Department of Biotechnology

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Bioprocess Control and Instrumentation Lab (BT67L)

Lab Manual

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LIST OF EXPERIMENTS

EXPERIMENT 1: LEVEL MEASUREMENT TRAINER

AIM: To Measure the liquid level in the process tank using capacitive level transmitter

THEORY: In industry, liquids such as water, chemicals, and solvents are used in various processes. The amount of such liquid stored can be found by measuring level of the liquid in a container or vessel. The level affects not only the quantity delivered but also pressure and rate of flow in and out of the container.

Level sensors detect the level of substances like liquids, slurries, granular materials, and powders. The substance to be measured can be inside a container or can be in its natural form (e.g. a river or a lake). The level measurement can be either continuous or point values.

Continuous level sensors measure the level to determine the exact amount of substance in a continuous manner.

Point-level sensors: Indicate whether the substance is above or below the sensing point. This is essential to avoid overflow or emptying of tanks and to protect pumps from dry run.

The selection criteria for level sensor include:

- The physical phase (liquid, solid or slurry)
- Temperature
- Pressure or vacuum
- Chemistry
- Dielectric constant of medium
- Density (specific gravity) of medium
- Agitation (action)
- Acoustical or electrical noise
- Vibration
- Mechanical shock
- Tank or bin size and shape

From the application point of view the considerations are:

- Price
- Accuracy
- Response rate
- Ease of calibration

- Physical size and mounting of the instrument
- Monitoring or control of continuous or discrete levels

Level measurements are broadly classified in two groups:

- Direct methods
- Indirect methods

In direct methods, the level is indicated directly by means of simple mechanical devices. The measurement is not affected by changes in material density. Few examples are:

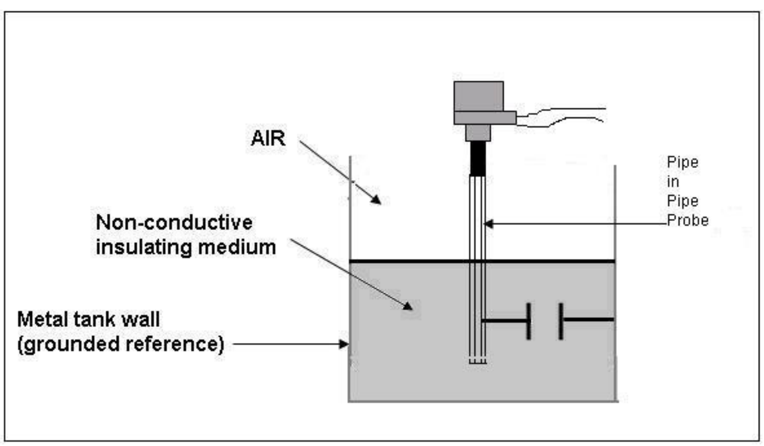
- Dip Stick
- Resistance Tapes
- Sight Glass
- Floats
- Ultrasonic
- Radar

In Indirect methods, the level is converted in a measurable signal using a suitable transducer. Change in the material affects the measurement. A corrective factor must be used in recalibrating the instrument. Few examples are:

- Hydrostatic head methods
- Load cell
- Capacitance
- Conductivity

Capacitance Level Measurement:

Capacitive level transducer is an example of indirect measurement of level



Capacitance level sensors are used for wide variety of solids, aqueous and organic liquids, and slurries. The technique is frequently referred as **RF** as radio frequency signals applied to the capacitance circuit. The sensors can be designed to sense material with dielectric constants as low as 1.1 (coke and fly ash) and as high as 88 (water) or more. Sludges and slurries such as dehydrated cake and sewage slurry (dielectric constant approx. 50) and liquid chemicals such as quicklime (dielectric constant approx. 90) can also be sensed. **Dual-probe** capacitance level sensors can also be used to sense the interface between two immiscible liquids with substantially different dielectric constants.

Since capacitance level sensors are electronic devices, phase modulation and the use of higher frequencies makes the sensor suitable for applications in which dielectric constants are similar.

PRINCIPLE:

The principle of capacitive level measurement is based on change of capacitance. An insulated electrode acts as one plate of capacitor and the tank wall (or reference electrode in a non-metallic vessel) acts as the other plate. The capacitance depends on the fluid level. An empty tank has a lower capacitance while a filled tank has a higher capacitance.

A simple capacitor consists of two electrode plate separated by a small thickness of an insulator such as solid, liquid, gas, or vacuum. This insulator is also called as dielectric.
Value of C depends on dielectric used, area of the plate and also distance between the plates.

$$C = E\,(K\,A/d)$$

Where:
C = capacitance in picofarads (pF)
E = a constant known as the absolute permittivity of free space
K = relative dielectric constant of the insulating material
A = effective area of the conductors
d = distance between the conductors
This change in capacitance can be measured using AC bridge.

Measurement:

Measurement is made by applying an RF signal between the conductive probe and the vessel wall.
The RF signal results in a very low current flow through the dielectric process material in the tank from the probe to the vessel wall. When the level in the tank drops, the dielectric constant drops causing a drop in the capacitance reading and a minute drop in current flow.

This change is detected by the level switch's internal circuitry and translated into a change in the relay state of the level switch in case of point level detection.

In the case of continuous level detectors, the output is not a relay state, but a scaled analog signal.

Level Measurement can be divided into three categories:

- Measurement of non-conductive material
- Measurement of conductive material
- Non-contact measurement

Non-conducting material:

For measuring level of non conducting liquids, bare probe arrangement is used as liquid resistance is sufficiently high to make it dielectric. Since the electrode and tank are fixed in place, the distance (d) is constant, capacitance is directly proportional to the level of the material acting as dielectric.

Conducting Material:

In conducting liquids, the probe plates are insulated using thin coating of glass or plastic to avoid short circuiting. The conductive material acts as the ground plate of the capacitor.

Proximity measurements (Non-contact type measurements):

In Proximity level measurement is the area of the capacitance plates is fixed, but distance between plates varies.

Proximity level measurement does not produce a linear output and are used when the level varies by several inches.

Advantages of Capacitive level measurement:

1. Relatively inexpensive
2. Versatile
3. Reliable
4. Requires minimal maintenance
5. Contains no moving parts
6. Easy to install and can be adapted easily for different size of vessels
7. Good range of measurement, from few cm to about 100 m
8. Rugged
9. Simple to use
10. Easy to clean
11. Can be designed for high temperature and pressure applications.

Applications:

Capacitance Level Probes are used for measuring level of

1. Liquids

2. Powered and granular solids
3. Liquid metals at very high temperature
4. Liquefied gases at very low temperature
5. Corrosive materials like hydrofluoric acid
6. Very high pressure industrial processes.

Disadvantages:

Light density materials under 20 lb/ft3 and materials with particle sizes exceeding 1/2 in. in diameter can be a problem due to their very low dielectric constants (caused by the large amount of air space between particles).

APPARATUS REQUIRED:

Capacitor level transmitter, ammeter, process tank, reservoir tank, pump, stopwatch, patch cards.

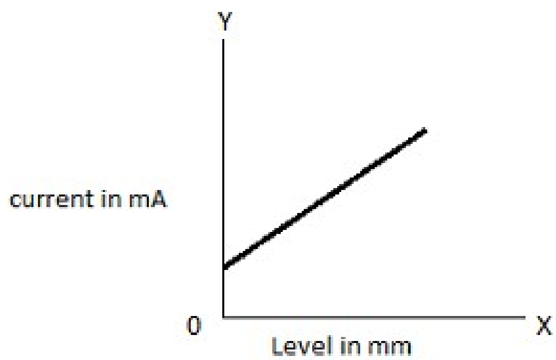
PROCEDURE:

1. Switch on the trainer.
2. Connect A1 to B1, A2 to B2 using patch cards.
3. Note down the value of ammeter reading for 0 level of liquid.
4. Raise the pump speed using variable speed knob.
5. Note down the ammeter reading for different level of fluid in the tank.
6. Plot the graph of level v/s ammeter reading .

TABULAR COLUMN

Level in mm	Current in mA

NATURE OF GRAPH:



RESULT:

EXPERIMENT 2: FLOW MEASUREMENT TRAINER

AIM: To study the characteristics of wheel flow meter and flow measurement using rota meter.

PRINCIPLE: The potential energy of fluid is being converted into mechanical energy that rotates the wheel blades, which in turn is converted into electrical energy. From the ammeter readings obtained for different rota meter valve settings, the relationship between the flow of water in wheel flow meter and the ammeter reading can be deduced.

THEORY: The accurate measurement of flow rate of liquids and gases is very essential for maintaining the quality of industrial processes. In fact, most of the industrial control loops control the flow rates of incoming liquids or gases in order to achieve the control objective. As a result, accurate measurement of flow rate is very important.

Flow measuring instruments may be broadly classified into

- Rate meters
- Quantity meters

The various rate meters are as follows:

- Head meters
- Area meters
- Velocity meters
- Thermal flow meters
- Electromagnetic meter etc

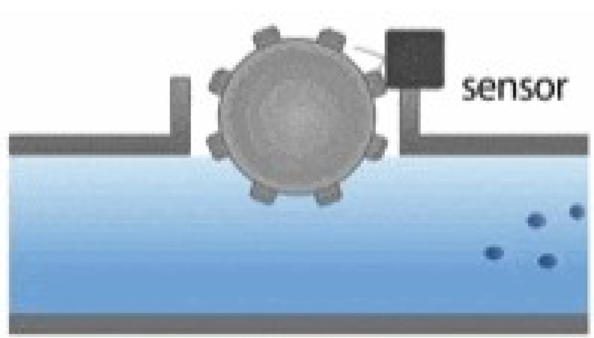
The various quantity meters are as follows:

- Nutating disc meter
- Rotarting lobe meter
- Reciprocating piston meter

- Tilting trap meter

Wheel Flow meter

A multiple jet or multijet meter is a velocity type meter which has an impeller which rotates horizontally on a vertical shaft. The impeller element is in a housing in which multiple inlet ports direct the fluid flow at the impeller causing it to rotate in a specific direction in proportion to the flow velocity. This meter works mechanically much like a single jet meter except that the ports direct the flow at the impeller equally from several points around the circumference of the element, not just one point; this minimizes uneven wear on the impeller and its shaft. Thus these types of meters are recommended to be installed horizontally with its roller index pointing skywards.



Rotameter: Rotameter is variable area meter that measures fluid flow by allowing the cross sectional area of the device to vary in response to the flow, causing some measurable effect that indicates the rate.

APPARATUS REQUIRED:

Rotameter, Wheel flow meter, Ammeter, Motor pump, Water reservoir, Variable speed knob

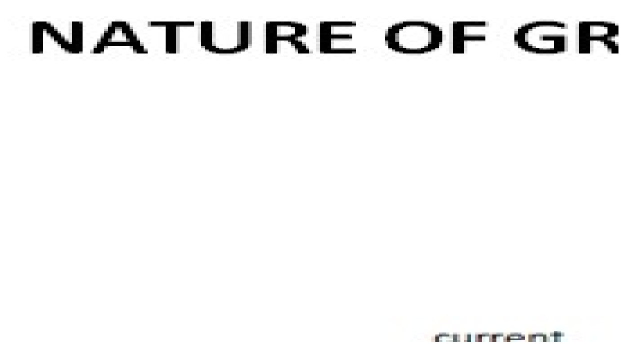
PROCEDURE:

1. Switch on the trainer.
2. Connect A1 to B1, A2 to B2 using patch cards.
3. Partially open the hand valve 1 to allow the water through wheel flow and rotameter
4. Raise the pump speed using variable speed knob.
5. Note down the ammeter reading for different flow rates in rotameter
6. Plot the graph of Flow rate v/s ammeter reading

TABULAR COLUMN:

Flow through rotameter LPH	Current in mA

NATURE OF GRAPH:



RESULT:

EXPERIMENT 3: STEP INPUT FOR THERMOMETER

AIM: To find the step response for step input change in a thermometer dipped in cold water & hot water.

PRINCIPLE:

Transfer function of 1st order system is given by $\left[\frac{1}{(\tau s+1)}\right]$

Step response of 1st order system is given by **A[1-**$e^{\frac{-t}{\tau}}$ **]**

APPARTUS REQUIRED

Mercury thermometer, beakers.

PROCEDURE:

1. Mercury thermometer was first placed in a beaker having cold/room temperature water
2. The first steady state temperature (t_s) was noted down.
3. Then suddenly the thermometer was placed in a beaker containing hot water.
4. The time taken for rise in temperature for every 10° C was noted down.
5. Time v/s Temperature graph was plotted.
6. The time constant was obtained from the graph.

TABULAR COLUMN

Temperature (^{o}C)	**Time (s)**

CALCULATIONS:

t_1 = First steady state temperature = ____________________

t_2 = Second steady state temperature = ____________________

T = t_1+ (t_1+ t_2) 0.632 = ________________

NATURE OF GRAPH:

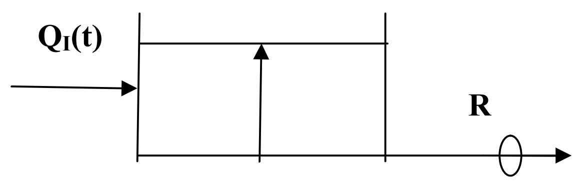
RESULT: From the graph, time constant of the system is τ = _______________

EXPERIMENT 4: SINGLE TANK SYSTEM

AIM: To find the response for a given step input in the single tank system

PRINCIPLE: Transfer function of first order system is given by 1/ (ƮS+1). Step response of first order system is given by A $(1-e^{-t/Ʈ})$

THEORY: Step input is the sudden input given to the system in steady state in order to obtain the response of the system.



PROCEDURE:

1. Switch on the unit
2. Set a flow of XLPH is in the rotameter by adjusting the valve HV1.
3. Wait for some time, so that level in the process tank1 reaches steady state valve.
4. Note down the steady level in process tank1.
5. Suddenly increase the inflow rate to process tank1 to Y LPH by adjusting HV1.
6. Tabulate the variation in level of process tank1 with respect to time until it reaches the new steady state.
7. Plot a graph of Level vs. time.
8. Calculate time constant of the system and Resistance of the system.

TABULAR COLUMN:

Level (cm)	**Time (s)**

CALCULATIONS:

h_1 = ______cm, where h_1 = steady state level of water,

h_2 = final level of water.

$H = h_1 + (h_2 - h_1)\ 0.632$

= _____ cm

Diameter of tank, d = _____ m

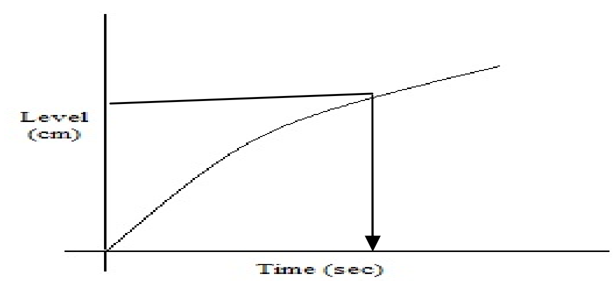
Area of tank, A = $(\pi d^2)/4$ = ______m^2

Ʈ from the graph =______sec

and

R = Ʈ / A = _____ Ω

NATURE OF GRAPH



RESULT: Time constant and resistance of the systems are……..

EXPERIMENT 5: NON INTERACTING SYSTEM

AIM: To find the response from the transfer function that relates H/Q for a given step input in the non-interacting tank system.

PRINCIPLE: The non-interacting fabricated is used for collecting the input, output data. In the setup, the water enters the atmosphere before entering tank2 (as shown in fig1). The steady state is attained in tank2 and the step input is provided from R1. The variation of the height at given periods of time, gives the behavioral graph of the apparatus. The observed step response of the tank level in different mode can be compared with mathematically predicted response and the process can be controlled.

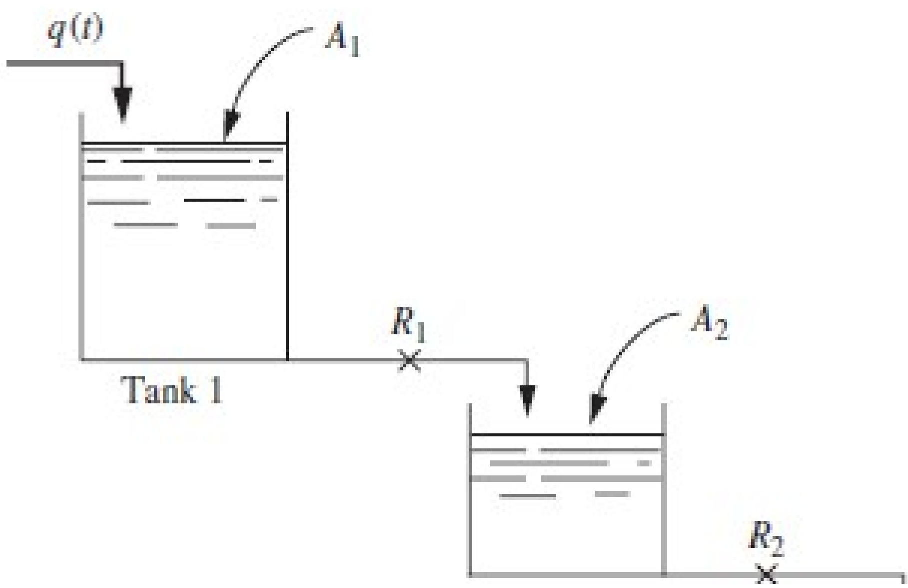


Fig 1:Schematic representation of non interacting system

PROCEDURE:

Tank 1:

1. Switch on the unit.
2. Set a flow rate of XLPH in the rotameter by adjusting the valve HV1.
3. Wait for some time, so that level in the process tank1 reaches steady state valve.
4. Note down the steady state level in process tank1 .

5. Give a step input of Y LPH by adjusting HV1.
6. Tabulate Variation in level of process tank1 with respect to time until it reaches the new steady state h_2.
7. Plot a graph and Calculate the resistance and constant for tank1.

Tank :2

1. Switch on the unit.
2. Set a flow rate of XLPH in the tank by adjusting the valve HV2.
3. Wait for some time, so that level in the process tank2 reaches steady state valve.
4. Note down the steady state level in process tank2 .
5. Give a step input of Y LPH by adjusting HV2.
6. Tabulate Variation in level of process tank1 with respect to time until it reaches the new steady state h_2.
7. Plot a graph and calculate the resistance and constant for tank2.

Overall system:

1. Attain a steady state in tank 2 by using all 3 valves.
2. Give the inflow rate to process tank2 by using hand valve2
3. Tabulate Variation in level of process tank2 with respect to time unit it reaches the new steady state h2 m.
4. Plot a graph of Level Vs time .
5. Calculate the resistance and time constant for overall process.

TABULAR COLUMN

Level in cm	Time in s

CALCULATIONS:

h_1 = ______cm, where h_1 = steady state level of water,

h_2 = final level of water.

$H = h_1 + (h_2 - h_1)\ 0.632$

= _____ cm

Diameter of tank, d = _____ m

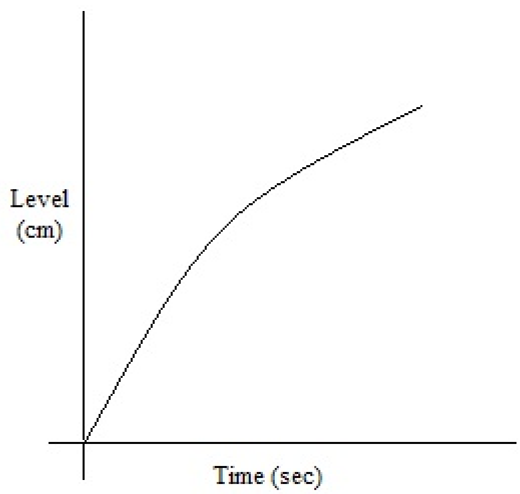
Area of tank, A = $(\pi d^2)/4$ =______m^2

Ʈ from the graph =______sec

and

R = Ʈ / A = _____ Ω

NATURE OF GRAPH:



RESULT:

EXPERIMENT 6: INTERACTING SYSTEM

AIM: To find the response from the transfer function that relates H/Q for a given step input in the interacting tank system.

PRINCIPLE: The interacting system is fabricated is used for collecting the input, output data. In the setup, the water enters the tank2 with out entering into atmosphere (as shown in fig1). The steady state is attained in tank2 and the step input is provided from R1. The variation of the height at given periods of time, gives the behavioral graph of the apparatus. The observed step response of the tank level in different mode can be compared with mathematically predicted response and the process can be controlled.

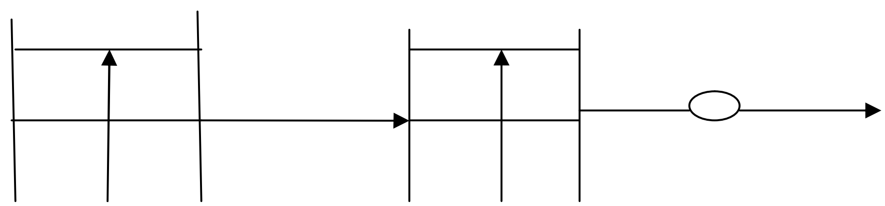


Fig 1:Schematic representation of non interacting system

PROCEDURE:

Tank 1:

1. Switch on the unit.
2. Set a flow rate of XLPH in the rotameter by adjusting the valve HV1.
3. Wait for some time, so that level in the process tank1 reaches steady state valve.
4. Note down the steady state level in process tank1 .
5. Give a step input of Y LPH by adjusting HV1.
6. Tabulate Variation in level of process tank1 with respect to time until it reaches the new steady state h_2.
7. Plot a graph and Calculate the resistance and constant for tank1.

Tank :2

1. Switch on the unit.
2. Set a flow rate of XLPH in the tank by adjusting the valve HV2.
3. Wait for some time, so that level in the process tank2 reaches steady state valve.
4. Note down the steady state level in process tank2 .

5. Give a step input of Y LPH by adjusting HV2.
6. Tabulate Variation in level of process tank1 with respect to time until it reaches the new steady state h_2.
7. Plot a graph and calculate the resistance and constant for tank2.

Overall system:

1. Attain a steady state in tank 2 by using all 3 valves.
2. Give the inflow rate to process tank by using hand valve2 without disturbing any valves.
3. Tabulate Variation in level of process tank2 with respect to time until it reaches the new steady state h2 m.
4. Plot a graph of Level Vs time .
5. Calculate the resistance and time constant for overall process.

TABULAR COLUMN

Level in cm	Time in s

CALCULATIONS:

h_1 = ______cm, where h_1 = steady state level of water,

h_2 = final level of water.

$H = h_1 + (h_2 - h_1)\, 0.632$

= _____ cm

Diameter of tank, d = _____ m

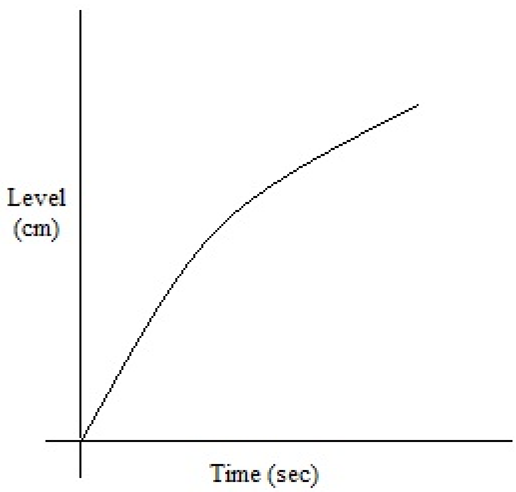
Area of tank, A = $(\pi d^2)/4$ = ______m^2

Ʈ from the graph =______sec

and

R = Ʈ / A = _____ Ω

NATURE OF GRAPH:



RESULT:

EXPERIMENT 7: THERMOCOUPLE TRAINER

AIM: To study the characteristics of thermocouple

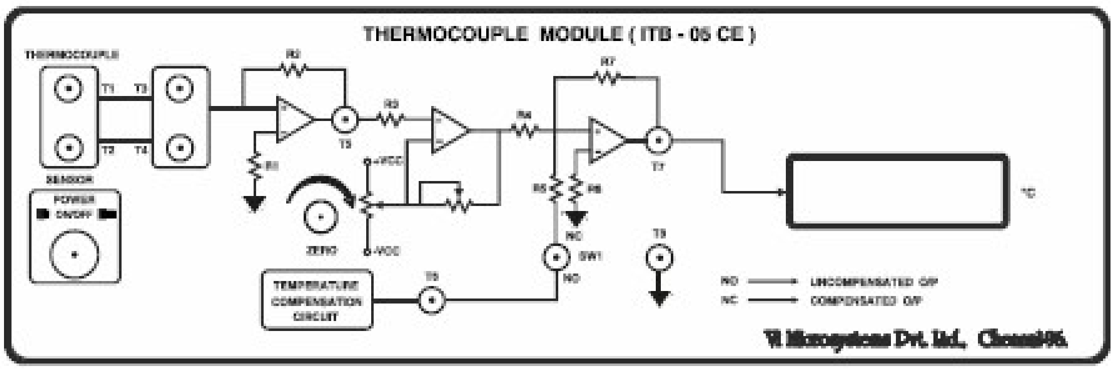
INTRODUCTION:
Temperature measurement plays a major role in industrial application. The various sensors which is used to measure the temperature are thermocouple, RTD, Thermistor etc. Due to the salient features of thermocouple, it is being widely used in industries. Based on the thermoelectric principle, it senses the temperature of the medium. The two junction temperature difference is directly proportional to the generated emf, which is a measure of temperature. This unit helps to study the characteristics of thermocouple with and without compensation. Temperature compensation is performed byAD590 temperature sensor. From this compensation technique, any one can calibrate the thermocouple for desired temperature measurement.

TECHNICAL SPECIFICATION
i. ITB - 05CE
- Unit & Working Temperature - 15°C - 50°C
- Accuracy - 1.5% of Full scale division.
- Linearity - 1875% of Full scale division.
- Size - 370 × 280 × 90m
- Cabinet - Mild Steel

ii. Thermocouple
- Type - J type
- Material - Iron constant
- Tube Diameter - 6mm
- Working Temperature - -200 to 760 °C
- Tube Length - 120mm
- Thermowell material - Stainless steel
- Coating - Nickel, Chromium

iii. LED Display
- Size - 50 × 20mm & Type - Common anode
- Display - 3.5 Digit
- Segment - 7 Segment
- Colour - Green iv Power Supply
- Input - 230V AC / 50Hz
- Output - +5V / 1A -5V / 500mA +12V / 500mA -12V / 500mA

FRONT PANEL DIAGRAM



FRONT PANEL DESCRIPTION

- Power ON/OFF - Power ON/OFF switch is used to ON/OFF the unit. (Push Button) T/C sensor (T1, T2) - Used to connect the thermocouple terminals.
- T3, T4 - Used to measure the thermocouple output (mV).
- T5 - To measure the amplified output.
- T6 - To measure the AD590 sensor output.
- T7 - To measure the signal conditioner output.
- T8 - GND
- SW1 - To select either uncompensated or compensated output.
  Compensated output : Place the switch SW1 towards NC.
  Uncompensated output : Place the switch SW1 towards NO.
- Zero - Adjust this knob to set 0°C in display at room temperature. When the compensated mode.
- (LED) display - Shows the temperature in Celsius

THEORY: The thermocouple is one of the simplest and most commonly used methods of measuring process temperatures. The operation of a thermocouple is based upon Seeback effect which states that when heat is applied to junction (hot junction) of two dissimilar metals, an emf is generated which can be measured at the other junction (cold junction). The two dissimilar metals form an electric circuit, and a current flows as a result of the generated emf as shown in Fig.1

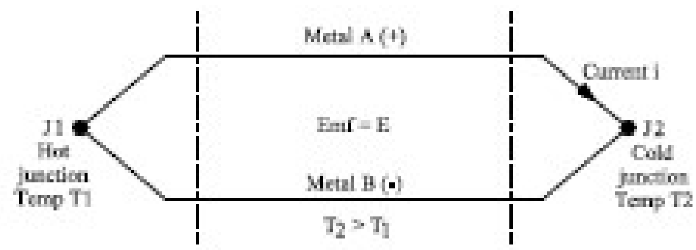


Figure 1

The emf produced is function of the difference in temperature of hot and cold junctions and is given by: $E = a\Delta\theta$ where $\Delta\theta$ = difference between temperatures of hot and cold junctions.

APPARATUS REQUIRED

i. ITB-05CE
ii. Thermocouple (J)
iii. Water bath
iv. Thermometer
v. Digital multi meter
vi. Power Chord.

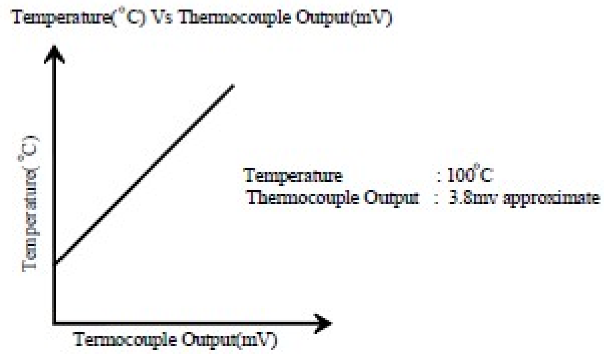
PROCEDURE

1. Connect the two terminals of the thermocouple across T1 & T2.
2. Insert the thermocouple and thermometer into the water bath.
3. Place the Multimeter (millivolts mode) across T3 and T4.
4. Switch ON the water bath and note the temperature in thermometer and mV in Multimerter.
5. Tabulate the readings temperature Vs mV and plot the graph.

TABULAR COLUMN

Actual Temperature (^{0}C)	Thermocouple Output (mV)

NATURE OF GRAPH



RESULT: Thus the characteristics of thermocouple was studied and graph is plotted.

EXPERIMENT 8: THERMOCOUPLE WITHOUT COMPENSATION

AIM: To study the characteristics of thermocouple without compensation

APPARATUS REQUIRED

i. ITB-05CE
ii. Thermocouple (J)
iii. Water bath
iv. Thermometer
v. Digital multi meter
vi. Power Chord.

PROCEDURE

1. Connect the two terminals of the thermocouple across T1 & T2.
2. Position the switch ‘SW1' towards ‘NO’.
3. Switch ‘ON’ the unit and note the displayed temperature.
4. If there is any difference in displayed temperature at room temperature, adjust the offset knob ‘Zero’ to set 0°C in display.
5. Insert the thermocouple and thermometer into the water bath.
6. Switch ‘ON’ the water bath.
7. Note the actual temperature in thermometer and displayed temperature simultaneously.
8. Tabulate the reading and calculate %Error using the formula.
9. Plot the graph actual Temperature Vs% Error.

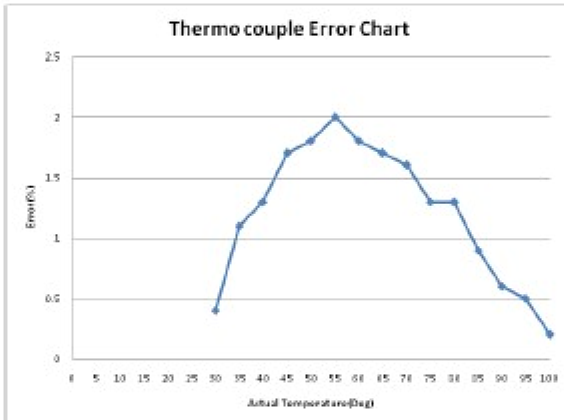
FORMULA:

$$\%E = \frac{\text{Actual Temp - Displayed Temp}}{\text{Full Scale division}} \times 100$$

TABULAR COLUMN

Actual Temperature (^{0}C)	Displayed Temperature (^{0}C)	% Error

NATURE OF GRAPH



RESULT: Thus the characteristics of thermocouple without compensation was studied and graph is plotted.

EXPERIMENT 9: THERMOCOUPLE WITH COMPENSATION

AIM: To study the characteristics of thermocouple with compensation

APPARATUS REQUIRED

i. ITB-05CE
ii. Thermocouple (J)
iii. Water bath
iv. Thermometer
v. Digital multi meter
vi. Power Chord.

PROCEDURE

1. Connect the two terminals of the thermocouple across T1 & T2.
2. Position the switch ‘SW1' towards ‘NO’.
3. If there is any difference in displayed temperature at room temperature, adjust the offset knob ‘Zero’ to set 0°C in display.
4. Switch ‘ON’ the unit and note the displayed temperature.
5. Insert the thermocouple and thermometer into the water bath.
6. Place the multimeter across T7 & T8.
7. Position the switch ‘SW1' towards the ‘NC’.
8. Switch ‘ON’ the water bath.
9. Note the actual temperature in thermometer, voltage in multimeter and displayed temperature simultaneously.
10. Tabulate the reading and calculate %Error using the formula.
11. Plot the graph for i. Actual Temperature Vs % Error. ii. Actual Temperature Vs signal conditioner output

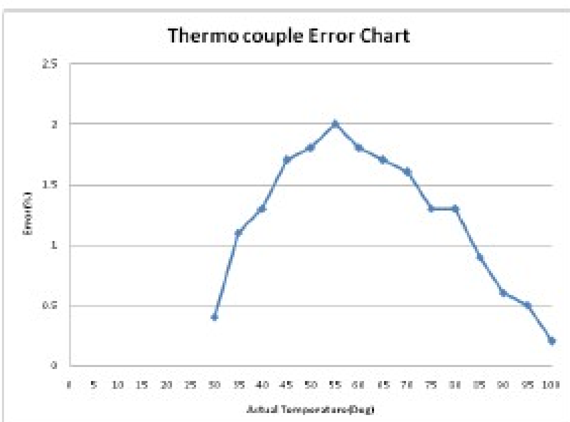
FORMULA:

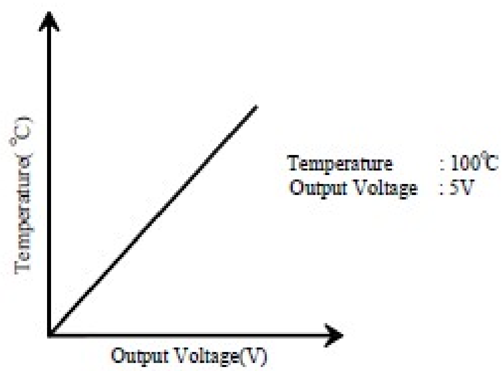
$$\%E = \frac{\text{Actual Temp - Displayed Temp}}{\text{Full Scale division}} \times 100$$

TABULAR COLUMN

Actual Temperature (^{0}C)	**Displayed Temperature (^{0}C)**	**Signal Conditioner Output (V)**	**% Error**

NATURE OF GRAPH





RESULT: Thus the characteristics of thermocouple with compensation was studied and graph is plotted

EXPERIMENT 10: RTD CHARACTERISTICS

THEORY: Temperature measurement is one of the earliest areas of metrology and its use in control and instrumentation is significant. This being one of the most important concept, we have released this ITB-06CE card in our series of Instrumentation Trainer Boards, which would help the students to bring out their ideas in a very simple way.

Temperature measurement

There are, in general, four types of sensors based on the following physical properties, which are temperature dependent:

1. Expansion of a substance with temperature, which produces a change in length, volume or pressure. In it's simplest form this is the common mercury-in-glass or alcohol-in-glass thermometer.
2. Changes in contact potential between dissimilar metals with temperature, thermocouple.
3. Changes in radiated energy with temperature, optical and radiation pyrometers.
4. Changes in electrical resistance with temperature, used in resistance thermometers and thermistors.

The fourth property is used in our design, to create a sensor. Resistance thermometry requires a resistor properly mounted to create a sensor and by means of measuring the resistance of the sensor.

TECHNICAL SPECIFICATIONS

RTD Sensor

- Type : Pt100 (100□ @ 0°C)
- Material : Platinum (Protected by stainless steel sheath)
- Resolution : 0.292 to 0.39□/°C
- Accuracy : ±0.6@100°C
- Temperature Range : -200 to 850°C
- Tube size : 120mm × 8mm
- Connection through two core retractable lead (1 Meter Extended)
- Thermowell material : Stainless steel
- Coating : Nickel, chromium

ITB-006CE

- Operating Temperature : 10°C - 55°C
- Cabinet Material : Mild Steel with powder coating
- Accuracy : 0.7% Full Scale Deflection

- Linearity : 1.8% Full Scale Deflection
- Dimension : 370mm × 280mm × 90mm

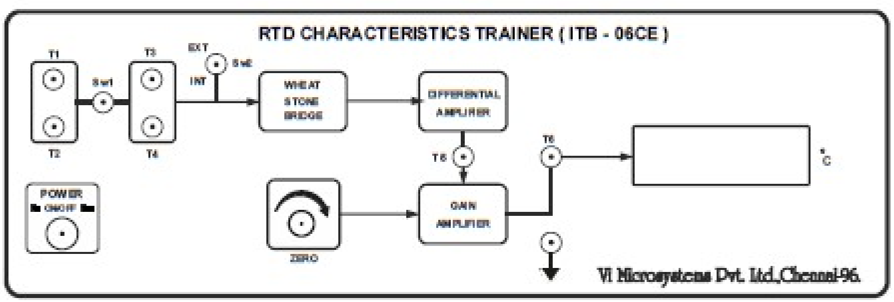
LED Display

- Size : 50 × 20 mm
- Type : Common Anode
- Display : 3.5 Digit
- Segment : Seven Segment
- Colour : Red

Power Supply

- Input : 230V AC / 50Hz
- Output : +5V / 1A
- -5V / 500mA
- +12V / 500mA
- -12V / 500mA

FRONT PANEL DIAGRAM



FRONT PANEL DESCRIPTION

- Power ON/OFF Switch : To Switch ON / OFF the unit.
- T1 & T2 : These are used to connect the two terminals of RTD.
- SW1 : To select the resistance mode.
- T3 & T4 : To measure the resistance value of RTD.
- SW2 : This switch is used to select the internal / External mode of
- operation.
- INT - place the switch SW2 towards downward.
- EXT - place the switch SW2 towards upward.
- T5 : To measure the differential amplifier output voltage.
- T6 : To measure the signal conditioner output voltage.
- T7 : This terminal is the common GND terminal.

- 3.5 LED Display : It displays the RTD sensor output interims of °C.

RTD CHARACTERISTICS TRAINER ITB-06CE

The lead wires used to connect the RTD to a readout can contribute to the measurement error, especially when there are long lead lengths involved, as often happens in remote temperature measurement locations. Those calculations are straight forward and there exist 3-wire and 4-wire designs to help minimize or limit such errors, when needed.

Often the lead error can be minimized through use of a temperature transmitter mounted close to the RTD. Transmitters convert the resistance measurement to an analog current or serial digital signal that can be sent long distances by wire or rf to a data acquisition or control system and/or indicator. RTDs, as mentioned above, work in a relatively small temperature domain, compared to thermocouple, typically from about -200°C to a practical maximum of about 650°C to 700 °C. RTDs can be made cheaply in Copper and Nickel, but the latter have restricted ranges because of non-linearities and wire oxidation problems in the case of Copper. Platinum is the preferred material for precision measurement because in its pure form the Temperature Coefficient of Resistance is nearly linear; enough so that temperature measurements with precision of ±0.1 °C can be readily achieved with moderately priced devices. Better resolution is possible, but equipment costs escalate rapidly at smaller error levels.

AIM(1) : To study the temperature Vs resistance characteristics of RTD

PRINCIPLE: All RTDs used in precise temperature measurements are made of Platinum and they are sometimes called PRTs to distinguish them. RTD works on the principle that electrical resistance
of the most metals increases linearly with temperature. If a metal wire has a Resistance R0 at 0°C,
then the resistance at T°C will be given by:

$$R_t = R_o (1+\alpha T)$$

The constant α is called the temperature coefficient of resistance.

A temperature transducer using the above principle is called Resistance Temperature Detectors(RTDs) These are simple to use, requiring no special wiring, are highly stable and very sensitive. RTD's commonly use Platinum, nickel and copper to form the sensor (see Figure-2), although iron, tungsten and alloys can be used. The former metals have the advantage that they can be obtained to high degrees of chemical purity.

APPARATUS REQUIRED

1. ITB-06CE
2. RTD sensor
3. Water Bath
4. Thermometer
5. Multimeter (optional)

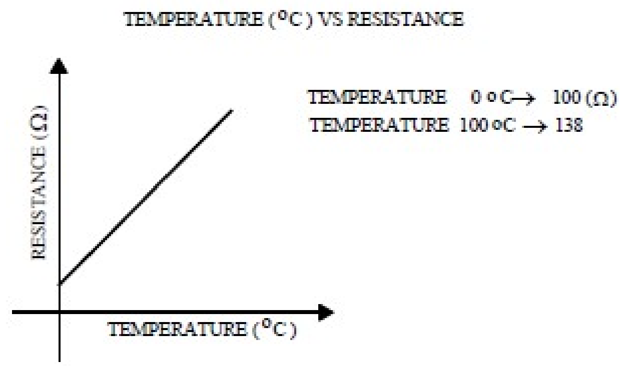
PROCEDURE

1. Patch the wires of RTD to the T1 and T2 terminal of the RTD input block and switch ON the unit.
2. Place the RTD and thermometer into the holes provides in the waterbath.
3. Keep the SW1 in right direction.
4. Place the multimeter in the resistance mode across T3 and T4 terminals.
5. Switch ON the waterbath and note the temperature in thermometer and corresponding resistance value in multimeter.
6. Plot the temperature Vs resistance graph.

TABULAR COLUMN

Temperature (^{0}C)	**Resistance (Ω)**

NATURE OF GRAPH



RESULT: Thus the study of Temperature Vs Resistance characteristics was studied and graph is plotted.

PRECAUTIONS
1. Gradually heat the water and note the corresponding resistance simultaneously.
2. The multimeter / ohmmeter should be in the range (0-200)Ω to measure for (0-100)°C.

AIM(2): To study the temperature Vs voltage characteristics and the accuracy of the signal conditioning board.

APPARATUS REQUIRED
1. ITB-06CE
2. RTD sensor
3. Water Bath
4. Thermometer
5. Multimeter (optional)
6. Power

PROCEDURE
1. Patch the wires of RTD to the T1 and T2 terminal of the RTD input block.
2. Switch ON the ITB-06CE Unit.
3. Keep the switch SW1 in left direction and switch SW2 in external mode.
4. Now adjust the 'Zero' Potentiometer to read 0°C at the display. This is done for initial setup

of the unit and this adjustment should be left undisturbed.

5. Place the multimeter in voltage mode across the T6 and T7 terminals.
6. Insert the RTD and thermometer into the waterbath and note the temperature without any heating at ambient condition.
7. Switch ON the waterbath and note down the actual temperature in thermometer, output voltage of the unit and the displayed temperature simultaneously.
8. Plot the graph for Actual Temperature Vs Voltage.
9. Calculate the % error and plot the graph for Temperature Vs % Error.

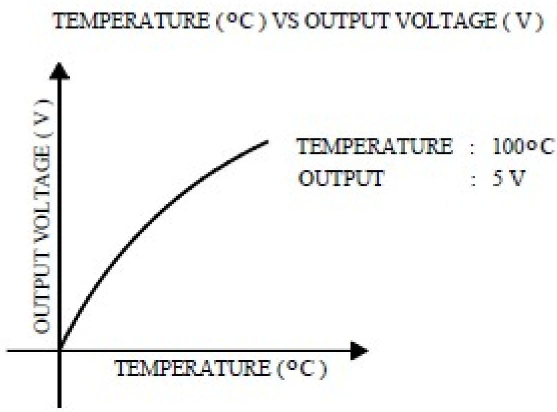
FORMULA

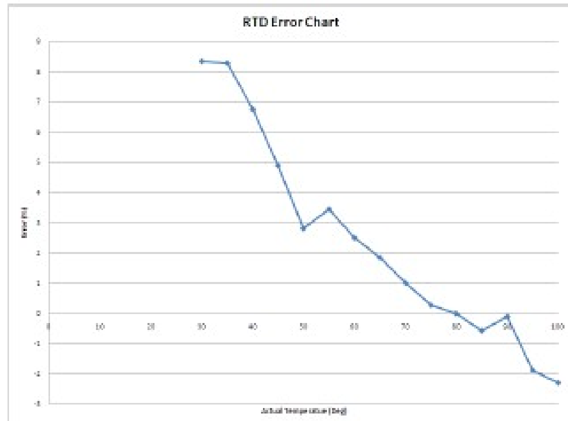
$$\%E = \frac{\text{Actual Temp - Displayed Temp}}{\text{Full Scale division}} \times 100$$

TABULAR COLUMN

Actual Temperature (^{0}C)	**Output Voltage (V)**	**Desired Temperature (^{0}C)**	**% Error**

NATURE OF GRAPH





RESULT: Thus the study of Temperature Vs Voltage and the accuracy of signal conditioning board was studied and the graph is drawn.

EXPERIMENT 11: PROCESS CONTROL SIMULATOR (OPEN LOOP)

INTRODUCTION:

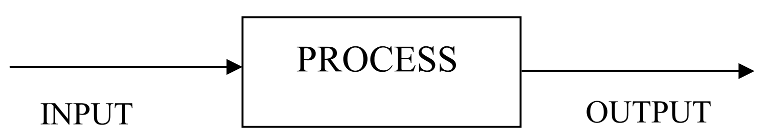
The process control simulator is a special purpose analog simulator with operational amplifiers. The simulator permits a detailed analysis of the first order, second order and third order systems and the application of proportional, integral and derivative control to the improvement of their performance. The simulator may be used at high speed for oscilloscope observation or at a low speed for meter observation.

AIM:

To study the open loop response of a simple process

PRINCIPLE:

A system in which no comparison is made between the actual value and the desired value of process variable is open loop system.



THEORY:

The open loop system is also called as feed forward control system. In this system there is no comparison between the input and output of the system. Hence error cannot be estimated. As a result there is no control over the output of the system

Proportional control:
To overcome the above problem Proportional control is used which is also called "Throttling" or "Gradual" or "Modulating" control action. This is defined as controlled action in which there is a continuous linear relation between value of controlled variable and position of the final control element with in proportional band.

$$(y - y_0) = Kp\ (x - x_0)$$

Where, $(y - y_0)$ is the change in valve position for a change in controlled variable $(x - x_0)$ form set-point and Kp is proportional gain.

Tuning parameters are;
1. Proportional Band
2. Proportional Gain (Kp)
3. Time delay

Proportional Band(PB): The percentage deviation in measured variable corresponding to 100% deviation in FCE.

$$PB(\%) = 100 / [Kp(\%)]$$

The disadvantage of this mode is sustained deviation from set-point which is called "Offset".

Proportional plus Integral control (PI):

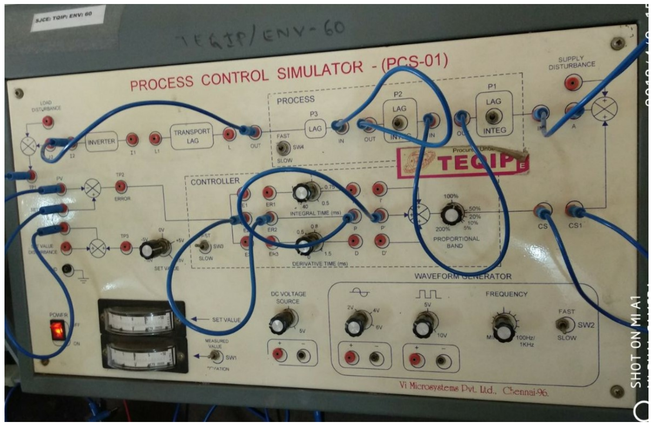
"Integral control" or "reset control" combined with proportional control gives a controller action which always acts to maintain the controlled variable at set-point. The proportional control mode provides stabilizing influence while integral mode will help to overcome Offset. Integral controller provides corrective action as long as there is deviation in controlled variable form set-point. Integral control has a phase lag of 90º over proportional control and this lagging feature will result in slow response. The combination is most popular in applications of flow and pressure controls.

Proportional plus Derivative control (PD):

"Derivative control" or "Rate control" combined with proportional control provides a good control on processes having lags, since lags are compensated by anticipatory nature of derivative control or it provides the boost necessary to counteract the time delay associated. This is due to the fact that derivative control leads the proportional control by 90º. Hence this control is 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 sustained load disturbance because of narrow proportional band. This control properly tuned can act to prevent controlled variable from deviating excessively and reduces the time required to stabilize.

Proportional plus Integral plus Derivative control (PID)

When all the three control effects are combined together, we obtain the benefits of each control action and moreover the effect duplicates the action of a good human operator. Three mode controller contains "stability" of proportional control and ability to eliminate "Offset" because of reset control and ability to provide an "immediate correction" (anticipatory control) for a disturbance because of rate control.



PROCEDURE:

1. The unit was switched on and the patch cords was connected as shown in figure
2. Using set value control different inputs are given
3. Note down the relative readings
4. Calculate the % Error
5. Also change control modes to PI, PD and PID and calculate the % Error

TABULAR COLUMN

SL.No	SET VALUE	MEASURED VALUE	% ERROR

FORMULA:

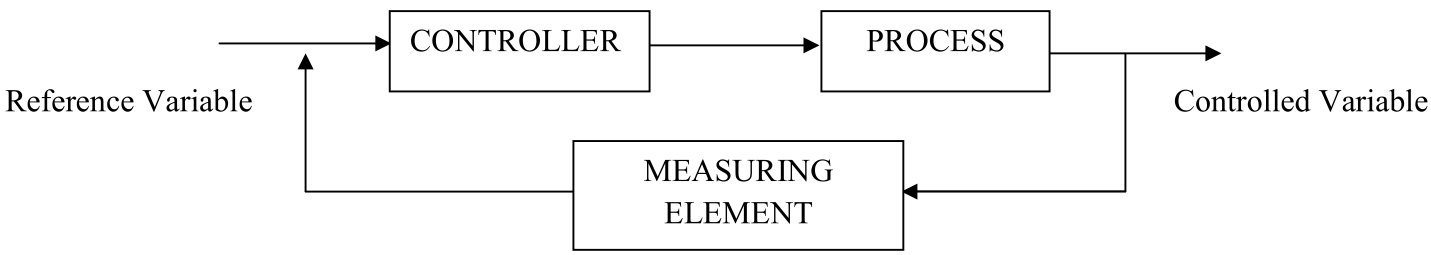
$$\% \text{ ERROR} = \frac{\text{Set Value} - \text{Measured Value}}{\text{Set Value}} \times 100$$

RESULT:

EXPERIMENT 12: PROCESS CONTROL SIMULATOR (CLOSED LOOP PROCESS)

AIM : To study the closed response of a simple process

PRINCIPLE: A control system in which comparision is made between actual value and desired value of process variables and then passes the information to the controller in such a way that it will reduce the deviation from its standard value is called closed loop control system



THEORY:

The closed loop system is also called feed backward control system. There is comparison between the input and output and uses difference between the two to drive the output in close correspondence.

Proportional control:

To overcome the above problem Proportional control is used which is also called "Throttling" or "Gradual" or "Modulating" control action. This is defined as controlled action in which there is a continuous linear relation between value of controlled variable and position of the final control element with in proportional band.

$$(y - y_0) = Kp\ (x - x_0)$$

Where, $(y - y_0)$ is the change in valve position for a change in controlled variable $(x - x_0)$ form set-point and Kp is proportional gain.

Tuning parameters are;

1. Proportional Band
2. Proportional Gain (Kp)
3. Time delay

Proportional Band(PB): The percentage deviation in measured variable corresponding to 100% deviation in FCE.

$$PB(\%) = 100 / [Kp(\%)]$$

The disadvantage of this mode is sustained deviation from set-point which is called "Offset".

Proportional plus Integral control (PI):

"Integral control" or "reset control" combined with proportional control gives a controller action which always acts to maintain the controlled variable at set-point. The proportional control mode provides stabilizing influence while integral mode will help to overcome Offset. Integral controller provides corrective action as long as there is deviation in controlled variable form set-point. Integral control has a phase lag of 90º over proportional control and this lagging feature will result in slow response. The combination is most popular in applications of flow and pressure controls.

Proportional plus Derivative control (PD):

"Derivative control" or "Rate control" combined with proportional control provides a good control on processes having lags, since lags are compensated by anticipatory nature of derivative control or it provides the boost necessary to counteract the time delay associated. This is due to the fact that derivative control leads the proportional control by 90º. Hence this control is 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 sustained load disturbance because of narrow proportional band. This control properly tuned can act to prevent controlled variable from deviating excessively and reduces the time required to stabilize.

Proportional plus Integral plus Derivative control (PID)

When all the three control effects are combined together, we obtain the benefits of each control action and moreover the effect duplicates the action of a good human operator. Three mode controller contains "stability" of proportional control and ability to eliminate "Offset" because of reset control and ability to provide an "immediate correction" (anticipatory control) for a disturbance because of rate control.

PROCEDURE:

1. The unit was switched on and the patch cords was connected as shown in figure
2. Using set value control different inputs are given
3. Note down the relative readings
4. Calculate the % Error
5. Also change control modes to PI, PD and PID and calculate the % Error

TABULAR COLUMN

SL.No	SET VALUE	MEASURED VALUE	% ERROR

FORMULA:

$$\% \text{ ERROR} = \frac{\text{Set Value} - \text{Measured Value}}{\text{Set Value}} \times 100$$

RESULT:

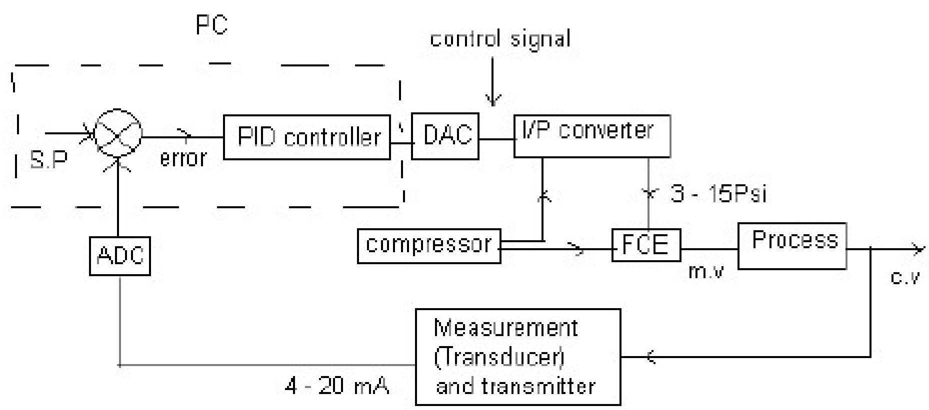
EXPERIMENT 13: PRESSURE PROCESS CONTROLLER

AIM: To study the action of following control modes for a pressure process using process control software

1. On-Off control
2. proportional control (P)
3. Proportional plus Integral control (PI)
4. Proportional plus Derivative control (PD)
5. PID control

Tools and Testing Equipment Required:

Work bench or process station
Patch cords
PC
Process control software



Block diagram of Pressure Process Control System

THEORY:

ON-OFF control:

"ON-OFF" control also referred as "Two-position" control and "Open and close" control in which the manipulated variable is quickly changed to either maximum or minimum value depending upon whether the controlled variable is greater than or less than set-point. If the controlled variable is below set-point the controller output is 100% and if the controlled variable is more than set-point the controller output is 0% considering "zero" differential gap. If differential gap is introduced, then the controller output is generated only when the controlled variable crosses above or below differential gap. Differential gap is defined as "A small range of values through which the controlled variable must pass in order to move the FCE to both its extreme positions".

This type of control applied to a process results in continuous oscillation of controlled variable and it never reaches steady value.

Proportional control:

To overcome the above problem Proportional control is used which is also called "Throttling" or "Gradual" or "Modulating" control action. This is defined as controlled action in which there is a continuous linear relation between value of controlled variable and position of the final control element with in proportional band.

$$(y - y_0) = Kp\ (x - x_0)$$

Where, $(y - y_0)$ is the change in valve position for a change in controlled variable $(x - x_0)$ form set-point and Kp is proportional gain.

Tuning parameters are;

1. Proportional Band
2. Proportional Gain (Kp)
3. Time delay

Proportional Band(PB): The percentage deviation in measured variable corresponding to 100% deviation in FCE.

$$PB(\%) = 100 / [Kp(\%)]$$

The disadvantage of this mode is sustained deviation from set-point which is called "Offset".

Proportional plus Integral control (PI):

"Integral control" or "reset control" combined with proportional control gives a controller action which always acts to maintain the controlled variable at set-point. The proportional control mode provides stabilizing influence while integral mode will help to overcome Offset. Integral controller provides corrective action as long as there is deviation in controlled variable form set-point. Integral control has a phase lag of 90º over proportional control and this lagging feature will result in slow response. The combination is most popular in applications of flow and pressure controls.

Proportional plus Derivative control (PD):

"Derivative control" or "Rate control" combined with proportional control provides a good control on processes having lags, since lags are compensated by anticipatory nature of derivative control or it provides the boost necessary to counteract the time delay associated. This is due to the fact that derivative control leads the proportional control by 90º. Hence this control is 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 sustained load disturbance because of narrow proportional band. This control properly tuned can act to prevent controlled variable from deviating excessively and reduces the time required to stabilize.

Proportional plus Integral plus Derivative control (PID)

When all the three control effects are combined together, we obtain the benefits of each control action and moreover the effect duplicates the action of a good human operator. Three mode controller contains "stability" of proportional control and ability to eliminate "Offset" because of reset control and ability to provide an "immediate correction" (anticipatory control) for a disturbance because of rate control.

PROCEDURE:

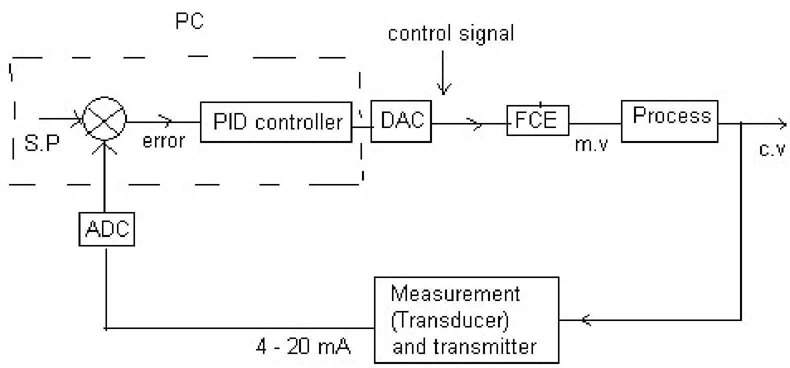
1. Ensure that the VPCS cable is connected between PC and Analyser.
2. Connect the air terminations FR1 TO FR2.
3. Using HV1 adjust the pressure to 20 PSI.
4. Run the process control software on the PC and select any of the control action by using "Control" menu.
5. Select ON-Off control mode
6. Set the desired values of Set point and Differential gap by using "settings/parameters‟ in Menu
7. View the response by changing set-point and differential gap.
8. Also by varying HV2 positions (pressure in the vessel) see the process response.
9. Change the control mode to "Proportional" and observe the response.
10. Also change control modes to PI, PD and PID and observe the responses.

RESULT:

EXPERIMENT 14: TEMPERATURE PROCESS CONTROLLER

AIM: To study the action of temperature process using,
1. On-Off control
2. proportional control
3. Proportional Integral control
4. Proportional Derivative control
5. PID control
and to obtain the characteristics for different control modes.

TOOLS AND TESTING EQUIPMENT REQUIRED:
Process station, Patch cords, PC, Process control software



Block diagram of Temperature Process System

THEORY:
Initially SCR unit is triggered ON which in turn switches the heater ON. Chamber gets heated up and temperature is sensed by thermocouple. Transmitter output is connected to PC through DA & C Board. Here PC acts as controller. When there is change in temperature from set-point control signals are generated depending on control mode which drives the SCR unit, in turn it controls the heater.

On-Off control:
"ON-Off" control also referred as "Two-position" control and "Open and close" control in which the manipulated variable is quickly changed to either maximum or minimum value depending upon whether the controlled variable is greater than or less than set-point. If the controlled variable is below set-point the controller output is 100% and if the controlled variable is more than set-point the controller output is 0% considering "0" differential gap. If differential gap is

introduced, then the controller output is generated only when the controlled variable crosses above or below differential gap. Differential gap is defined as "A small range of values through which the controlled variable must pass in order to move the FCE to both its extreme positions". Here in this experiment "the number of degrees of temperature change necessary to go from ON to OFF or vice-versa of FCE"

This type of control applied to a process results in continuous oscillation of controlled variable and it never reaches steady value.

Proportional control:

To overcome the above problem Proportional control is used which is also called "Throttling" or "Gradual" or "Modulating" control action. This is defined as control action in which there is a continuous linear relation between value of controlled variable and position of the final control element with in proportional band.

$$(y - y_0) = Kp\ (x - x_0)$$

Where, $(y - y_0)$ is the change in valve position for a change in controlled variable (x – x0) form set-point and Kp is proportional gain.

Tuning parameters are;

1. Proportional Band
2. Proportional Gain
3. Time delay

Proportional Band: The percentage deviation in measured variable corresponding to 100% deviation in FCE.

$$P.B = \frac{\Delta x}{\Delta y}\ \frac{1}{Up}\ 100$$

The disadvantage of this mode is sustained deviation from set-point which is called "OFFSET".

Proportional Integral control:

"Integra control" or "reset control" combined with proportional control gives a controller action which always acts to maintain the controlled variable at set-point. The proportional control mode provides stabilizing influence while integral mode will help to overcome Offset. Integral controller provides corrective action as long as there is deviation in controlled variable form set-point. Integral control has a phase lag of 90º over proportional control and this lagging feature will result in slow response. The combination is most popular on applications of flow and pressure controls.

$$\frac{dy}{dt}\ \alpha\ (x - xo)$$

Proportional Derivative control:

"Derivative control" or "Rate control" combined with Proportional Control provides a good control on processes having lags, since lags are compensated by anticipatory nature of derivative control or it provides the boost necessary to counter act the time delay associated. This is due to the fact that derivative control leads the proportional control by 90º. Hence this control is used on most multicapacity process applications.

Where the process lag is short, this combination could not be used. This controller combination does not eliminate Offset after sustained load disturbance because of narrow proportional band. This control properly tuned can act to prevent controlled variable from deviating excessively and reduces the time required to stabilize.

$$(y-yo) = -Ur \frac{dx}{dt}$$

Proportional Integral Derivative control:

When all the three control effects are combined together, we obtain the benefits of each control action and moreover the effect duplicates the action of a good human operator. Three mode controller contains "stability" of proportional control and ability to eliminate "Offset" because of reset control and ability to provide an "immediate correction" (anticipatory control) for a disturbance because of rate control.

PROCEDURE:

1. Make the connections as shown in the diagram.
2. Ensure that the VPCS cable is connected between PC and Analyzer.
3. Put the heater supply in ON position.
4. Run the process control software on the PC and press any of the control action by using "Control" menu.
5. Place the control mode in „On-Off" mode.
6. In „settings / parameters" menu set set-point & Differential gap. Observe the response.
7. View the response by changing set-point and differential gap.
8.Change the control mode to „Proportional" and observe the response.
9. Also change control modes to PI, PD and PID observe the responses. Also observe responses by change of settings.

RESULT: