

PROCESS CONTROL LAB LAB MANUAL

For Temperature Control Trainer

List of Experiments:-

1. To study Tuning of controller (Using Auto Tuning method)
2. Study of open loop response (Manual control)
3. Study of on/off controller
4. Study of proportional controller
5. Study of proportional integral controller
6. Study of proportional derivative controller
7. Tuning of controller (Open loop method)
8. Tuning of controller (Closed loop method)
9. To study Tuning of controller (Using Auto Tuning method)
10. Study of stability of the system (Bode plot)

For Pressure Control Trainer

List of experiments:-

1. To study of open loop response (manual control)
2. To study of on/off controller.
3. To study of proportional controller
4. To study of proportional integral controller
5. To study of proportional derivative controller
6. To study of proportional integral derivative controller
7. To tuning of controller (open loop method)
8. To tuning of controller (closed loop method)
9. To tuning of controller (using auto tuning method)
10. To study stability of the system (Bode plot)

For Level Control Trainer

List of experiments:-

1. To study of open loop response (manual control)
2. To study of on/off controller.
3. To study of proportional controller
4. To study of proportional integral controller
5. To study of proportional derivative controller
6. To study of proportional integral derivative controller
7. To tuning of controller (open loop method)
8. To tuning of controller (closed loop method)
9. To tuning of controller (using auto tuning method)
10. To study stability of the system (Bode plot)

Temperature Control Trainer

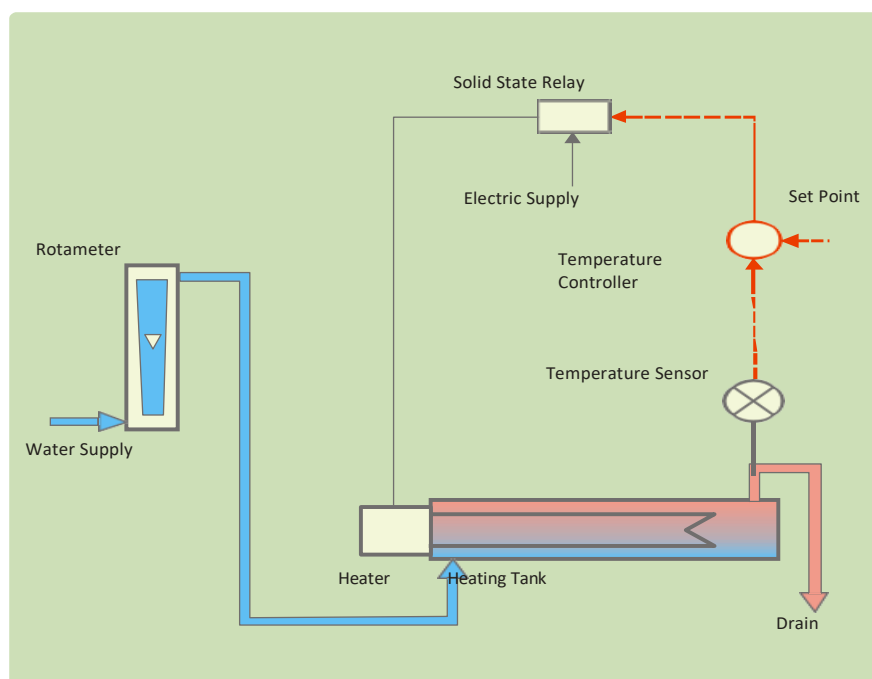
1. Aim of the experiment:-

Study of open loop response (Manual control)

Apparatus required:-

Temperature Control Trainer

Theory: - :- Temperature control trainer is designed for understanding the basic temperature control principles. The process setup consists of heating tank fitted with SSR controlled heater for on-line heating of the water. The flow of water can be manipulated and measured by rotameter. Temperature sensor (RTD) is used for temperature sensing. The process parameter (Temperature) is controlled by microprocessor based digital indicating controller which manipulates heat input to the process. These units along with necessary piping and fitting are mounted on support frame designed for tabletop mounting.



Procedure

- ☐ Start up set up as explained in general instructions.
- ☐ Click Select Experiment, select Open Loop and click Start
- ☐ Decrease the controller output to 0%. Note down steady state process value.
- ☐ Apply the step change by 10% to controller output and wait for the temperature to reach

the steady state value. Note down the process value.

- ☐ Repeat the above step until the controller output reaches to maximum i.e. 100% and for each change, note steady state process value.

Observations

Tabulate the observations as follows

Controller output in %	Process Value in $^{\circ}\text{C}$
0	
10	
20	
...	
100	

- ☐ From the above data, note the output required for maintaining the temperature at desired set points.

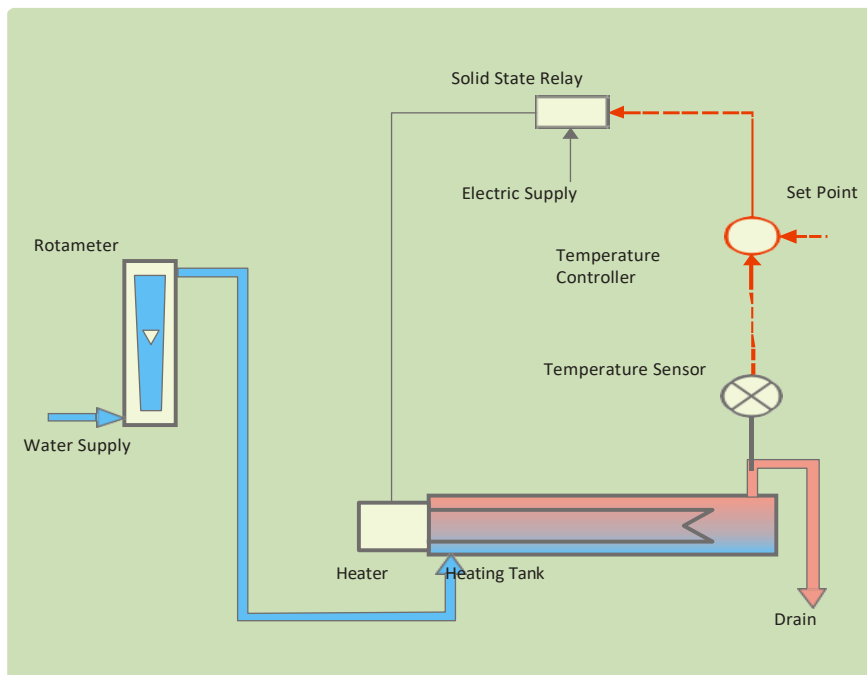
2. AIM OF THE EXPERIMENT:-

Study of on/off controller

Apparatus required:-

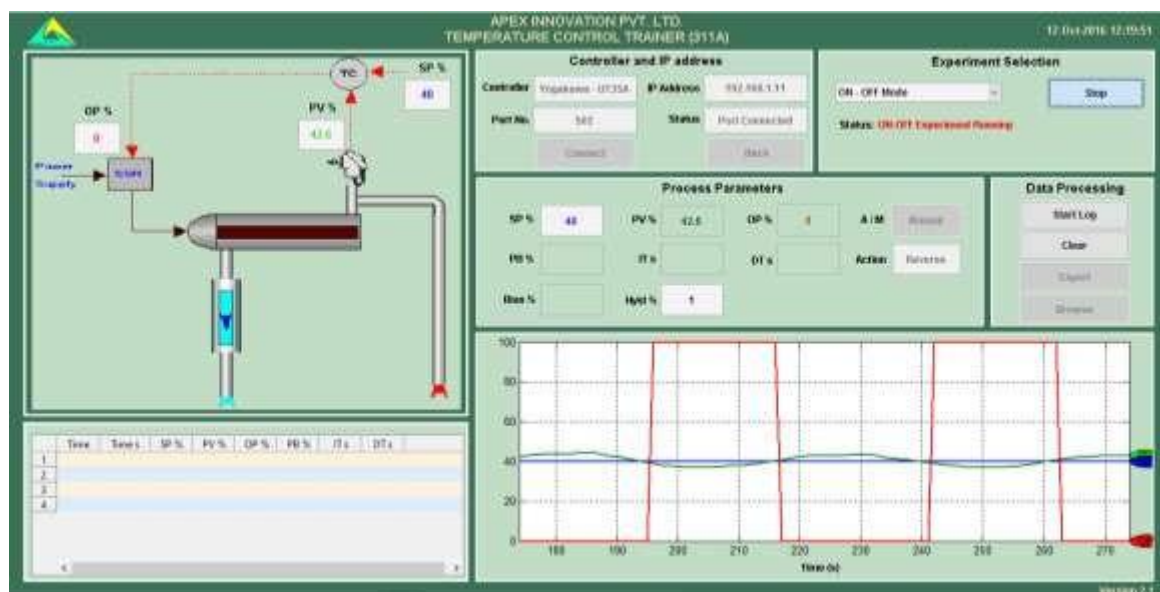
Temperature Control Trainer

THEORY: - :- Temperature control trainer is designed for understanding the basic temperature control principles. The process setup consists of heating tank fitted with SSR controlled heater for on-line heating of the water. The flow of water can be manipulated and measured by rotameter. Temperature sensor (RTD) is used for temperature sensing. The process parameter (Temperature) is controlled by microprocessor based digital indicating controller which manipulates heat input to the process. These units along with necessary piping and fitting are mounted on support frame designed for tabletop mounting.



Procedure:-

- ☐ Start up set up as explained in general instructions.
- ☐ Click Select Experiment, select On-Off Mode and click Start
- ☐ Change Hysteresis value to 1 %.(Range 0.1-10%)
- ☐ Change the values of the set point and observe the On-Off control operation.



Observations

Observe that if process value exceeds the set point and increases than the value of $(0.5 \times \text{Hysteresis})$, controller switches off the SSR and if process value decreases below the set point by $(0.5 \times \text{Hysteresis})$, SSR switches on i.e. controller operates like On/Off switch.

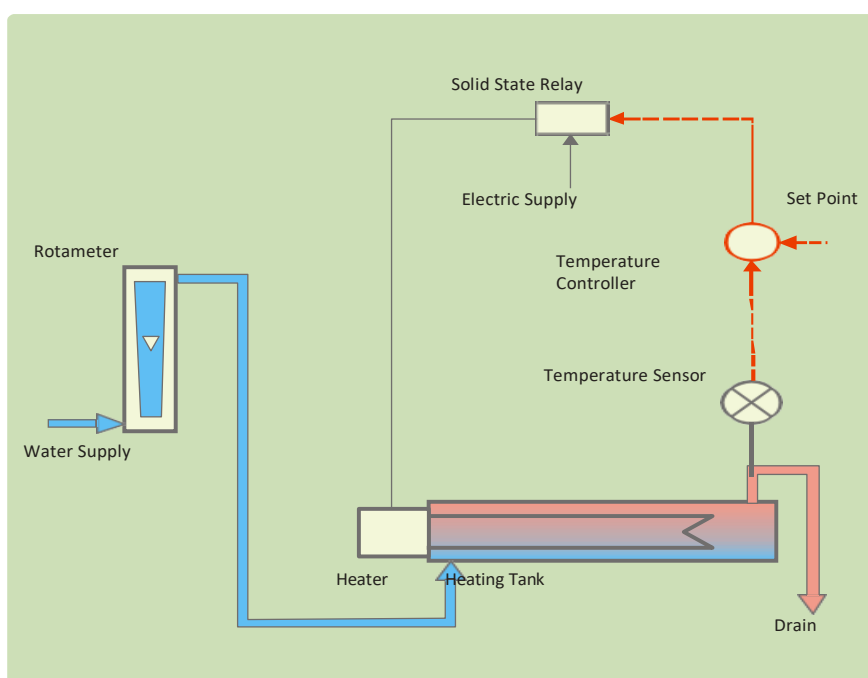
3. Aim of the experiment:-

Study of proportional controller

Apparatus required:-

Temp. Control trainer

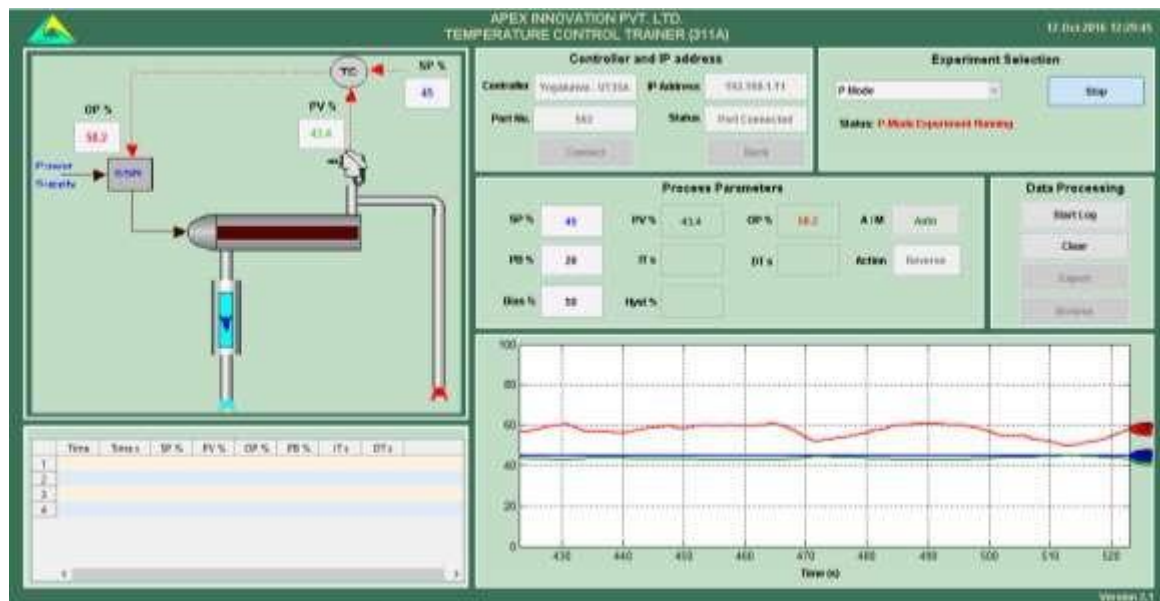
Theory: - Temperature control trainer is designed for understanding the basic temperature control principles. The process setup consists of heating tank fitted with SSR controlled heater for on-line heating of the water. The flow of water can be manipulated and measured by rotameter. Temperature sensor (RTD) is used for temperature sensing. The process parameter (Temperature) is controlled by microprocessor based digital indicating controller which manipulates heat input to the process. These units along with necessary piping and fitting are mounted on support frame designed for tabletop mounting.



Procedure

- ☐ Start up set up as explained in general instructions.
- ☐ Click Select Experiment, select P Mode and click Start
- ☐ Keep the set point to 40%. (Set point should be 10% more than inlet water temperature)
Change output mode to Manual. Adjust output values so as to match the process value with set point and apply this output value as bias value to the controller. Adjust the proportional band to 50%.
- ☐ Switch the controller to Auto mode.
- ☐ Apply step change to set point, step change should be of 2 to 3 % and observe the response.

- Switch the controller to Manual mode. Decrease proportional band to half of the previous value & then shift controller to Auto mode. With each decrease, obtain a new response of the step change. Ensure that the set point changes are around the same operating point (@ 2-3% only).
- Using trial and error approach, find a value of proportional bands so that the response to a step change has at most one overshoot and one undershoot.
- Set the controller to the settings obtained in the above step and wait for the system to reach at steady state.



Observations

- Observe steady state error decreases as proportional band decreases.
- Observe the effect of very low proportional band values (system works in oscillatory mode).
- Observe the response of the system to load change. Load change can be given by slightly varying the inlet flow rate.

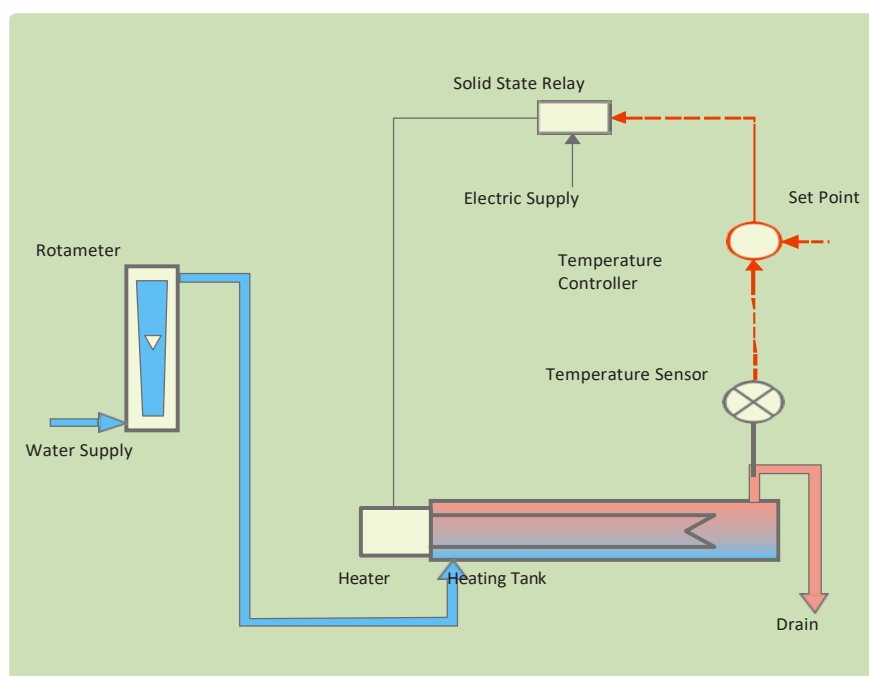
4. Aim of the experiment:

To Study of proportional integral controller

Apparatus required:-

Temp control trainer

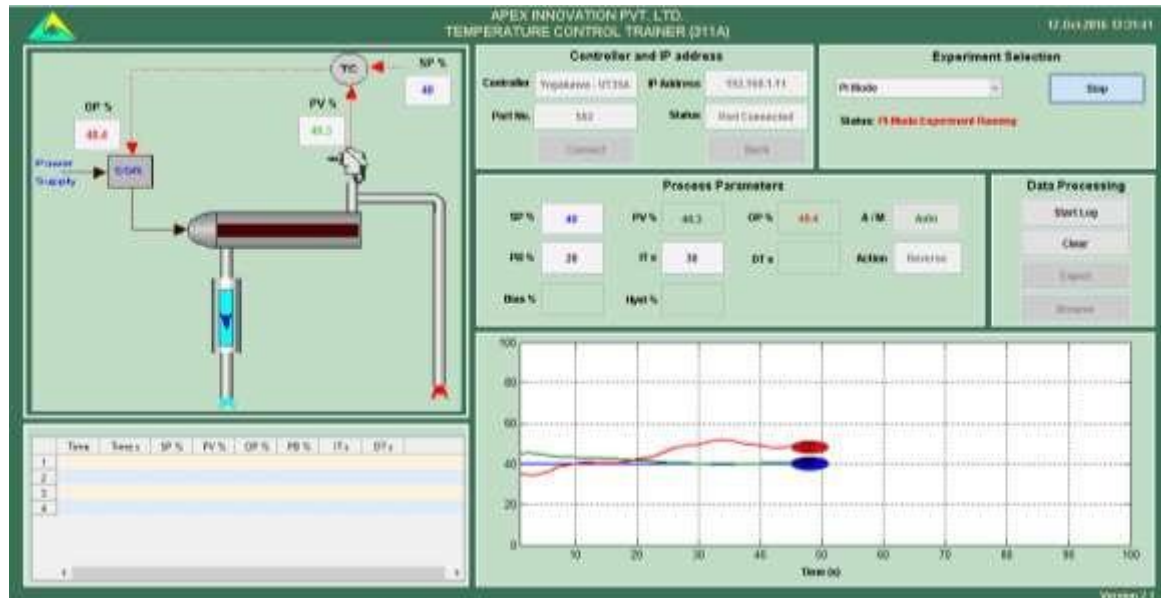
Theory: - Temperature control trainer is designed for understanding the basic temperature control principles. The process setup consists of heating tank fitted with SSR controlled heater for on-line heating of the water. The flow of water can be manipulated and measured by rotameter. Temperature sensor (RTD) is used for temperature sensing. The process parameter (Temperature) is controlled by microprocessor based digital indicating controller which manipulates heat input to the process. These units along with necessary piping and fitting are mounted on support frame designed for tabletop mounting.



Procedure

- ☐ Start up set up as explained in general instructions.
- ☐ Click Select Experiment, select PI Mode and click Start
- ☐ Adjust the process value by changing the output of controller in manual mode to a particular temperature (set point = 40%).
- ☐ Set the proportional band estimated from Proportional control (from previous experiment). Start with derivative time = 0 and integral time = 1000 sec., which will cut off the derivative action and widen the effect of integral action.
- ☐ Allow the process to reach at steady state. Record the steady state error.

- ☐ Switch on the controller to manual mode. Reduce the integral time to half of the previous value. Switch to Auto mode and apply step change to the set point by 2 to 3%. Note the response of the system.
- ☐ Using trial and error, find out an integral time, which gives satisfactory response to the step change in setpoint.



Observations

- ☐ Observe the effect of reducing integral time on offset and on the response of the process.

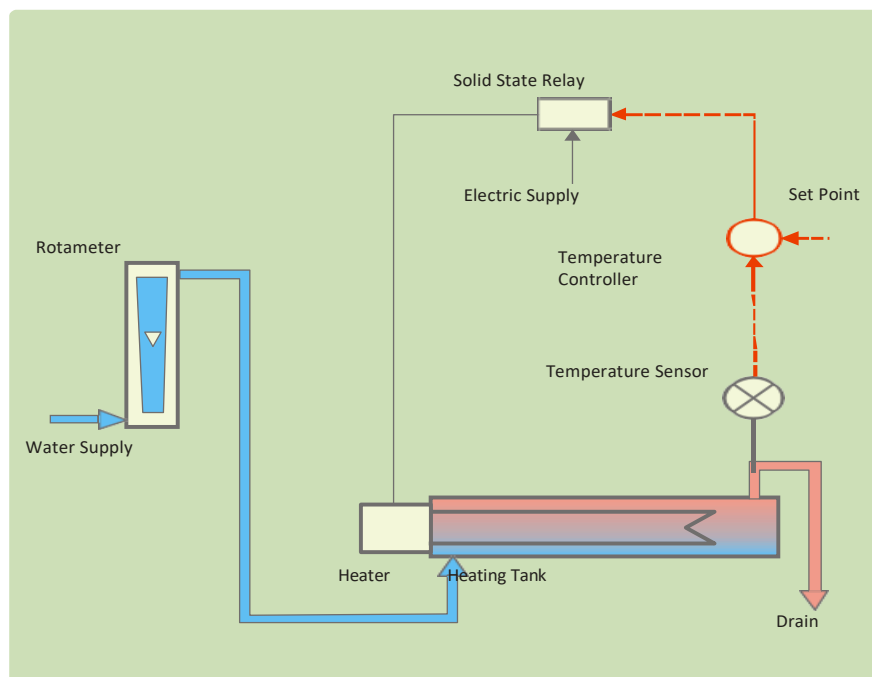
5. Aim of the experiment:-

To Study of proportional derivative controller

Apparatus required:-

Temp control trainer

Theory: - Temperature control trainer is designed for understanding the basic temperature control principles. The process setup consists of heating tank fitted with SSR controlled heater for on-line heating of the water. The flow of water can be manipulated and measured by rotameter. Temperature sensor (RTD) is used for temperature sensing. The process parameter (Temperature) is controlled by microprocessor based digital indicating controller which manipulates heat input to the process. These units along with necessary piping and fitting are mounted on support frame designed for tabletop mounting.

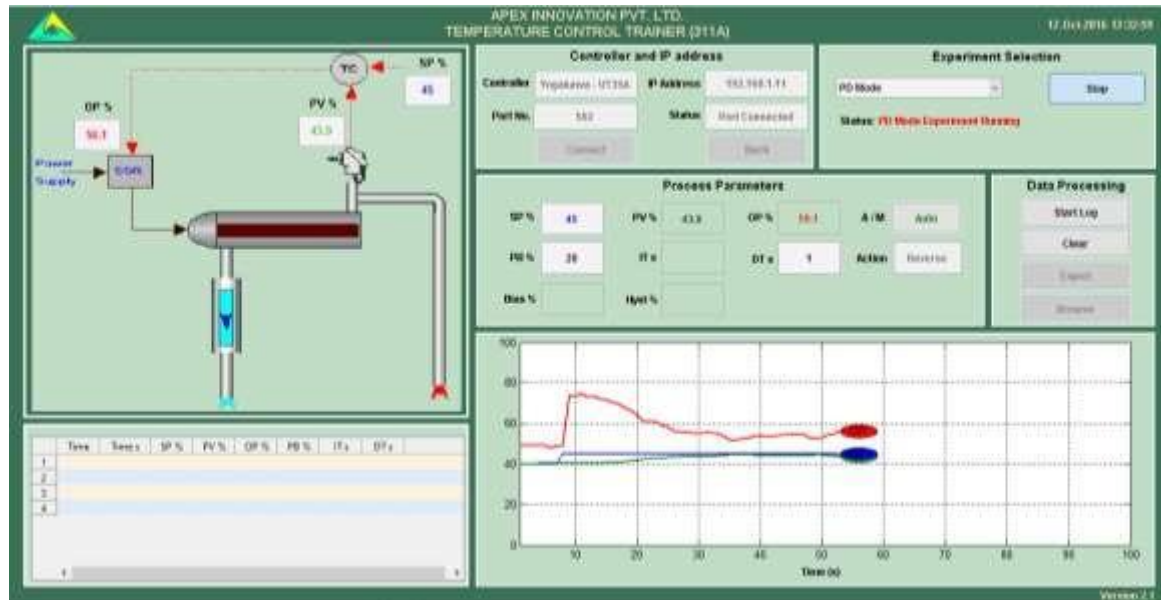


Procedure

- ☐ Start up set up as explained in general instructions.
- ☐ Click Select Experiment, select PD Mode and click Start
- ☐ Set the proportional band estimated from Proportional control (P only). Start with derivative time=0 and integral time=6000 sec., which will cut off the derivative action and widen the effect of integral action.
- ☐ Set the set point to desired temperature (@40%). Allow the process to reach at steady state.

Note the response of the system.

- ☐ Switch on the controller to manual mode. Increase the derivative time by 1 sec. Switch to Auto mode and apply step change to the set point by 2 to 3%. Note the response of the system.
- ☐ Increase the derivative time gradually and observe the process response for step change.



Observations

- ☐ Observe the effect of increasing derivative time. Also note that the process may show offset as effect of integral action is cut off.

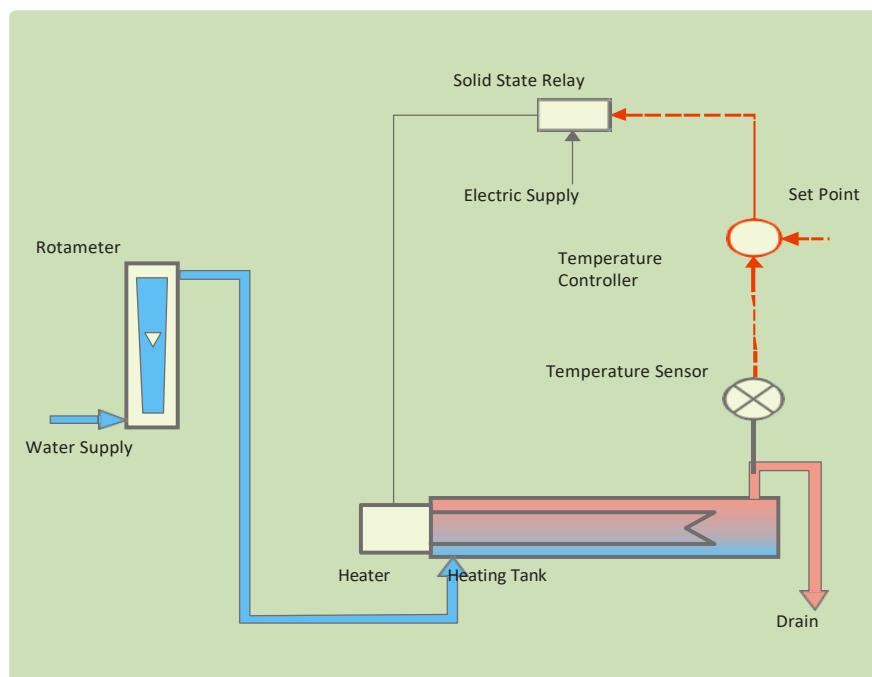
6. Aim of the experiment:-

To Study of proportional integral derivative controller

Apparatus required:-

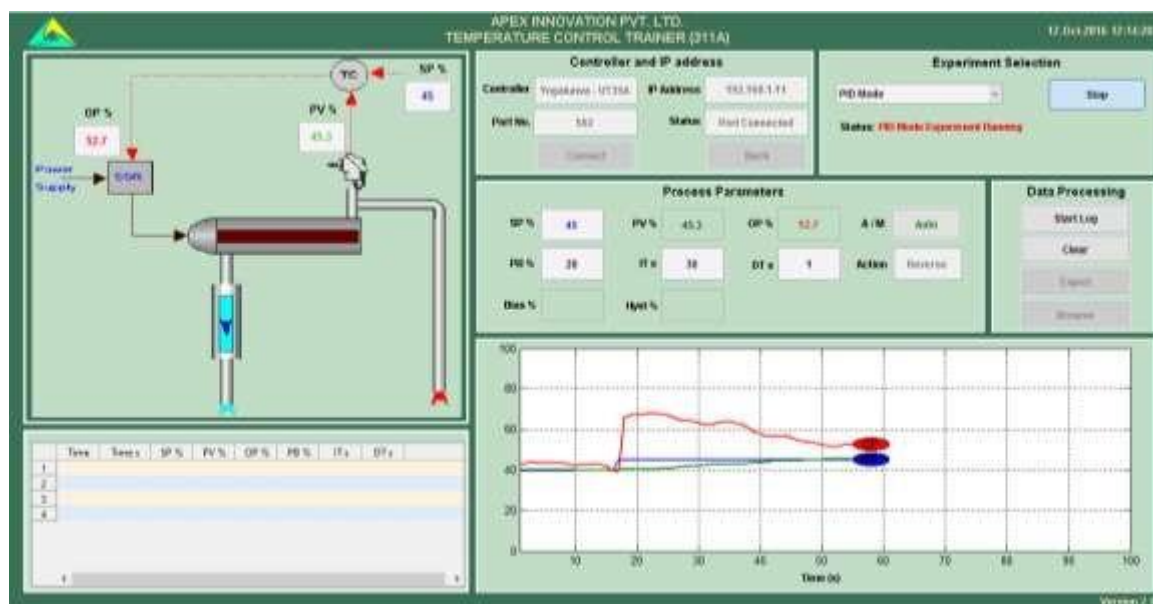
Temperature control trainer

Theory: - Temperature control trainer is designed for understanding the basic temperature control principles. The process setup consists of heating tank fitted with SSR controlled heater for on-line heating of the water. The flow of water can be manipulated and measured by rotameter. Temperature sensor (RTD) is used for temperature sensing. The process parameter (Temperature) is controlled by microprocessor based digital indicating controller which manipulates heat input to the process. These units along with necessary piping and fitting are mounted on support frame designed for tabletop mounting.



Procedure

- ☐ Start up set up as explained in general instructions.
- ☐ Click Select Experiment, select PID mode and click Start
- ☐ 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 experiments.
- ☐ Change the controller to Auto mode. Apply step change by 2 to 3% to the set point and observe the response of the process.
- ☐ Change the proportional band, integral time, derivative time and observe the response of the process for step change for each change in setting.



Observations

- ☐ Compare the steady state response of the PID controller with P, PI and PD controller obtained in the previous experiments.

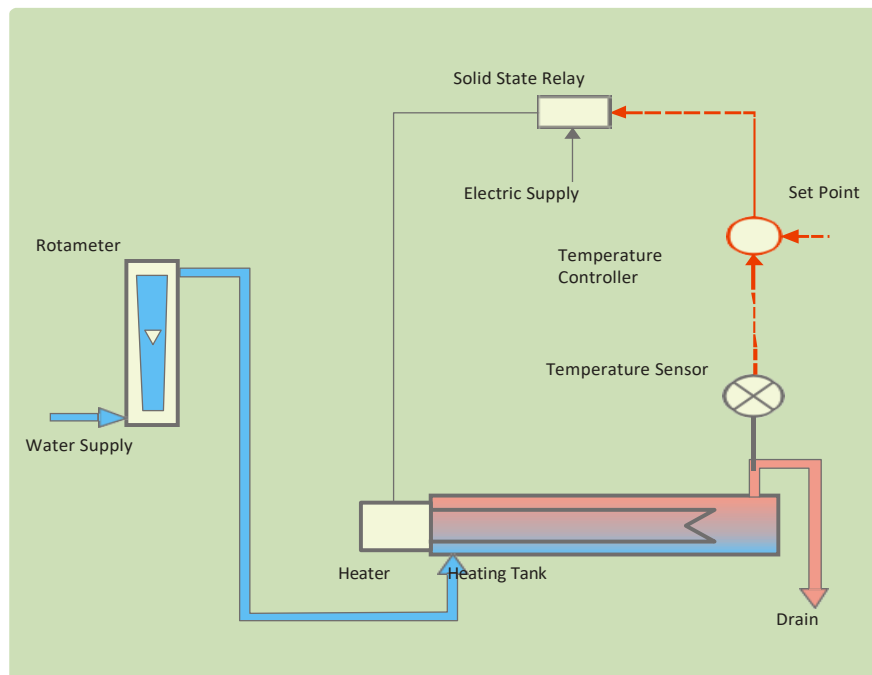
7. Aim of the experiment:-

To study Tuning of controller (Open loop method)

Apparatus required:-

Temp.control trainer

Theory: - Temperature control trainer is designed for understanding the basic temperature control principles. The process setup consists of heating tank fitted with SSR controlled heater for on-line heating of the water. The flow of water can be manipulated and measured by rotameter. Temperature sensor (RTD) is used for temperature sensing. The process parameter (Temperature) is controlled by microprocessor based digital indicating controller which manipulates heat input to the process. These units along with necessary piping and fitting are mounted on support frame designed for tabletop mounting.



Procedure

- ☐ Start up set up as explained in general instructions.
- ☐ Click Select Experiment, select Process Reaction and click Start
- ☐ Adjust the controller output and bring the process near set point of 40%.
- ☐ Allow the system to reach steady state. Start data logging.
- ☐ With the controller still in manual mode impose a step change of 30 - 40 % in controller output. Record the step response. Wait for the steady state. Stop data logging.
- ☐ Plot the step response (Process reaction curve) from stored data. Find out the value of slope at the point of inflection and time lag.
- ☐ Calculate P I D settings for different modes.
- ☐ Select PID Mode option for control from software. (Click on “Change Expt.” Button, click on “Change”, Click on “PID Mode” button.) Switch on the controller to manual mode and Keep the set point to 40%. Adjust output value so as to match the process value to set point.
- ☐ Set the PID values obtained from the calculations. Switch on the controller to Auto mode. Apply the step change & observe the response of the system. Allow the system to reach steady state.

Observations

(Refer Theory process control for formula.)

- ☐ Step change to the system $\Delta P = \text{Initial output} - \text{Final output of the controller}$.
- ☐ Plot the graph of process value Vs Time on a graph paper.
- ☐ From process reaction curve:
 - o Slope of the process reaction curve $R =$
 - o Time lag $L =$
- ☐ Calculate P, PI, and PID setting from above values.
- ☐ Observe response of the system for different PID settings.

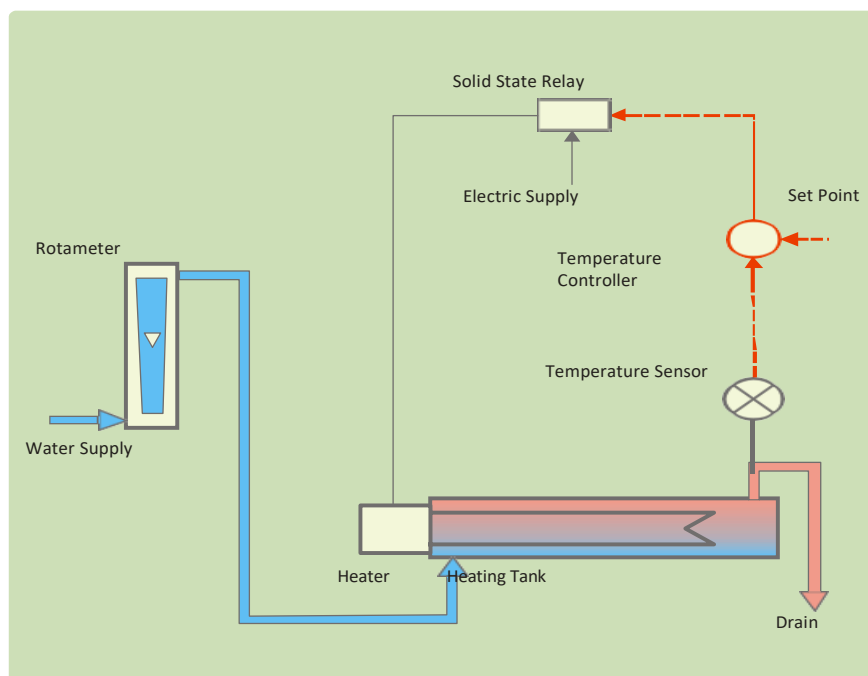
8. Aim of the experiment:-

To study Tuning of controller (Closed loop method)

Apparatus required:-

Temp. Control trainer

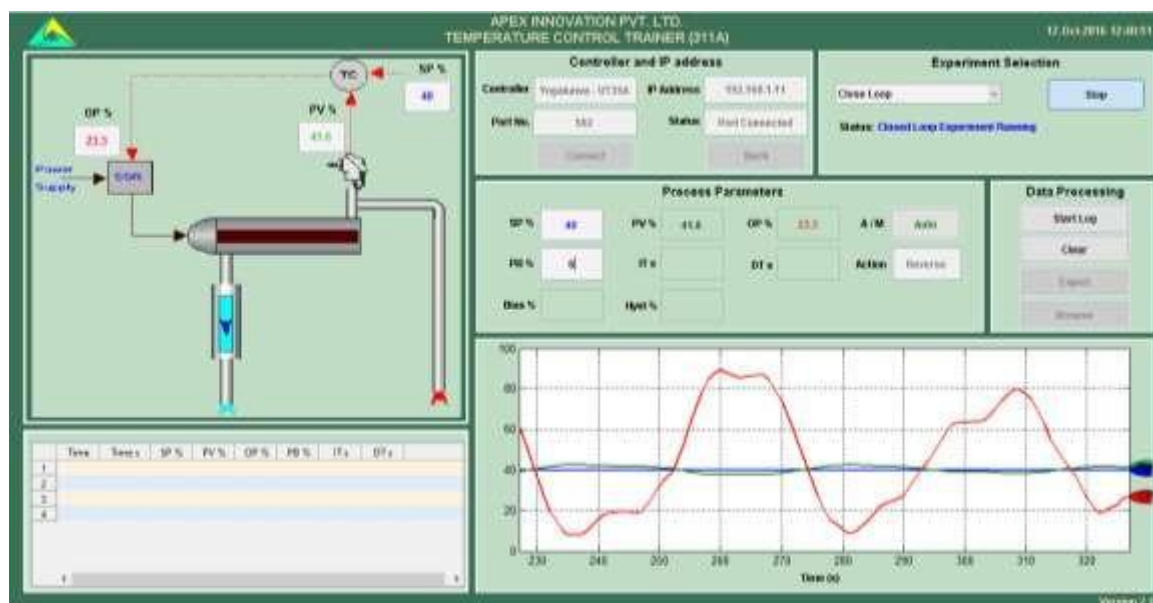
Theory: - Temperature control trainer is designed for understanding the basic temperature control principles. The process setup consists of heating tank fitted with SSR controlled heater for on-line heating of the water. The flow of water can be manipulated and measured by rotameter. Temperature sensor (RTD) is used for temperature sensing. The process parameter (Temperature) is controlled by microprocessor based digital indicating controller which manipulates heat input to the process. These units along with necessary piping and fitting are mounted on support frame designed for tabletop mounting.



Procedure

- ☐ Start up set up as explained in general instructions.
- ☐ Click Select Experiment, select Close Loop and click Start
- ☐ Set the proportional band value to maximum (Say 100). Set the controller to manual mode and adjust the output so that the process is nearly at set point 40%.
- ☐ Set controller to auto mode and impose step on the process by moving the set point for a few seconds & then return to its original value (or apply the step change to the set point of 2%). Wait for some time & observe the response.

- ☐ Decrease the proportional band to the half of previous and impose step on the process as mentioned above. Wait for some time & observe the response.
- ☐ Repeat the above procedure and find out correct value of proportional band for which the system just goes unstable i.e. continuous oscillations are observed in the output of controller.
- ☐ Record the ultimate proportional band and ultimate period from the response.
- ☐ Calculate the PID values from the table. Select the PID controller and apply the parameter values obtained from the above steps. Observe the response of the process to a step change with these settings.



Observations

- ☐ Record the ultimate proportional band (P_{bu}) and ultimate period (T_u) from above experiment.
- ☐ Calculate PID values by referring theory part for different control actions.
- ☐ Observe the process response for these settings.

Compare the values obtained with open loop response me

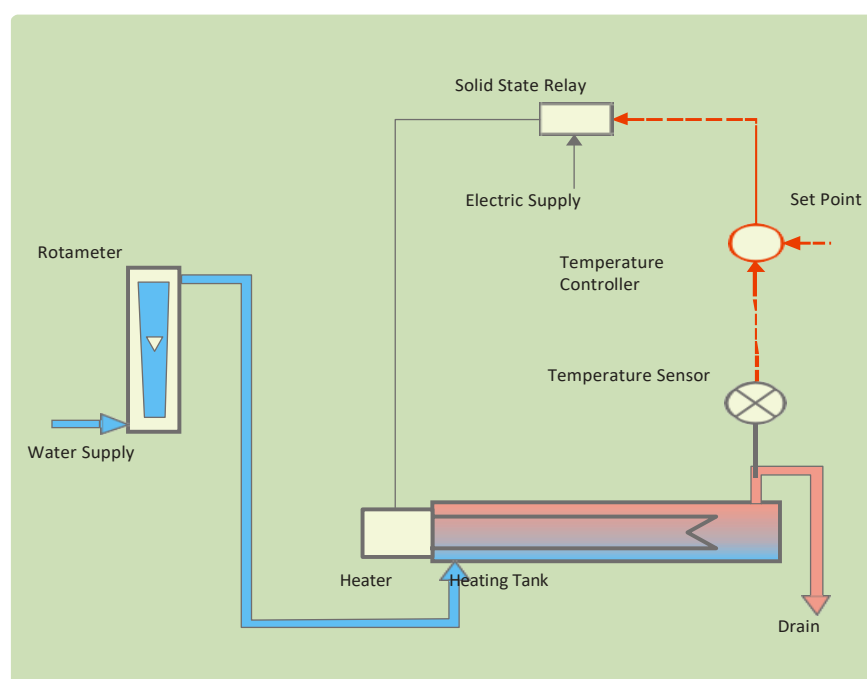
9. Aim of the experiment:-

To study Tuning of controller (Using Auto Tuning method)

Apparatus required:-

Temperature control trainer

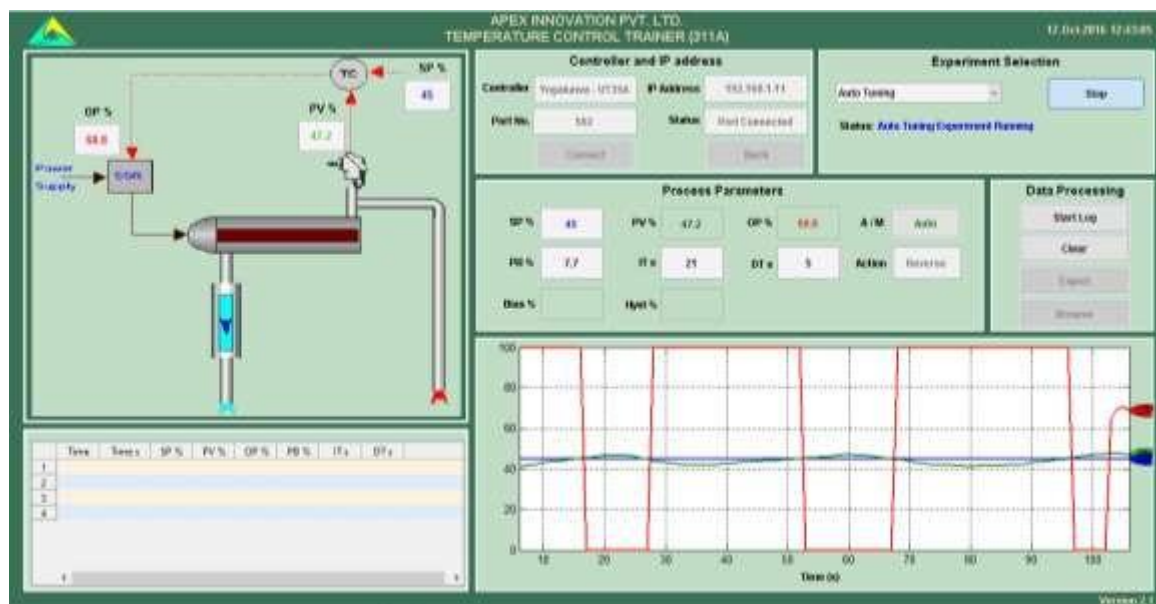
Theory: - Temperature control trainer is designed for understanding the basic temperature control principles. The process setup consists of heating tank fitted with SSR controlled heater for on-line heating of the water. The flow of water can be manipulated and measured by rotameter. Temperature sensor (RTD) is used for temperature sensing. The process parameter (Temperature) is controlled by microprocessor based digital indicating controller which manipulates heat input to the process. These units along with necessary piping and fitting are mounted on support frame designed for tabletop mounting.



The controller can be connected to computer through Ethernet / USB port for monitoring the process in SCADA mode.

Procedure:-

- ☐ Start up set up as explained in general instructions.
- ☐ Click Select Experiment, select Autotune and click Start
- ☐ Wait Till Auto tune is complete. (Blinking of green LED stops).
- ☐ Controller automatically finds the PB, IT & DT values.
- ☐ Find out PID values at different set points /flow rates.



Observations

- ☐ The controller has preprogrammed logic for finding “Auto tune” values. Based on the response of the process the controller calculates PID values or comes out without finding the “Auto tune” values.

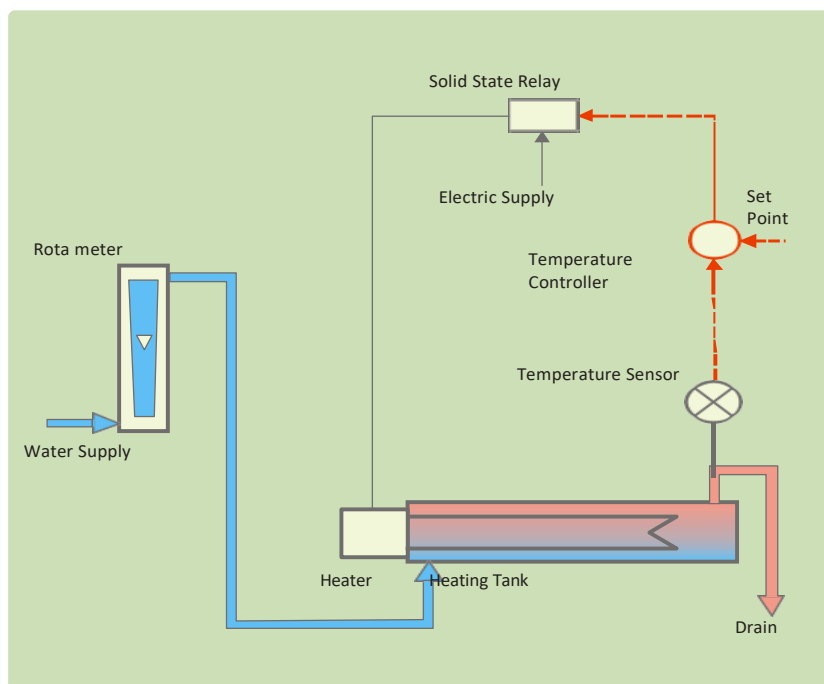
10. Aim of the experiment:-

Study of stability of the system (Bode plot)

Apparatus required:-

Temp control trainer

Theory: - Temperature control trainer is designed for understanding the basic temperature control principles. The process setup consists of heating tank fitted with SSR controlled heater for on-line heating of the water. The flow of water can be manipulated and measured by rotameter. Temperature sensor (RTD) is used for temperature sensing. The process parameter (Temperature) is controlled by microprocessor based digital indicating controller which manipulates heat input to the process. These units along with necessary piping and fitting are mounted on support frame designed for tabletop mounting.



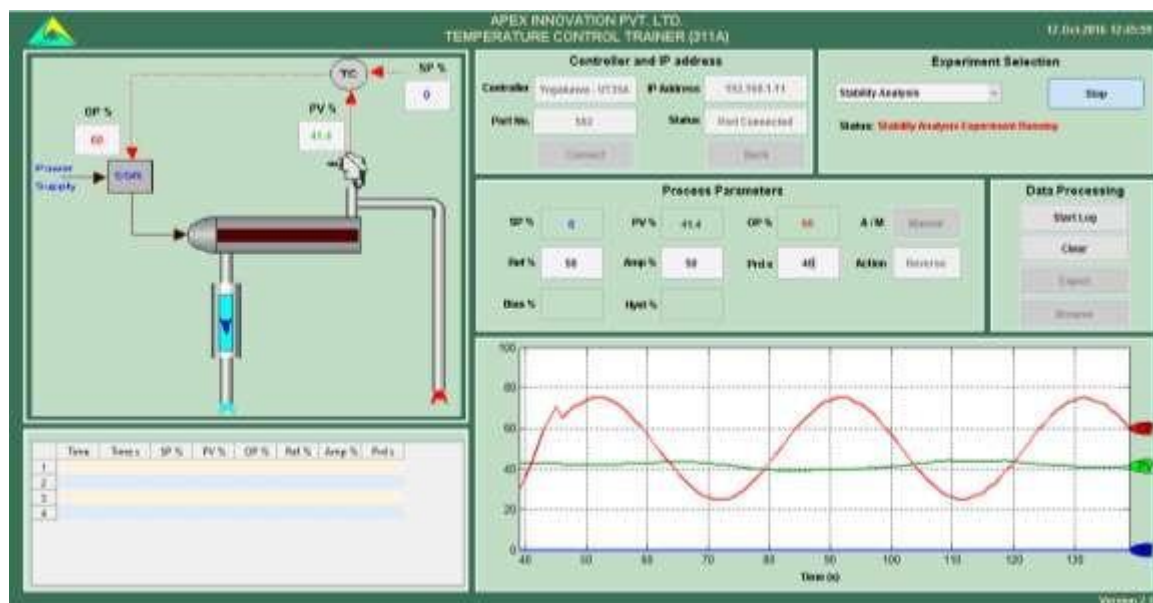
The controller can be connected to computer through Ethernet / USB port for monitoring the process in SCADA mode.

Procedure

- ☐ Start up set up as explained in general instructions.
- ☐ Click Select Experiment, select Stability analysis and click Start

- ☐ Select function generator to apply the sinusoidal input to the output of the controller.
- ☐ Enter Reference point, Amplitude and Period.
- ☐ Observe the sinusoidal output of the controller and sinusoidal response of the process.
- ☐ Log the data for records.
- ☐ Change the period and repeat the observation for 3-4 different values of the period.

Note: As the temperature process is very slow responsive, the amplitude and period for the sinusoidal input should be large enough to observe response.



Observations

- ☐ Form the data file stored note down the
- ☐ Observe the output response of the process and note down the output amplitude. Measure output wave period and note down as T sec. Measure the phase lag x and note down in sec.

Obs. No.	Input amplitude A1 %	Output amplitude A2 %	Output Period T in sec	Lag X In sec	Frequency

Calculations

- ☐ Calculate for each observation

Magnitude ratio as $M =$

$A2/A1$ Phase angle $= (X/T)$

$\times 360$ Frequency $= 1/T$

cycles/sec.

- ☐ Draw the graphs of:
 - Magnitude Vs frequency on log - log scale
 - Phase angle Vs frequency on semi-log coordinates.
- ☐ Study the graph for stability conditions mentioned in the theory

FOR PRESSURE CONTROL TRAINER

1. Aim of experiment:-

To Study of open loop response (Manual control)

Apparatus Required:-

Pressure control Trainer

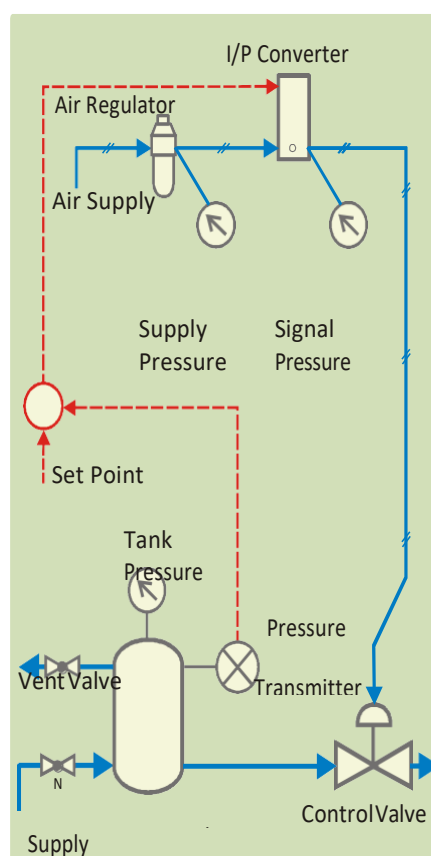
Theory: - Pressure control trainer is designed for understanding the basic principles of pressure control. The process set up consists of pressure vessel fitted with pneumatic control valve. Pressure transmitter is used for pressure sensing. The process parameter (Pressure) is controlled by microprocessor based digital indicating controller which manipulates pneumatic control valve fitted at Outlet of pressure tank outlet through I/P converter. These units along with necessary piping are fitted on support housing designed for tabletop mounting.

The controller can be connected to computer through Ethernet /USB port for monitoring the process in SCADA mode.

Procedure:-

Start up set up as explained in general instructions.

- ☐ Click Select Experiment, select Open Loop and click Start
- ☐ Close the control valve by increasing the controller output to 100%. Note down steady state



process value.

- ☐ Apply the step change by 10% to controller output and wait for the process value to reach the steady state value. Note down the process value.
- ☐ Repeat the above step until the controller output reaches to minimum 0%.

Observations

Tabulate the observations as follows

Controller output in %	Process Value in %
100	
90	
80	
...	
0	

- ☐ From the above data, note the output required for maintaining the process at desired set points. (For particular vent valve opening).
- ☐ Set the output of the controller to the noted value and at steady state apply the load change to the process. Load change can be given by slightly varying the vent valve. Observe new steady state process value.

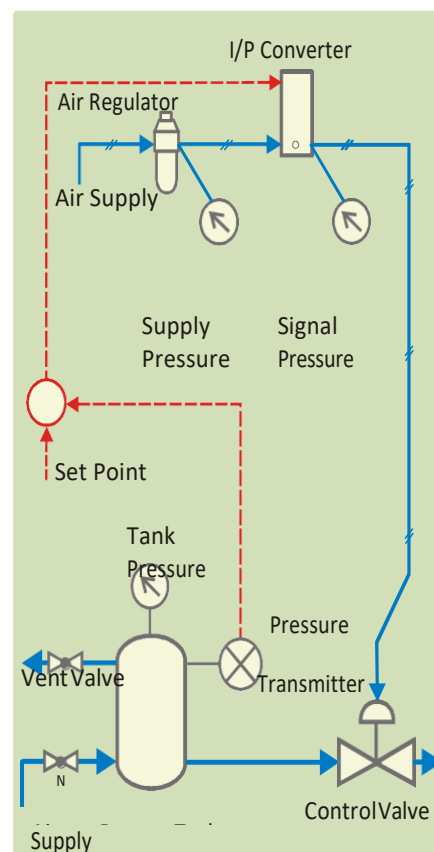
2. Aim of the experiment:-

To Study of on/off controller

Apparatus required:-

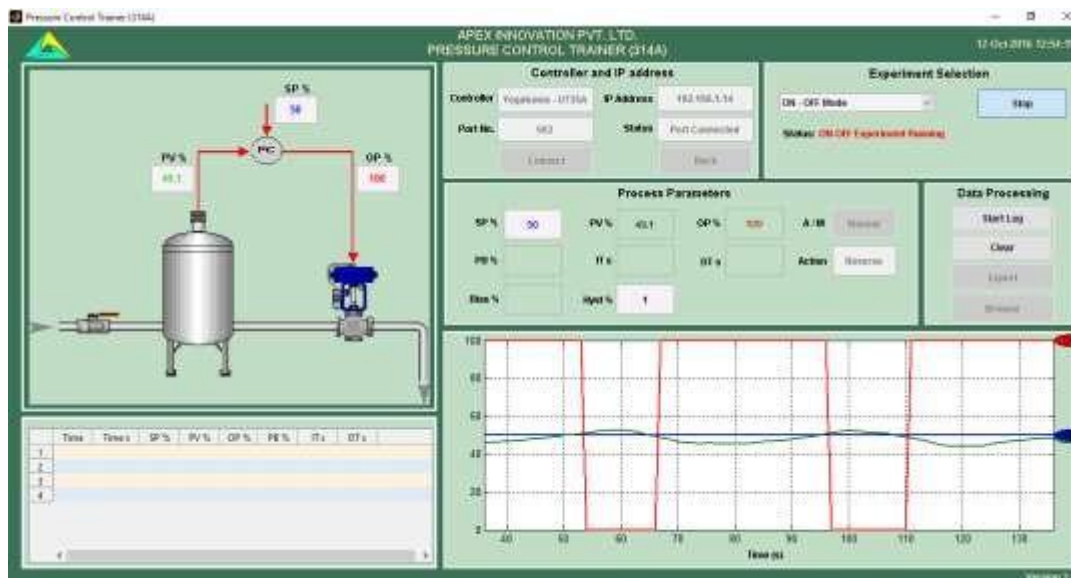
Pressure control trainer

Theory: - Pressure control trainer is designed for understanding the basic principles of pressure control. The process set up consists of pressure vessel fitted with pneumatic control valve. Pressure transmitter is used for pressure sensing. The process parameter (Pressure) is controlled by microprocessor based digital indicating controller which manipulates pneumatic control valve fitted at Outlet of pressure tank outlet through I/P converter. These units along with necessary piping are fitted on support housing designed for tabletop mounting. The controller can be connected to computer through Ethernet /USB port for monitoring the process in SCADA mode.



Procedure:-

- ☐ Start up set up as explained in general instructions.
- ☐ Click Select Experiment, select On-Off Mode and click Start
- ☐ Change Hysteresis value to 1 %.(Range 0.1-10%)
- ☐ Change the values of the set point and observe the On-Off control operation.



Observations

- Observe that if process value exceeds the set point and increases above the value of $(0.5 \times \text{Hysteresis})$, control valve is full open and if process value decreases below the set point by $(0.5 \times \text{Hysteresis})$, the control valve closes fully i.e. controller operates like On/Off switch.

3. Aim of the experiment:-

Study of proportional controller

Apparatus required:-

Pressure control trainer

Theory: - - Pressure control trainer is

designed for understanding the basic

principles of pressure control. The process

set up consists of pressure vessel fitted with

pneumatic control valve. Pressure

transmitter is used for pressure sensing.

The process parameter (Pressure) is

controlled by microprocessor based digital

indicating controller which manipulates

pneumatic control valve fitted at

Outlet of pressure tank outlet through I/P

converter. These units along with necessary

pipings are fitted on support housing designed for tabletop mounting.

The controller can be connected to computer

through Ethernet /USB port for monitoring

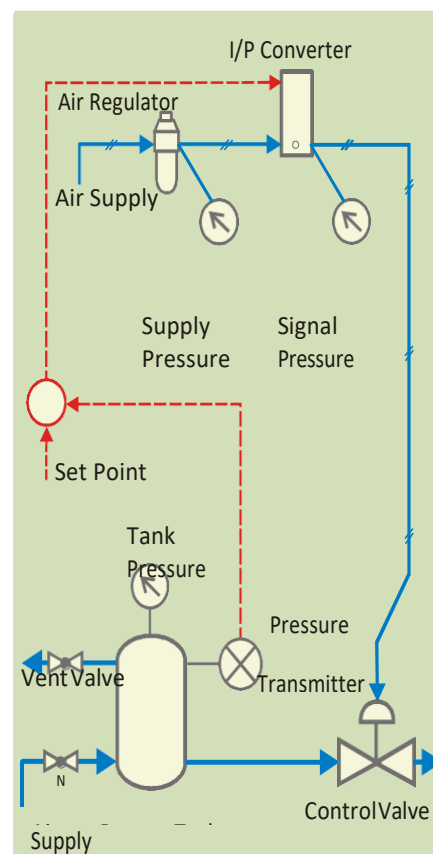
the process in SCADA mode.

Procedure:-

Start up set up as explained in general

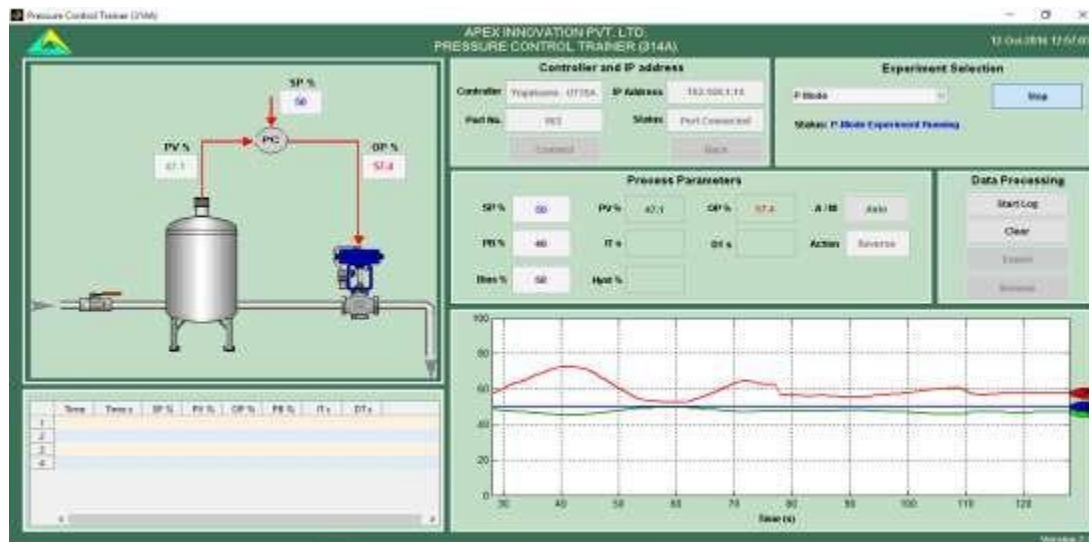
instructions.

- ☐ Click Select Experiment, select P Mode and click Start
- ☐ Keep the set point to 60%. Change output mode to Manual. Adjust output values so as to match the process value with set point and apply this output value as bias value to the controller. Adjust the proportional band to 50%.
- ☐ Switch the controller to Auto mode.
- ☐ Apply step change of 10% to set point and observe the response.
- ☐ Switch the controller to Manual mode. Decrease proportional band to half of the previous value & then shift controller to Auto mode. With each decrease, obtain a new response of the



step change. Ensure that the set point changes are around the same operating point (@ 5-10% only).

- Using trial and error approach, find a value of proportional band so that the response to a step change has at most one overshoot and one undershoot.
- Set the controller to the settings obtained in the above step and wait for the system to reach at steady state.



Observations

- Observe steady state error decreases as proportional band decreases.
- Observe the effect of very low proportional band values (system works in oscillatory mode).
- Observe the response of the system at load change. Load change can be given by slightly manipulating the vent valve of the tank.
- Study of proportional integral controller

4. Aim of the experiment:-

Study of proportional integral controller

Apparatus required:-

Pressure control trainer

Theory: - Pressure control trainer is designed for understanding the basic principles of pressure control. The process set up consists of pressure vessel fitted with pneumatic control valve. Pressure transmitter is used for pressure sensing.

The process parameter (Pressure) is controlled by microprocessor based digital indicating controller which manipulates pneumatic control valve fitted at

Outlet of pressure tank outlet through I/P converter. These units along with necessary piping are fitted on support housing designed for tabletop mounting.

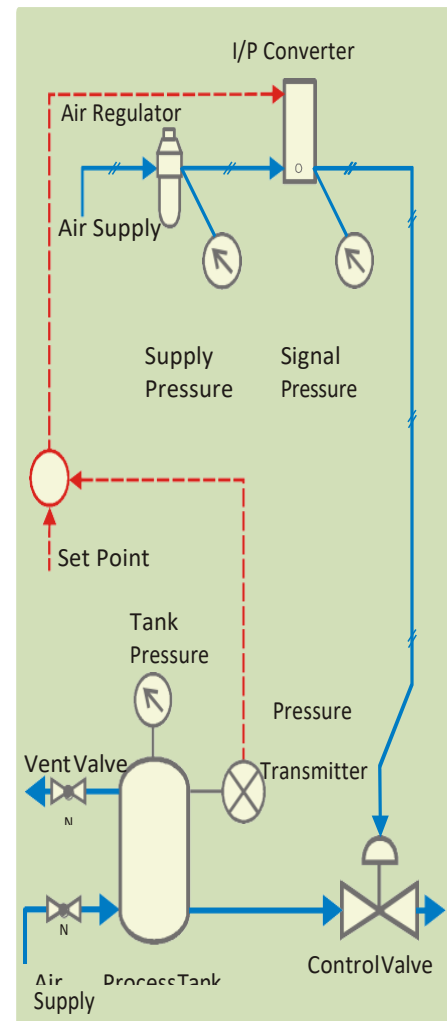
The controller can be connected to computer through Ethernet /USB port for monitoring the process in SCADA mode.

Procedure:-

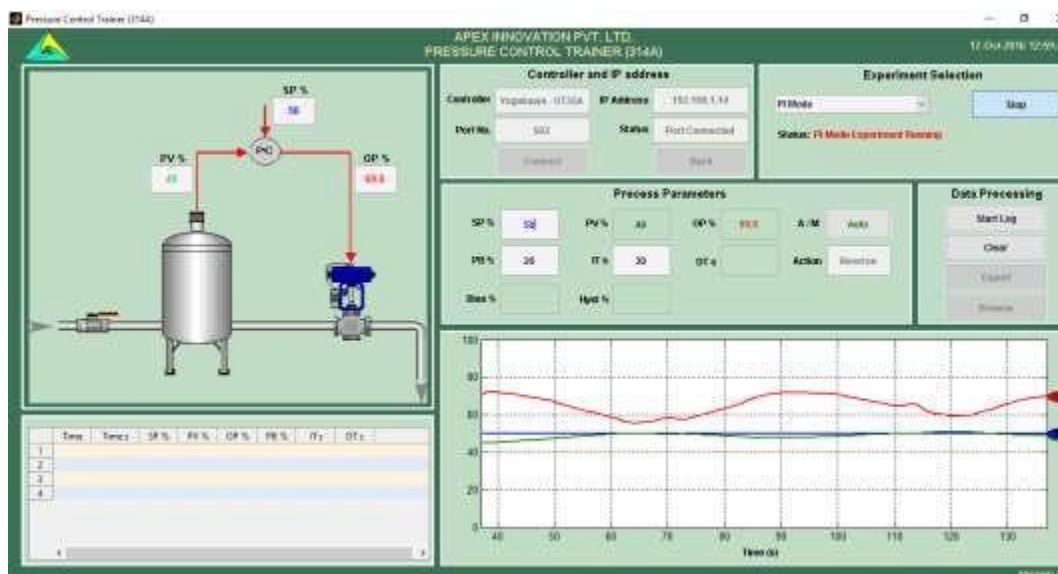
Start up set up as explained in general instructions.

- ❑ Click Select Experiment, select PI Mode and click Start
- ❑ Adjust the process value by changing the output of controller in manual mode to a particular pressure (set point=60%).
- ❑ Set the proportional band estimated from Proportional control (from previous experiment). Start with derivative time=0 and integral time=1000 sec., which will cut off the derivative action and widen the effect of integral action.
- ❑ Set the set point to desired pressure (@60%). Allow the process to reach at steady state.

Record the steady state error.



- Switch on the controller to manual mode. Reduce the integral time to half of the previous value. Switch to Auto mode and apply step change to the set point by 2 to 3%. Note the response of the system.
- Using trial and error, find out an integral time, which gives satisfactory response to the step change in set point.



Observations

- Observe the effect of reducing integral time on offset and on the response of the process.

5. Aim of the experiment:-

Study of proportional derivative controller

Apparatus required:-

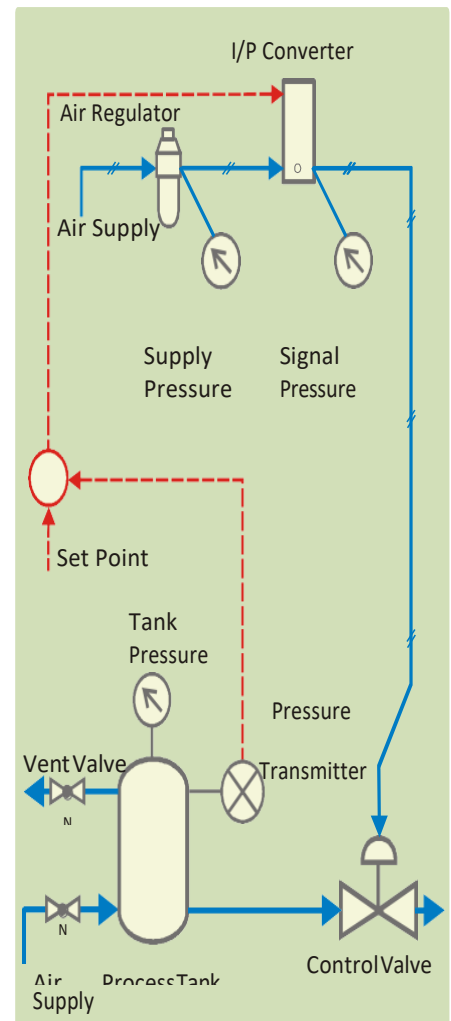
Pressure control trainer

Theory: - Pressure control trainer is designed for understanding the basic principles of pressure control. The process set up consists of pressure vessel fitted with pneumatic control valve. Pressure transmitter is used for pressure sensing. The process parameter (Pressure) is controlled by microprocessor based digital indicating controller which manipulates pneumatic control valve fitted at Outlet of pressure tank outlet through I/P converter. These units along with necessary piping are fitted on support housing designed for tabletop mounting. The controller can be connected to computer through Ethernet /USB port for monitoring the process in SCADA mode.

Procedure:-

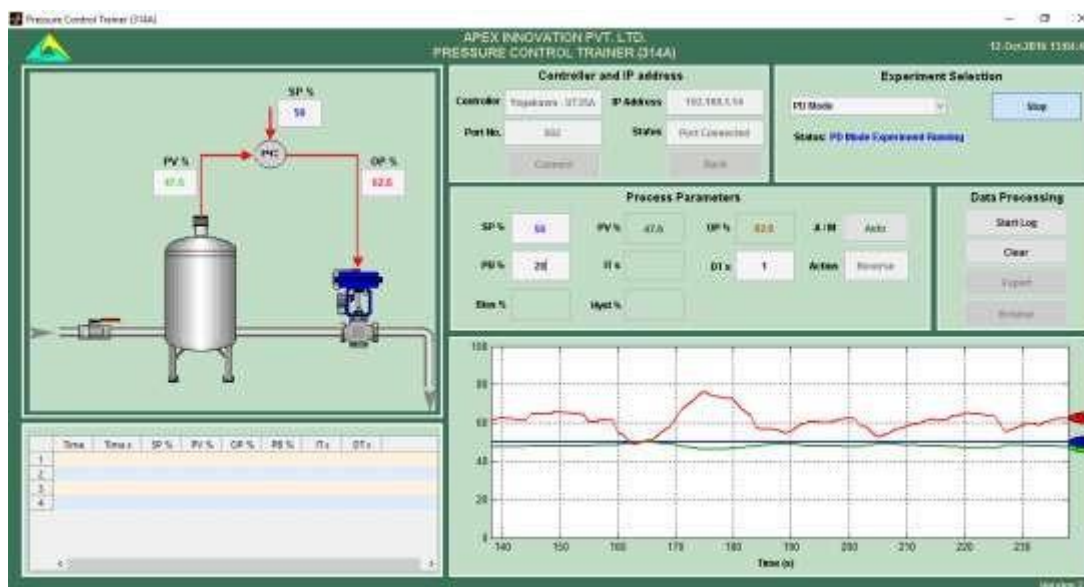
Start up set up as explained in general instructions.

- ☐ Click Select Experiment, select PD Mode and click Start
- ☐ Select PD controller. Set the proportional band estimated from Proportional control (P only). Start with derivative time=0 and integral time=6000 sec., which will cut off the derivative action and widen the effect of integral action.
- ☐ Set the set point to desired pressure (@60%). Allow the process to reach at steady state. Note the response of the system.
- ☐ Switch on the controller to manual mode. Increase the derivative time by 1 sec. Switch to Auto mode and apply step change to the set point by 2 to 3%. Note the response of the



system.

- ☐ Increase the derivative time gradually and observe the process response for step change.



Observations

- ☐ Observe the effect of increasing derivative time. Also note that the process may show offset as effect of integral action is cut off.

6. Aim of the experiment:-

Study of proportional integral derivative controller

Apparatus required:-

Pressure control trainer

Theory: - Pressure control trainer is designed for understanding the basic principles of pressure control. The process set up consists of pressure vessel fitted with pneumatic control valve. Pressure transmitter is used for pressure sensing.

The process parameter (Pressure) is controlled by microprocessor based digital indicating controller which manipulates pneumatic control valve fitted at

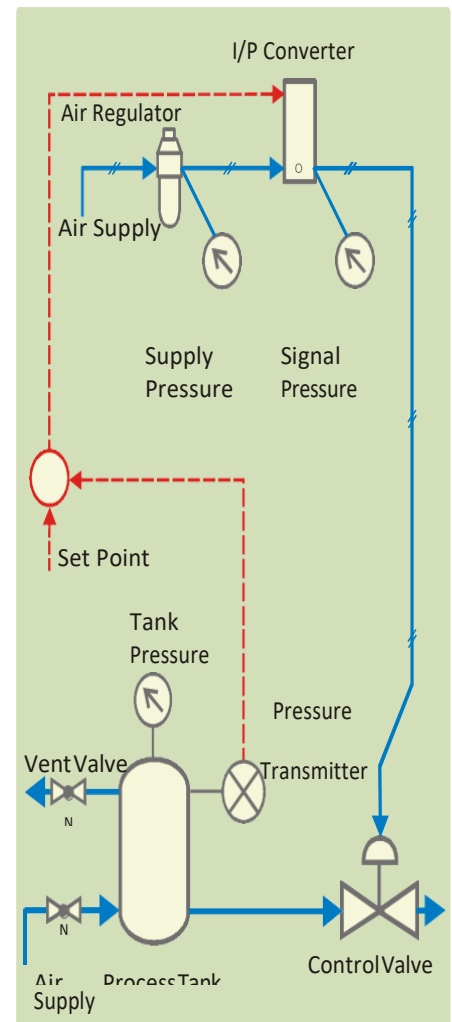
Outlet of pressure tank outlet through I/P converter. These units along with necessary piping are fitted on support housing designed for tabletop mounting.

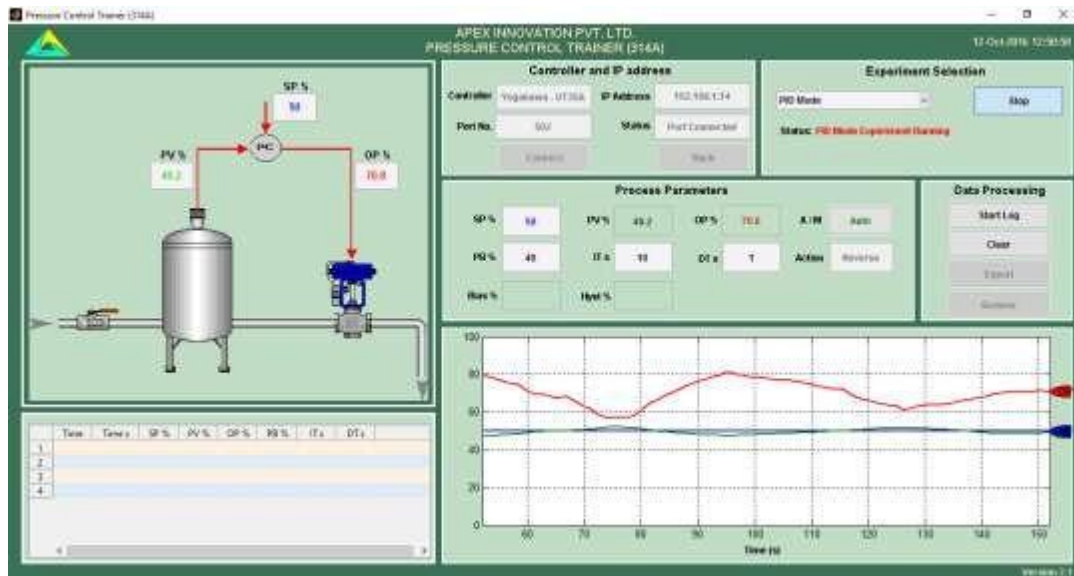
The controller can be connected to computer through Ethernet /USB port for monitoring the process in SCADA mode.

Procedure:-

Start up set up as explained in general instructions.

- ☐ Click Select Experiment, select PID mode and click Start
- ☐ 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 experiments.
- ☐ Change the controller to Auto mode. Apply step change by 2 to 3% to the set point and observe the response of the process.
- ☐ Change the proportional band, integral time, derivative time and observe the response of the process for step change for each change in setting.





Observations

- Compare the steady state response of the PID controller with P, PI and PD controller obtained in the previous experiments.

7. Aim of the experiment:-

Tuning of controller (Open loop method)

Apparatus required:-

Pressure control trainer

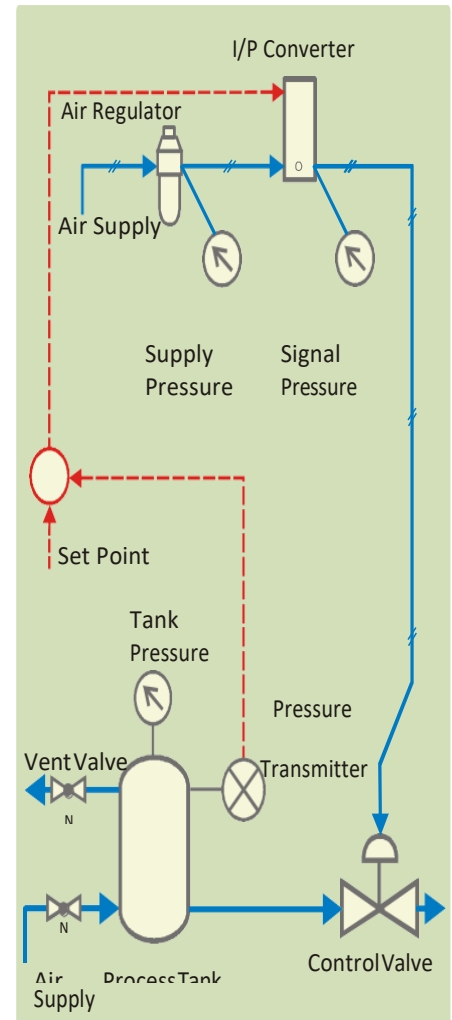
Theory: - Pressure control trainer is designed for understanding the basic principles of pressure control. The process set up consists of pressure vessel fitted with pneumatic control valve. Pressure transmitter is used for pressure sensing.

The process parameter (Pressure) is controlled by microprocessor based digital indicating controller which manipulates pneumatic control valve fitted at Outlet of pressure tank outlet through I/P converter. These units along with necessary piping are fitted on support housing designed for tabletop mounting.

The controller can be connected to computer through Ethernet /USB port for monitoring the process in SCADA mode.

Procedure:-

Start up set up as explained in general instructions.



- ☐ Click Select Experiment, select Process Reaction and click Start
- ☐ Adjust controller output, so that the process value is maintained at 60%.
- ☐ Start data logging.
- ☐ With the controller still in manual mode impose a step change apply a 20-30% change to controller output. (Open the control valve) Record the step response. Wait for the steady state.
- ☐ Stop data logging.
- ☐ Plot the step response (Process reaction curve) from stored data. Find out the value of slope at the

point of inflection and time lag.

- ☐ Calculate P I D settings for different modes.
- ☐ Select PID Mode option for control from software. (Click on “Change Expt.” Button, click on “Change”, Click on “PID Mode” button.) Switch on the controller to manual mode and Keep the set point to 60%. Adjust output value so as to match the process value to set point.
- ☐ Set the PID values obtained from the calculations. Switch on the controller to Auto mode. Apply the step change & observe the response of the system. Allow the system to reach steady state.

Observations:-

(Refer Theory process control for formula.)

- ☐ Step change to the system $P = \text{Initial output} - \text{Final output of the controller}$.
- ☐ Plot the graph of process value Vs Time on a graph paper.
- ☐ From process reaction curve:

Slope of the process reaction curve $R = \frac{\text{Time}}{\text{Slope}}$

lag $L =$

- ☐ Calculate P, PI, and PID setting from above values.
- ☐ Observe response of the system for different PID settings.

8. Aim of the experiment:-

To study the Tuning of controller (Closed loop method)

Apparatus required:-

Pressure control trainer

Theory: - Pressure control trainer is designed for understanding the basic principles of pressure control. The process set up consists of pressure vessel fitted with pneumatic control valve. Pressure transmitter is used for pressure sensing.

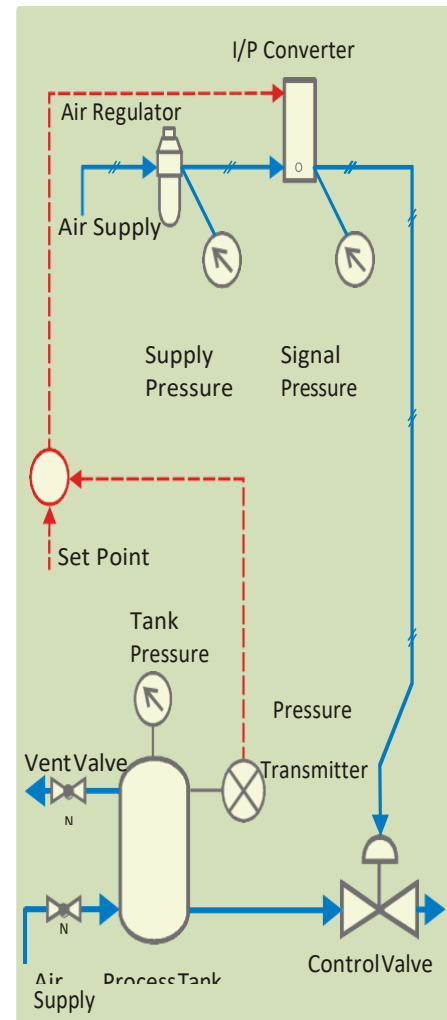
The process parameter (Pressure) is controlled by microprocessor based digital indicating controller which manipulates pneumatic control valve fitted at Outlet of pressure tank outlet through I/P converter. These units along with necessary piping are fitted on support housing designed for tabletop mounting.

The controller can be connected to computer through Ethernet /USB port for monitoring the process in SCADA mode.

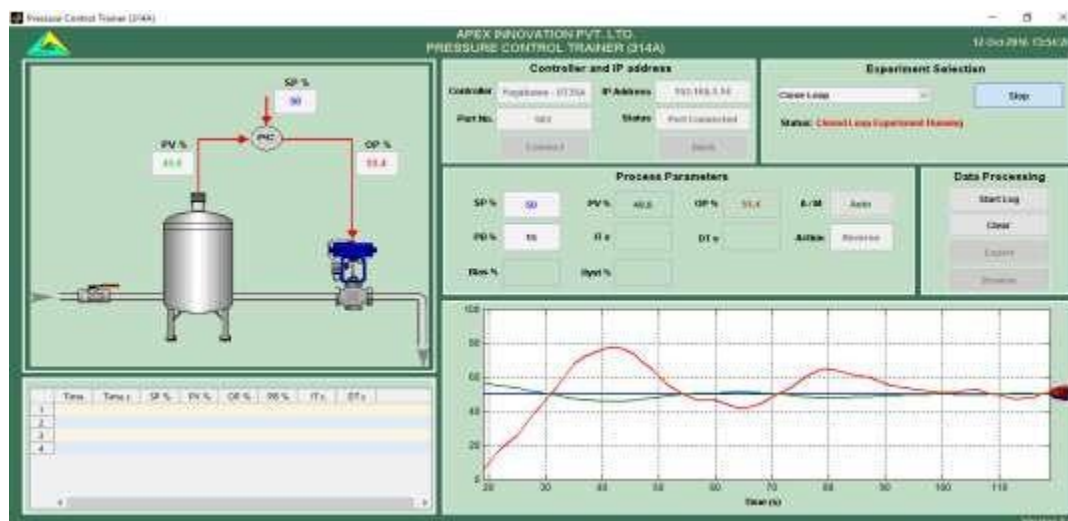
Procedure:-

Start up set up as explained in general instructions.

- ☐ Click Select Experiment, select Close Loop and click Start
- ☐ Set the proportional band value to maximum (Say 100). Set the controller to manual mode and adjust the output so that the process is nearly at set point (60%).
- ☐ Set controller to auto mode and impose step on the process by moving the set point for a few seconds & then return to its original value (or apply the step change to the set point of 5%).
Wait for some time & observe the response.
- ☐ Decrease the proportional band to the half of previous and impose step on the process as mentioned above. Wait for some time & observe the response.



- Repeat the above procedure and find out correct value of proportional band for which the system just goes unstable i.e. continuous oscillations are observed in the output of controller.
- Record the ultimate proportional band and ultimate period from the response.
- Calculate the PID values from the table. Select the PID controller and apply the parameter values obtained from the above steps. Observe the response of the process to a step change with these settings.



Observations

- Record the ultimate proportional band (Pbu) and ultimate period (Tu) from above experiment.
- Calculate PID values by referring theory part for different control actions.
- Observe the process response for these settings.
- Compare the values obtained with open loop response method.

9. Aim of the experiment:-

To study the Tuning of controller (Using Auto Tuning method)

Apparatus Required:-

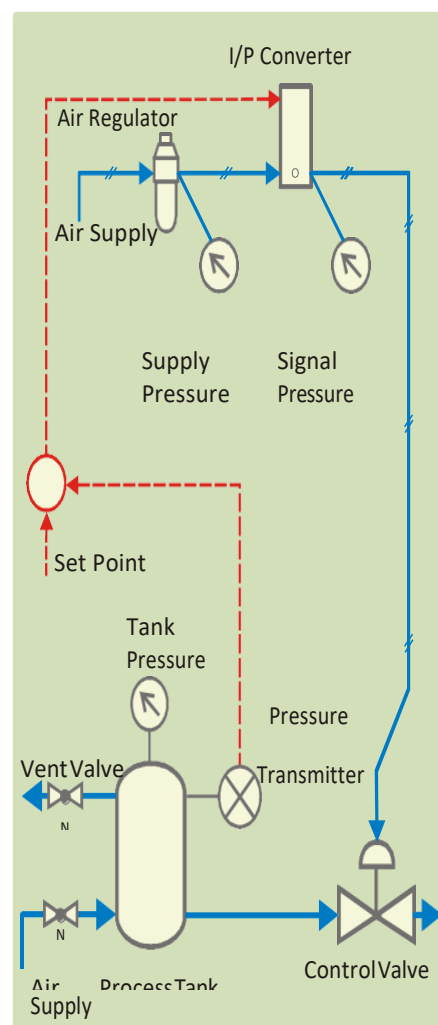
Pressure control trainer

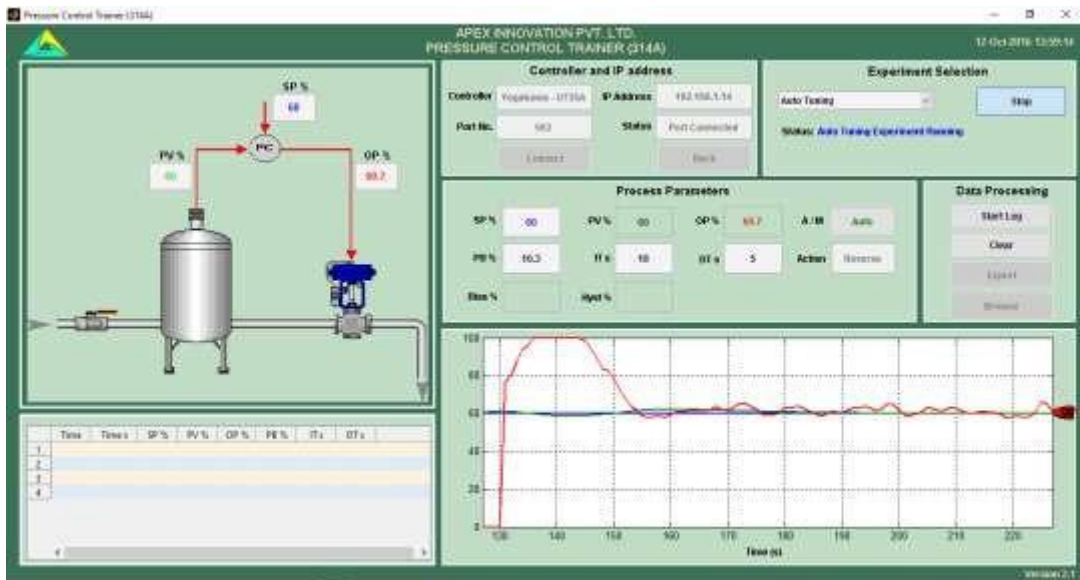
Theory: - Pressure control trainer is designed for understanding the basic principles of pressure control. The process set up consists of pressure vessel fitted with pneumatic control valve. Pressure transmitter is used for pressure sensing. The process parameter (Pressure) is controlled by microprocessor based digital indicating controller which manipulates pneumatic control valve fitted at Outlet of pressure tank outlet through I/P converter. These units along with necessary piping are fitted on support housing designed for tabletop mounting. The controller can be connected to computer through Ethernet /USB port for monitoring the process in SCADA mode.

Procedure:-

Start up set up as explained in general instructions.

- ☐ Click Select Experiment, select Auto tune and click Start
- ☐ Wait Till Auto tune is complete. (Blinking of green LED stops).
- ☐ Controller automatically finds the PB, IT & DT values.
- ☐ Find out PID values at different set points /vent valve positions rates.





Apparatus required:-

Theory: - Pressure control trainer is designed for understanding the basic principles of pressure control. The process set up consists of pressure vessel fitted with pneumatic control valve. Pressure transmitter is used for pressure sensing.

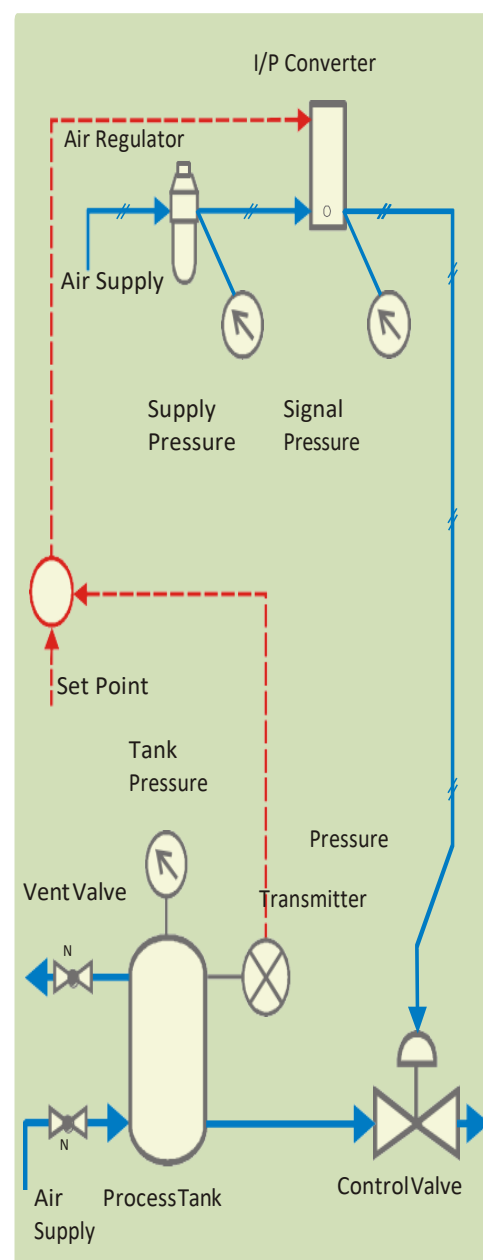
The process parameter (Pressure) is controlled by microprocessor based digital indicating controller which manipulates pneumatic control valve fitted at

Outlet of pressure tank outlet through I/P converter. These units along with necessary piping are fitted on support housing designed for tabletop mounting.

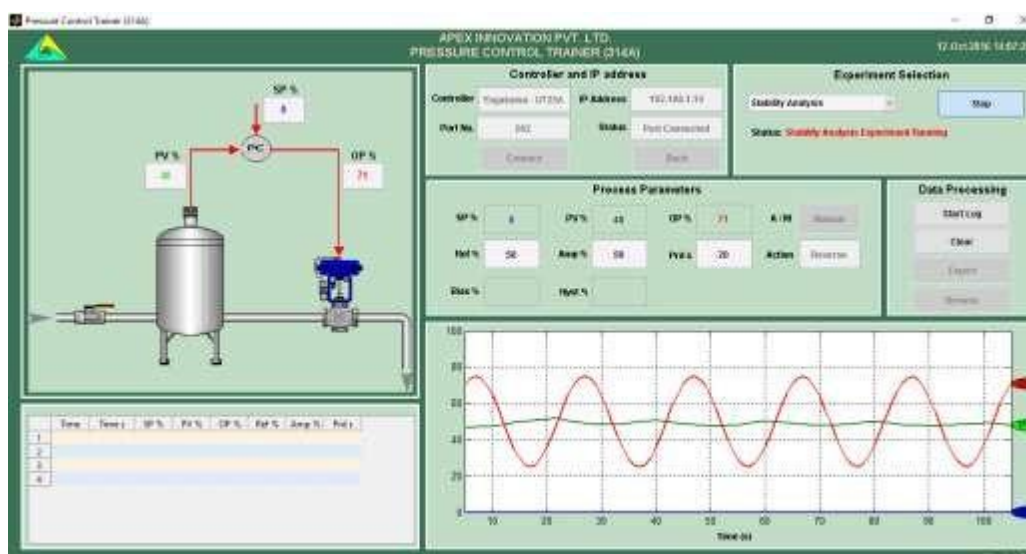
The controller can be connected to computer through Ethernet /USB port for monitoring the process in SCADA mode.

Procedure:-

Start up set up as explained in general instructions.



- ☐ Click Select Experiment, select Stability analysis and click Start
- ☐ Select function generator to apply the sinusoidal input to the output of the controller.
- ☐ Enter Reference point, Amplitude and Period.
- ☐ Observe the sinusoidal output of the controller and sinusoidal response of the process.
- ☐ Log the data for records.
- ☐ Change the period and repeat the observation for 3-4 different values of the period.



Observations

- ☐ Form the data file stored note down the
- ☐ Observe the output response of the process and note down the output amplitude. Measure output wave period and note down as T sec. Measure the phase lag ϕ and note down in sec.

Obs. No.	Input amplitude A1 %	Output amplitude A2 %	Output Period T in sec	Lag ϕ In sec	Frequency

Calculations

- ☐ Calculate for each observation
 Magnitude ratio as $M = A2/A1$
 Phase angle = $(\phi/T) \times 360$
 Frequency = $1/T$ cycles/sec.
- ☐ Draw the graphs of: Magnitude Vs frequency on log - log scale
 Phase angle Vs frequency on semi-log coordinates.
- ☐ Study the graph for stability conditions mentioned in theory

Level Control Trainer

1. Aim of the experiment:-

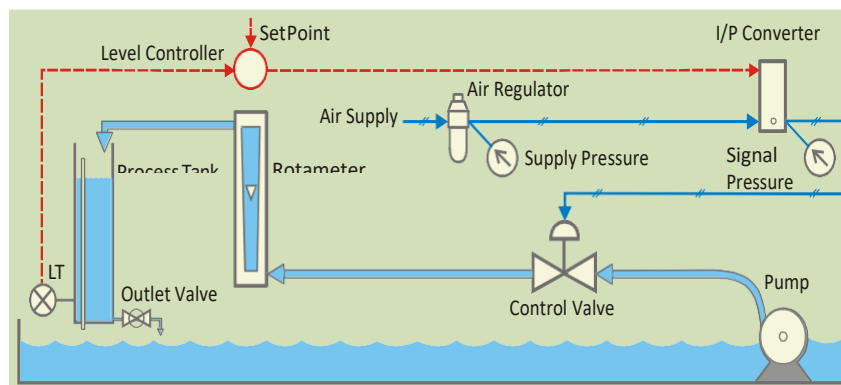
To Study of open loop response (Manual control)

Apparatus required:-

Level control Trainer

Theory: - Level control trainer is designed for understanding the basic principles of level control. The process setup consists of supply water tank fitted with pump for water circulation. The level transmitter used for level sensing is fitted on transparent process tank. The process parameter (level) is controlled by microprocessor based digital indicating controller which manipulates pneumatic control valve through I/P converter. A pneumatic control valve adjusts the water flow in to the tank. These units along with necessary piping are fitted on support housing designed for tabletop mounting.

The controller can be connected to computer through Ethernet / USB port for monitoring the process in SCADA mode.

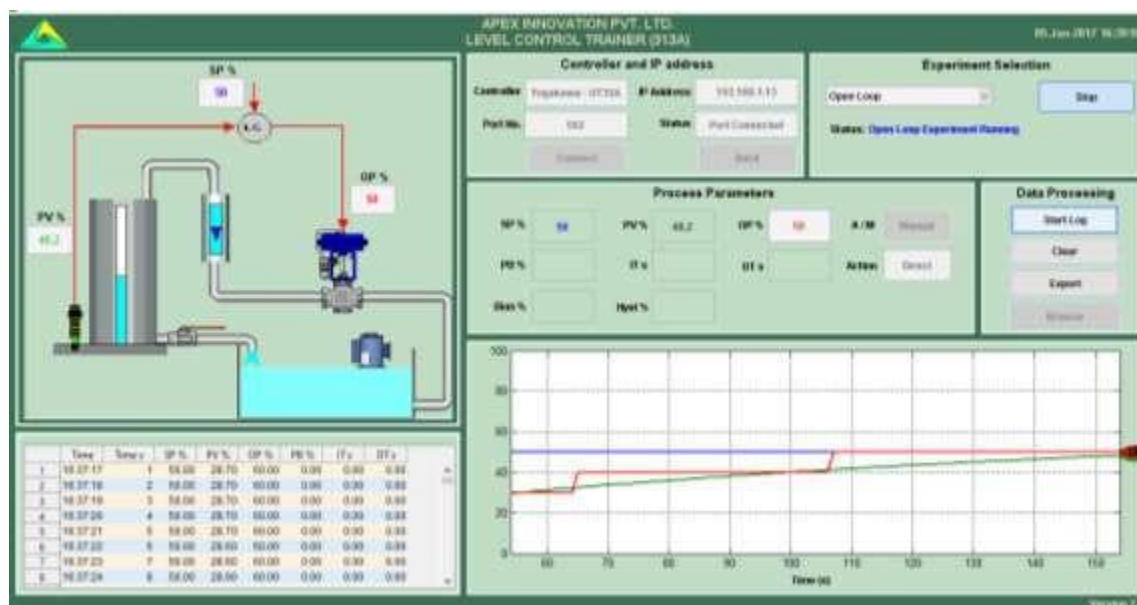


Procedure:-

- ☐ Start up set up as explained in general instructions.
- ☐ Click Select Experiment, select Open Loop and click Start
- ☐ Open the control valve fully by decreasing the controller output to 0%. (Click on Auto, Change it to Man then change OP to 0%)
- ☐ Adjust the tank drain valve such that the tank level shall remain between 90 and 100%
Change the controller to Auto mode
- ☐ Close the control valve by increasing the controller output to 100%.
- ☐ Apply the step change by 10% to controller output in manual mode, wait for the level

Department of Chemical Engineering, Veer Surendra Sai University of Technology Burla
to reach the steady state value.

- ☐ Repeat the above step until the controller output reaches to minimum i.e. 0%.



Observations

- ☐ Tabulate the results as follows

Controller output in %	Process Value in %
100	
90	
...	
0	

- ☐ From the above data, note the output required for maintaining the level at desired set points. (For particular drain valve opening).
- ☐ Set the output of the controller to the noted value and at steady state apply the load change to the process. Load change can be given by slightly varying the drain valve. Observe new steady state process value.

2.Aim of the experiment:--

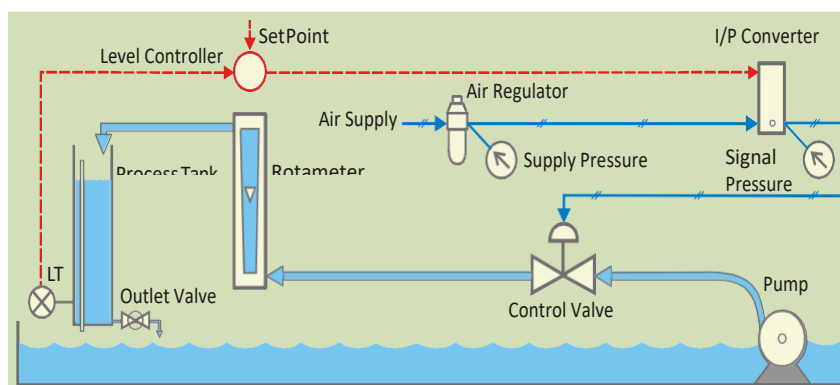
To Study of on/off controller

Apparatus Required:-

Level control Trainer

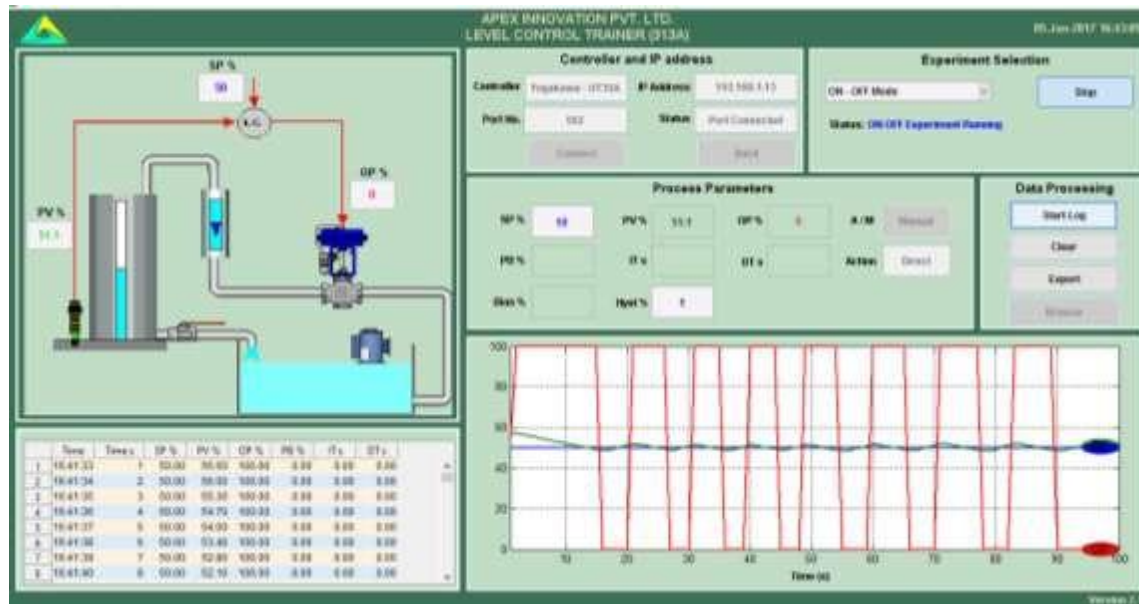
Theory: - - Level control trainer is designed for understanding the basic principles of level control. The process setup consists of supply water tank fitted with pump for water circulation. The level transmitter used for level sensing is fitted on transparent process tank. The process parameter (level) is controlled by microprocessor based digital indicating controller which manipulates pneumatic control valve through I/P converter. A pneumatic control valve adjusts the water flow in to the tank. These units along with necessary piping are fitted on support housing designed for tabletop mounting.

The controller can be connected to computer through Ethernet / USB port for monitoring the process in SCADA mode.



Procedure:-

- ☐ Start up set up as explained in general instructions.
- ☐ Click Select Experiment, select On-Off Mode and click Start
- ☐ Open the control valve fully by decreasing the controller output to 0%. (Click on Auto, Change it to Man then change OP to 0%)
- ☐ Adjust the tank drain valve such that the tank level shall remain between 90 and 100% Change the controller to Auto mode
- ☐ Change Hysteresis value to 5%. (Range 0.1-10%)
- ☐ Change the values of the set point and observe the On-Off control operation.



Observations

- Observe that if process value exceeds the setpoint and increases above the value of (0.5x Hysteresis), control valve is fully closed and if process value decreases below the set point by (0.5x Hysteresis), the control valve opens fully i.e. controller operates like On/Off switch.

3. Aim of the experiment:-

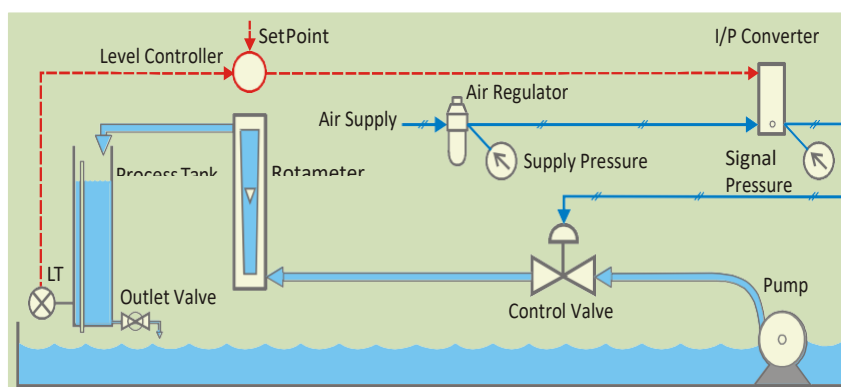
Study of proportional controller

Apparatus Required:-

Level control Trainer

Theory: - Level control trainer is designed for understanding the basic principles of level control. The process setup consists of supply water tank fitted with pump for water circulation. The level transmitter used for level sensing is fitted on transparent process tank. The process parameter (level) is controlled by microprocessor based digital indicating controller which manipulates pneumatic control valve through I/P converter. A pneumatic control valve adjusts the water flow in to the tank. These units along with necessary piping are fitted on support housing designed for tabletop mounting.

The controller can be connected to computer through Ethernet / USB port for monitoring the process in SCADA mode.

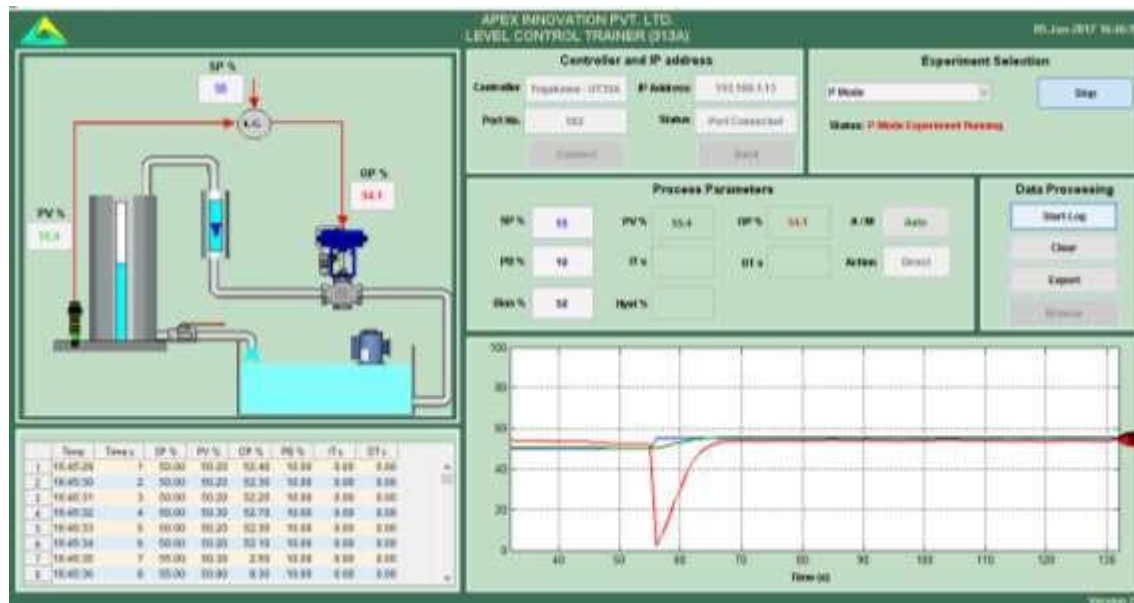


Procedure:-

- ☐ Start up set up as explained in general instructions.
- ☐ Click Select Experiment, select P Mode and click Start
- ☐ Open the control valve fully by decreasing the controller output to 0%. (Click on Auto, Change it to Man then change OP to 0%)
- ☐ Adjust the tank drain valve such that the tank level shall remain between 90 and 100% Change the controller to Auto mode
- ☐ Adjust the process value by switching the controller to manual mode to a particular level (say 50 %) on the screen and apply output of the controller as bias value. Change the proportional band to 100%.
- ☐ Switch the controller to auto mode.
- ☐ Apply step change of 10% to set point.

Department of Chemical Engineering, Veer Surendra Sai University of Technology Burla

- Switch the controller to manual mode. Decrease proportional band to half of the previous value. With each decrease, obtain a new response of the step change. Ensure that the set point changes are around the same operating point (Say 50%).



Observations

- Observe the effect of very low proportional band values (system works as on-off control).
- Observe the response of the system at load change. Load change can be given by slightly manipulating the drain valve of the tank.

4 .Aim of the Experiment:-

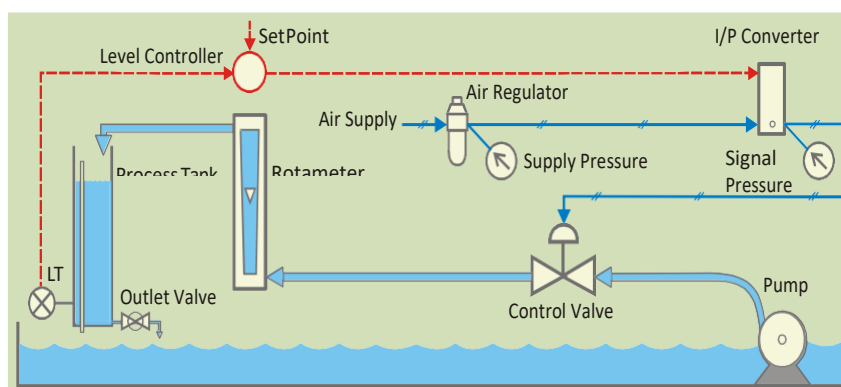
Study of proportional integral controller

Apparatus Required:-

Level Control Trainer

Theory: - Level control trainer is designed for understanding the basic principles of level control. The process setup consists of supply water tank fitted with pump for water circulation. The level transmitter used for level sensing is fitted on transparent process tank. The process parameter (level) is controlled by microprocessor based digital indicating controller which manipulates pneumatic control valve through I/P converter. A pneumatic control valve adjusts the water flow in to the tank. These units along with necessary piping are fitted on support housing designed for tabletop mounting.

The controller can be connected to computer through Ethernet / USB port for monitoring the process in SCADA mode.



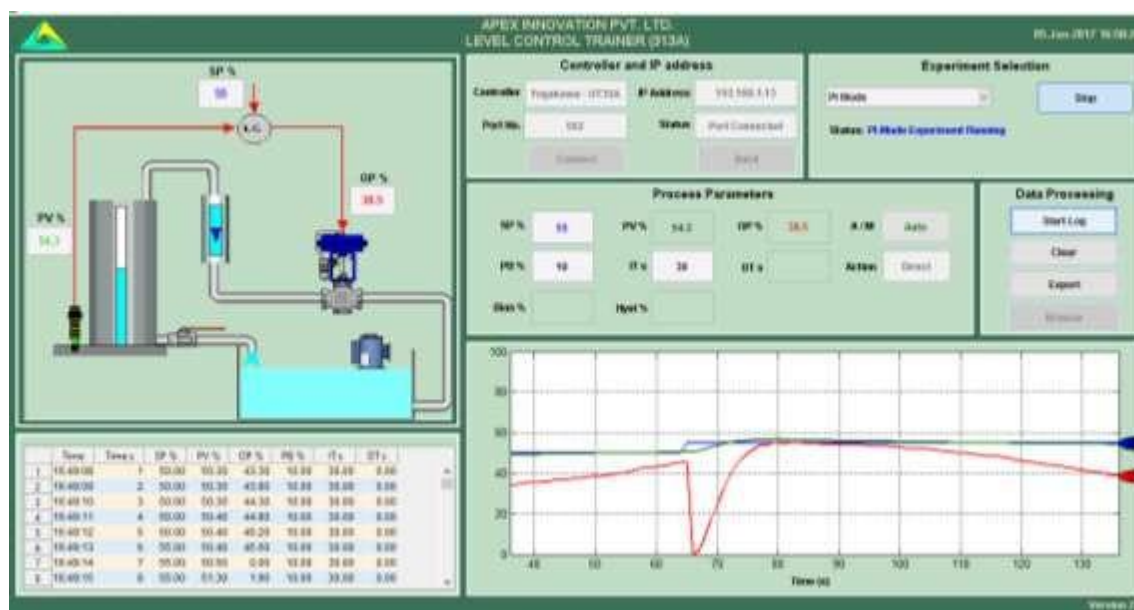
Procedure:-

- ☐ Start up set up as explained in general instructions.
- ☐ Click Select Experiment, select PI Mode and click Start
- ☐ Open the control valve fully by decreasing the controller output to 0%. (Click on Auto, Change it to Man then change OP to 0%)
- ☐ Adjust the tank drain valve such that the tank level shall remain between 90 and 100%
Change the controller to Auto mode
- ☐ Set the proportional band estimated in Proportional control. Set derivative time to 0 sec and integral time 6000 sec, which will cut off the derivative action and widen the effect of integral action.

17-04-2019 Set the set point to desired level value (@50%). Allow the process to reach at steady state

Department of Chemical Engineering, Veer Surendra Sai University of Technology Burla
Record the steady state error.

- ☐ Switch the controller to manual mode. Reduce the integral time to half of the previous value. Switch to Auto mode and apply step change (+/- 10%) to the set point. Note the response of the system.
- ☐ Repeat above step to observe the effect of changes in Integral setting.



Observations

- ☐ Observe the effect of reducing integral time on the response of the process.

5. Aim of the Experiment:-

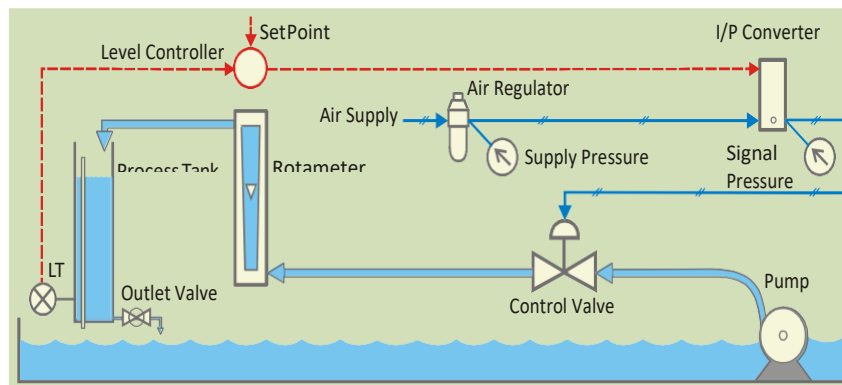
Study of proportional derivative controller

Apparatus Required:-

Level control trainer

Theory: - Level control trainer is designed for understanding the basic principles of level control. The process setup consists of supply water tank fitted with pump for water circulation. The level transmitter used for level sensing is fitted on transparent process tank. The process parameter (level) is controlled by microprocessor based digital indicating controller which manipulates pneumatic control valve through I/P converter. A pneumatic control valve adjusts the water flow in to the tank. These units along with necessary piping are fitted on support housing designed for tabletop mounting.

The controller can be connected to computer through Ethernet / USB port for monitoring the process in SCADA mode.

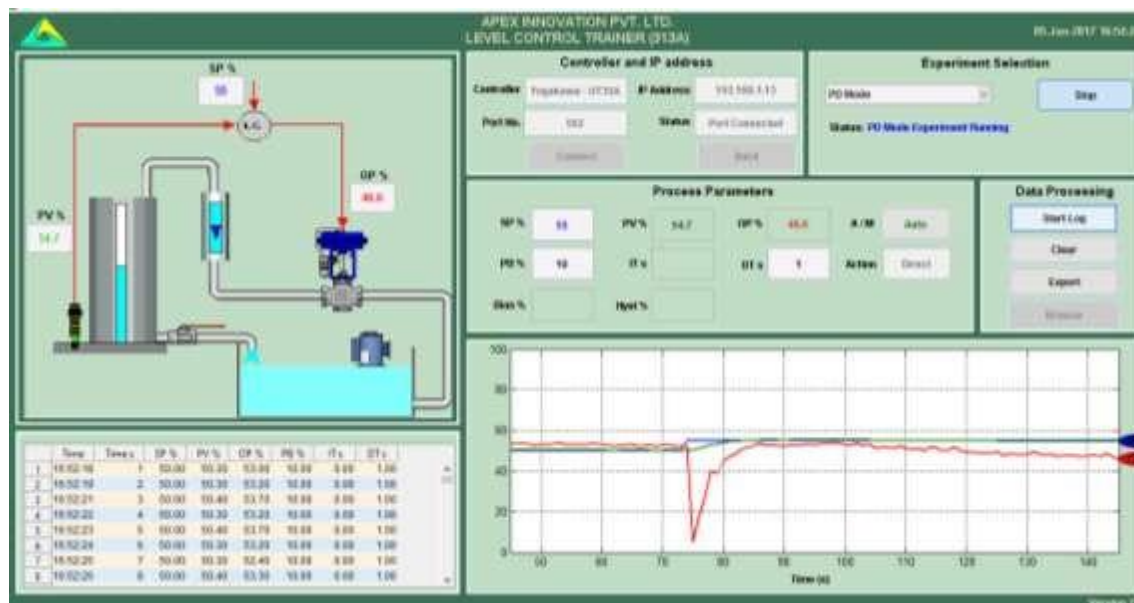


Procedure:-

- ☐ Start up set up as explained in general instructions.
- ☐ Click Select Experiment, select PD Mode and click Start
- ☐ Open the control valve fully by decreasing the controller output to 0%. (Click on Auto, Change it to Man then change OP to 0%)
- ☐ Adjust the tank drain valve such that the tank level shall remain between 90 and 100%
Change the controller to Auto mode
- ☐ Set the proportional band estimated from Proportional control (P only) Set derivative time to 0 and integral time=6000 sec.
- ☐ Set the setpoint to desired value. Allow the process to reach at steady state. Note the response of the system.

Department of Chemical Engineering, Veer Surendra Sai University of Technology Burla

- Switch the controller to manual mode. Increase the derivative time by 1 sec. Switch to Auto mode and apply step change to the set point by 5 to 10%. Note the response of the system.
- Increase the derivative time gradually and observe the process response for step change.



Observations

- Compare the steady state response of the PD controller with PI controller obtained in the previous experiment.

6. Aim of the experiment:-

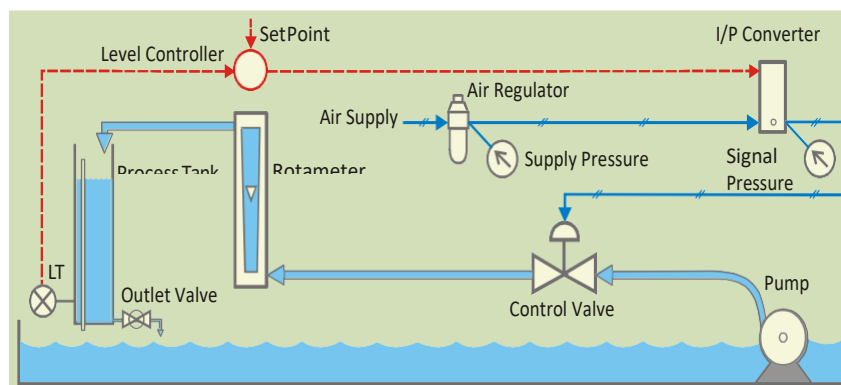
Study of proportional integral derivative controller

Apparatus Required:-

Level control Trainer

Theory: - Level control trainer is designed for understanding the basic principles of level control. The process setup consists of supply water tank fitted with pump for water circulation. The level transmitter used for level sensing is fitted on transparent process tank. The process parameter (level) is controlled by microprocessor based digital indicating controller which manipulates pneumatic control valve through I/P converter. A pneumatic control valve adjusts the water flow in to the tank. These units along with necessary piping are fitted on support housing designed for tabletop mounting.

The controller can be connected to computer through Ethernet / USB port for monitoring the process in SCADA mode.

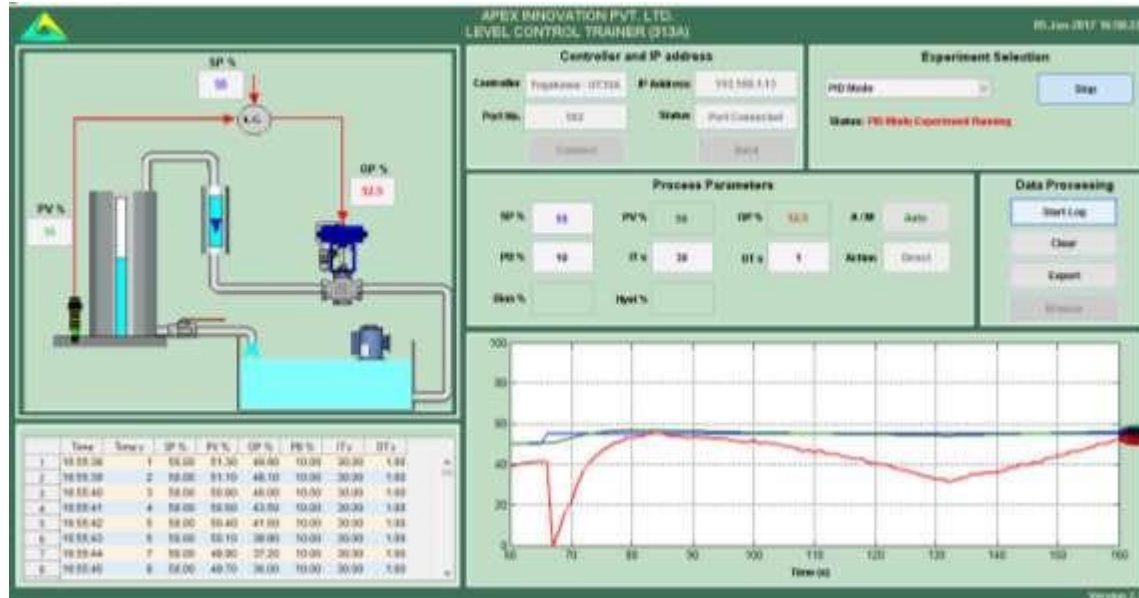


Procedure:-

- ☐ Start up set up as explained in general instructions.
- ☐ Click Select Experiment, select PID mode and click Start
- ☐ Open the control valve fully by decreasing the controller output to 0%. (Click on Auto, Change it to Man then change OP to 0%)
- ☐ Adjust the tank drain valve such that the tank level shall remain between 90 and 100%
Change the controller to Auto mode
- ☐ 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 experiments.
- ☐ Adjust the set point to @ 50%. Switch the controller to auto mode. Apply step change of

Department of Chemical Engineering, Veer Surendra Sai University of Technology Burla
10%. Observe the process response.

- ☐ Change the proportional band, integral time, derivative time and observe the response of



the process for step change for each change in setting.

Observations:-

- ☐ Compare the steady state response of the PID controller with P, PI and PD controller obtained in the above experiment.

7. Aim of the Experiment:-

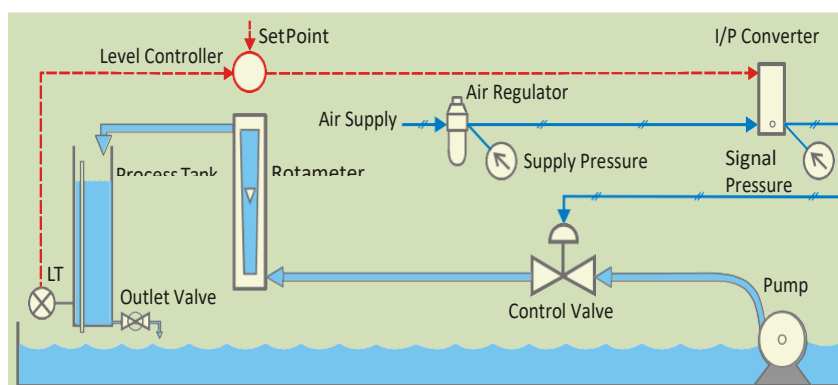
Tuning of controller (Open loop method)

Apparatus Required:-

Level control trainer

Theory: - Level control trainer is designed for understanding the basic principles of level control. The process setup consists of supply water tank fitted with pump for water circulation. The level transmitter used for level sensing is fitted on transparent process tank. The process parameter (level) is controlled by microprocessor based digital indicating controller which manipulates pneumatic control valve through I/P converter. A pneumatic control valve adjusts the water flow in to the tank. These units along with necessary piping are fitted on support housing designed for tabletop mounting.

The controller can be connected to computer through Ethernet / USB port for monitoring the process in SCADA mode.

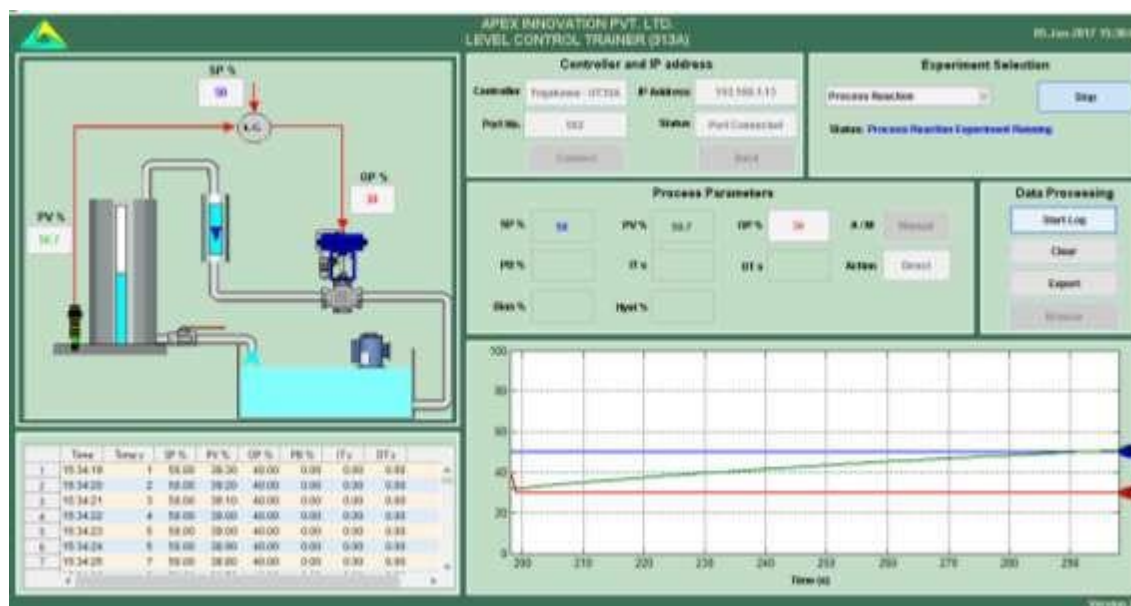


Procedure:-

- ☐ Start up set up as explained in general instructions.
- ☐ Click Select Experiment, select Process Reaction and click Start
- ☐ Open the control valve fully by decreasing the controller output to 0%. (Click on Auto, Change it to Man then change OP to 0%)
- ☐ Adjust the tank drain valve such that the tank level shall remain between 90 and 100%
Change the controller to Auto mode
- ☐ Adjust controller output, so that the process value is maintained at 50%.
- ☐ Start data logging.
- ☐ Apply a 20-30% change to controller output. (Open the control valve) Record the step response. Wait for the steady state.

Department of Chemical Engineering, Veer Surendra Sai University of Technology Burla

- Stop data logging.
- ☐ Plot the step response (Process reaction curve) from stored data. Find out the value of slope at the point of inflection and time lag.
- ☐ Calculate P I D settings for different modes.
- ☐ Select **close loop**, switch auto manual key to auto mode and then select controller to study. Set the PID values obtained from the calculations. Apply the step change & observe the



response of the system. Allow the system to reach steady state.

Observations

(Refer Theory process control for formulae.)

- ☐ Step change to the system $P = \text{Initial output} - \text{Final output of the controller}$.
- ☐ Plot the graph of process value Vs Time on a graph paper from process reaction curve:
 - Slope of the process reaction curve $R =$
 - Time lag $L =$
- ☐ Calculate P, PI, and PID setting from above values.
- ☐ Observe response of the system for different PID settings.

8. Aim of the experiment:-

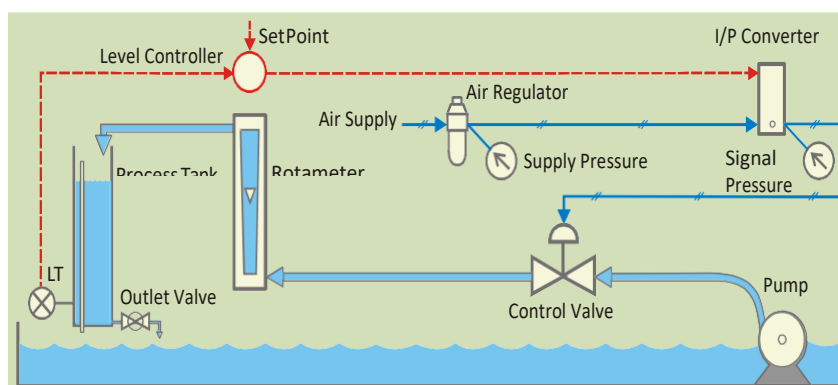
Tuning of controller (Closed loop method)

Apparatus Required:-

Level control Trainer

Theory: - Level control trainer is designed for understanding the basic principles of level control. The process setup consists of supply water tank fitted with pump for water circulation. The level transmitter used for level sensing is fitted on transparent process tank. The process parameter (level) is controlled by microprocessor based digital indicating controller which manipulates pneumatic control valve through I/P converter. A pneumatic control valve adjusts the water flow in to the tank. These units along with necessary piping are fitted on support housing designed for tabletop mounting.

The controller can be connected to computer through Ethernet / USB port for monitoring the process in SCADA mode.

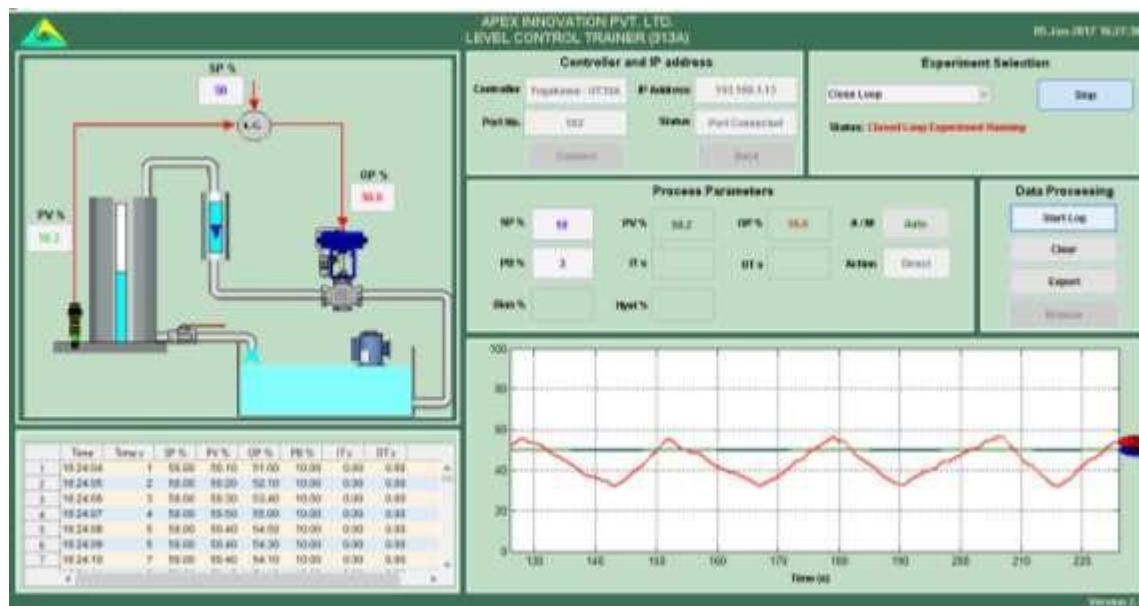


Procedure:-

- ☐ Start up set up as explained in general instructions.
- ☐ Click Select Experiment, select Close Loop and click Start
- ☐ Open the control valve fully by decreasing the controller output to 0%. (Click on Auto, Change it to Man then change OP to 0%)
- ☐ Adjust the tank drain valve such that the tank level shall remain between 90 and 100%
Change the controller to Auto mode
- ☐ Select P controller only. Set the proportional band value to maximum (Say 100). Set the controller to manual mode and adjust the output so that the process value reaches to 50%.
- ☐ Switch the controller to auto mode and decrease the proportional band and apply the step change to the set point and observe the process response.

Department of Chemical Engineering, Veer Surendra Sai University of Technology Burla

- Repeat the above procedure and find out correct value of proportional band for which the system just goes unstable i.e. continuous oscillations are observed in the output of controller.
- Record the ultimate proportional band and ultimate period from the response.
- Calculate the PID values from the table. Select the PID controller and apply the parameter values obtained from the above steps. Observe the response of the process to a step change with these settings.



Observations

- Record the ultimate proportional band (P_{bu}) and ultimate period (T_u) from above experiment.
- Calculate PID values by referring theory part for different control actions. Observe the process response for these settings.
- Compare the values obtained with open loop response method.

9. Aim of the experiment:-

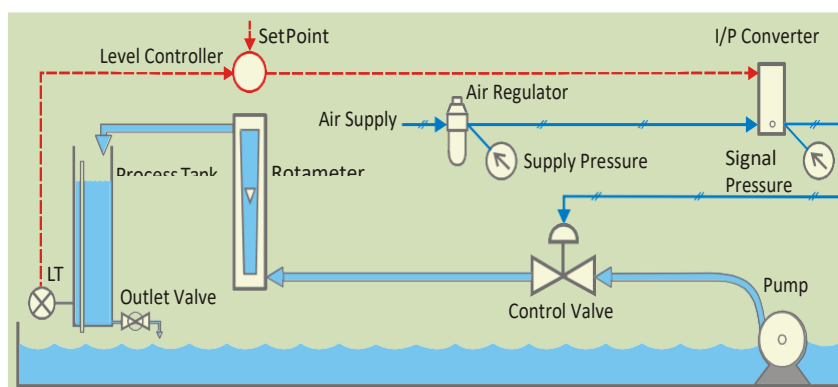
Tuning of controller (Using Auto Tuning method)

Apparatus Required:-

Level Control Trainer

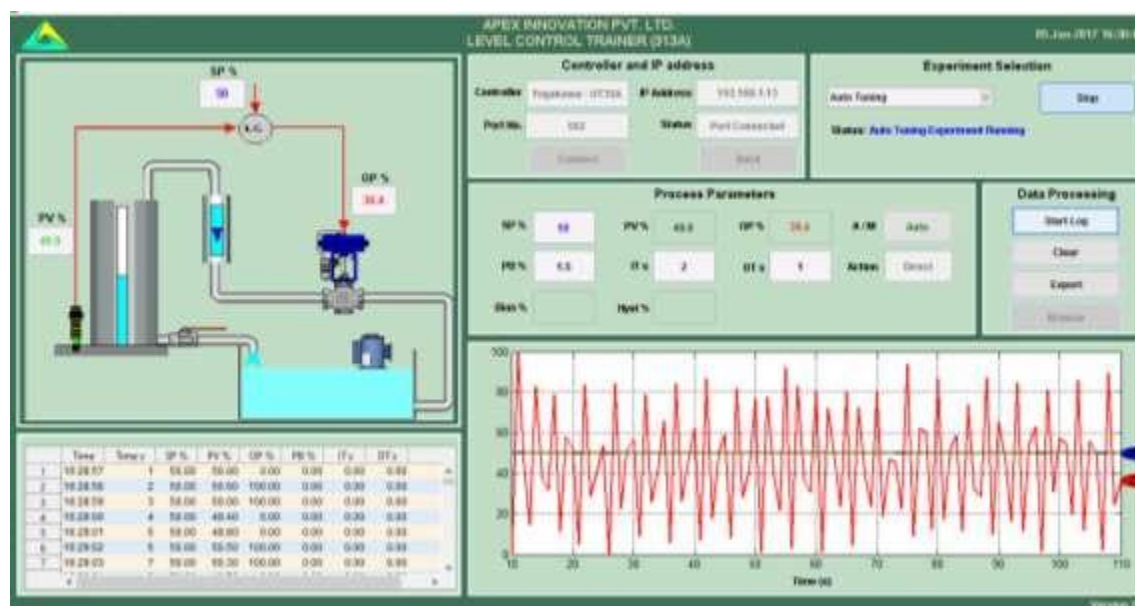
Theory: - Level control trainer is designed for understanding the basic principles of level control. The process setup consists of supply water tank fitted with pump for water circulation. The level transmitter used for level sensing is fitted on transparent process tank. The process parameter (level) is controlled by microprocessor based digital indicating controller which manipulates pneumatic control valve through I/P converter. A pneumatic control valve adjusts the water flow in to the tank. These units along with necessary piping are fitted on support housing designed for tabletop mounting.

The controller can be connected to computer through Ethernet / USB port for monitoring the process in SCADA mode.



Procedure:-

- ☐ Start up set up as explained in general instructions.
- ☐ Click Select Experiment, select Auto tune and click Start
- ☐ Wait Till Auto tune is complete. (Blinking of green LED stops).
- ☐ Controller automatically finds the PB, IT & DT values.
- ☐ Find out PID values at different set points/flow rates



Observations

- The controller has preprogrammed logic for finding “Auto tune” values. Based on the response of the process the controller calculates PID values or comes out without finding the “Auto tune” values.

10. Aim of the Experiment:-

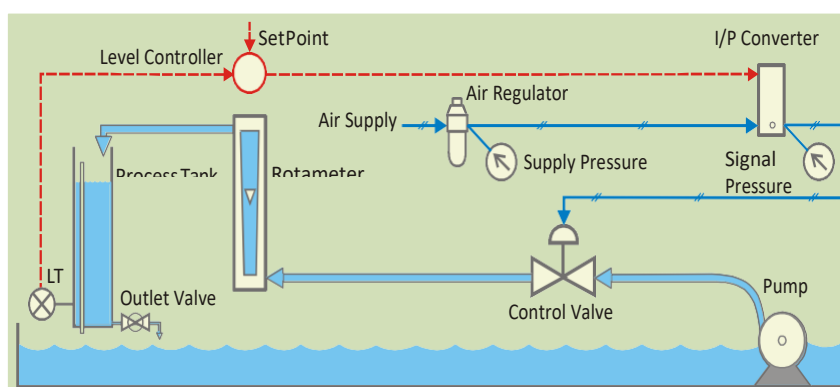
To study stability of the system (Bode plot)

Apparatus required:-

Level Control Trainer

Theory: - Level control trainer is designed for understanding the basic principles of level control. The process setup consists of supply water tank fitted with pump for water circulation. The level transmitter used for level sensing is fitted on transparent process tank. The process parameter (level) is controlled by microprocessor based digital indicating controller which manipulates pneumatic control valve through I/P converter. A pneumatic control valve adjusts the water flow in to the tank. These units along with necessary piping are fitted on support housing designed for tabletop mounting.

The controller can be connected to computer through Ethernet / USB port for monitoring the process in SCADA mode.

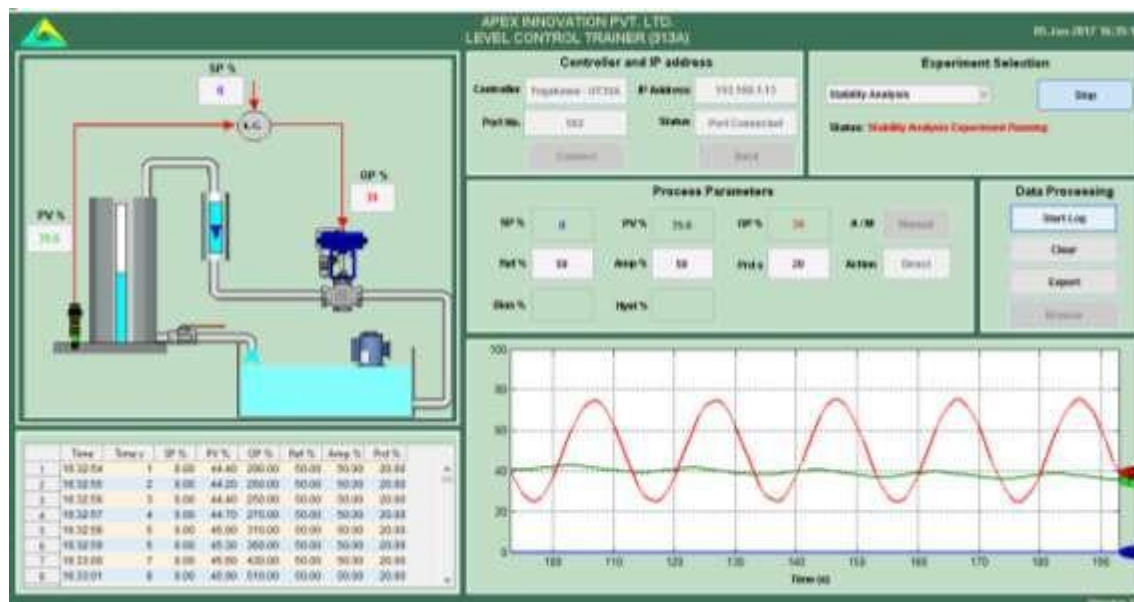


Procedure:-

- ☐ Start up set up as explained in general instructions.
- ☐ Click Select Experiment, select Stability analysis and click Start
- ☐ Open the control valve fully by decreasing the controller output to 0%. (Click on Auto, Change it to Man then change OP to 0%)
- ☐ Adjust the tank drain valve such that the tank level shall remain between 90 and 100% Change the controller to Auto mode
- ☐ Start data logging.
- ☐ Select function generator to apply the sinusoidal input to the output of the controller.

Department of Chemical Engineering, Veer Surendra Sai University of Technology Burla

- ☐ Enter Reference point, Amplitude and Period.
- ☐ Observe the sinusoidal output of the controller and sinusoidal response of the process.
- ☐ Log the data for records.
- ☐ Change the period and repeat the observation for 3-4 different values of the period.
- ☐ Repeat above procedure for different amplitude and period values.



Observations

- ☐ From the data file stored observe the output response of the process and note down the output amplitude.
- ☐ Measure output wave period and note down as T sec. Measure the phase lag ϕ and note down in sec.