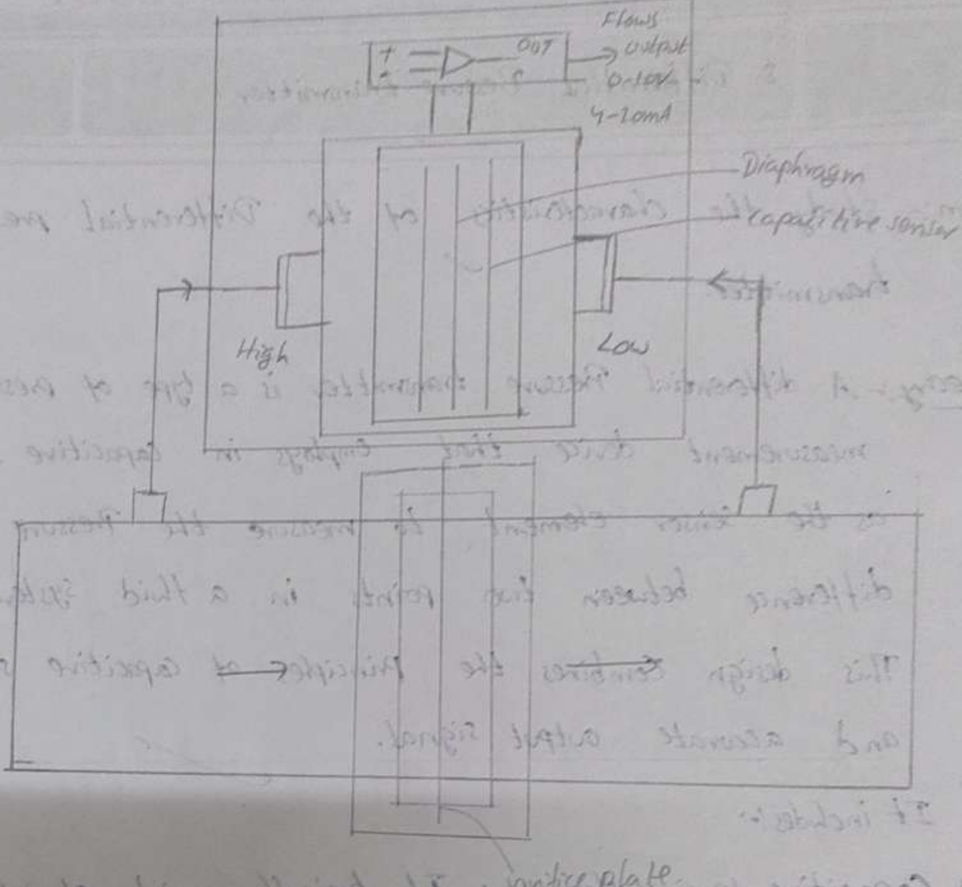


Fig. Differential Pressure transmitter

Number

INDIAN INSTITUTE OF TECHNOLOGY

DATE

SHEET NO. 31

Observation table:-

$\rho_{water} = 1000 kg/m^3$ $P = \rho g h$

$g = 9.8 m/s^2$

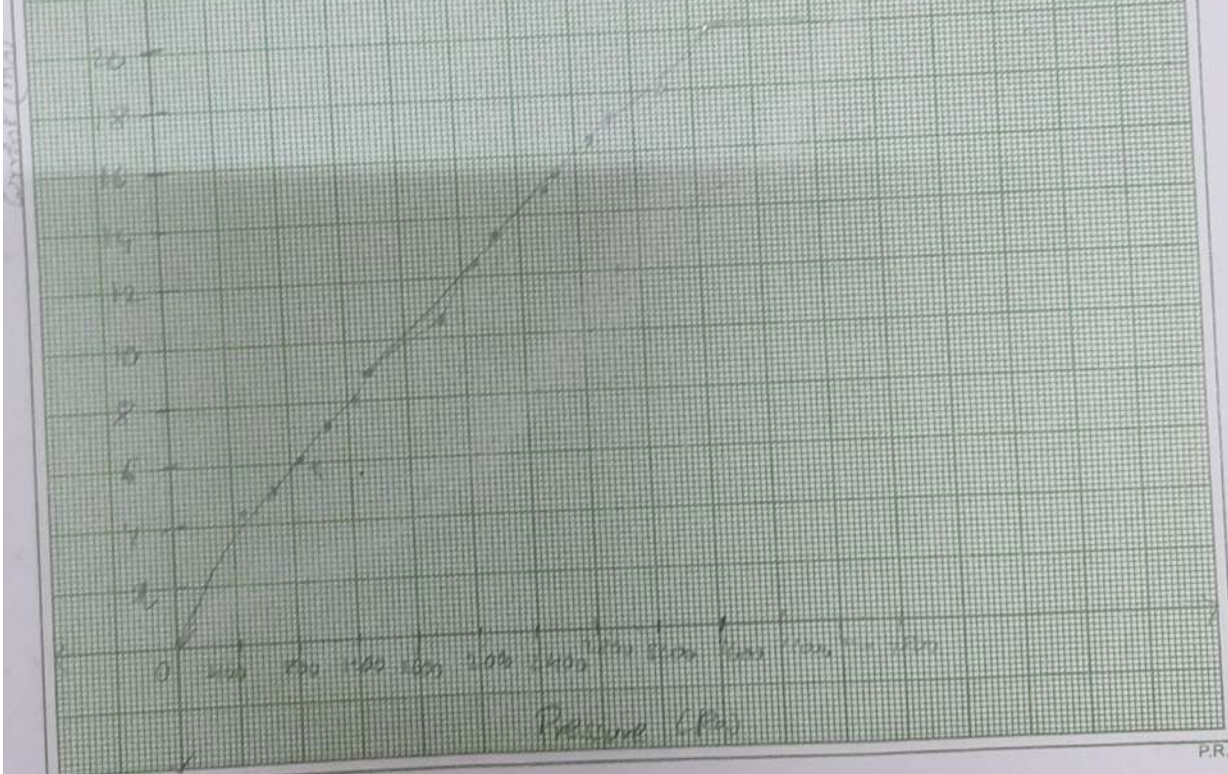
Table number ?

	Height (cm)	Current (mA)	Pressure (Pa)
1.	37.5	20	3675
2.	34	18	3332
3.	32	17.5	3136
4.	29.5	16.5	2891
5.	28	15.5	2744
6.	26	15	2548
7.	24	13.5	2352
8.	22	12.5	2156
9.	20	12	1960
10	18	10.5	1764
11.	15	9	1470
12.	13	8	1274
13.	11	7.5	1078
14	9	6	882

P.R.E.

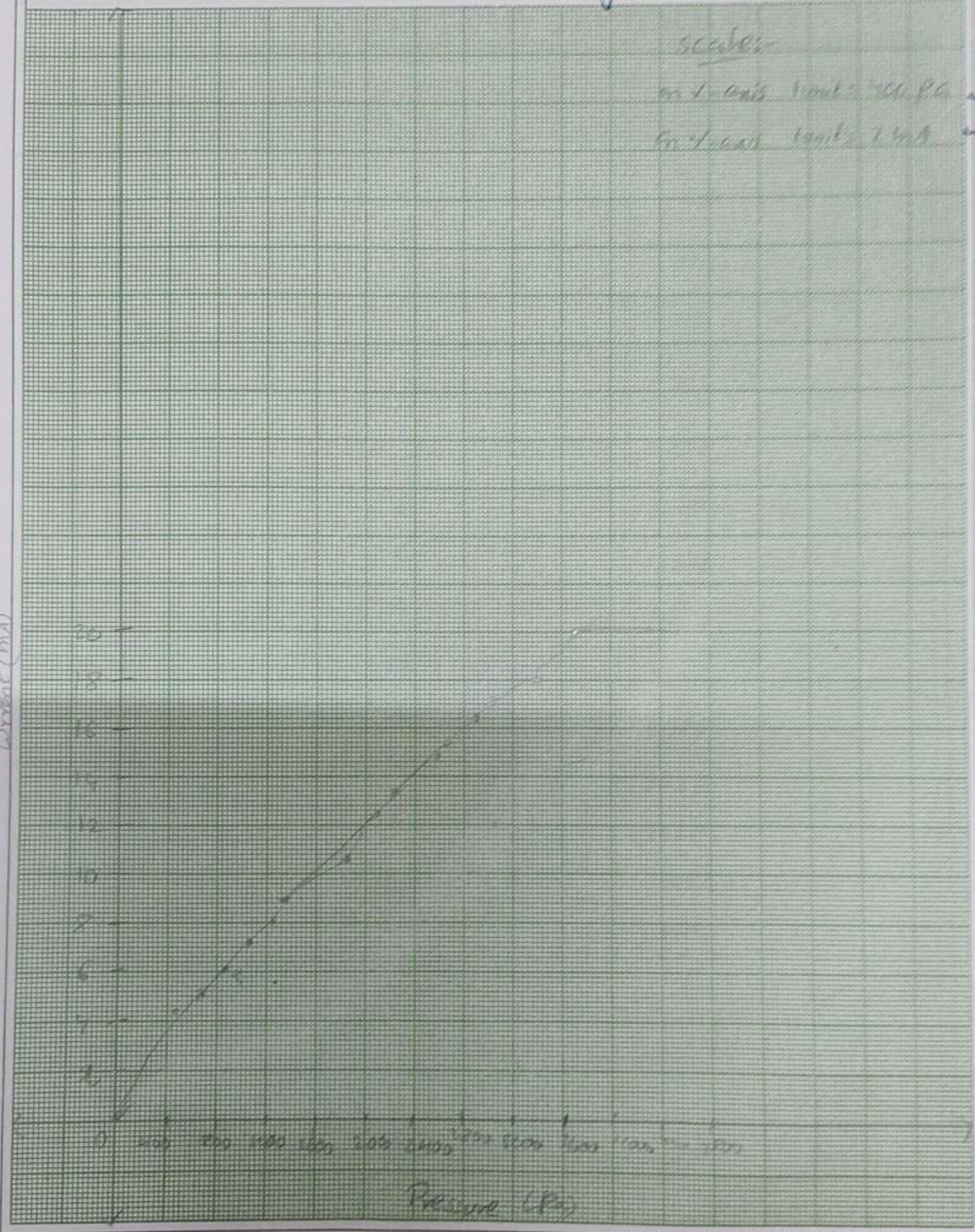
Pressure .vs. current graph Number

Scale:-
On X axis 1 unit = 100 Pa
On Y axis 1 unit = 2 mA



P.R.E.

Pressure .vs. current Graph Number



INDIAN INSTITUTE OF TECHNOLOGY

DATE

SHEET NO 32

15.	7	5	686
16.	4.5	3.5	441
17.	0	2	0
18.	4	2	392
19.	9	2	882
20.	17	4.5	1666
21.	21	6	2058
22.	25.5	8	2499
23.	28.6	10	2802
24.	31.5	12	3087
25.	37	14	3626
26.	40	16	3920
27.	45.5	18	4459
28.	47	20	4606

INDIAN INSTITUTE OF TECHNOLOGY

DATE

SHEET NO 33

Discussion:-

1. Differential Pressure transmitter has a wide range of applications across various industries due to its ability to measure Pressure difference between 2 points accurately in a fluid system.

2. Flow measurement - It can be used to measure flow rates in pipes and ducts. By placing an ~~observation~~ obstruction (an orifice plate) / (vertical tube), the Pressure difference across the obstruction can be used to calculate the flow rate.

3. Level measurement - When transmitter is installed at the bottom and top of container, the Pressure difference corresponds to the level of substance.

4. It can be used for pressure const, hydraulic and Pneumatic systems.

5. The accuracy of these transmitter can vary depending on factors like the types of sensor, quality of calibration and the application.

P.R.E.

INDIAN INSTITUTE OF TECHNOLOGY

DATE 14/9/23 | Exp: 1st and 2nd order experiment. | SHEET NO.

Aim : To study step response of mercury manometer.

Procedure :

Fill the heating bath with clean water by opening the inlet valve of heating bath. Then switch on the beeper and set the pe beep to 3 sec.

Ensure that the cyclic timer is set to 30 sec off the time. Switch on Mains to heat the water in heating bath to its boiling point.

Switch off the mains.

The water in the heating bath is now near its boiling point.

Note the thermometer in the each beed till it reaches steady state.

P.R.E

Theory:

$$y(t) = KM \times \left\{ 1 - e^{-\xi t/\tau} \left[\cos\left(\frac{\sqrt{1-\xi^2}}{\tau} t \right) + \frac{\xi}{\sqrt{1-\xi^2}} \sin\left(\frac{\sqrt{1-\xi^2}}{\tau} t \right) \right] \right\}$$

$y(t)$ = response at any time 't'

K = Gain factor = 1

$$\xi = \frac{8L\mu}{\rho g D^2} \sqrt{\frac{2g}{L}}$$

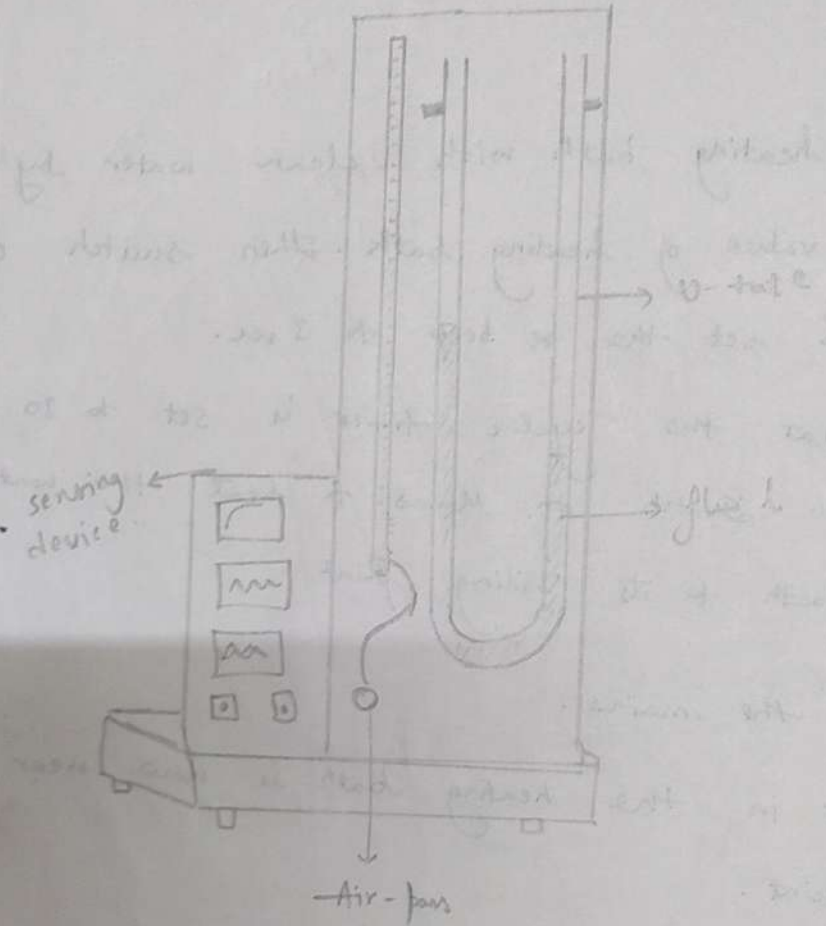
L = length

ρ = density of mercury

D = diameter in m

μ = Dynamic viscosity (kg/m-s)

$\tau = \frac{2\pi}{\omega_n}$ (in sec)



Exp- set-up

INDIAN INSTITUTE OF TECHNOLOGY

DATE | | SHEET

<u>Data</u> :

fluid = Hg

μ = 0.0016 kg/m.s

ρ = 13550 kg/m^3

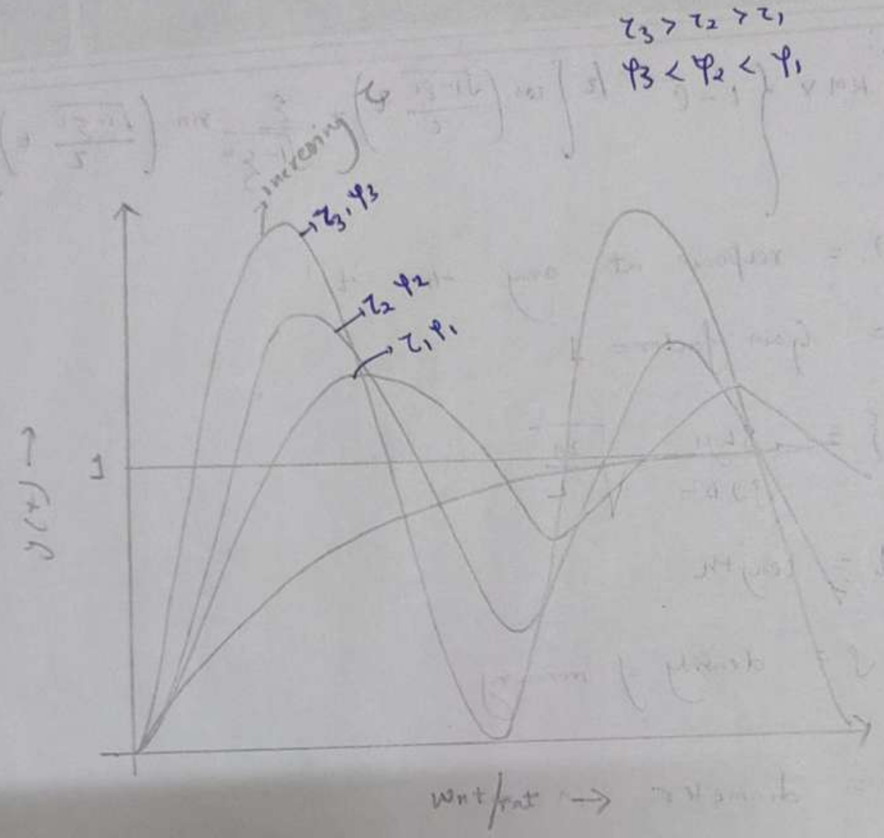
L = 0.76 m

d = 0.005 m

stg wing (m) =

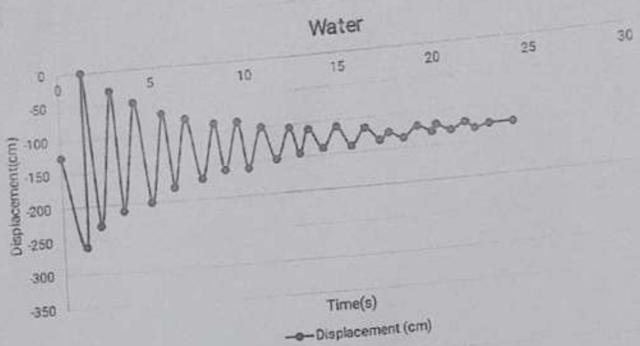
<u>Observations</u> :

Time/a (sec)	height (cm)
0	130
10	128
20	135
30	158
40	183
50	135
60	105
70	108
80	120
90	128
100	130
110	128



Sample response.

Fig no. ?


Water
Displacement(cm)
Time(s)
Displacement (cm)

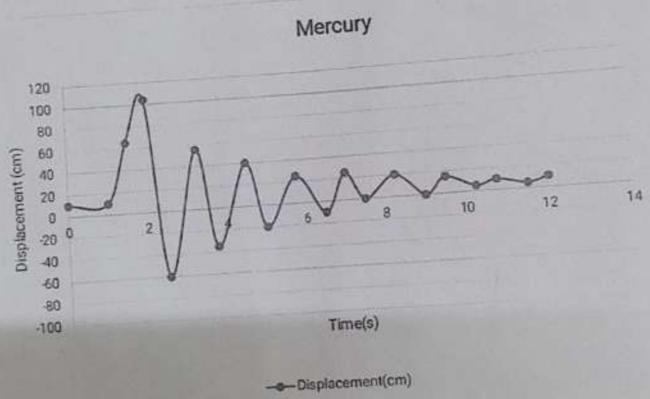

Mercury
Displacement (cm)
Time(s)
Displacement(cm)

Fig No. ?

INDIAN INSTITUTE OF TECHNOLOGY

DATE

SHEET NO.

Calculation (H, 0)

From the response cure of 2^{nd} order system, ($H_{2}O$)

we get :-

rise time (t_r) = 1.2

→ Damping coefficient (φ) = $\frac{8L\mu}{\rho g D^2}\sqrt{\frac{2g}{L}}$

∵ $\rho = 998\ kg/m^3$

$\mu = 0.001\ kg/m^2$

$L = 1.050\ m$

$D = 0.022\ m$

→ we get φ = = 0.00767

→ Decay ratio (DR) = $\exp\left(\frac{-2\pi\varphi}{\sqrt{1-\varphi^2}}\right)$

= 0.9529

→ Overshoot = $\sqrt{DR}$ = 0.976165

INDIAN INSTITUTE OF TECHNOLOGY

DATE | | SHEET NO.

Calculation : (Hg)

→ Natural frequency (ω_n) $= 2\pi\sqrt{\frac{2g}{L}}$ (in rad/sec) = 31.924 rad/sec

→ Damping coefficient (ξ) $= \frac{8L\mu}{\rho g D^2}\sqrt{\frac{2g}{L}}$ = 0.0148

→ $P = \frac{2\pi}{\omega_n \times \sqrt{1-\xi^2}}$ = 0.1968

→ $DR = \exp\left(\frac{-2\times\pi\times\xi}{\sqrt{1-\xi^2}}\right)$ = 0.9112

→ $OS = a/b = \sqrt{DR}$ = 0.9545

→ frequency (f) $= \frac{\omega_n\sqrt{1-\xi^2}}{2\pi}$ (in cps) = 4.9815 (in cps)

→ characteristic time (τ) $= \frac{2\pi}{\omega_n}$ (in sec) = 0.1968 sec

Discussion :

- The step response of a first order system approaches its S.S. (as $t\to\infty$).
- larger 'τ' values indicates slower responses.
- The overshoot is influenced by damping ratio, with lower ξ values leading to larger overshoots.
- Settling time is also influenced by damping ration, with large ξ value leading to faster settling times.

INDIAN INSTITUTE OF TECHNOLOGY

DATE 14/9/23 | Exp: 1^{st} and 2^{nd} order experiment | SHEET NO

Aim: To study the step response of thermometer.

Theory:

The dynamic response of 1^{st} order type instruments to a step change be represented by

$$\tau \frac{d\theta}{dt} + \theta = \theta_f$$

where,

θ = temperature indicated by thermometer

θ_f = final stedy state temperature

t = time

T = time - interval

The linear 1^{st} order differential has the particular solution for given initial conditions

$$\frac{\theta}{\theta_f} = 1 - e^{-t/\tau}$$

The time constant T is the time required to indicate 63.2% of the complete change. The time 'T' is numerically equal to the product of resistance & capacitance.

INDIAN INSTITUTE OF TECHNOLOGY

DATE | | SHEET NO.

Procedure :

Fill the heating bath with clean water by opening the inlet valve of heating bath. Then switch on the the beeper and set the beep to 3 sec.

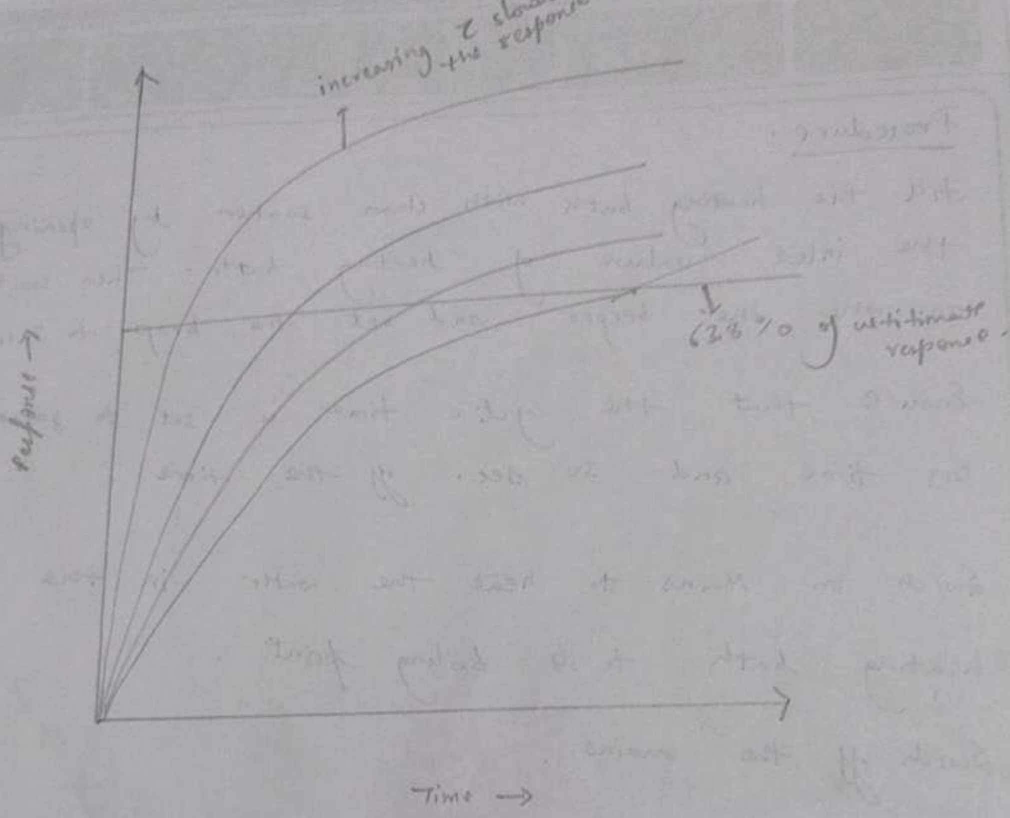
Ensure that the cyclic timer is set to 30 sec. on time and 30 sec. off the time.

Swich on Mains to heat the water in the heating bath to its boiling point.

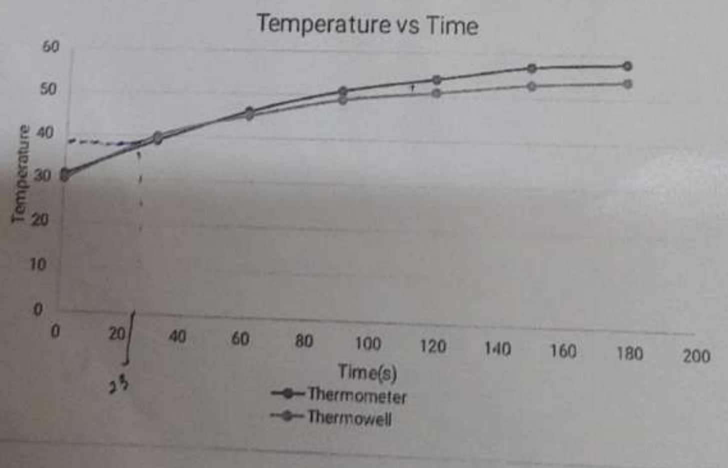
Swich off the mains.

The water in the heating bath is now near its boiling point. Insert the themomtr in the bath.

Note the thermomtr at each beep till it reached steady - state.



Sample response



INDIAN INSTITUTE OF TECHNOLOGY

DATE

SHEET NO.

Observation :

Thermowell (°C)	Themometer (°C)
31	30
39	40
48	45
53	49
57	52
59	53
60	54
32	29
39	36
46	42
51	46
54	51
57	55
58	55

INDIAN INSTITUTE OF TECHNOLOGY

DATE

SHEET NO.

Calculation:

We use the relation:

Theoritical temp =

→ Initial temp $_{(=30°)}$ + (step change $_{(25)}$ × 1 − exp $\left(\frac{-1 \times time}{time\ constan}\right)$))
                                                                                                                 23
— ①

→ step change = Final temp − Initial temp
— ②

→ Time constant.

☆ For 1 ~~data~~ data at $t = 10$ sec

$$Th\ temp = 30° + \left(25 \times \left(1 - exp\left(\frac{-1 \times 10}{23}\right)\right)\right)$$

$$= 16.30\ °C$$

INDIAN INSTITUTE OF TECHNOLOGY

DATE | | SHEET NO.

Discussions :

The 1st order system, in this case thermometer has time constant of 23 this means that it takes 'τ' sec. for the thermometer to reach 63.2% of its final value.

For the second order system, the rise time was measured while decay ration and overshoot were calculated for both water and mercury manometer. The results shows that the mercury manometer has a faster rise time compared to later.

Time constant value had to be calculated for two cases:

1. Thermometer without thermowell
2. Thermometer with thermowell.

9/10 Rajdeep 12/10/23

P.R.E.

INDIAN INSTITUTE OF TECHNOLOGY

DATE | Experiment 10 : Study of P/I and I/P Converter. | SHEET NO.

AIM : To Study the operation of P/I and I/P Converter.

Objective :

1) To Study the working Principle and Calibration pressure of P/I and I/P Converter
2) To Study the linearity, hysterisis, accuracy and repeatabiling of I/P and P/I Converter

Theory :

I/P Converter :-

- An current to pressure converter convert electrical signal to a pressure signal. The input signal is applied to a coil, which creats a magnetic field. The magnetic field is then used to make a diaphragm, which generate a pressure signal.
- The output signal of I/P converter is proportional to the input signal. The proportionality constant is called the gain of the converter.

INDIAN INSTITUTE OF TECHNOLOGY

DATE

SHEET NO

P/I converter :-

- An Pressure to current converter convert pressure signal to an electrical signal. The input signal is applied to a diaphragm which is proportion to the pressure. The deflection of the diaphragm is then converts to an electric signal by strain gauge or piezoelectric sensor.
- The output signal is proportional to input signal and the proportionality constant is called gain of the converter. The gain of P/I converter can be adjusted by changing the calibration of the converter

Procedure :

I/P Converter

1. Put the current source/sink indicator source mode by pressing and confirm source LED is glowing.
2. Give current input in the step of 4mA from 4 to 20mA by slowly rotate the knob of source indicator.

P/I Converter

1. Put p current source-/sink indicator sink mode by pressuring and confirm sink LED is glowing.

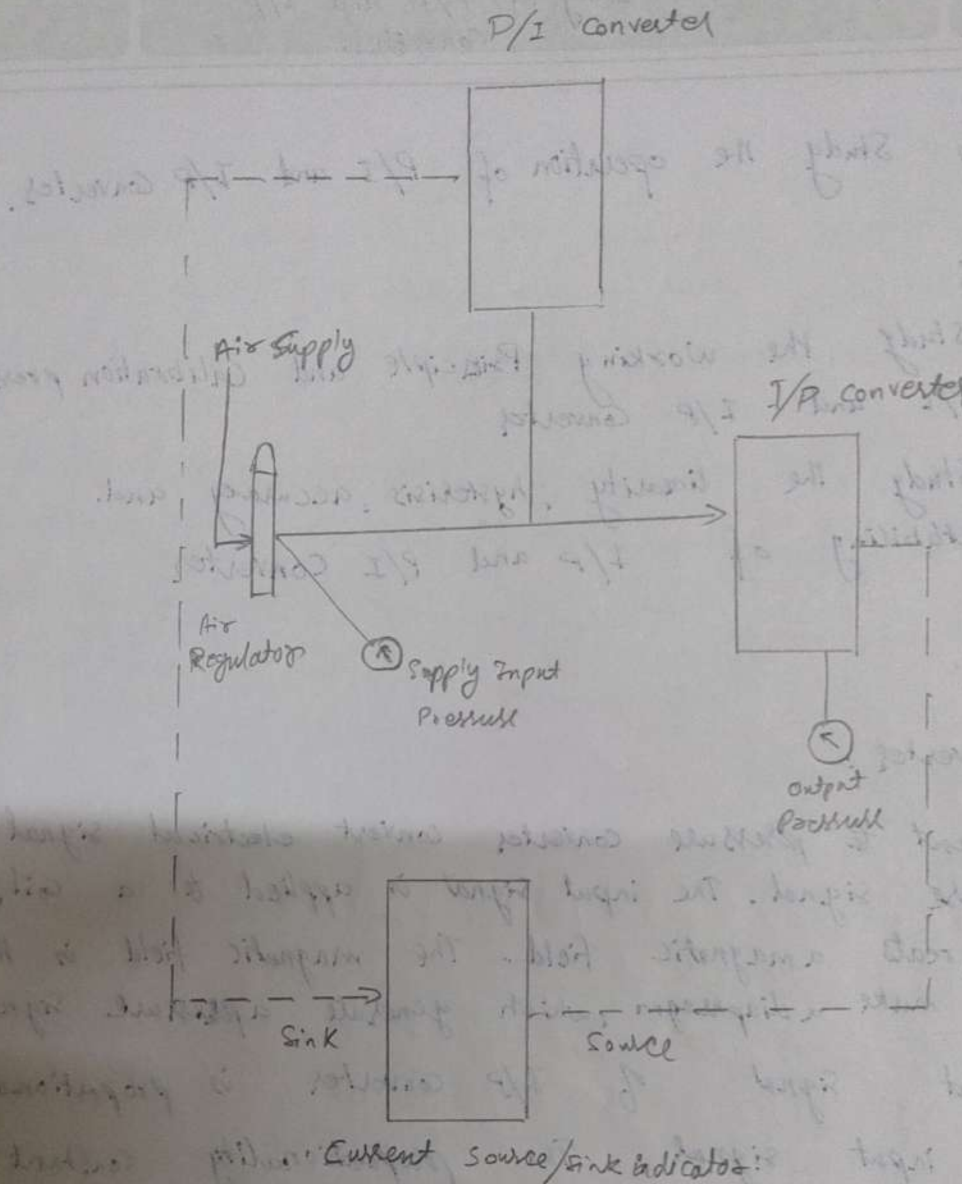


Fig : Basic components of the circuit.

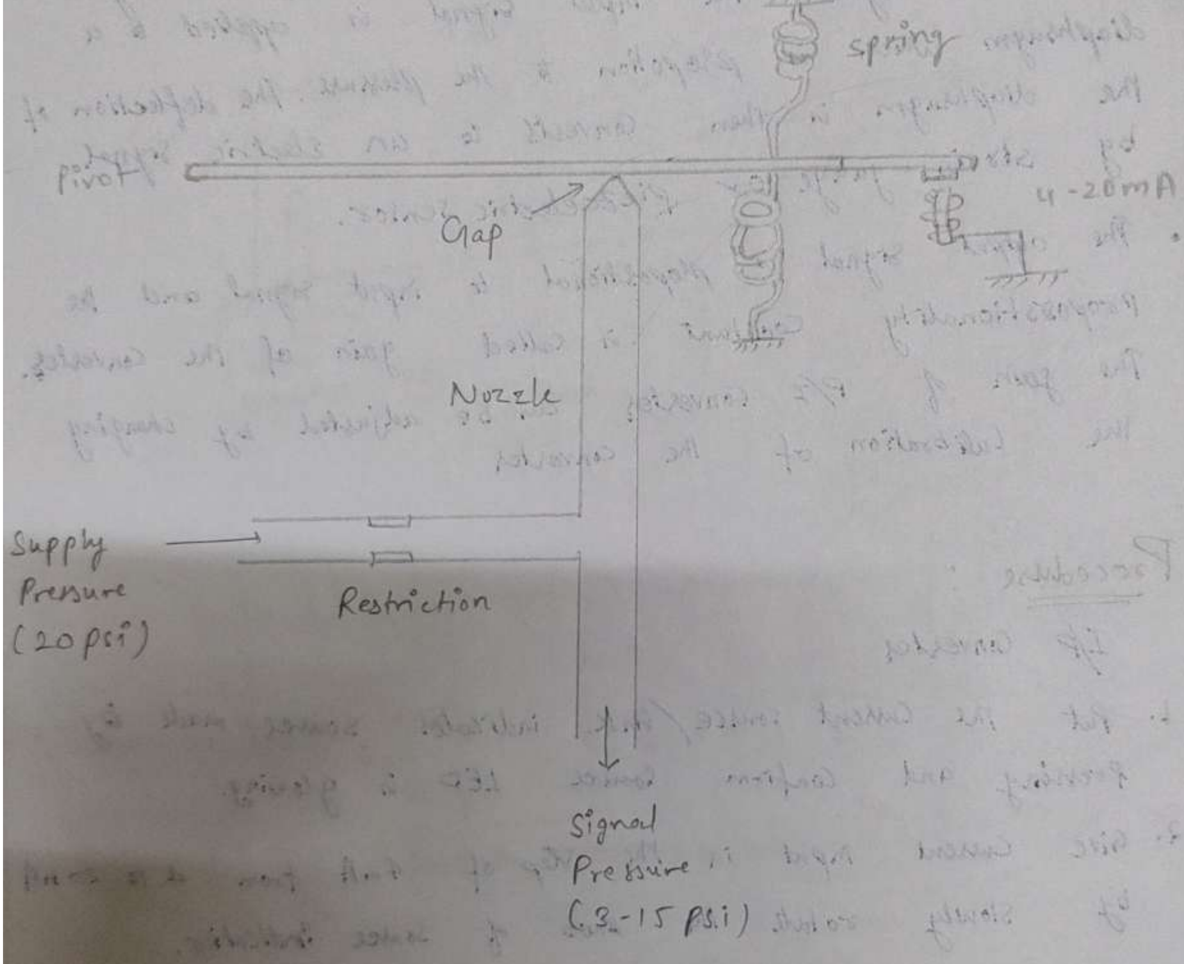
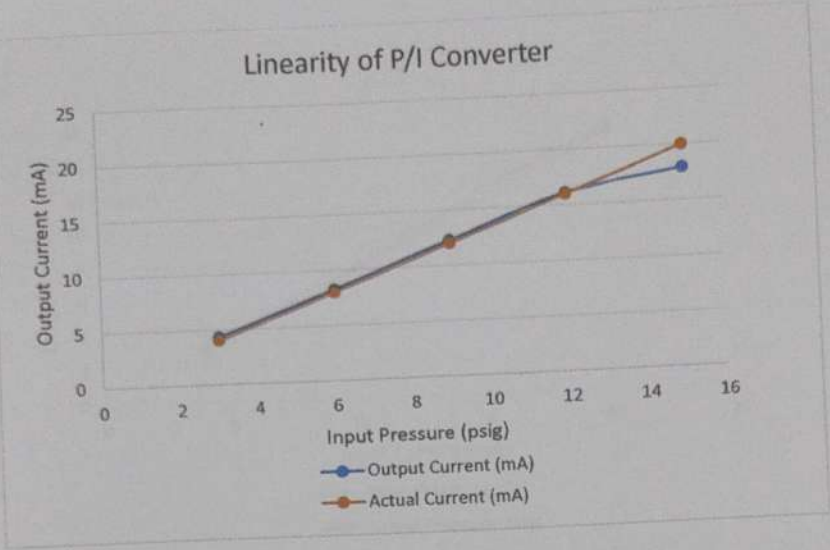
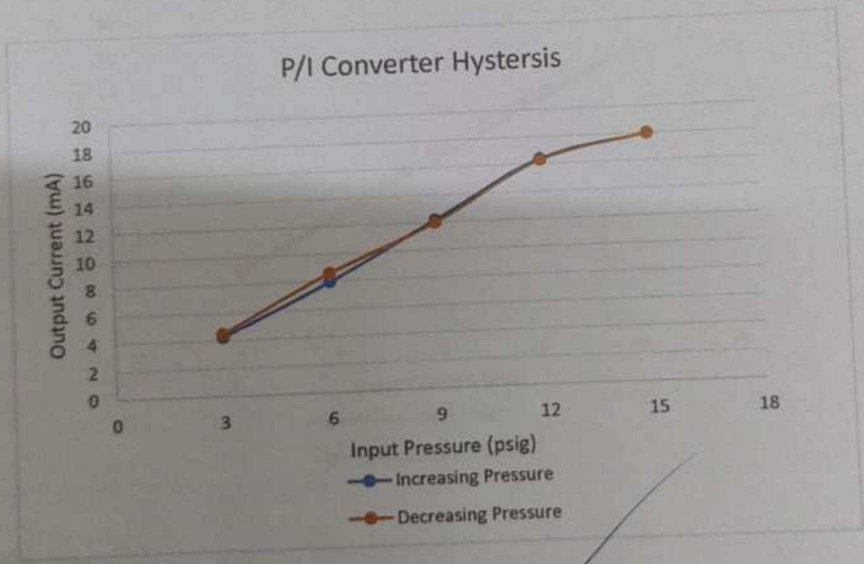
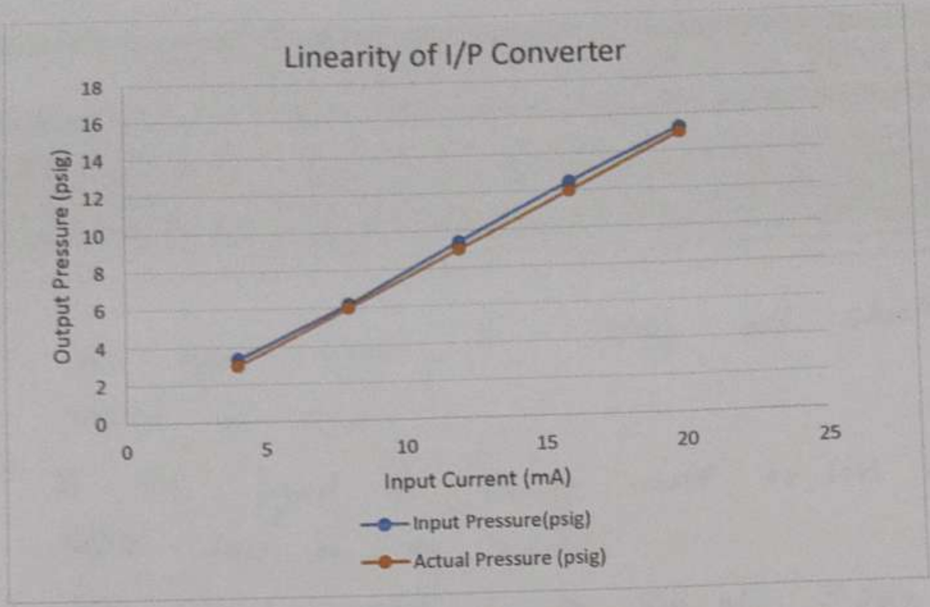
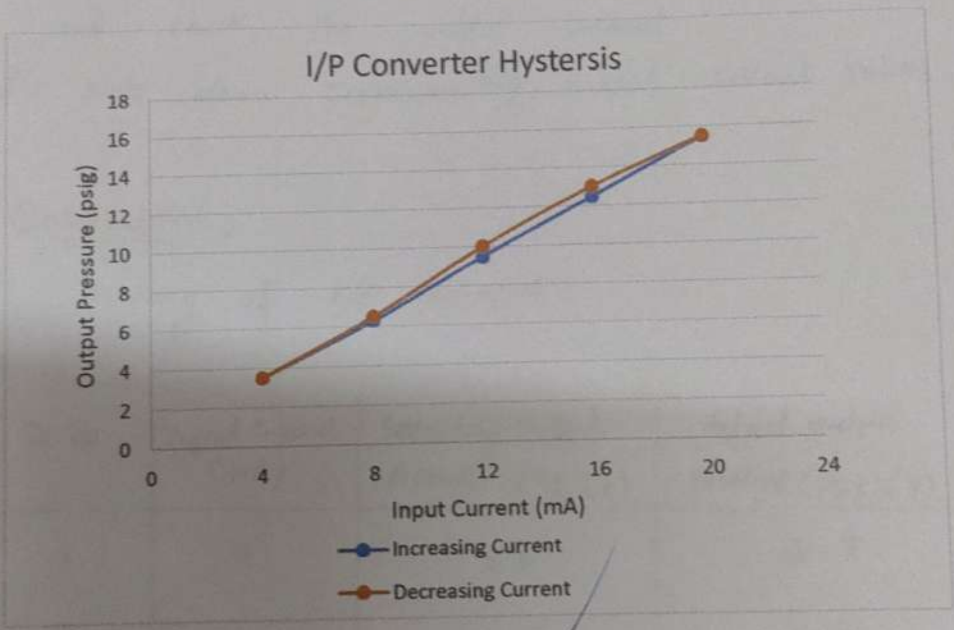


Fig: Principle of a Current to pressure Converter


Linearity of P/I Converter
Output Current (mA)
25
20
15
10
5
0
0
2
4
6
8
10
12
14
16
Input Pressure (psig)
Output Current (mA)
Actual Current (mA)


P/I Converter Hystersis
Output Current (mA)
20
18
16
14
12
10
8
6
4
2
0
0
3
6
9
12
15
18
Input Pressure (psig)
Increasing Pressure
Decreasing Pressure


Linearity of I/P Converter
Output Pressure (psig)
Input Current (mA)
Input Pressure(psig)
Actual Pressure (psig)


I/P Converter Hystersis
Output Pressure (psig)
Input Current (mA)
Increasing Current
Decreasing Current

INDIAN INSTITUTE OF TECHNOLOGY

DATE

SHEET NO.

2. Set input signal to 3psig and check the output current as 4mA
3. If the signal is showing more or less than 4mA then adjust zero on the isolator.
4. Give input signal in the step of 3psig from 3 to 15 psig and check the output current
5. Note down corresponding output current values.

Observation :

1. Accuracy of I/P converter :

Sl. no.	Input current (mA)	Secondary output pressure (psig)(x)	Actual output pressure (psig)(y)	Deviation (psig) (y - x)
1	4	3.5	3.5	0
2	8	6.3	6.5	0.2
3	12	9.5	~~8~~ 10	0.5
4	16	12.5	~~10~~ 13	0.5
5	20	15.5	~~15~~ 15.5	0
6				

INDIAN INSTITUTE OF TECHNOLOGY

DATE

SHEET NO

2. Hysteresis of I/P Converter :

Sr. no.	Input current (mA)	Output Pressure (Psig) (x)	Input current (mA)	Output Pressure (Y)	Hysteresis (Psig) (Y-x)
	Increasing input signal		Decreasing Input	Signal	
1	4	3.5	4	3.5	0
2	8	6.2	8	6.5	0.3
3	12	9.3	12	9.5	0.2
4	16	12.5	16	13	0.5
5	20	15.2	20	15.2	0.

3. Repeatability of I/P Converter :

Sl. no.	Input current (mA)	output pressure (Psig) (X)	Input current (mA)	output Pressure (psig) (Y)	Deviation in output (Psig) (Y-X)
1	4	3.2	4	4	0.8
2	8	6.2	8	6.5	0.3
3	12	9.5	12	10	0.5
4	16	12.5	16	13	0.5
5	20	15.2	20	15.2	0

P.R.E.

INDIAN INSTITUTE OF TECHNOLOGY

DATE | | SHEET NO

1. Accuracy of P/I Converter.

S.No.	Input Pressure (Psig)	Standard output current (mA)(X)	Accurate output current (mA)(Y)	Deviation (mA) (Y-X)
1.	3	4.5	4.5	0
2.	6	8.5	8.6	0.1
3.	9	12.2	12.4	0.2
4.	12	16.4	16.3	0.1
5.	15	18	18	0

2. Hysteresis of P/I Converter:

Sl.no.	Input pressure (Psig)	Output Current (mA)(X)	Input pressure (Psig)	Output current (mA)(Y)	Hysteresis (mA) (Y-X)
	Increasing input current		Decreasing input current		
1	3	4.3	3	4.5	0.2
2	6	8.0	6	8.4	0.4
3.	9	12.3	9	12	0.3
4.	12	16.0	12	16	0
5.	15	18.0	15	18	0.

3. Repeatability of P/I Converter:

Sl. no.	Input pressure (Psig)	Output Current (mA) (X)	Input pressure (Psig)	Output current (mA) (Y)	Deviation in output (mA) (Y-X)
1	~~4~~3	4.3	3	4.6	0.3
2	6	8.5	6	8.6	0.3
3	9	12.4	9	12.4	0
4	12	16.0	12	16.1	0.1
5	15	18	15	18	0.

Discussion :

- The purpose of I/P Converter to convert the analoge signal output of a control system into an accurate repeatable value of pressure to control pneumatic operations. Pneumatic valves, dampers etc.

- The accuracy of the I/P &P/I Converter was generally measured output pressure, being within the known value of the overall. The results of the experiment was satisfacory. There were a few minor measured deviations from the ideal result of the experiment apparatus.

- I/P &P/I converters are commonly used in control systems Pneumatic automation and oil and gas industries.

- ~~Dat~~ Deviation is actually much less less in I/P Converter.

- when we draw the staightline in linearity of P/I Converter graph. we can see it doesn't fit for more points with actual output current the maximum in 12 Psig to 15 psig.

- we can see that linearity of I/P converter is affected, actually we have to get one unique value for each input value, but there is -some deviation. [It is according to the manufactures specification]

- From the graph we can say that the output pressure was generally directly proportional to P/I ~~&~~ ~~I/p Converter.~~ Input input current with a few minor deviations. This indicates the graph of I/P & P/I Converter are mostly linear but not that accurate. ~~be~~ Hence there was some hysteresis, mean that output pressure was not always the same for given ~~p~~ input signal depending on the direction of the change in input signal.
- We can observe from the graph that ~~P/I~~ ~~I/P~~ ~~Converter~~ I/P hysteresis there is some deviation from the actual output since it depend on accuracy.

Conclusion :

The relationship between current and pressure in the experiment on P/I & I/P converters is that the output signal is directly proportional to the input signal. These currents are commonly used in industries setting a regulate pressure in pipe-lines, tubes and reactors. In this experiment allows to observe and measure the relationship b/w input & output signals in both converters types.

9/10

Magani
12/5/23

INDIAN INSTITUTE OF TECHNOLOGY

DATE 12/10/23 | Exp 1: Pressure Control Trainer | SHEET NO.

Aim :- To find the parameters of the controllers in the Pressure Trainer.

Objectives :-

(1) Understanding Pressure control principle concepts of setpoints, control algorithms, feedback loops and the interaction between various components in a pressure control system.

(2) Sensor - Actuator Interaction: How the pressure transmitter continuously senses the process variable and sends signals to the control module to adjust the actuator accordingly.

(3) Control Algorithms Preparation, Integral and derivative control algorithms and their role in maintaining a stable pressure level within the tank.

(4) The process parameter (pressure) is controlled through a computer.

Theory :

Process controller : In an automatically controlled process the parameter to be controlled is measured and compared with the setpoint by the process controller.

P.R.E.

The difference b/w the measured signal and the setpoint is an error. The controller performs online calculations based on error and other setting parameter and generates an output signal. The output signal drives the final control elements like a control valve or a damper to control the process to the set point.

Proportional (P) controller:

1. Generates a control output linearly proportional to the deviation lectures the set point and process variable.
2. Helps regulate processes by adjusting the control output based on the error signal.
3. The controller output (OP) is given by the formulae

$$OP = [100/_{PB} \times e] + b$$

∴ b helps to decide value of OP where error is zero.

4. The proportional controller usually show some difference between the set point and process variable called offset. Offset can be reduced by decreasing PB or by readjusting the bias.

There are 2 types of controller activities

1. Increase = Increase ~~in~~ which output decreases measurement increases.

(e = measurement − set point)

INDIAN INSTITUTE OF TECHNOLOGY

DATE

SHEET NO.

2. Decrease : Decrease in which output decreases as measurement increases. (error e = set point - measurement)

Proportional Derivative (PD) :

This mode of control is described by the relationship

$$OP = b + \frac{100}{PB}\left(e + T_d \cdot \frac{de}{dt} \right)$$

∴ Smaller is the proportional band the larger is the derivative action. In order to achieve faster, response and more stable operation in slow processes derivative action is added to apply an output component proportional to the rate of change of input (error).

Proportional - Integral - Derivative (PID)

PID controllers are used for controlling almost all process variables like temperatures, flow, level, pressure etc. In a continous or batch process. The output of a PID controller is given by,

$$OP = b + \frac{100}{PB}\left(e + \frac{1}{T_i}\int e\,dt + T_d \frac{de}{dt} \right)$$

Selection of proportional band, Integral time and derivative time to achieve desired process response to ~~load~~ load changes is called tuning of controller.

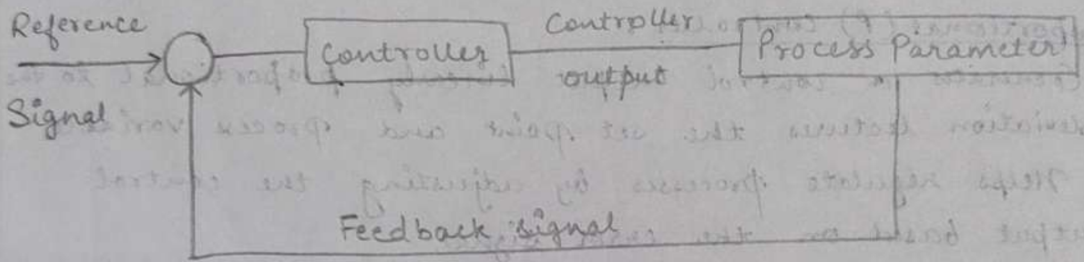


Figure 1 : Block Diagram of Typical Controller

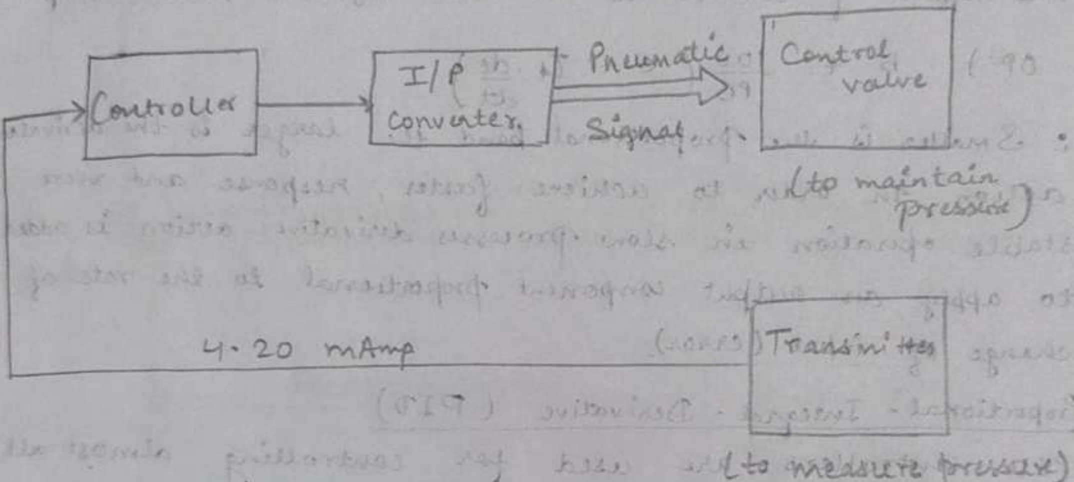


Figure2: Pressure Control System Diagram

1. Study of open-loop response (Manual control)

Procedure:

→ The mains supply was switched on

→ The compressor was switched on ~~the~~ and the air was adjusted to flow ~~at~~ at a constant rate

→ The digital calibrator was kept at manual mode

→ The controller output was changed in steps of 10% from 100% and waited till the steady state was achieved.

→ The process value was noted for each step change

2. To study the P-only controller:

Procedure:

→ The digital calibrator was kept at auto model.

→ The software was opened in the computer and the controller was chosen as P

→ The P bandwidth value was set.

→ The set point value was changed twice during the run cycle.

→ The cycle was repeated thrice with different controller parameters.

3. To study the PD controller:

→ The digital calibrator was kept at auto mode.

→ The softwar was opened in the computer and the controller was chosen as PD

INDIAN INSTITUTE OF TECHNOLOGY

DATE | | SHEET NO.

→ The P bandwidth and derivative time constant value were set.

→ The setpoint value was changed twice during the runcycle

→ The cycle was repeated thrice with different controller parameters.

4. Study of the PID controller :

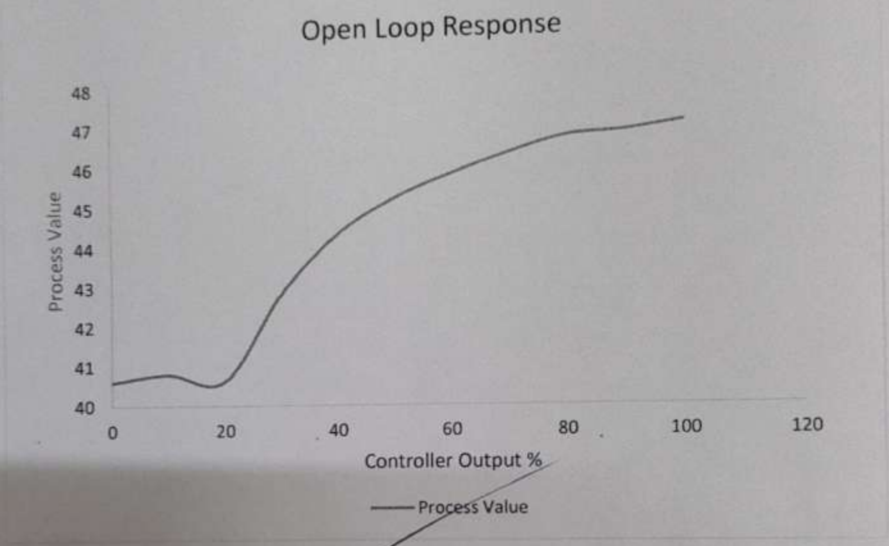
→ Start up the set up. Select close loop option for control from software.

→ Select PID controller.

→ Switch the controller to manual mode

→ Change the proportional band to the value that estimated in proportional controller. Set integral time and derivative time based on the responses in previous experiment.

→ Adjust the set point to 50%. Switch the controller to auto mode. Apply step change of 10%. Observe the process response.



\# when is process reaction curve?

INDIAN INSTITUTE OF TECHNOLOGY

DATE SHEET NO.

Observation :-

OPEN LOOP RESPONSES

Controller Output in %	Process Value
0	40.6
10	40.8
20	40.62
30	42.8
40	44.3
50	45.2
60	45.8
70	46.3
80	46.7
90	46.8
100	47

CLOSE LOOP RESPONSE

1. P-only Controller

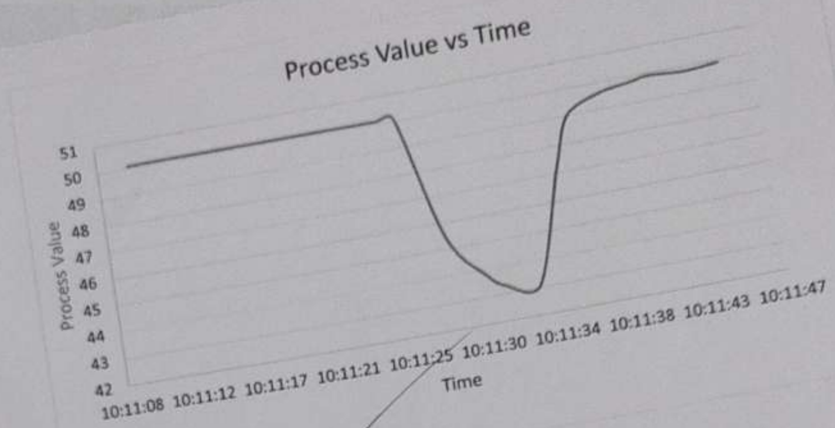
SP = Set Point PV = Process variable

Kc	SP	PV	Offset
5	44.5	45.3	0.8
10	44.5	45.9	1.4
15	44.5	45.9	1.4
20	44.5	46.5	2

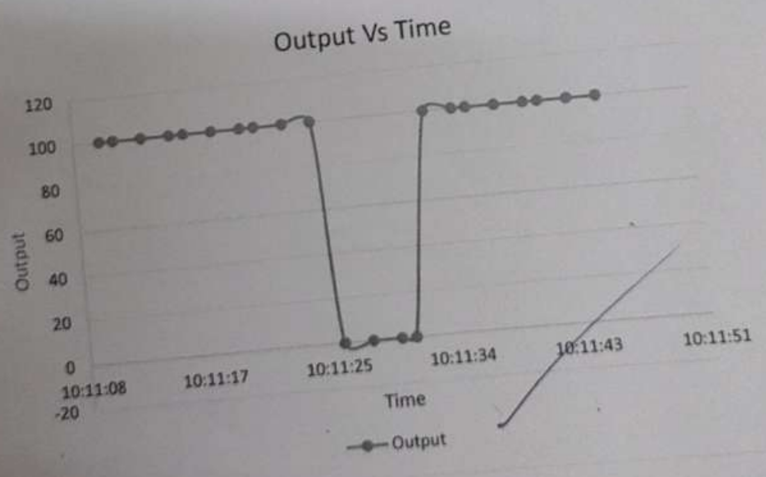
offset = |SP - PV|

min offset = 0.8

P.R.E.



Process Value vs Time
Process Value
51
50
49
48
47
46
45
44
43
42
10:11:08 10:11:12 10:11:17 10:11:21 10:11:25 10:11:30 10:11:34 10:11:38 10:11:43 10:11:47
Time



Output Vs Time
Output
120
100
80
60
40
20
0
-20
10:11:08 10:11:17 10:11:25 10:11:34 10:11:43 10:11:51
Time
Output

2) PD Controller :-

K_c	τ_D	SP	PV	Offset
5	1	44.5	45.2	0.7
5	5	44.5	46	1.5
5	10	44.5	46.3	1.8

min offset = 0.7.

3) PID controller

K_c	τ_D	τ_i	SP	PV	Offset
5	1	1	44.5	44.6	0.1
5	1	5	44.5	45	0.5
5	1	10	44.5	44.8	0.3
5	1	20	44.5	44.6	0.1

min offset = 0.1

Result :-

PID controller is the most effective in eliminating offset, followed by PD controller.
P controller tends to have the most significant offset because it lacks integral and derivative actions to address steady-state errors and anticipatory control.

INDIAN INSTITUTE OF TECHNOLOGY

DATE | | SHEET NO

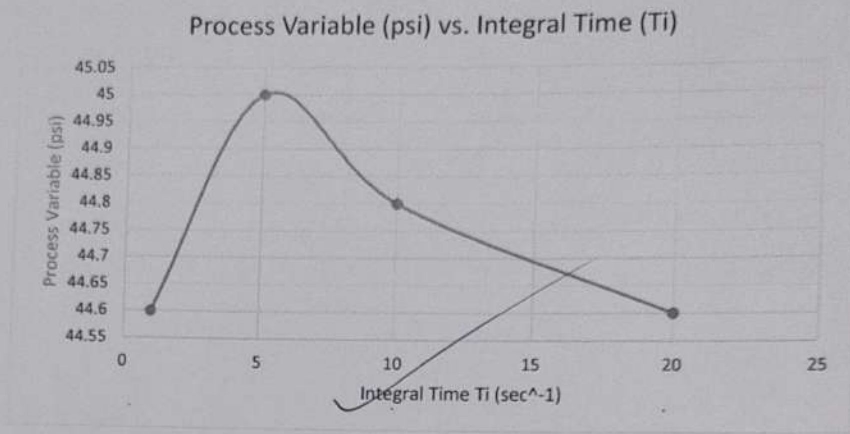
Discussion:-

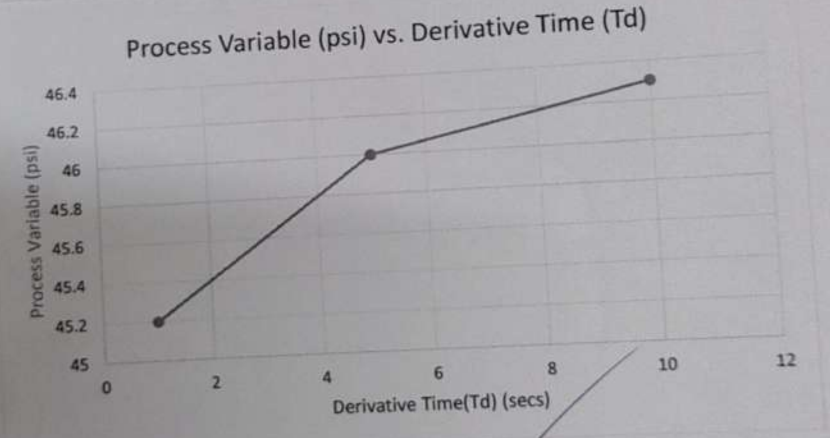
(1) While carrying out the experiment, it was observed that the readings attained steady values after some time despite step changes in input in many cases. This is a crucial general observation implying the latency involved in the input-output information/disturbance transfer, and the role of controllers in the whole process.

(2) For all three control schemes, the response corresponding to monotonic decreases / increase in the parameters (K_c, τ_d, τ_i) was not itself monotonic. This means that in the experimental realm the parameters can be fine tuned to achieve an optimum offset and that cannot be achieved by indefinite increasing / decreasing.

(3) In ideal system, P-controller tends to have most significant offset because it lacks integral and derivative actions to address steady state errors and anticipatory control. But here, in our experiment process is not ideal.

P.R.E


Process Variable (psi) vs. Integral Time (Ti)
Process Variable (psi)
45.05
45
44.95
44.9
44.85
44.8
44.75
44.7
44.65
44.6
44.55
0
5
10
15
20
25
Integral Time Ti (sec^-1)


Process Variable (psi) vs. Derivative Time (Td)
Process Variable (psi)
46.4
46.2
46
45.8
45.6
45.4
45.2
45
0
2
4
6
8
10
12
Derivative Time(Td) (secs)

INDIAN INSTITUTE OF TECHNOLOGY

DATE

SHEET NO

Sources of Errors:-

(1) Inaccuracies in the pressure measurement instruments such as pressure sensors or gauges can lead to incorrect data acquistion.

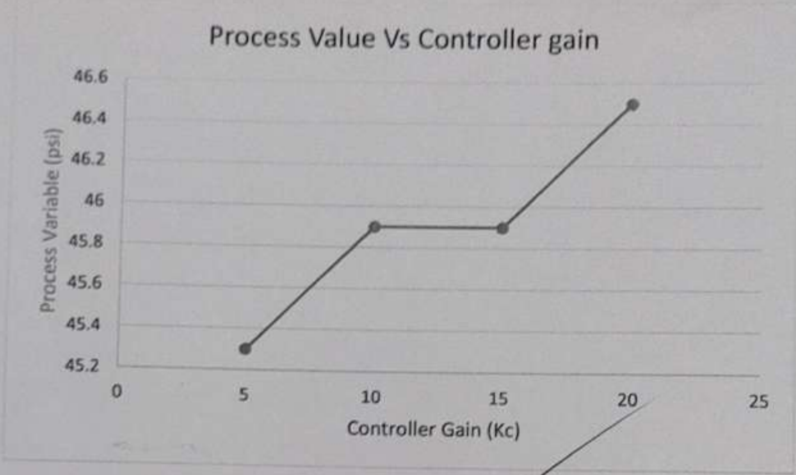
(2) Incorrect tuning or controllers (P, PD & PID) can lead to unexpected behaviour and offset elimination.

Precautions :-

(1) Calibrate instruments and sensors properly.

(2) Place setup on stable, vibration free surface.

P.R.E.



Process Value Vs Controller gain
Process Variable (psi)
46.6
46.4
46.2
46
45.8
45.6
45.4
45.2
0
5
10
15
20
25
Controller Gain (Kc)

DATE	Exp-2 Temperature control trainer	SHEET NO.

Aim:-

To tune the parameters of the controlled in the temperature control trainer.

OBJECTIVE:-

→ To study the open loop response of a temperature control trainer.

→ To study feedback proportional control (P control)

→ To study steady state and transet response to a Proportional + derivative control.

→ To study steady state and transient response to a Propertional + Integral + Derivative controller.

THEORY

1. study of open loop response

The feedback controlled variable is measure and compared with referance input and difference in signal to the control elements if the main variable is not used to input adjust any of the input automatically system is an open loop control system.

PROCEDURE:-

→ The set was started up and valve was adjusted.

→ select open loop action.

→ Decrease control output to 0%.

→ start date logging on the computer

→ Apply the step change by 10% to controller output in manually. wait untill temperature reaches steady state.

→ Repeat the above steps untill the controller output reaches to max is 100%

2. study of Proportional controller:-

THEORY:-

The control algorithm that generate a linear control output Proportional to deviation. ~~at~~ it called Proportional action. In Proportional action the amount of change is measured value (in deviation) is supressed that is required to cause the control output to change from 0 to 100% is called the proportional.

The equation for proportional controller output as

$$P = k_P [SP - PV] + P_0$$

k_p = Proportional gain

PROCEDURE:-

→ setup is started and in closed loop is sealed.

→ Controller is set to P mode.

→ Process value is adjusted by changing controller to manual mode and output of controller is applied as bias proportional band is changed to 100%.

→ controller is switched back to auto.

→ set point is changed.

→ Controller is switched to manual mode and different set is taken.

3. Study of Proportional Derivative controller

THEORY:-

This mode of control is derived by the relation

$$k_c = \frac{100}{\text{Proportional band}}$$

$$P = K_c e + K_c \tau_d \frac{de}{dt} + P_s$$ error $e = SP - PV$

τ_d = derivative time

τ_i = integral time

K_c = Proportional gain

The derivative action generally used for low pressure and larger derivative time larger is the action smaller in the Proportional band larger in the derivative action.

PROCEDURE:-

→ start the setup and choose closed loop option for control

→ select PD controller set the proportional band from Proportional control (P only)

→ change the derivate time and apply step change to the process.

→ increase the derivative time and apply step change to the present.

→ trail and error, select a set of proportional band and derivative time which give satisfying response to the step change in set point.

4) Study of Proportional Integral Derivative (PID)

THEORY:-

The mode of control is derived by the relationship

$$P = K_c e - \frac{K_c}{T_i} \int \epsilon \, dt + K_c \epsilon \, r_d \frac{d\epsilon}{dt} + P_s$$

error $e = SP - PV$

$$K_c = \frac{1}{\text{Proportional Band}} \times 100$$

r_d = derivative time

t_i = integral time

K_c = Proportional gain

PROCEDURE:-

→ Start up the set up and choose close loop option for central system.

→ Select PID controller.

→ Switch the controller to manual mode

→ Change the proportional band to the value & set estimated in proportional controller & integral and derivative time

→ in the responses in previous experiments

→ Adjust the set point to 50% switch the controller to manual mode. Apply change of 10% . observe the pressure response.

INDIAN INSTITUTE OF TECHNOLOGY

DATE

SHEET NO.

Observation table :-

open loop -

controller output (%)	Process variable (°c)
0	36
10	36
20	39
30	43
40	47
50	50
60	54
70	57
80	59.5
90	64
100	64

The median value of process variable comes out to be 50, and this value will be chosen as set point for closed loop analysis of P, PD and PID Controller

P.R.E

INDIAN INSTITUTE OF TECHNOLOGY

SHEET NO.

DATE

At 50% output

time	Process value
0	64.9
10	64.9
20	64.9
30	64.7
40	63.1
50	60.6
60	58.2
70	56.4
80	55.3
90	54.2
100	53.5
110	52.9
120	52.2

P controller -

K_c	Set Point (°C)	Process variable (°C)	offset
10	50	51	1
20	50	52	2
30	50	52	2

minimum offset at $K_c = 10$

↳ not K_c. It is PB%.

P.

PD controller -

T_D	Set Point (°c)	Process Variable (°c)	offset
1	50	51	1
5	50	51	1
10	50	51	1

minimum offset is same at any T_D and $K_c = 10$

PID controller -

T_I	Set Point (°C)	Process Variable (°c)	offset
1	50	47	3
5	50	51.65	1.65
10	50	51.6	1.6
20	50	50.4	0.4

minimum offset found at $T_I = 20$, $T_D = 1$, $K_c = 10$

Result and conclusion :-

Controller tuning parameter obtained are

$K_c = 10$

$T_D = 1$

$T_I = 20$

PID controller is most effective in eliminating offset followed by PD controller

INDIAN INSTITUTE OF TECHNOLOGY

DATE

SHEET NO.

- P only controller shows the most deviation because it lacks integral and derivative actions to address steady state errors.

Discussion :-

- In this experiment, we used temperature control trainer for understanding the basic temp. control principle where water temperature was controlled and flow rate was fixed.
- We used three different schemes P, PI, PID for which temperature responses were noted with time.
- In P only controller, value of K_c determines the closeness of control action towards set point.
- In PD controller, we used different P and D tuning parameters and offset decreases as compared to P only controller
- In PID controller, we can see from graph oscillations increased as the value of D increases.

P.R.E.

INDIAN INSTITUTE OF TECHNOLOGY

DATE

SHEET NO.

Precautions:-

- The readings of the process control variable shows some changes initially. Thus the readings of the process variable should only be taken when it stabilizes.
- No abrupt changes in input or control parameters should be done. This changes should be slowly and in steady state.

X axis - 1 unit = 10%

Y axis - 1 unit = 5%

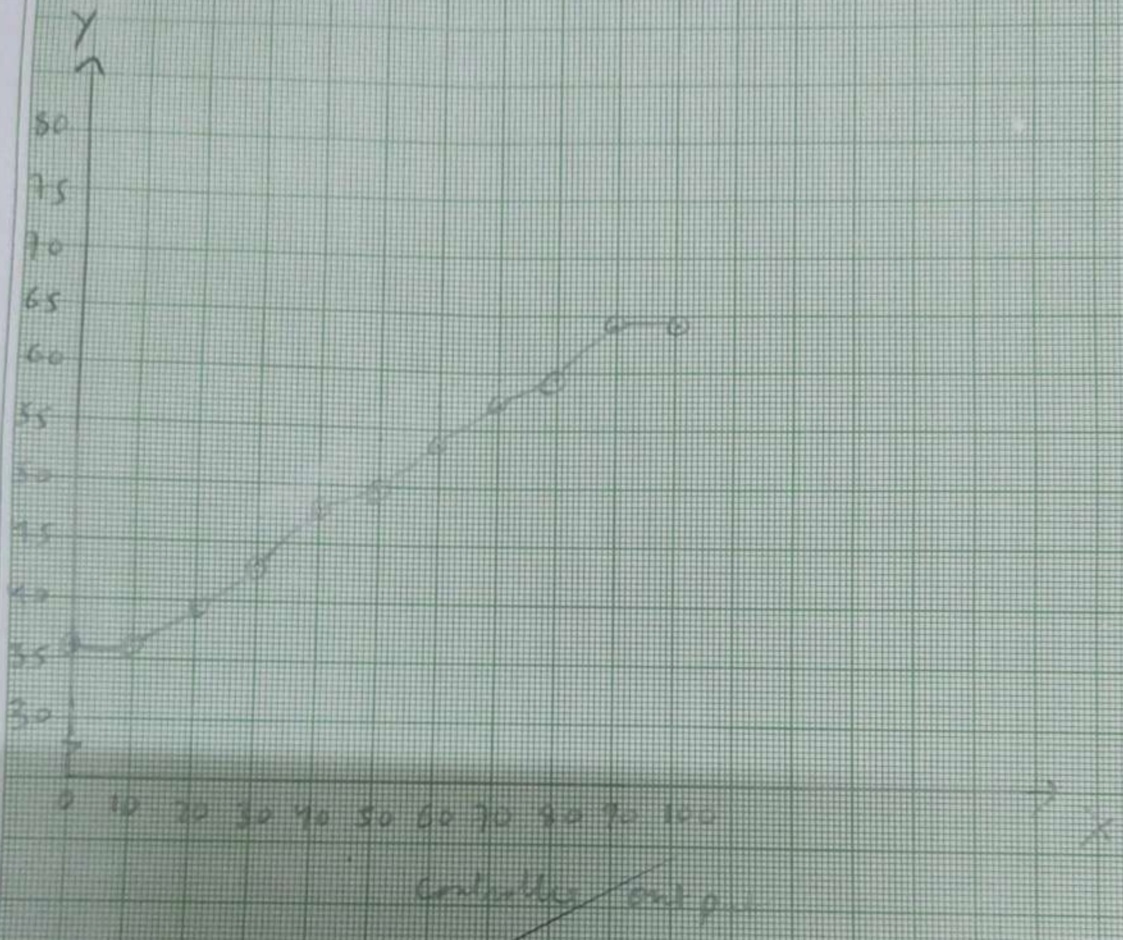


fig title & no.

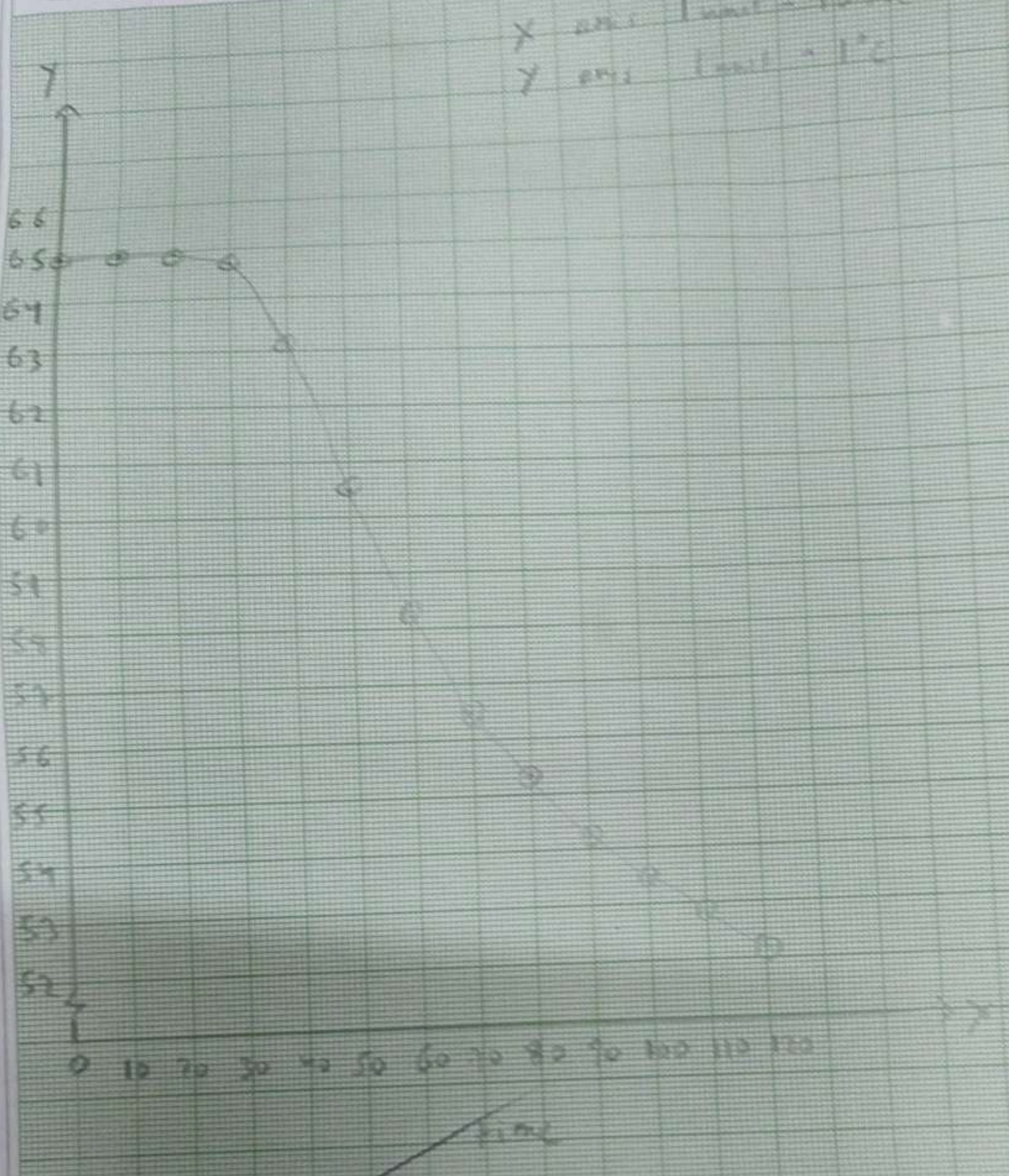
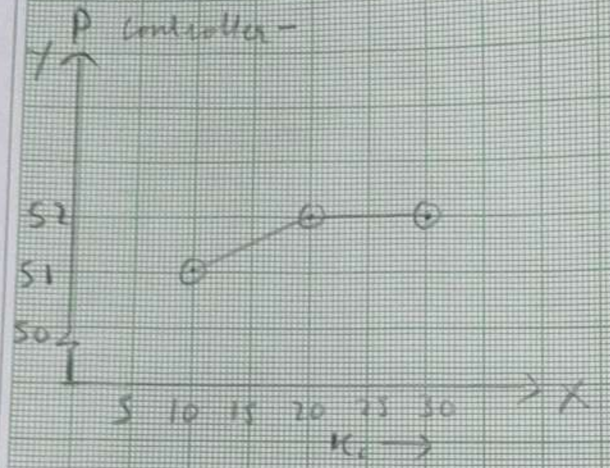
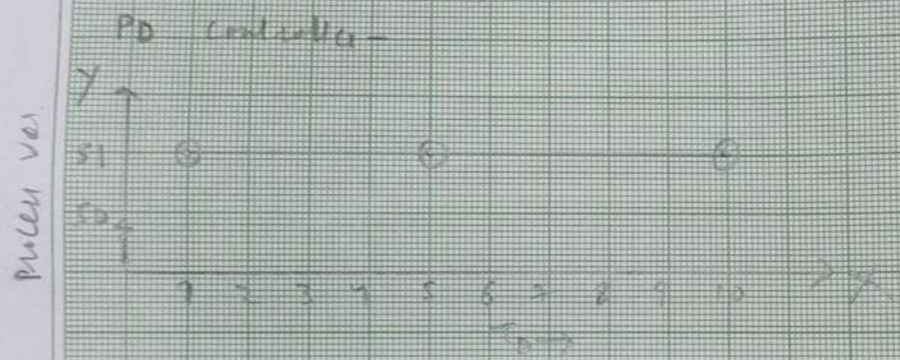
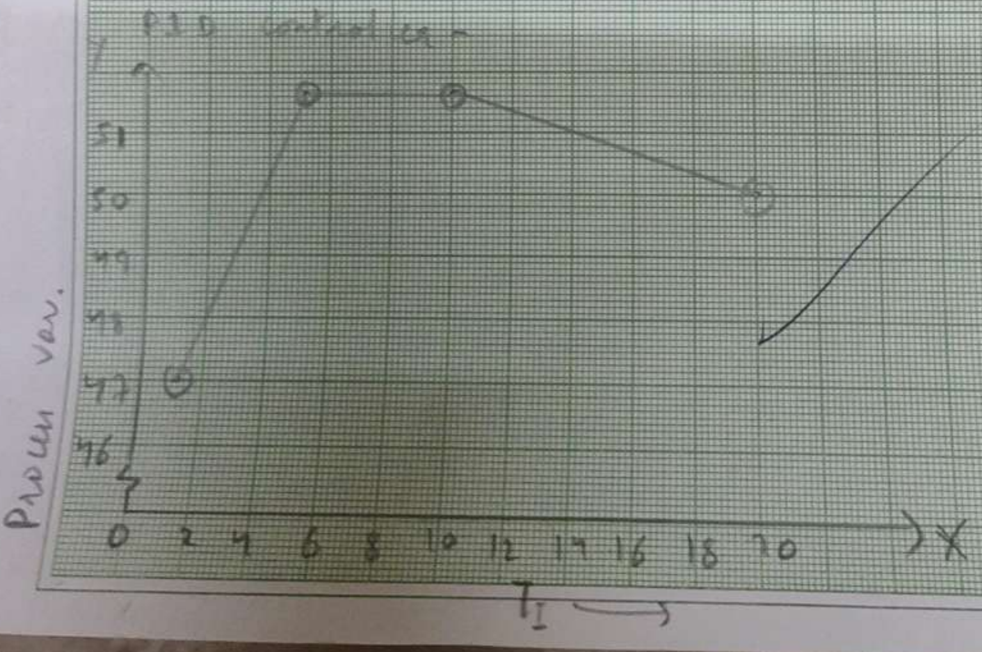

X axis 1 unit = 10 sec
Y axis 1 unit = 1°C
Y
66
65
64
63
62
61
60
59
58
57
56
55
54
53
52
X
0 10 20 30 40 50 60 70 80 90 100 110 120
time

fig title & no.


P Controller -
Process var.
Y
52
51
50
5 10 15 20 25 30
X
K_c


PD Controller -
Process var.
Y
51
50
1 2 3 4 5 6 7 8 9 10
X


PID Controller -
Process var.
Y
51
50
49
48
47
46
0 2 4 6 8 10 12 14 16 18 20
X
T_I