FLOW CONTROL TRAINER

Product Code 312A

(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.

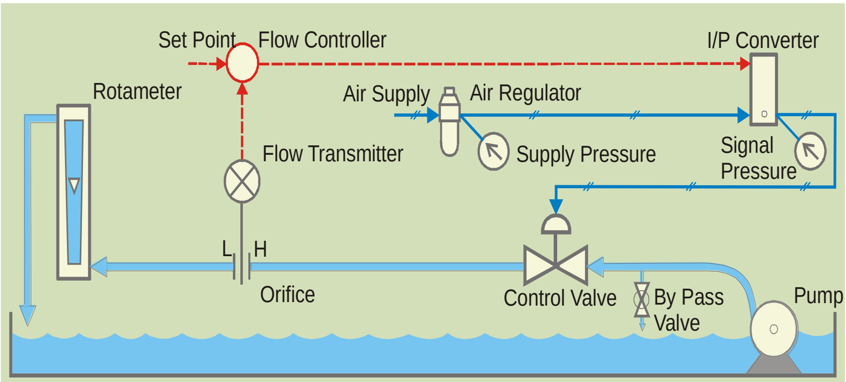
File name	Document description
Im311A.pdf	Product Instruction manual & Experiments
Theory Process Control.pdf	Describes theoretical aspects of process control study
Components.pdf	Additional details of the components used

Description

Flow control trainer is designed for understanding the basic principles of flow control. The process setup consists of supply water tank fitted with pump for water circulation. A DP transmitter is used for flow sensing which measures differential pressure across orifice meter. The process parameter (flow) is controlled by microprocessor based digital indicating controller which manipulates pneumatic control valve through I/P converter. The control valve is fitted in water flow line.

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.



Specifications

Product	Flow control trainer
Product code	312A
Type of control	SCADA
Control unit	Digital indicating controller with Ethernet communication
Communication	Ethernet / USB
Differential pressure transmitter	Type Capacitance, two wire, Range 0–200 mm, Output 4–20 mA sq.root
I/P converter	Input 4-20mA, Output 3-15 psig, make Control Air
Control valve	Type: Pneumatic; Size: 1/4", Input: 3–15 psig, Air to close
Rotameter	10-100 LPH
Pump	Fractional horse power, type submersible
Supply tank	SS304
Flow measurement	Orifice meter
Air filter regulator	Range 0-2.5 kg/cm^2
Pressure gauge	Range 0-2.5 kg/cm^2(1No), Range 0-7 kg/cm^2(1No)
Overall dimensions	550Wx480Dx525H mm
Optional	Mini Compressor

Packing slip

Shipping details

Gross volume 0.17m^3, Gross weight 67kg, Net weight 34kg

Box No.1/2	Size W575xD500xH525 mm; Vol:0.15m^3	Gross weight: 42 kg Net weight: 21 kg
1	Set up assembly Control valve outlet to rotameter inlet pipe	1 No
Box No.2/2	Size W375xD350xH175 mm; Vol:0.02m^3	Gross weight: 25 kg Net weight: 13 kg
1	Supply tank, pump (Piping set & Male stud 2nos)	1 No
2	Communication cable	1 No
3	Tool kit	1 No
4	Set of instruction manuals consisting of: “PCTSoft” CD (Apex Innovations) I/P converter manual (ControlAir) User’s manual for DPT	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.)

Water supply

Distilled water @10 liters

Air supply

Clean, oil and moisture free air, pressure 2 Bar, consumption 50 LPH

Computer

Standard configuration

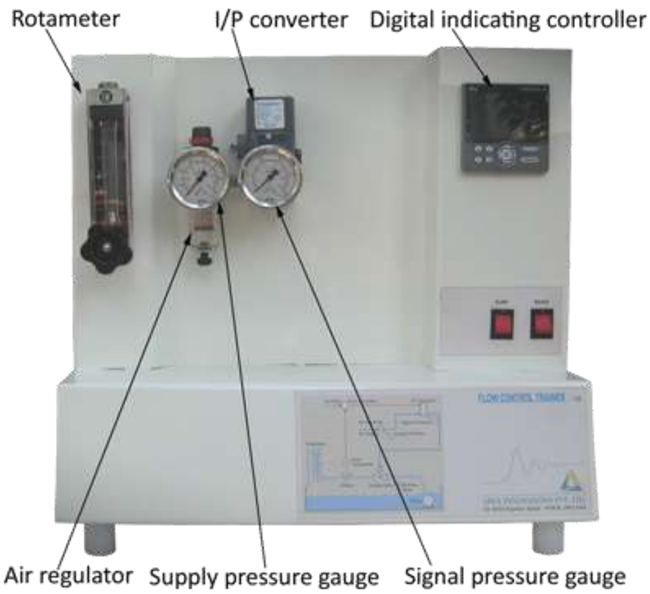
Support table

Size: 800Wx800Dx750H in mm

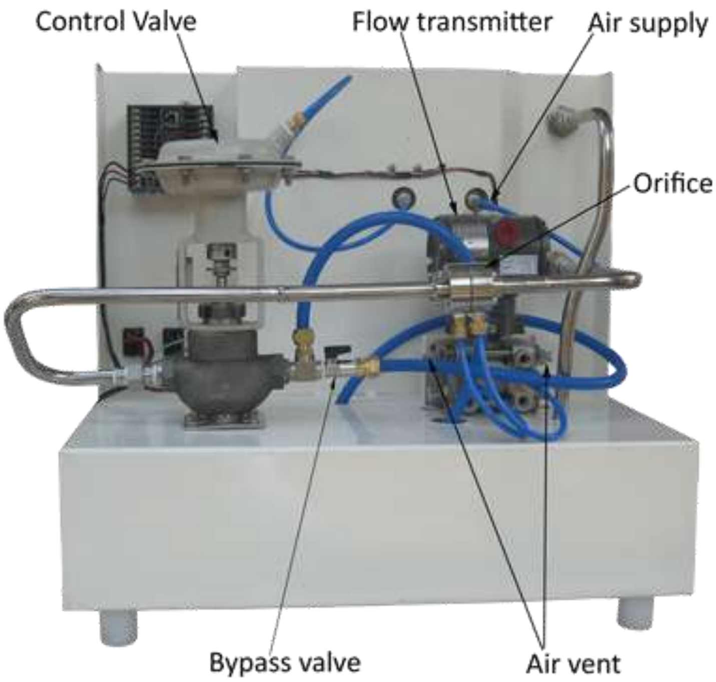
Installation commissioning

Installation (Ethernet port equipment)

Front view:

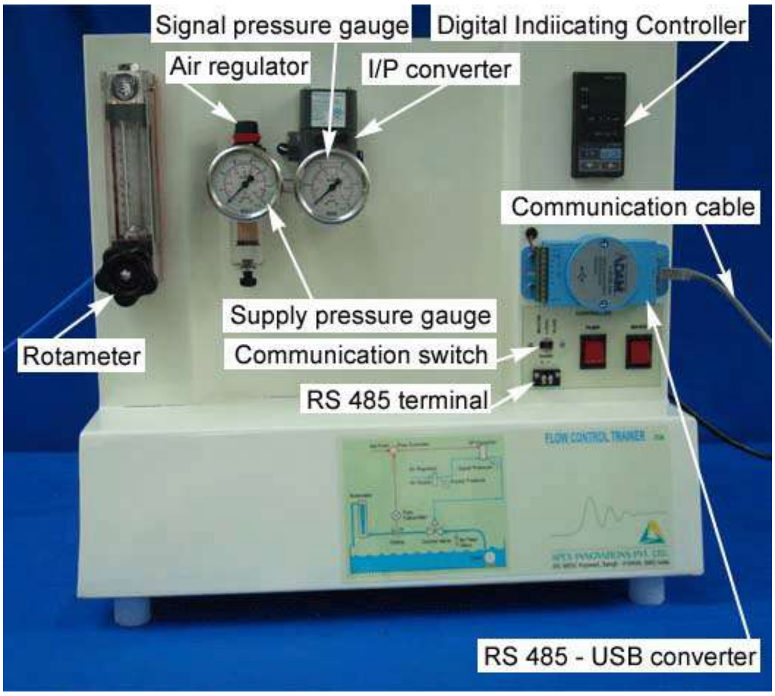


Back view:

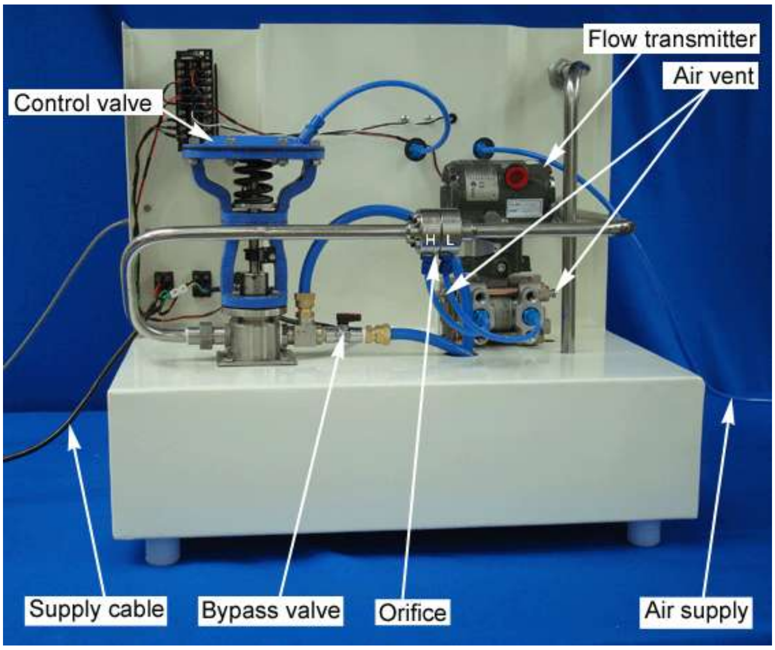


Installation (USB port equipment)

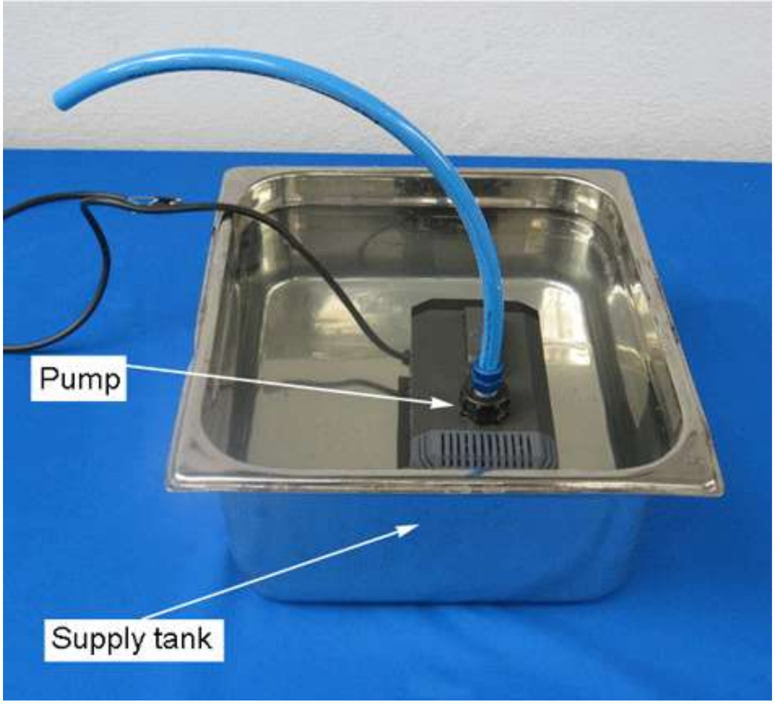
Front View:



Back view:



Pump and supply tank:



- Unpack the box(es) 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.
- Remove packing wire inserted in the ***Rotameter*** by removing plug on the top of the rotameter. (Use small nose pliers)
- Connect SS pipe (supplied loose) from rotameter outlet to supply tank
- Air supply: Ensure that clean and oil free air is received from compressed air source (compressor / mini compressor) by venting out the air for few minutes. Then connect air supply to the set up.
- Clean the ***Supply tank***. Remove pump from its box.

Commissioning

- Ensure that flow transmitter is connected to orifice meter placed in flow line. The connection should have proper polarity. (Note: Orifice meters and flow transmitters are marked as H and L).
- Fill supply tank with distilled water and keep the ***Pump*** inside the water.

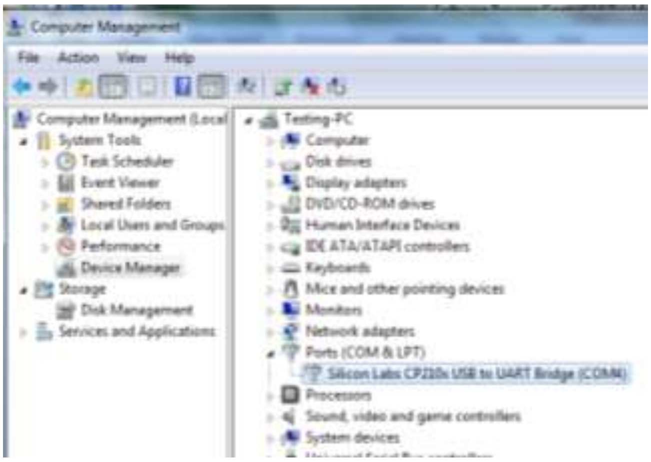
- Keep the setup over the tray. Take the pump cable and pump outlet tube to the top side through the hole on the base plate. Connect the cable to the pump switch and connect the pump outlet tube to the inlet of control valve.
- Return the bypass line back to SS tray through the hole provided on the base plate.
- Switch on electric supply. Switch on Mains.
- Switch on the pump and ensure that flow through rotameter is above 100 LPH.
- Confirm that flow signal reading is displayed at controller. (For 100 LPH flow the reading should be @100%. If not, remove air from the pressure signal connections of ***Flow transmitter*** by loosening vent plugs provided on it).
- Ensure that ***Air regulator*** is fully open by rotating anticlockwise. Switch on the compressed air source and adjust the Air regulator to set supply air pressure at @ 25 psig.
- Set the controller to manual mode by pressing the A/M key.
- Increase output of controller from 0 to 100% in steps of 25%. Check the pressure on pressure gauge at the output of ***I/P converter*** is varying from 3-15 psig and ensure that ***Control valve*** operates from full open to fully close position.
- 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.

NOTE: For longer shut down, remove water from the supply tank and clean it.

Troubleshooting

Note: For component specific problems refer Components' Manual

Problems	Possible causes / remedies
Incorrect flow reading	• Air trap in pressure signal line to flow transmitter • Choked pressure signal connections from orifice to flow transmitter due to scaling in water. • Reversed High-Low pressure signal connections from orifice to the flow transmitter
Control valve does not operate	• Valve diaphragm leakage/breakage • Faulty I/P converter • No output from Controller
I/P converter does not work	• Insufficient supply air pressure • Faulty electrical input signal • Clogged orifice
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 192.168.1.12 **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	Flow control trainer
Product code	312A
Differential pressure transmitter	Make Yokogawa, Model EJA110E-JMS5J-912NN, Calibration range 0-200 (SQ RT) mm H2O, Output square root Make Yokogawa, Model UT321/UT32A(with RS 485 communication)+ RS485-USB converter, Model ADAM 4561 Make Advantech
Digital indicating controller	Make Yokogawa, Model UT35A-002-11-00 with Ethernet communication
I/P converter	Make Control air inc, Type T500-AC, Input 4-20 mA DC, output 3-15 psig, end connection 1/4 NPT
Control valve	Make Pneucon, Type globe 2 way, Model 119, size 1/2"x1/8", Screwed end(F), Body CCS, Trim SS, Travel 14.3, CV=0.63, Air to CLOSE, Spring range 0.2-1, actuator 12 sq inch.
Rotameter	Make Eureka, Model MG 11, Range 10-100 lph, Connection ¼" BSP back, screwed, Packing PTFE + Silicon
Pump	Model HQB 4500, Head max. 4.5m, Output 5000 lph, Watts 100, Volts 220-240 AC, 50Hz.
Air filter regulator	Make Airmatic, Model MB10-02-1-PAP-PD (Alu body, Polycarbonate bowl, G1/4 BSP, Range 0-2 Kg/cm^2, Relieving, 25M Plastic element, Bunan diaphragm.
Pressure gauge	Make Wika, Dia.2.5", Gly. filled, Brass internls, S.S. casing, Range 0-2.5 Kg/cm^2 and 0-35 PSI, 1/4"BSP (M) back connection without bracket.
Pressure gauge	Make Wika, Dia.2.5", Gly. filled, Brass internls, S.S. casing, Range 0-7 Kg/cm^2 and 0-100PSI, 1/4"BSP (M) back connection without bracket.

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.

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Experiments

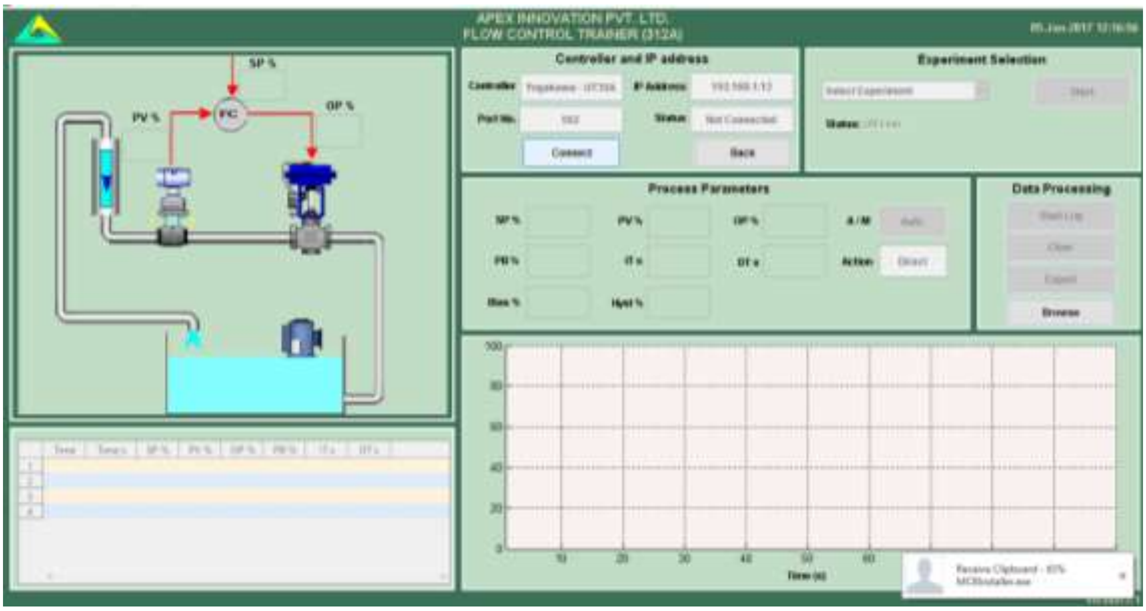
General Instructions

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

2 Startup Setup

- Switch on electric supply. Switch on Mains.
- Switch on electric supply. Switch on Mains.
- Switch on the pump and adjust the bypass valve to set rotameter flow at 100 LPH.
- Switch on the compressed air source and adjust the air regulator to set supply air pressure at @ 2 kg/cm^2
- Double click on Apex_Process_Trainers icon on the desktop

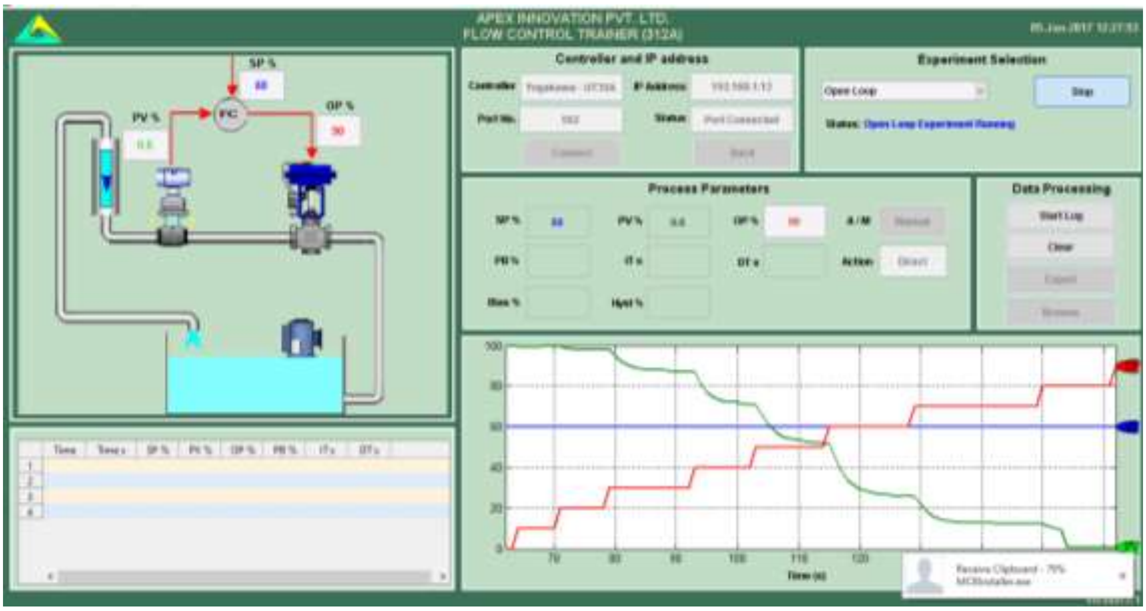
- Select product Flow Control Trainer (312A), select Controller Yokogawa (UT35A or UT321E or UT32A whichever available with you) and Click Continue



- 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)

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



Observations

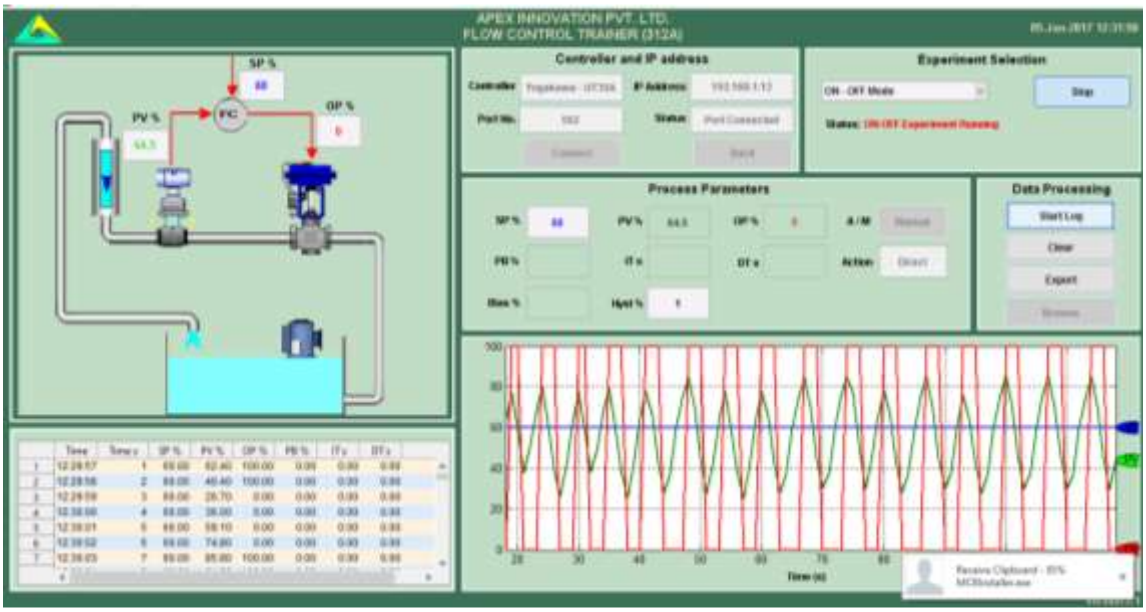
Tabulate the observations as follows

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

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

2 Study of on/off controller

- **Start up** set up as explained in general instructions.
- Click Select Experiment, select **On-Off Mode** and click Start
- Change Hystresis value to 5%.(Range 0.1-10%)
- Change the values of the set point and observe the On-Off control operation.

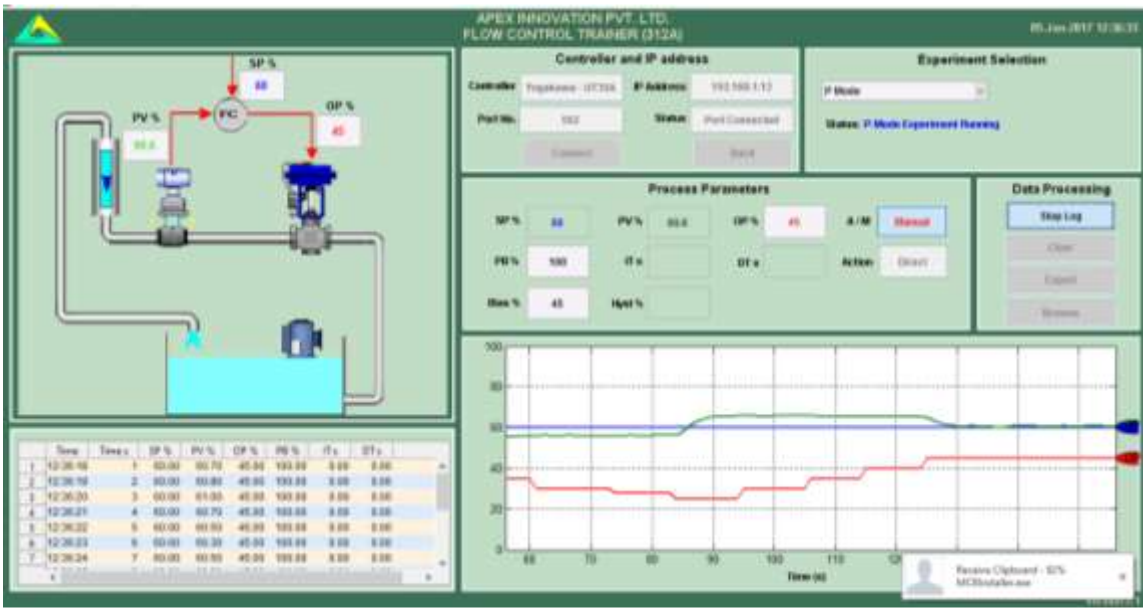


Observations

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

3 Study of proportional controller

- **Start up** set up as explained in general instructions.
- Click Select Experiment, select **P Mode** and click Start
- Adjust the process value by switching the controller to manual mode to a particular flow (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.
- 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%).
- Using trail 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.

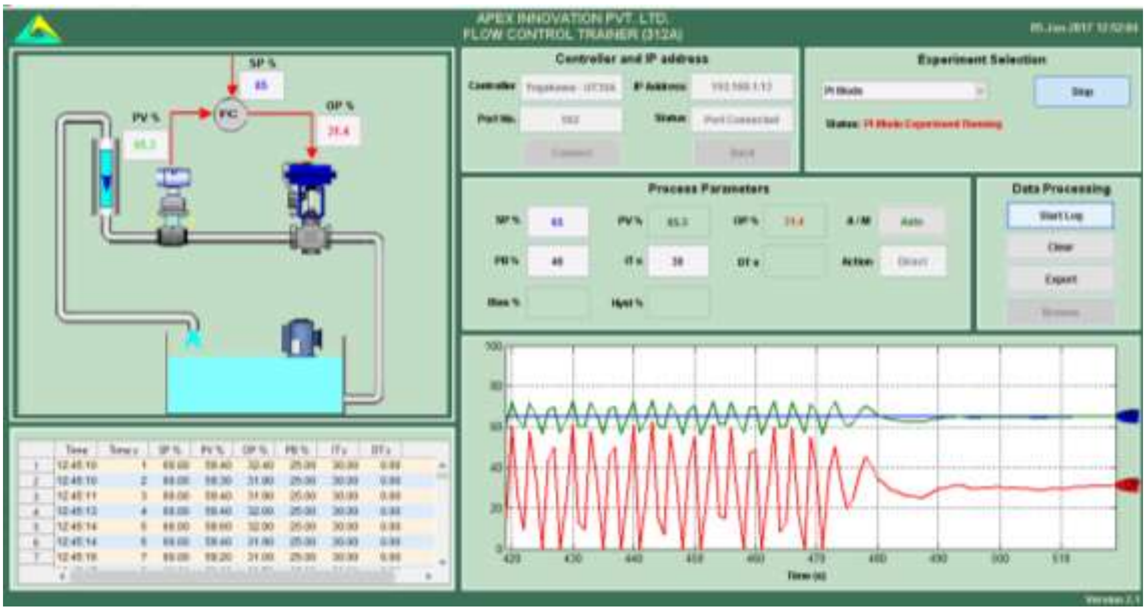


Observations

- Observe steady state error decreases as proportional band decreases.
- Observe the effect of very low proportional band values (system works as on-off control).
- Observe the response of the system at load change. Load change can be given by slightly varying the flow rate with the help of rotameter manually.

4 Study of proportional integral controller

- **Start up** set up as explained in general instructions.
- Click Select Experiment, select **PI Mode** and click Start
- 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.
- Set the set point to desired flow value (@70%). Allow the process to reach at steady state. 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.

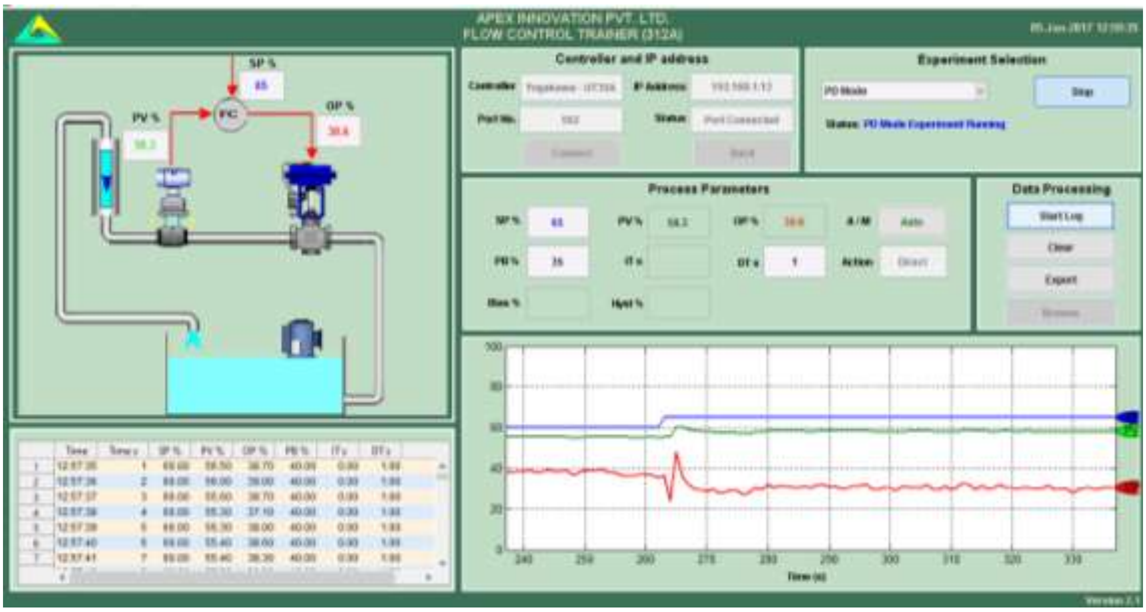


Observations

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

5 Study of proportional derivative controller

- **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) Set derivative time to 0 and integral time=6000 sec.
- Set the set point to desired value (@70%). Allow the process to reach at steady state. Note the response of the system.
- 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.



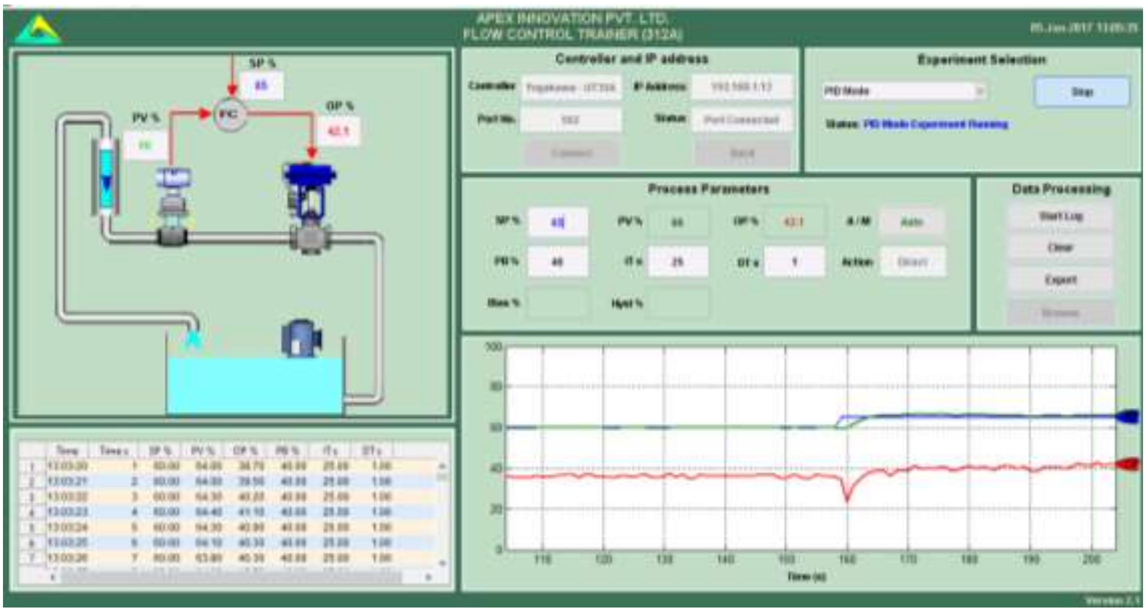
Observations

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

Note the effect of noisy flow measurement on the derivative action.

6 Study of proportional integral derivative controller

- **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.
- Adjust the set point to @ 50 %. Switch the controller to auto mode. Apply step change of 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.

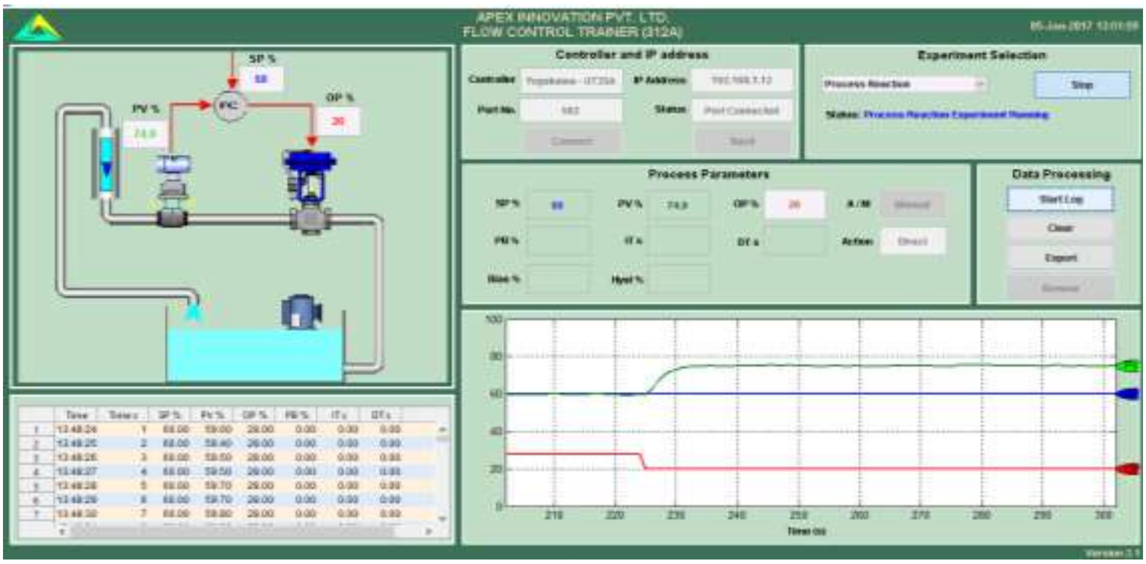


Observations

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

7 Tuning of controller (Open loop method)

- **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 70%.
- Start data logging.
- Apply a 20 - 30 % change to controller output. (Open the control valve) Record the step response. Wait for the steady state and 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.



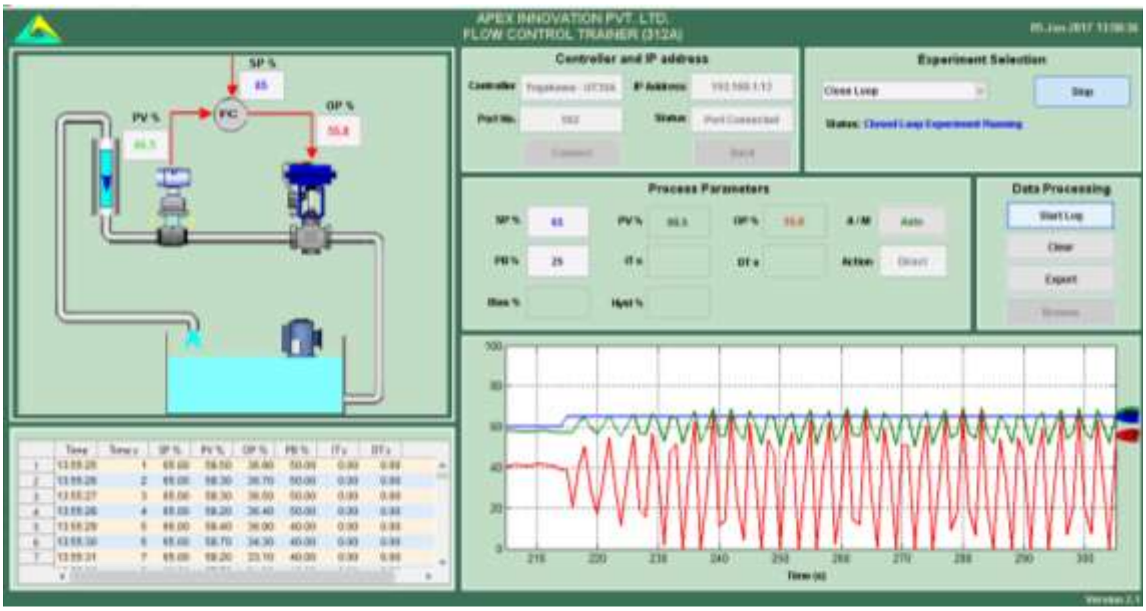
Observations: (Refer "Theory Process control" for formulae.)

- Step change to the system □ P = 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)

- **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 value reaches to 70%.
- 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.
- 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.



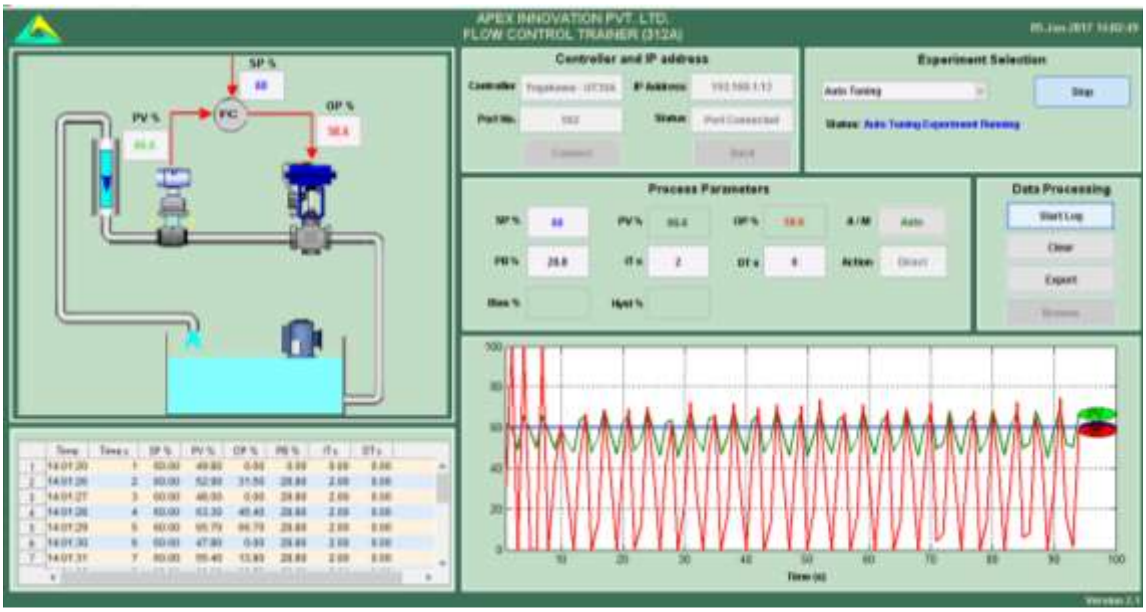
Observations

- 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)

- **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

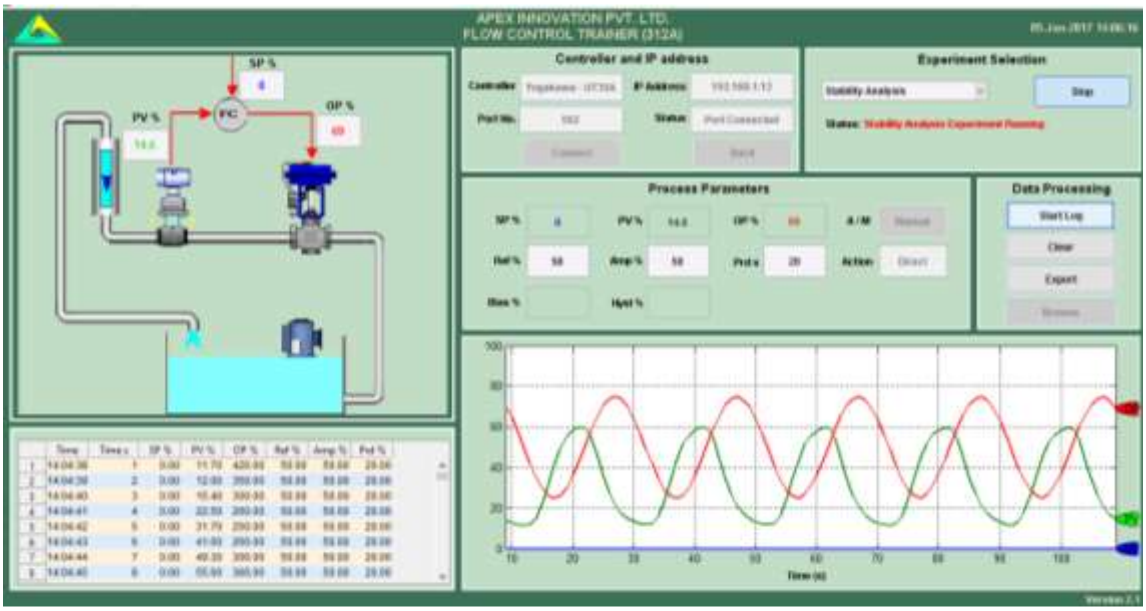


Observations

- 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 To study stability of the system (Bode plot)

- **Start up** set up as explained in general instructions.
- Click Select Experiment, select **Stability analysis** and click Start
- Start data logging.
- 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.
- 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 x and note down in sec.

Obs. No.	Input amplitude A1 %	Output amplitude A2 %	Output Period Tin 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 stable conditions mentioned in theory.