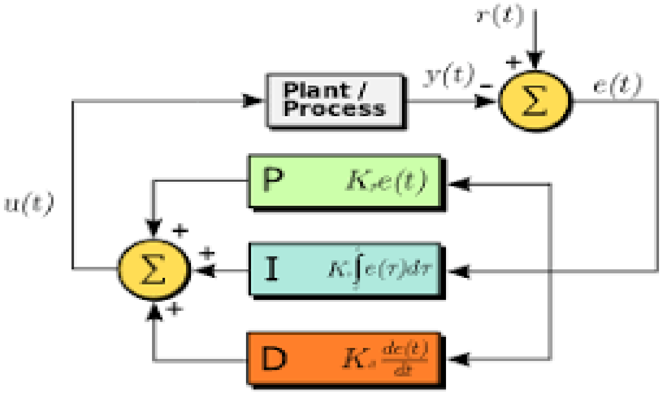
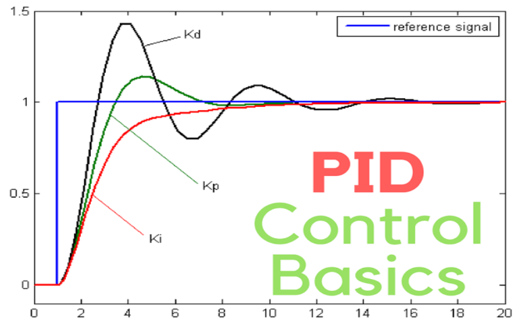
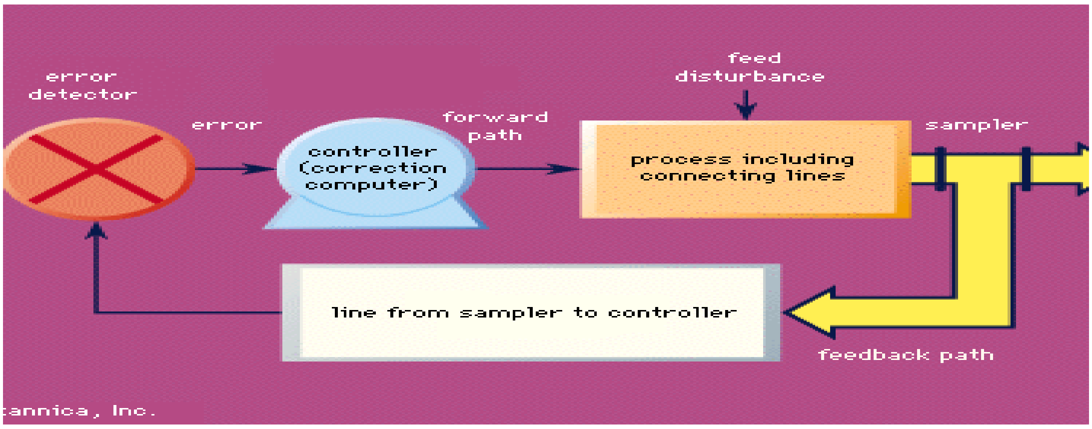
LABORATORY MANUAL

INSTRUMENTATION LAB-III







Department of Instrumentation Engineering

JORHAT ENGINEERING COLLEGE

Assam-785007

3^{RD} SEMESTER BE (IN)

INSTRUMENTATION LAB-III

Course code	Course title	Hours per week L-T-P	CREDIT-2
IE181614	Instrumentation lab-II	0-0-2	1

Experiment No	Title of the experiments	Objective of the experiments
1	Study of pressure control loop	Study of pressure control loop working with the PID controller and Observe the response of pressure control loop at various PID controller conditions 1. Close loop control with digital PID Close loop control with set point change 2. Proportional control with change in set point Pressure control system 3. Proportional + Integral control with change in set point Pressure control system 4. Proportional + Integral + Derivative control with change in set point (Zieglar Nichols Tuning Method) Pressure control system
2	To study the Air Flow Control Loop	Study of flow control loop work with PID controller & Observe the response of air flow control loop at various PID controller conditions. 1. Close loop control with Digital PID Close loop with set point change 2. Proportional control with change in set point Airflow control system 3. Proportional + Integral control with change in set point Airflow control system 4. Proportional + Integral + Derivative control with change in set point (Zieglar Nichols Tuning Method)

		Airflow control system
3	Study of temperature control loop	Study of temperature control loop work with PID controller & Observe the response of temperature control loop at various |PID controller conditions. 1. Close loop control with Digital PID Close loop control with set point change 2. Proportional control with change in set point Temperature control system 3. Proportional + Integral + Derivative control with change in set point(Zieglar Nichols tuning method) Temperature control system

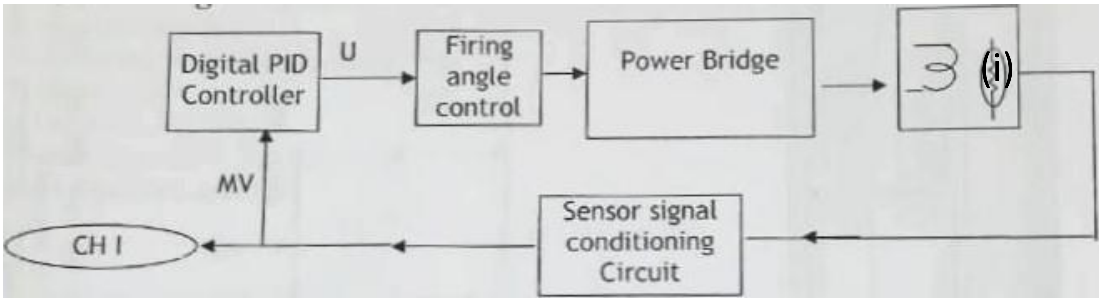
EXPERIMENTS No:- 01A

AIM OF THE EXPERIMENT: Study of pressure control loop

OBJECTIVE: Closed loop control with Temperature control system

Proportional control with manual change in set point —

Block diagram



(Un)=100%, Ti=64000,Td=0

iring seq.: EMT8 (14) EMT9 (7), EMT8 (15) .EMT9 (8), EMT9 (9)-Heater(+ve) EMT9 (13)-Heater(-ve), EMT9 CIP CHI, CIP6-EMT9 (1), EMT9 (14)-CMT8 (6), EMT9 (15)-EMT8 (7).

Fill 2 litres of water inside the tank using pump through V4 valve (while doing this air may get trapped inside the tank so frequently open the dafty valve manually & then continue filling water).

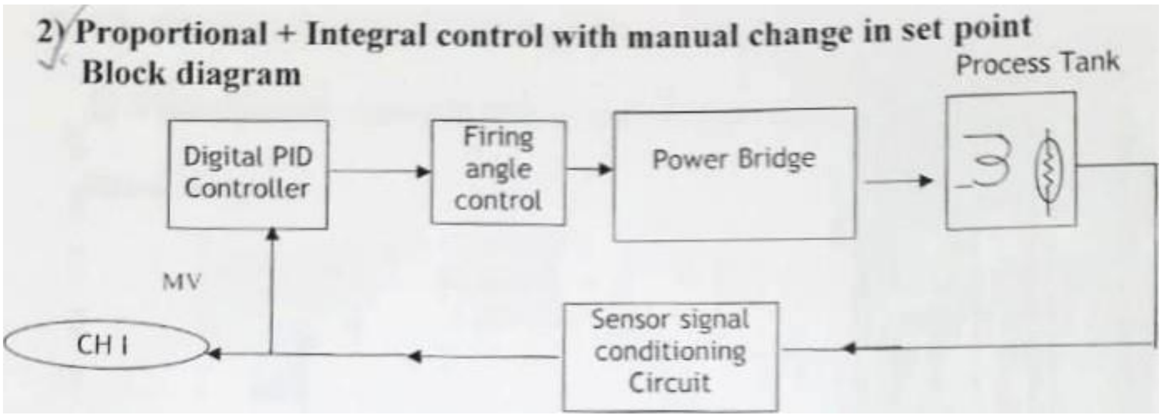
Connect the test set up as shown in the wiring sequence. In setting windows select channel I for measure variable, source for set value from panel, reverse action, unit=%, ratio factor = 1. In PID windows select Ts=15, Kd=10, o/p lower limit(Un)=0%,o/p upper Limit(Un)100%, Ti=64000, Td=0.
From open loop response (EXPT RTAi) of the system we had already determined the transfer function of our temperature process.

For using only P controller, we will have to set Pb 12 %. Now set Pb 12%, Keep drains valve VS open, V1, V3 open and V2, V4 closed. Fill the process tank with water through inlet valve VS up to half of glass window. EMT-9 panel SP (pot) Keep OFF position fully CCW] & sensor selecting S/W [IP2W] select temperature. Make the Heater supply On. Set 10 LPM constant air flow using knob of AFR2 on Rotameter RI & observe the system response of the process for set point change. Vary the set point on the panel from 40 v' 60% manually. Hence, we will use set point from the panel. Observe the graph of measured variable Vs set point. From the graph it can be observed that at 12 % Pb system settles with constant error.

EXPERIMENTS No:- 01B

AIM OF THE EXPERIMENT: Study of pressure control loop

OBJECTIVE:



Wiring seq.: EMT8 i14) .EhT9 (7), EMT8 (15) EMT9 EMT9 (9)-Heater eve), EMT9 (13).Heater eve), EMT9 (14). CIP CHI, CIP6.EMT9 EMT9 (14).EMT8 (6), EMT9 (15).EMT8

Fill 2 litres or water inside the tank using pump through V'4 valve (while doing this air may' get trapped inside the tank so frequently open the dafty valve manually & then continue filling water).

In setting windows select channel I for MV, source for set value from panel, unit= %, ratio factor=l, reverse action. In main pid window select Ts=15, Kd=10, o/p lower o/p upper limit & rest of the setting are deselected.

Now to reduce the error using only P Controller We will add I action in the system. According to Ziegler Nichols method PI controller will be with following P & I parameters. Pb = 14 Ti=600sec

Hence for using PI controller set Pb 14 % & Ti 600 Sec on the panel of digital PID. Keep drain valve V5 open,Vl,V3 open and V2_V4 closed. Fill the process tank with water through inlet valve V5 up to half of glass window EMT-9 panel SP (pot) Keep OFF position fully CCW] & sensor selecting S/W [I P2W] select temperature. Make the Heater supply On.

Set 10 LPM constant air flow using knob of AFR2 on Rotameter RI observe the performance of measured variable Vs set point with manually changing the set point from 40 to 60%. But while changing the set point always let the sensor o/p to settle.

The graph will be as shown below. Addition of I action removes error with only P controller. The process settles with some overshoot without error.

EXPERIMENTS No:- 01C

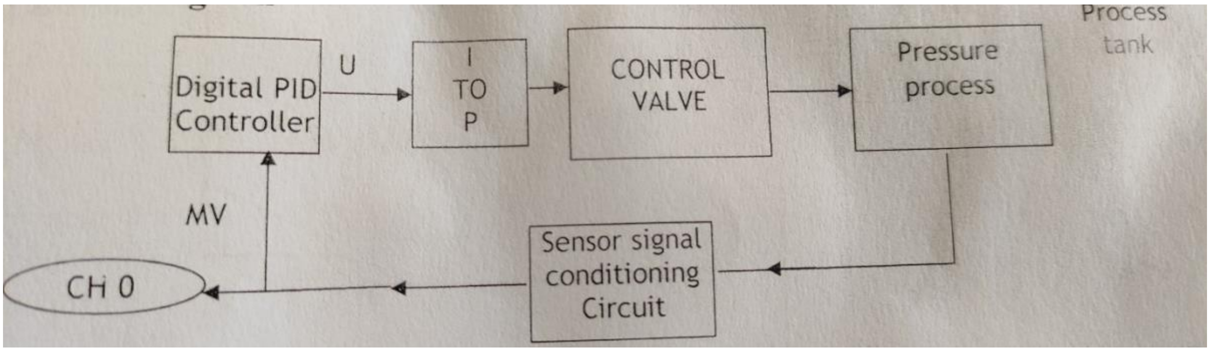
AIM OF THE EXPERIMENT: Study of pressure control loop

OBJECTIVE: At the completion of this unit you will be able to understand how real-life processes work with PID controller. Observe the response of pressure control loop at various PID controller conditions.

This can be done as

a) Input output curve plotting.
b) Open loop response characteristics.
c) Close loop response characteristics.

THEORY:



When a closed tank is maintained under some pressure then the value of pressure parameter inside the tank depends upon the inlet pressure to the tank & the air going out from the closed tank. Thus the amount of air-in exceeds the amount of air going out of the tank then the pressure inside the tank will slowly increases and it may attain a steady value depending upon the period of pressure process. We use open-loop system response method to determine this period(time), which can be used for adjusting I & D values of pressure controller. The save process vessels may used as per need for bom temperature loop (with water inside cooled by air bubbler flow) or pressure loop (empty, water drained out using drain valve, with all exit valve should closed except inlet air flow through CV).

Pressure process variable is fast changing hence the pressure process goes from one steady to another steady state within short time. Also pressure oscillates with very small amplitude. Thus if we give larger gain values in PID action then pressure variation may become oscillatory.

Following is the list of experiment can be performed with this panel.

Name of the expt.	**Name**				
	V1	**V2**	**V3**	**V4**	**V5**
Pressure	Open	Closed	Open	Closed	Slightly open

List of Experiments

Sr. no	**Experiment**	**File Name**	**test**	**set**
A	Input Verses output curve plotting	-	-	-
B	Open loop response characteristics Pressure control system with Digital PID controller tunning using Ziegler Nichols method & determination of PID parameters.			

WIRING SEQ: Pressure O/P(16 of signal conditioning EMT9)-CIP CH0, CIP6-CIP9,CIP10-(+ve)of I to P,(-ve) of I to P- CIP20, Pressure O/P(16 of EMT9)-DPM +ve, DPM(-ve)-GND

Procedure: -

1. In setting windows select channel 0 for MV, source for set value from panel, unit =%,ratio factor=1, reverse action. In main PID window select Ts =0.1, Kd=10, o/p lower limit = 0%, o/p upper limit =100% & rest of the setting are deselected.
2. Now to reduce the overshoot we will try the system with PID controller. According to Ziegler Nichols we can set following PID parameters.Pb=35%, Ti=10 sec, Td=0.15 sec
3. Therefore set Pb 35%, Ti 10 sec and Td 0.15 sec. Observed the system performance with change in set point and graph of measured variables Vs set point .
4. The graph will be as shown in fig below. Addition of D action minimizes the overshoot with P+I controller. The process settles with small overshoot without error.

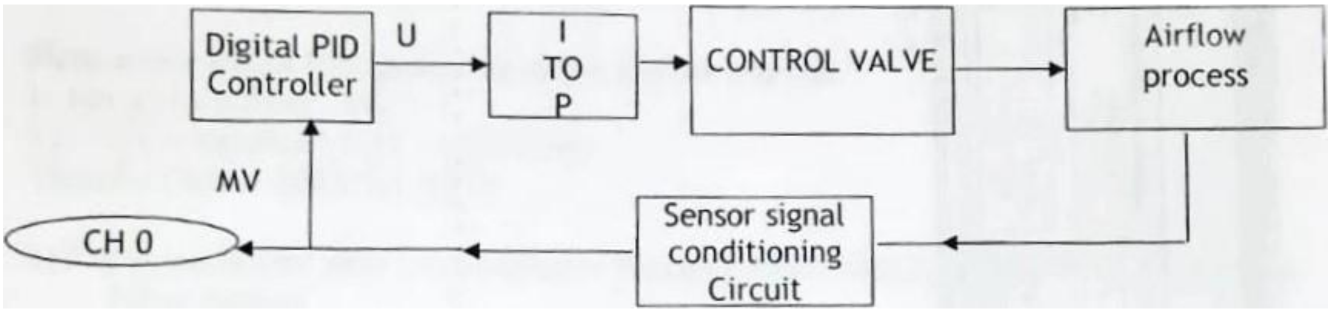
EXPERIMENTS NO: - 02A

AIM OF THE EXPERIMENT: -To study the Air Flow Control Loop

OBJECTIVE: - Closed loop control with Airflow control system

Proportional control with manual change in set point—

Block diagram



Wiring seq.: Airflow O/P (14 of signal conditioningEMT9)- CIP CHO, CIP6 CIP9, CIPIO -(+ve) of I to P, (-ve) of I to P- CIP20, Airflow O/P (14 of EMT9)-DPM +ve, DPM(-ve) -GND

Connect the test set up as shown in the wiring sequence. In setting windows select channel O for measure variable, source for set value from panel, ratio factor .1n main PID windows select lower limit(Un)=0%,o/p upper limit (Un)=100%, From Ziegler Nichils tuning second method (EXPT RAFB_i) of the system we had already determined the parameters for PID controller.

For using only P controller we will have to set Pb 40 %. Now set Pb 40% & observe the system response of the process for set point change. Vary the set point on the panel from 30 to 70 % manually. Hence we will use set point from the panel. Observe the graph of measured variable Vs set point. From the graph it can be observed that at 40 % Pb system settles with constant error.

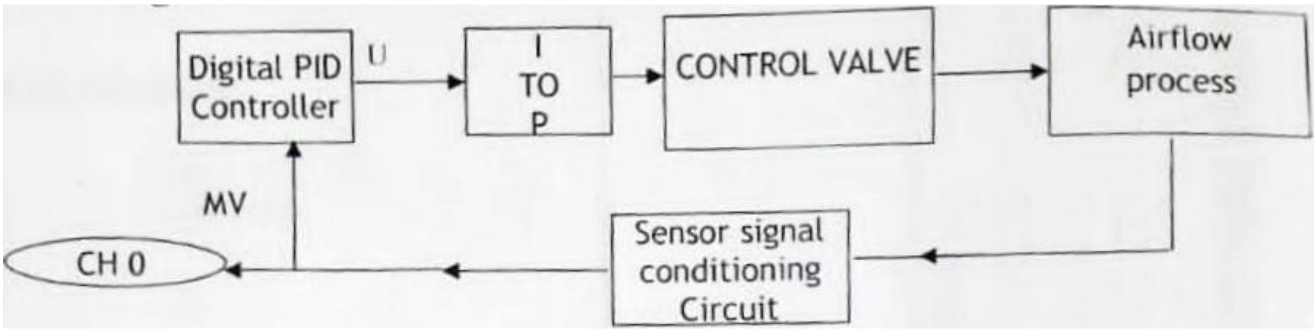
Note: I. Allow tolerance of 20% between mechanical Rotameter electronic DPM showing LPM. Rotameter readings should be used as supporting while DPM hi' for accuracy.

2. You may need to increase Pb value to set the graph.

EXPERIMENTS NO :- 02B

AIM OF THE EXPERIMENT: -To study the Air Flow Control Loop

OBJECTIVE :- Proportional + Integral control with manual change in set point — N/Block diagram



Wiring seq. : Airflow O/P(14 of signal conditioningEMT9)- CIP CHO, CIP6 - CIP9, CIPIO –(+ve) of I to P, (-ve) of I to P- CIP20, Airflow O/P(14 of EMT9)-DPM +ve, DPM (-ve)- GND

In setting windows select channel 0 for M V, source for set value from panel, unit = %, ratio factor=l, reverse action. In main pid window select Ts=0.1, Kd=10, o/p lower limit=0 %, o/p upper limit =100%, & rest other setting are deselected.

Now to reduce the error using only P controller we will add I action in the system.
According to Ziegler Nichols method PI controller will be with following P & I parameters.

Pb = 40%

Ti = 2 Sec

Hence for using PI controller set Pb 40 % & Ti 2 Sec on the panel of digital PID. Observe the performance of measured variable Vs set point with manually changing the set point from 40 to 60%. But while changing the set point always let the sensor o/p to settle.

The graph will be as shown below RAFC2 i. Addition of I action removes error with only P controller. The process settles with some overshoot without error.

Note: l. Allow tolerance of 20% between mechanical Rotameter & electronic DI' V showing LPM. Rotameter readings should be used as supporting while DPM may be used for accuracy.

2. You may need to increase Pb value to set the graph.

EXPERIMENTS NO :- 02C

AIM OF THE EXPERIMENT: -To study the Air Flow Control Loop

OBJECTIVE :- At the completion of this unit you will be able to understand how real life processes work with PID controller. Observe the response of air flow control loop at various PID controller conditions.

This can be done as:

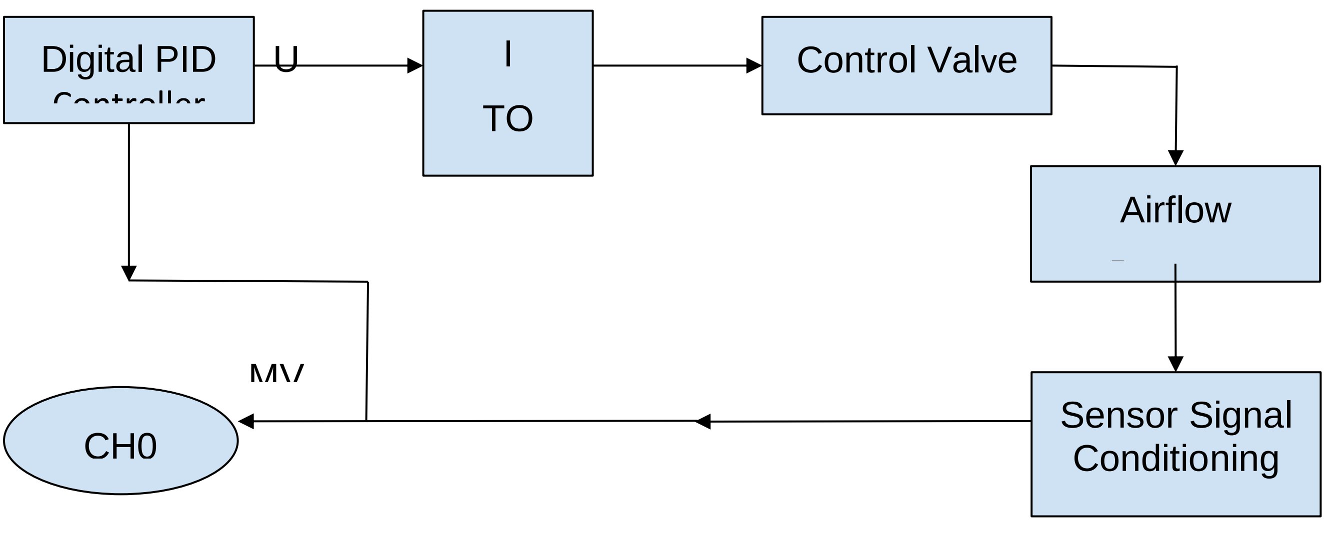
d) Input verses output curve plotting
e) Close loop response PID parameters determination by Ziegler Nichols second method.
f) Closed loop response characteristics

THEORY

<u>Note</u>:

1) Keep temperature, intensity/flow switch at flow position.
2) Don't give air pressure above 2-3 bar for safety air flow sensor.

<u>Block Diagram</u>



Calibration of Airflow sensor:

For calibration of airflow sensor keep V1, V3 and V5 fully open and V2, V4 fully closed. Connect the turbine flow sensor to signal conditioning panel EMT9 using 5-pin DIN male connector. Connect the tag no 14 of EMT9 to 8^{th} of EMT8 and 15 of EMT9 to 9^{th} of EMT8. By keeping control valve fully open make the compressor ON. Adjust AFR1 air pressure using knob on AFR1 about 1.4 bars seeing dial on pressure gauge. Do not connect I to P, 4 to 20mA supply. Now adjust AFR2 airflow such that the Rotameter shows 0 LPM by using knob on AFR2.

Now adjust the output at tag no 14 of signal conditioning panel = 0V for 0 LPM of airflow. Now increase the airflow of AFR2 such that the Rotameter shows 50LPM. Now adjust the output at tag no 14 of signal conditioning panel = 2.5V for 50LPM of airflow using span pot VR10. Repeat the above procedure 2-3 times & confirm Zero and span. Apply the same procedure for FS2 airflow sensor by opening valve V2 and AFR3.

Airflow process variable is fast changing hence the air flow process goes from one steady state to another steady state within short-time. Also airflow oscillates with very small amplitude. Thus if we give larger gain values in PID action then airflow variations may become oscillatory.

NAME OF THE EXPT.	NAME				
	V1	V2	V3	V4	V5
Air flow	Open	Closed	Open	Closed	Open

Proportional + Integral + Derivative control with manual change in set point

Wiring seq.: Airflow O/P (14 of signal conditioning EMT9) – CIP CH0, CIP6 – CIP9, CIP10 – (+ve) of I to P – CIP20, Airflow O/P (14 of EMT9) – DPM +ve, DPM (-ve) - GND

Procedure: -

In setting windows select channel 0 for MV, source for set value from panel, unit = %, ratio factor =1, reverse action. In main PID window select $T_S = 0.1$, Kd = 10, O/P lower limit = 0%, O/P upper limit = 100% & reset of the setting are deselected.

For P+I+D Controller

Kp = 0.6 x Kcr = 0.6 x 12.5 = 7.5

Pb = 100/Kp = 100/7.5 = 13.33%

Ti = 0.5 x Pcr = 0.5 x 2.592 = 1.296 sec

Td – 0.125 x Pcr = 0.125 x 2.592 = 0.324 sec

These are chances of I to P getting damaged due to continuous oscillatory setting of PID parameters leading to continuous chance of I to P plunger. Very small Pb gives faster response but it will also make control valve work more quickly leading to fatigue. Hence following values of PB are recommended.

So we are using following values for PID controller at the cost of slightly sluggish response but for sake of longetivity.

i) For P controller only

PB = 40%

ii) For P+I controller

PB = 40%, Ti= 2 SEC

iii) For P+I+D controller

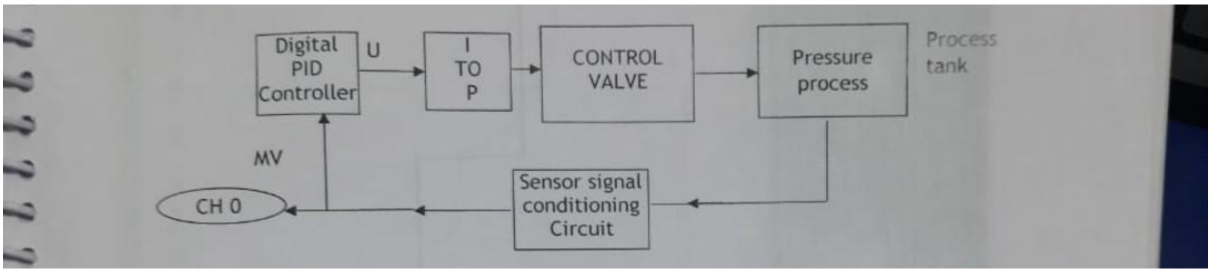
PB = 40%, Ti = 2 sec, Td = 0.3 sec

EXPERIMENT NO: 03A

Aim of the experiment: Study of temperature loop

Objective: Closed loop control with pressure control system

1)Proportional control with manual change in set point-



Wiring sequence: Pressure O/P (16 of signal conditioningEMT9)- CIP CHO, CIP6-CIP, CIP10-(+ve) of I to P, (-ve) of I to P-CIP20, Pressure O/P (16 of EMT9)- DPM +ve, DPM(-ve)- GND

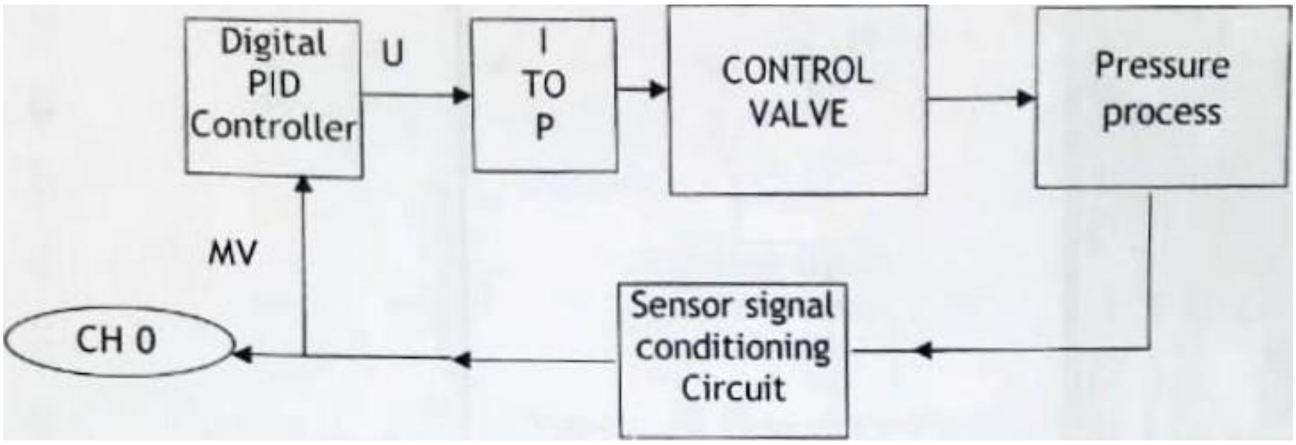
Connect the test set up as shown in the wiring sequence. In setting windows select channel 0 for measuring variable, source for set value from panel, unit=%, ratio factor=1. In the main PID windows select Ts=0.10, Kd=10,O/P lower unit (un)= 0%, O/P upper limit (un) =100%, Ti= 64000, Td=0 from Ziegler Nichols tuning second method (EXPT RPAi) of the system we had already determined the parameters for PID controller.

For using only P controller we will have to set Pb 35% . Now set Pb 35% & observe the system response of the process for set point change. Vary the set point on the panel from the40 to 60% manually. Hence we will set point from the panel. Obsereve the graph of measured variable Vs set point. From the graph it can be obsereved that at 35% Pb system settles with constant error.

EXPERIMENT NO: 03B

Aim of the experiment: Study of temperature loop

Objective: Proportional + Integral control with manual change in set point — Block diagram



Process tank

Wiring seq.: Pressure O/P(16 of signal conditioningEMT9)- CIP CHO, CIP6 CIP9, CIPIO -(+ve) of I to p, (-ve) of I to P- CIP20, Pressure 0/P(16 of EMT9)-DPM +ve. DPM I-vel- GND

In setting windows select channel 0 for MV, source for set value from panel, unit —0/0, ratio factor=l,reverse action. In main pid window select Ts=0, Kd=10,o/p lower limit—O %, o/p upper limit = 100%, Td=0 & rest of the setting are deselected.

Now to reduce the error using only P controller we will add I action in the system.
According to Ziegler Nichols method PI controller will be with following P & I parameters.
Pb -35%
Ti=10 sec

Hence for using PI controller set Pb 35 % & Ti 10 Sec on the panel or digital PID. Observe the performance of measured variable Vs set point with manually changing set point from 40 to 60%. But while changing the set point always let the sensor of o/p to settle.

The graph will be as shown below RPB2 i. Addition of I action removes error only p controller. The process settles with some overshoot without error.

EXPERIMENT NO: 03C

Aim of the experiment: Study of temperature loop

Objective: At the completion of this unit you will be able to understand how real-life processes work with PID controller. Observe the response of temperature control loop at various |PID controller conditions. This can be done as:

1. Open loop response characteristics
2. Closed loop response characteristics.

Theory: RTD is used as a temperature measurement sensor in this process. The resistance of RTD increases linearly as the temperature increases and vice versa. The sensor mounted inside SS tube is fitted in the process tank using ½ inch threading and connected to the sensor conditioning circuit in TAP panel through five core cable with shield as ground fitted in the five pin DIN connector available on left side on the panel. The circuit shows the signal conditioning circuit.

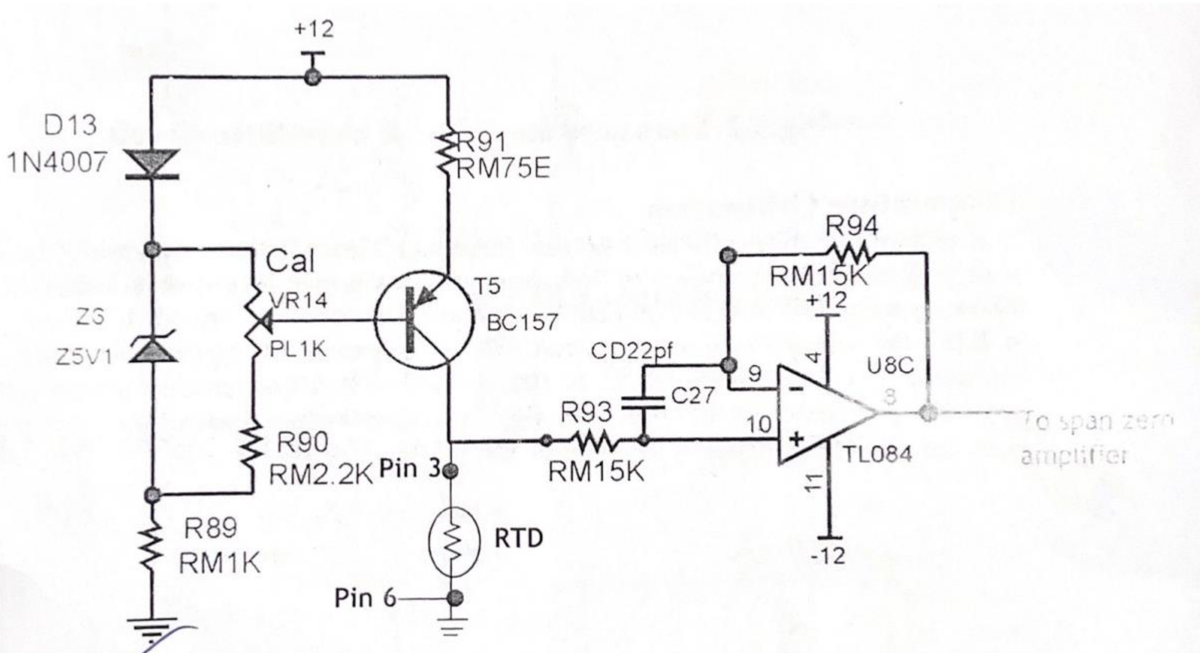
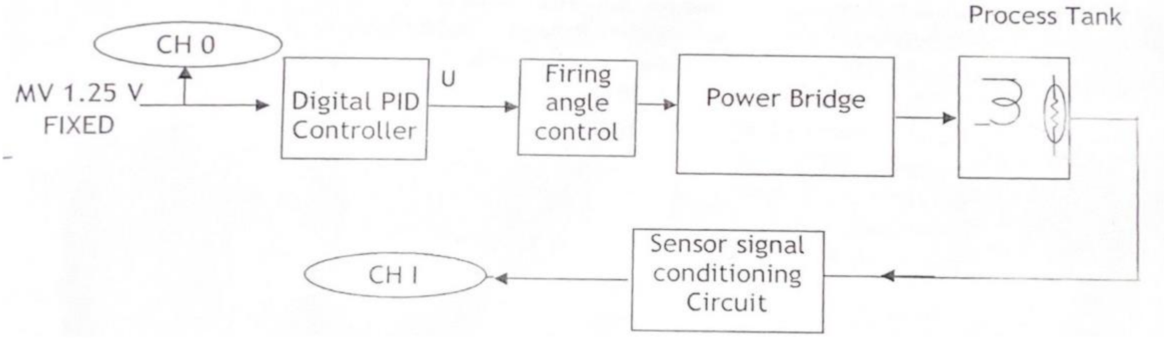


Fig. 3.1 RTD Sensor circuit.

The thyristor actuator panel needs ±12V DC, 17V unregulated supply 15V AC sync and 230V ac supply. The variable DC high voltage generated by actuator panel is given as a control supply to the heater(750w) mounted on the process vessel. It is assumed that you have already calibrated sensor outputs.

System Block Diagram for Temperature loop

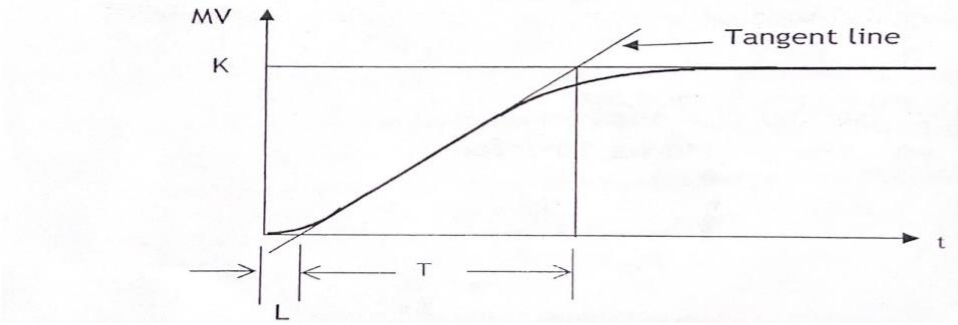


Wiring sequence: EMT8(14) -EMT9(7) -EMT8(15) -EMT9(8) -EMT9(9) -Heater(+), EMT9(13) -Heater(-), EMT9(14) -CIP CH1, CIP6 -EMT9(1), -EMT9(14) -EMT8(6), EMT9(15) -EMT8(7), CIP CH0 -Fixed1.25V (From 14 of CIP by setting pot P1)

Theory: Fill 2l of water inside the tank through V4 valve(while doing this air may get trapped inside the tank so frequently open the dafty valve manually and then continue filling water). Connect the test set up as per the wiring sequence. Set PB100%, Ts=15, Kd=10, set value=20 on digital PID. Do not select I & D action (i.e. integral time=64000 max and derivative time =0). Set controller output lower limit= 0% and upper limit = 100%. In setting windows setting channel 0 for MV and source for set value from panel, reverse action, unit = %, ratio factor =1 and rest of the setting are deselected. Keep drain valve V5 open, V1,v3 open and V2,V4 closed. Fill the process tank with water through inlet valve V5 upto half of glass window. EMT-9 panel SP (pot) keep OFF position [fully CCW] and sensor selecting S/W [1P2W] select temperature. Make the heater supply on. Set 10 LPM constant airflow using knob of AFR2 on Rotameter R1. Observe the graph for channel 1 Vs set point on PC with 15sec sampling time with 30 samples/Div. As the process is slow sampling time should be large to see the graph of proper shape. During observation wait till we get steady state. After getting steady state now make set value = 30. Now again wait up to steady state. Here we are going to calculate the transfer function for the process. Take a print of your graph for calculations. The graph will be as shown below. Since the response of the process is of S type we can approximate the process as:

$$GPS = \frac{K e^{-LS}}{Ts+1}$$

K,T & L can be determine from the responses.



The diagram above shows the S shape curve of the o/p. Here L is the delay time, T is the time constant & K is the gain of the system. From the graph we can calculate the above parameters. Take a print of your graph & measure the parameters as indicated on the graph.

From the graph we observe that the delay time required is

Therefore L= 12 sample = (12 * 15 sec) = 180 Sec

Time constant T= 171 samples = (171*15sec) = 2565 sec.

K = output/input

Calculate the % of input & output.

% Input = 10%

% Output = 18.23%

Therefore gain K= 18.23/10 = 1.8

Thus from the equation

$$Gps = \frac{K\,e^{-Ls}}{Ts + 1}$$

Transfer function of our Temperature process is

$$Gps = \frac{1.8\,e^{-180S}}{2565\,s + 1}$$

If dead time is zero, then this method is not applicable, however from the open loop response of the process PID parameters may be determine.

Determination of PID parameters:

Hence comparing equation 2 with I we will get

K= 1.8

1=180 sec

T = 2565 sec

Using these parameters & following table we can determine controller settings.

i) For only P controller

Kp = (1/K)T/L = (1/1.8)*(2565/180)

= 7.9

Therefore Pb = 1/Kp * 100 = 12.6 %

ii) For PI controller

Kp = 0.9(1/K)(T/L) = 0.9 X 7.9 = 7.1

∴ **PB** =1/Kp X 100=14 %

Ti = L/0.3 = 180/0.3 = 600 Sec.

iii) For PID controller

Kp=1.2 x 7.9 = 9.48,

∴**PB** =10.5 %

Ti = 2x L =360 Sec,

Td =0.5 x L =90 sec

Warning: so we are using following values for PID controller for better performance

i) For P controller only

PB = 12 %

ii) For P+I controller

PB = 14 %, Ti =600 Sec.

iii) For P+I+D controller

PB = 5 %, Ti = 150 Sec, Td=15Sec.

Procedure: -

1. In setting windows select channel 1 for MV, source for set value from panel, unit =%,ratio factor=1, reverse action. In main PID window select Ts =15, Kd=10, o/p lower limit = 0%, o/p upper limit =100% & rest of the setting are deselected.
2. Now to reduce the overshoot we will try the system with PID controller. According to Ziegler Nichols we can set following PID parameters. Pb=5%, Ti=150 sec, Td=35 sec
3. Therefore, set Pb 5%, Ti 150 sec and Td 35 sec
4. Keep drain valve V5open,V1,V3open andV2,V4 closed. Fill the water tank with water through inlet valveV5 up to half of glass window EMT9- panels SP keep OFF position &S/W for selecting temperature

5. The graph will be as shown in fig below. Addition of D action minimizes the overshoot with P+I controller. The process settles with small overshoot without