TEMPERATURE CONTROL TRAINER

Product Code 311A

(PCT version)

(With Ethernet / USB communication)

Instruction manual

Contents

Apex Innovations

Documents to be referred

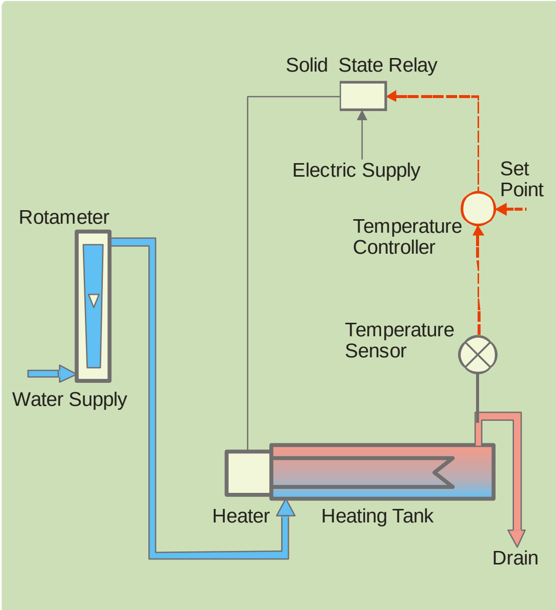
Following table lists various documents available in **PCTSoft** CD which needs to be referred while working with the product.

File name	Document description
Im311A.pdf	Product Instruction manual & Experiments
Theory Process Control.pdf	Describes theoretical aspects of process control study
Components.pdf	Additional details of the components used

Description

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.



Specifications

Product	Temperature control trainer
Product code	311A
Type of control	SCADA
Control unit	Digital indicating controller with Ethernet communication
Communication	Ethernet / USB
Temperature sensor	Type RTD, PT100
Heating control	Proportional power controller (SSR), Input 4-20 mA, Capacity 50 A.
Heater	Type Electrical 2 coil, Capacity 3 KW
Rotameter	6-60 LPH
Process tank	SS304, Capacity 0.5 lit, insulated
Overall dimensions	550Wx480Dx525H mm

Packing slip

Shipping details

Gross volume 0.15m^3, Gross weight 34kg, Net weight 21kg

Box No.1/1	Size W575xD500xH525 mm; Vol:0.15m^3	Gross weight: 34 kg Net weight:21 kg
1	Set up assembly	1 No
2	Piping set (2 Pieces)	1 No
3	Male stud	1 No
4	Communication cable	1 No
5	Tool kit	1 No
6	Set of instruction manuals consisting of: “PCTSoft” CD (Apex Innovations) User’s manual Yokogawa	1 No

Installation requirements

Electric supply

Provide 230 VAC single phase electric supply with proper earthing. (Neutral – Earth voltage less than 5 VAC)

- 5A, three pin socket with switch (1 No.)
- 15A, three pin socket with switch (1 No.)

Water supply

Continuous, clean and soft water supply @100 LPH with suitable drain arrangement.

Computer

Computer with standard configuration

Support table

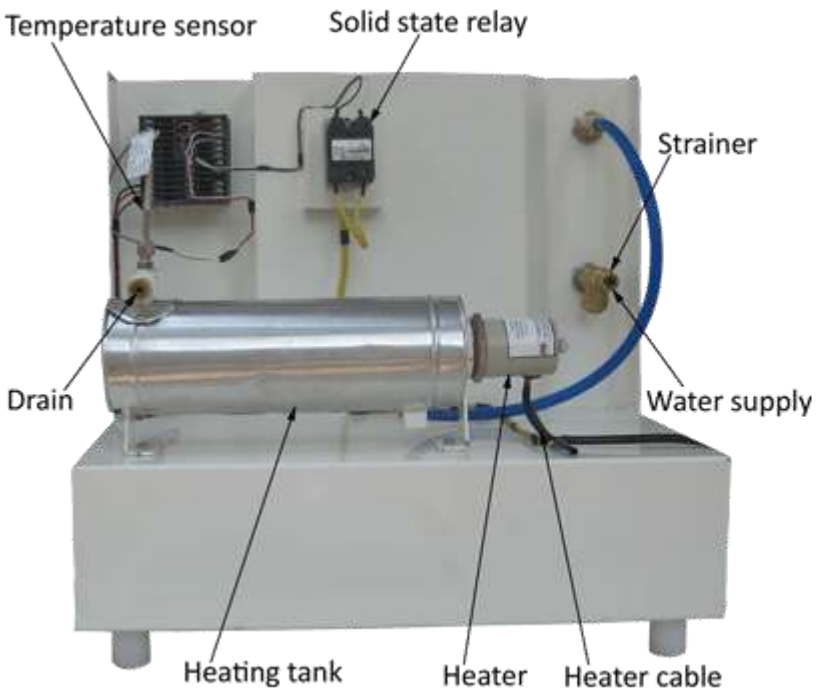
Size: 800Wx800Dx750H in mm

Installation commissioning

Installation (Ethernet port equipment)

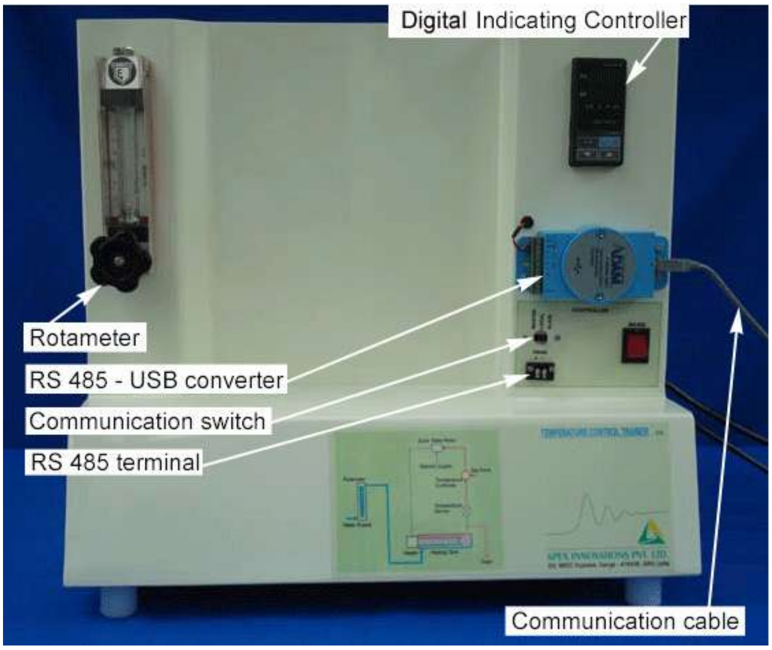
Front view

Back view:

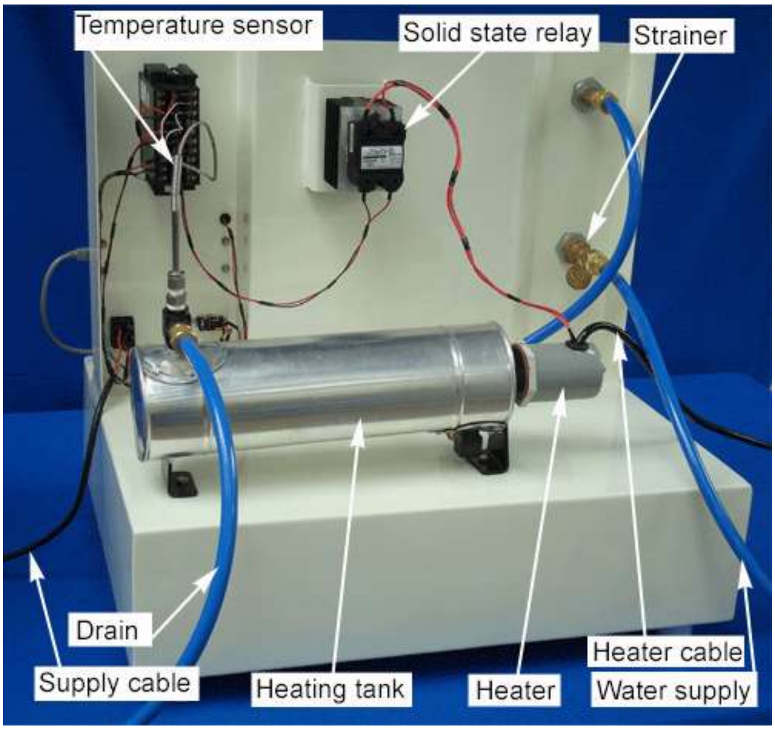


Installation (USB port equipment)

Front view



Back view:



- Unpack the box received and ensure that all material is received as per packing slip (provided in instruction manual). In case of short supply or breakage contact Apex Innovations / your supplier for further actions.
- Place the set up on table
- Water supply: Drain the supply water line for few minutes to ensure clean water is received. Then connect ***Water supply*** (PU tube) to the water supply connection. You may use ½" male stud provided with the set up.
- Connect ***Drain*** (PU tube) supplied at the outlet of ***Heating tank***. Route the outlet water to drain line.
- Remove packing wire inserted in the ***Rotameter*** by removing plug on the top of the rotameter. (Use small nose pliers)
- Connecting electric supply. Ensure that supply voltage is 230 V AC and earth neutral voltage is less than 5 V Ac.

Commissioning

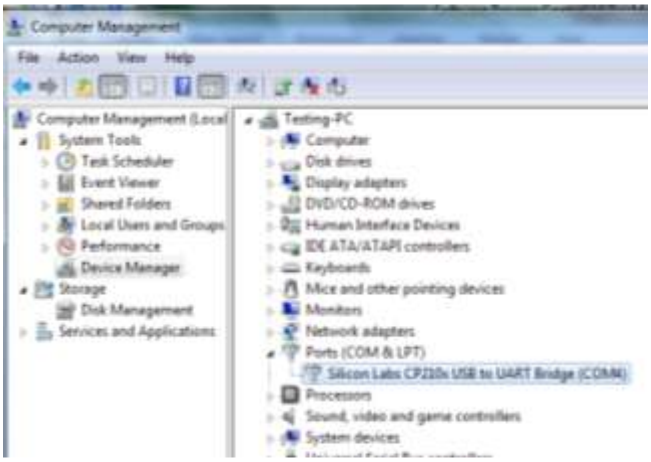
- Open the rotameter valve and circulate the water. Adjust water flow to @40 LPH.
- Connect electric ***Supply cable*** and ***Heater cable*** to the electric supply points.
- Switch on the supply for both connection and switch on "Mains".
- Set the ***Digital indicating controller*** to manual mode by pressing A/M key. Increase output from 0 to 100% in steps of 25%. Check the temperature indicated on the controller increases gradually.
- Switch on the computer and install "MCRInstaller " provided on PCTSoft CD
- Copy the file "Apex_Process_Trainers " at any drive/ folder.
- Create the desktop icon for the "Apex _Process_Trainers" for further use.
- **For Ethernet port equipment**

  Set computer IP address as **192.168.1.2**

  For USB port Equipment

  Install ADAM-4561 USB Drivers provided on ADAM Driver CD / PCT Soft CD

  - Note to which port ADAM-4561 is connected
  - Click Start | Right Click on Computer | Click Manage | Click Device Managaer |
  - Click Ports and Note the COM port Number to which the ADAM is connected.
  - Following screen shows it is connected to COM4



- Execute the software and ensure correct signals are displayed on computer.

Troubleshooting

Note: For component specific problems refer Components' Manuals

Problems	Possible causes / remedies
Temperature does not rise	• Low electric supply voltage • Burnt heater coil. Replace the heater • Faulty Solid State Relay
No communication with computer	**For Ethernet port equipment** • Check communication settings for IP addresses of computer and controller. Default setting computer 192.168.1.2 and controller 192.168.1.11 **For USB port equipment** • Improper USB port connection • Computer USB port not configured. • Ensure that the communication switch position is "Local" • Check communication settings P.SL, bPS, PrI, StP, dLn, Adr setting of the controller (Refer "Parameter setting sheet" provided in "Software Process control")

Components used

Product	Temperature control trainer
Product code	311A
Temperature sensor	Make Radix, Type Pt100, Sheath Dia.6mmX110mmL, SS316, Connection 1/4"BSP(M) adjustable compression fitting
Digital indicating controller	Make Yokogawa, Model UT35A-002-11-00 with Ethernet communication Make Yokogawa, Model UT321/UT32A(with RS 485 communication)+ RS485-USB converter, Model ADAM 4561 Make Advantech
Heating control (SSR)	Make Unison, Model UNI 701 PHT 24 25 420 (Back To Back SCR), Input 4-20 mA, O/P 230VAC with Heat sink, Rating: 25Amp. (765+89)
Heater	Type - 3.0 kw, 2 coil, industrial, Size - 1.25 " BSPx10 " L, Input 230VAC
Rotameter	Make Eureka, Model MG 10, Range 6 -60 lph, connection 1/4`` back, screwed, packing PTFE + Silicon

Warranty

This product is warranted for a period of 12 months from the date of supply against manufacturing defects. You shall inform us in writing any defect in the system noticed during the warranty period. On receipt of your written notice, Apex at its option either repairs or replaces the product if proved to be defective as stated above. You shall not return any part of the system to us before receiving our confirmation to this effect.

The foregoing warranty shall not apply to defects resulting from:

Buyer/ User shall not have subjected the system to unauthorized alterations/ additions/ modifications.

Unauthorized use of external software/ interfacing.

Unauthorized maintenance by third party not authorized by Apex.

Improper site utilities and/or maintenance.

We do not take any responsibility for accidental injuries caused while working with the set up.

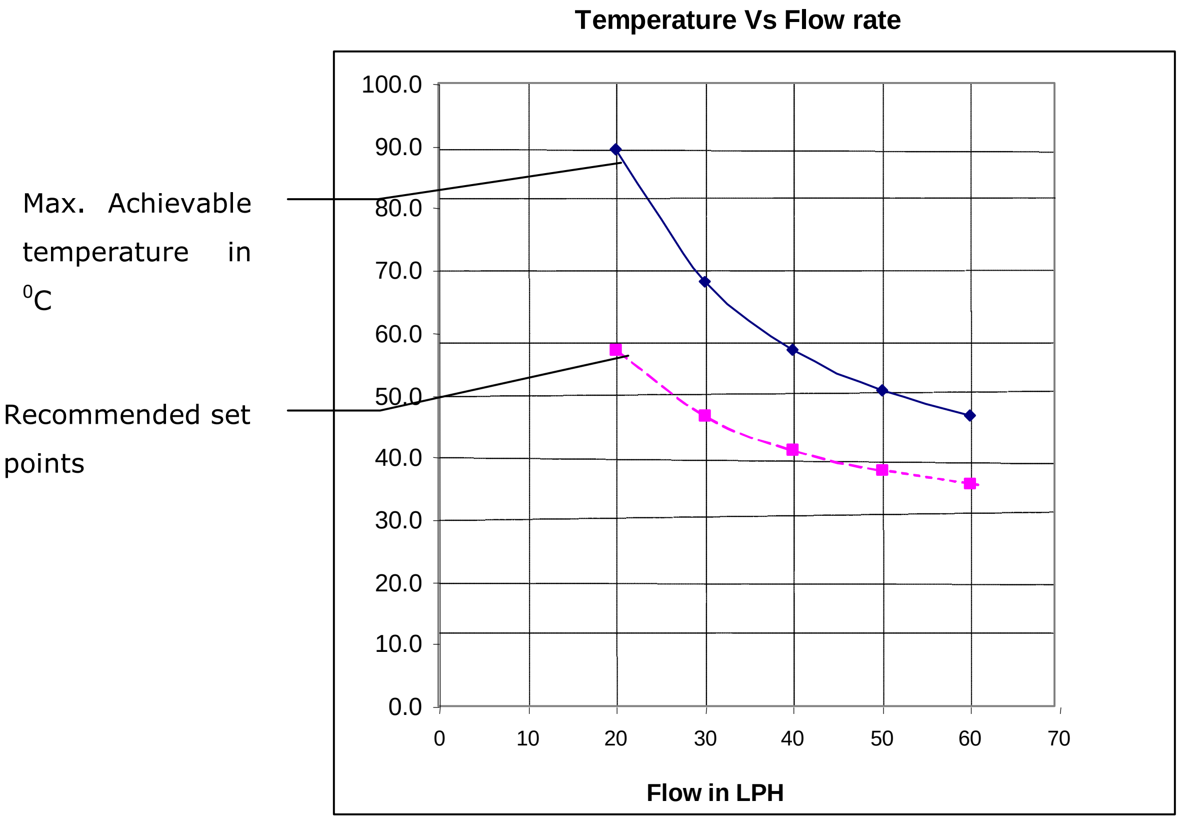
Apex Innovations Pvt. Ltd.
E9/1, MIDC, Kupwad, Sangli-416436 (Maharashtra) India
Telefax:0233-2644098, 2644398
Email: support @apexinnovations.co.in Web: www.apexinnovations.co.in

Experiments

General Instructions

1 One heater with two coils (1.5 kW each) is fitted on process tank. Two coils are connected to the SSR. Hence maximum achievable temperature at 3.0 kW energy (at 230 VAC supply voltage) for different water flow rates is shown in the following graph. (Water inlet temperature assumed 25^{0}C)

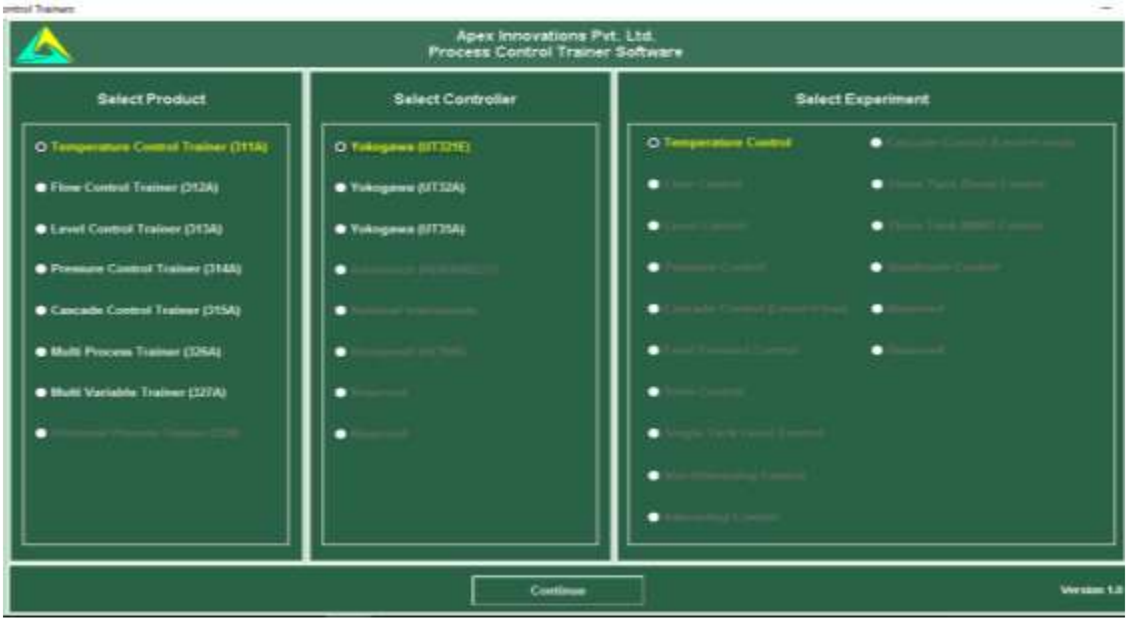
Considering the radiation and other losses recommended range for the set points for the particular flow of water is indicated in dotted line graph. It is advised to keep the flow rate of rotameter in the range of 30 to 50 LPH.



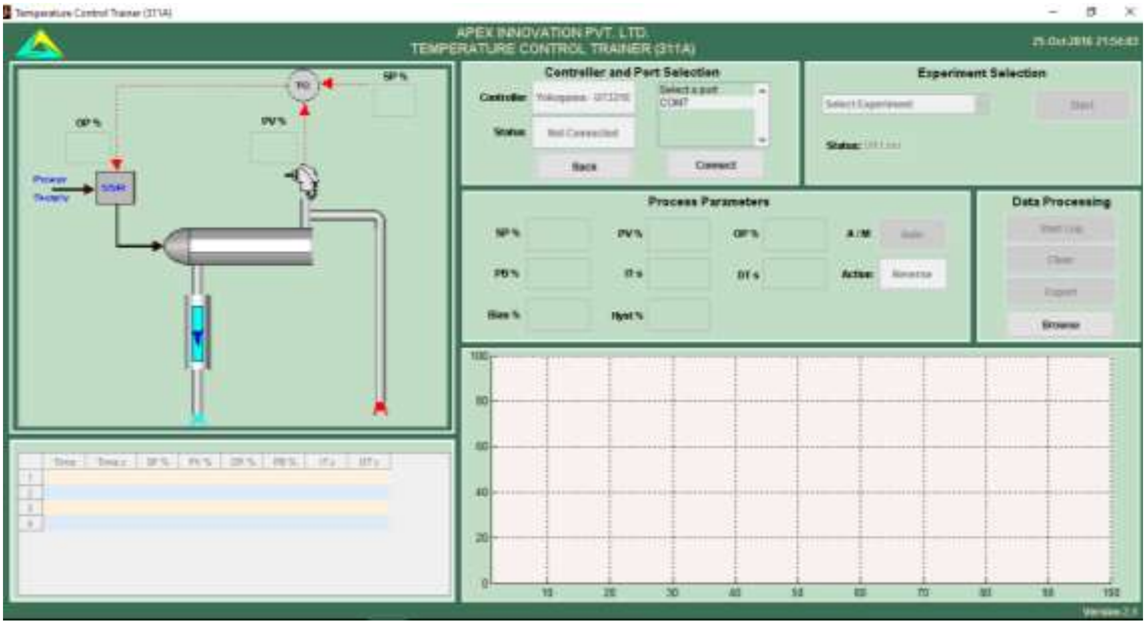
2 The experiment nos 1 thr 6 are to get feel of the process and PID settings.

3 Startup Setup

- Switch on electric supply. Switch on Mains.
- Adjust rotameter flow rate to 40 LPH.
- Switch on the heater
- Double click on Apex_Process_Trainers icon on the desktop



- Select product Temperature Control Trainer (311A), select Controller Yokogawa (UT35A or UT321E or UT32A whichever available with you) and Click Continue



- For Ethernet port equipment Click Connect
- For USB port equipment select Port to which ADAM 4561 is connected and Click Connect

1 Study of open loop response (Manual control)

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

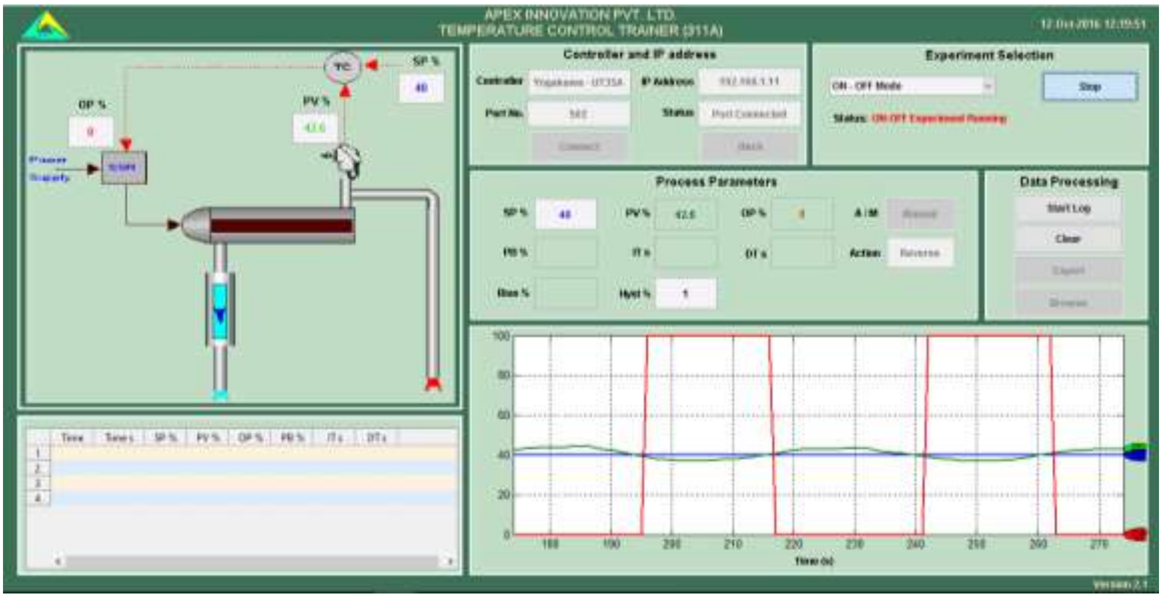
Controller output in %	Process Value in ^{0}C
0	
10	
20	
…	
100	

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

2 Study of on/off controller

Procedure

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



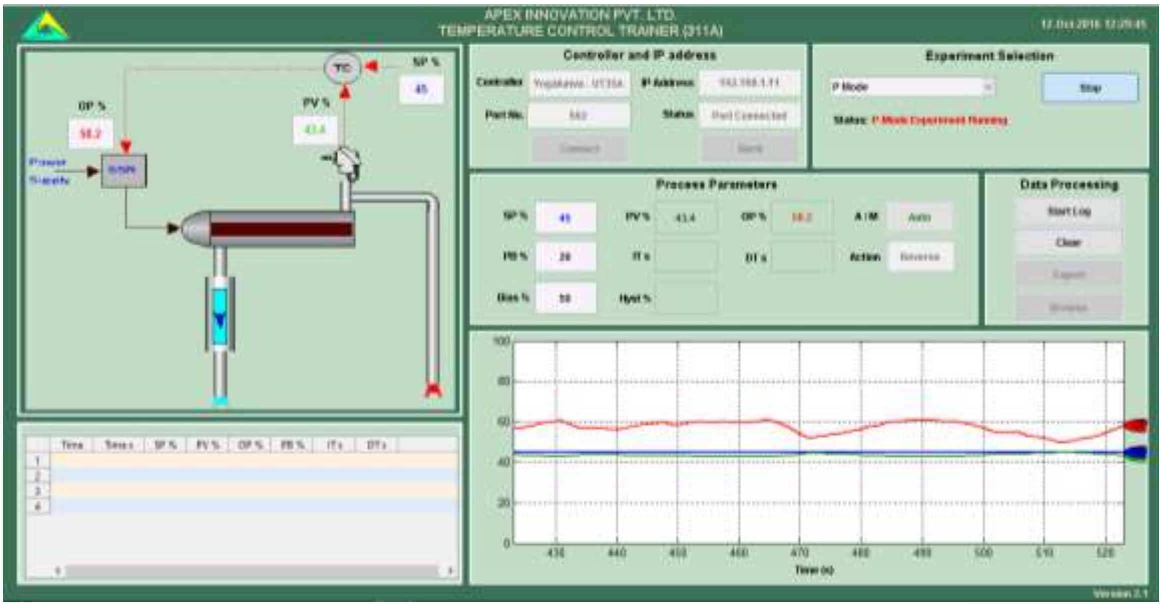
Observations

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

3 Study of proportional controller

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 value 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 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

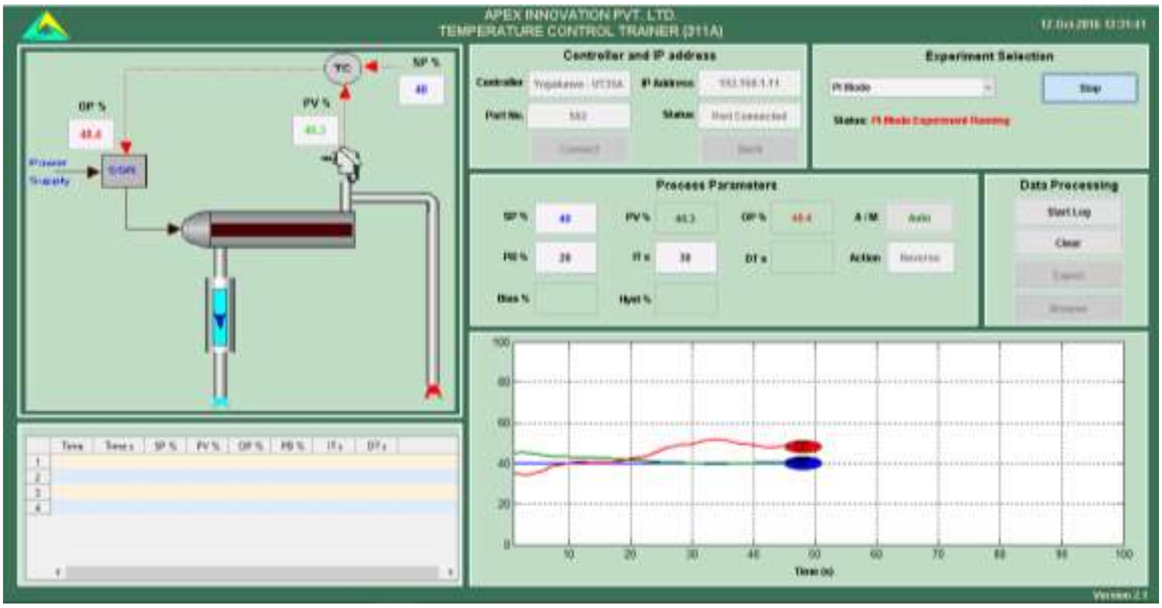
- Observe steady state error decreases as proportional band decreases.
- Observe the effect of very low proportional band values (system works in oscillatory mode).

- Observe the response of the system to load change. Load change can be given by slightly varying the inlet flow rate.

4 Study of proportional integral controller

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 set point.



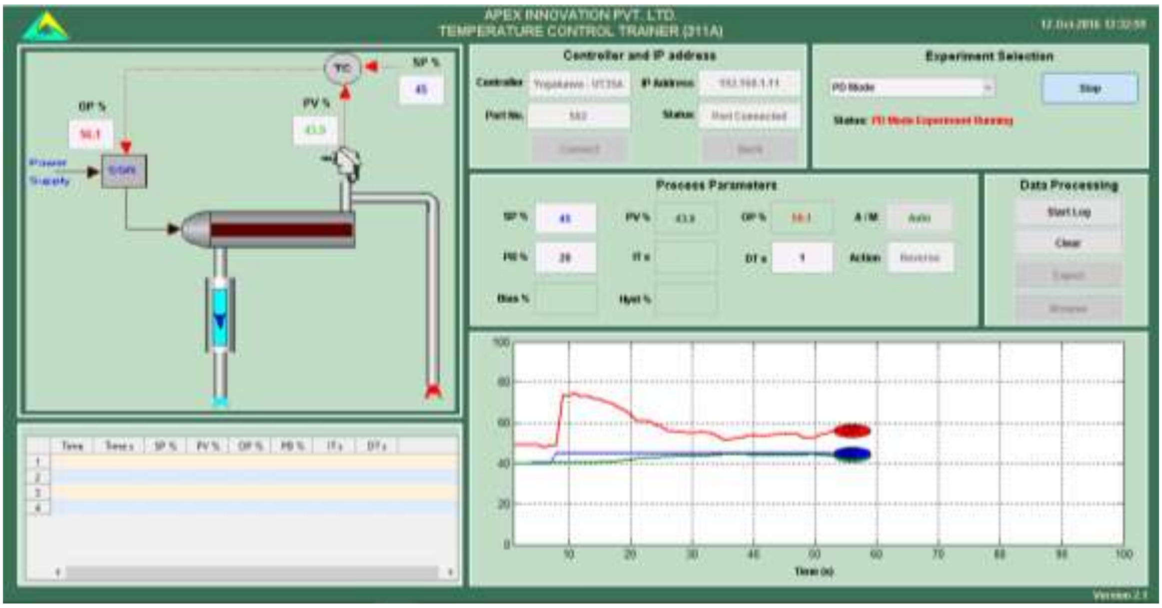
Observations

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

5 Study of proportional derivative controller

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.



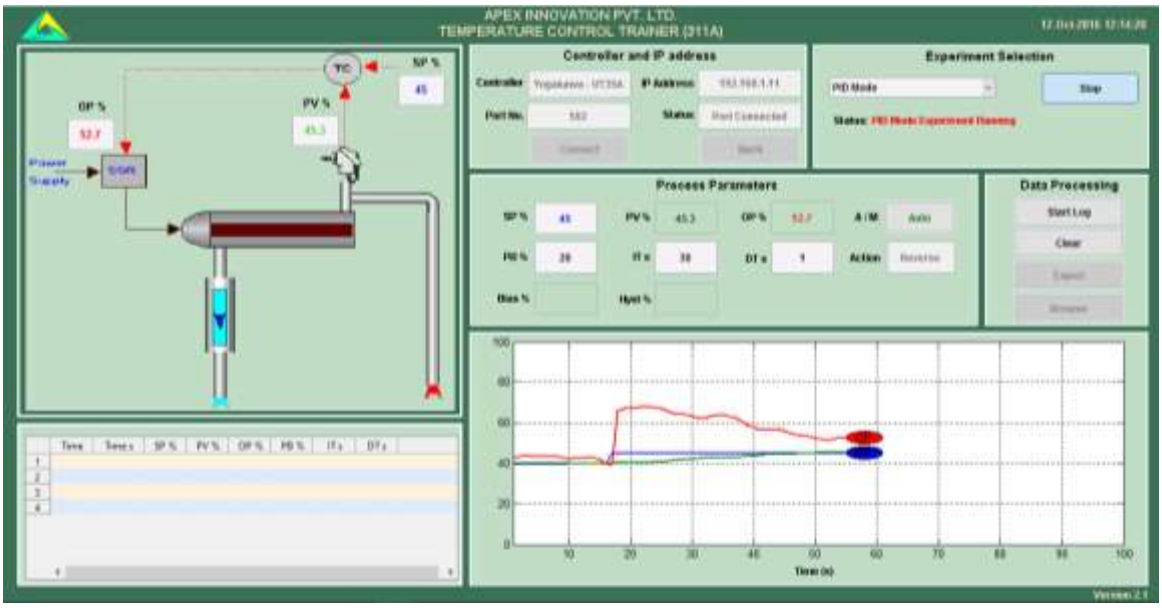
Observations

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

6 Study of proportional integral derivative controller

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 Tuning of controller (Open loop method)

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

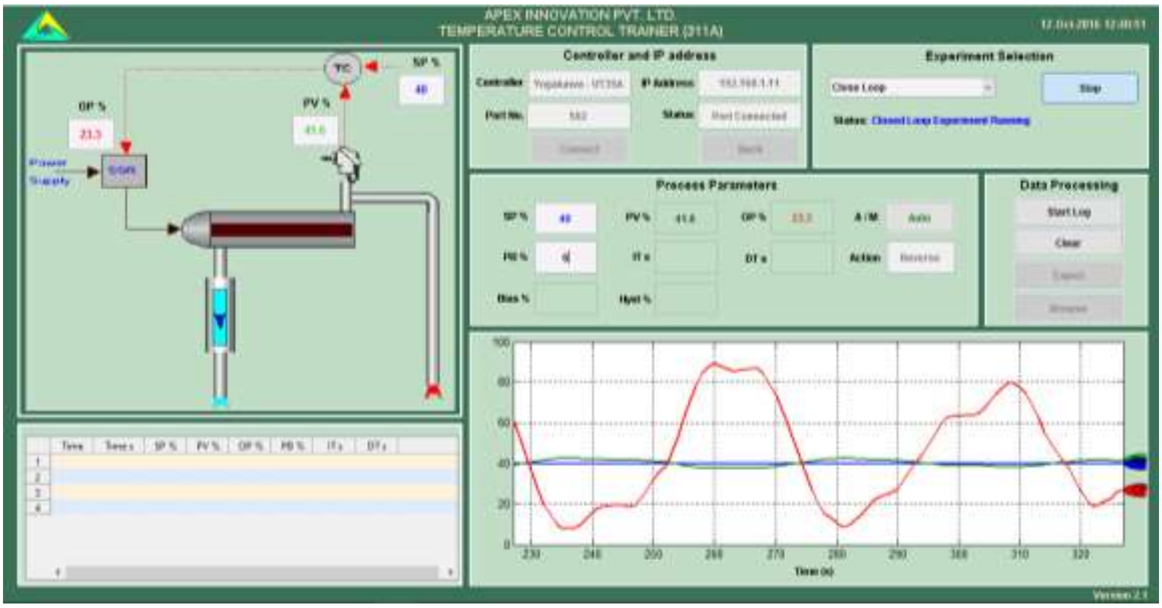
(Refer Theory process control for formula.)

- Step change to the system □ P = Initial output - 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, PID setting from above values.
- Observe response of the system for different PID settings.

8 Tuning of controller (Closed loop method)

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

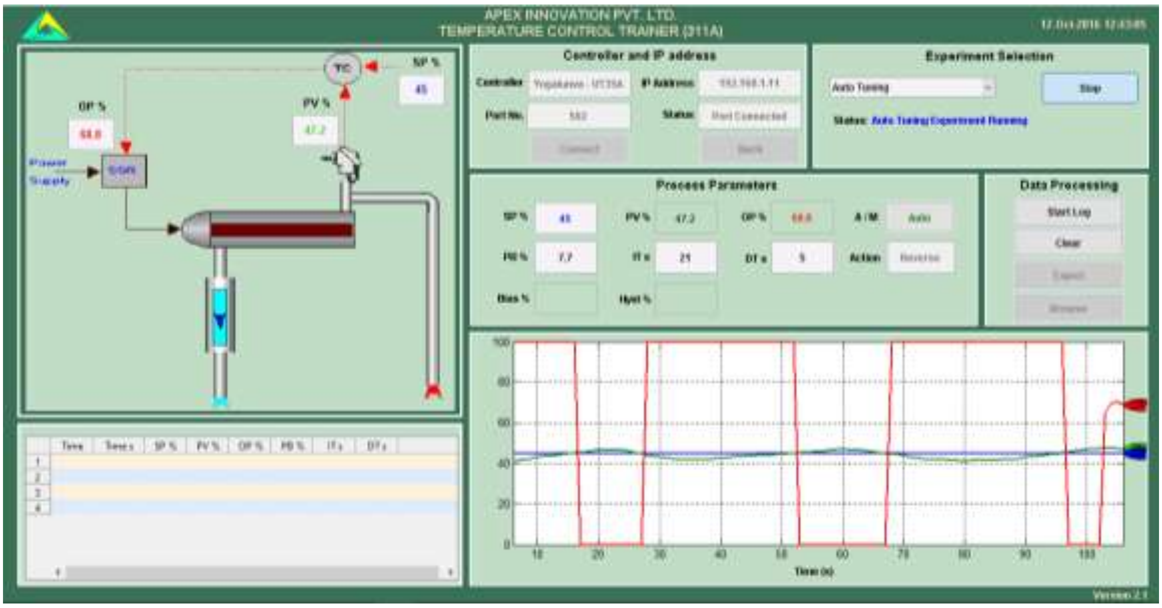
- Record the ultimate proportional band (Pbu) and ultimate period (Tu) from above experiment.
- Calculate PID values by referring theory part for different control actions.

- Observe the process response for these settings.
- Compare the values obtained with open loop response method.

9 Tuning of controller (Using Auto Tuning method)

Procedure

- **Start up** set up as explained in general instructions.
- Click Select Experiment, select **Autotune** and click Start
- Wait Till Autotune 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

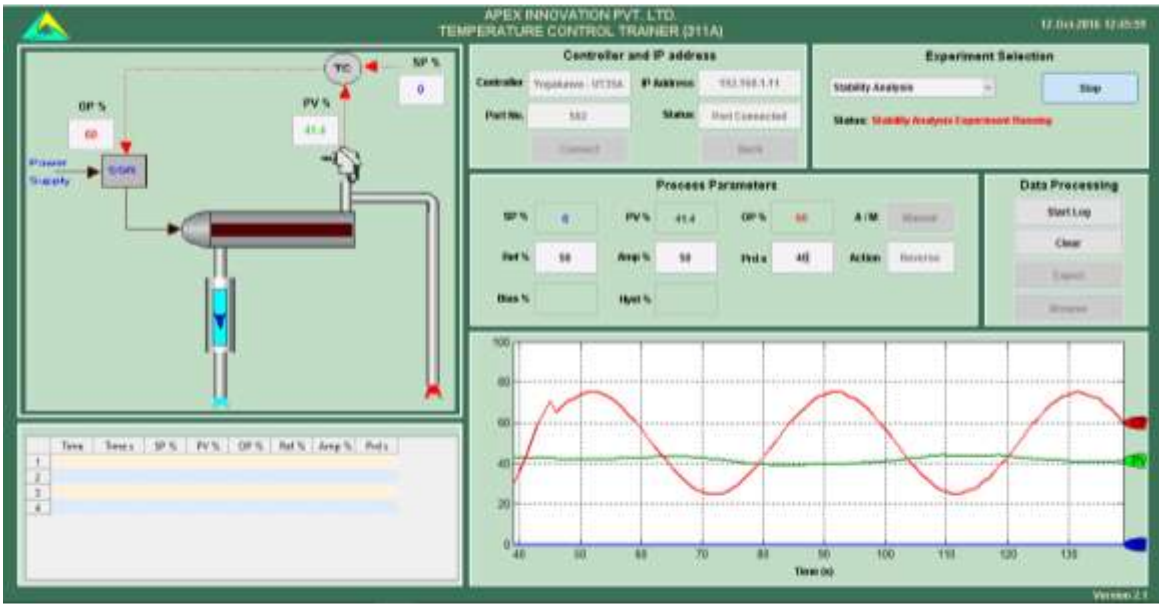
- The controller has preprogrammed logic for finding “Auto tune” values. Based on the response of the process the controller calculates PID values or comes out without finding the “Auto tune” values.

10 Study of stability of the system (Bode plot)

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) x 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.