MULTI PROCESS TRAINER

Product Code 326A

(PCT version)

Instruction manual

Contents

Apex Innovations

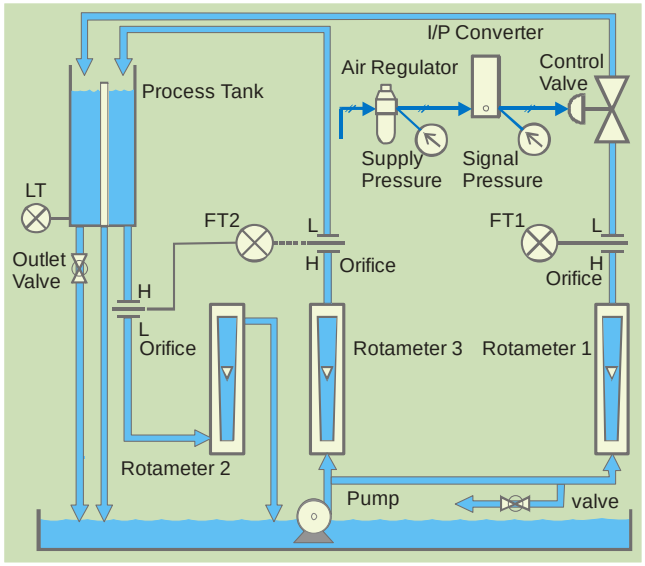
Documents to be referred

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

File name	Document description
Im326A.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

The setup is designed to understand the advanced control methods used for complex processes in the industries. Different experiments like Flow, level, cascade, feed forward and ratio control can be configured and studied with the setup. It consists of water supply tank, pump, level transmitter, transparent level tank, orifice meters with differential pressure transmitters, rotameters, pneumatic control valve, I/P converter and serial based dual loop controller. These units along with necessary piping are mounted on stand-alone type structure. The set up is connected to computer through USB port for monitoring and control by using PID logics. in SCADA mode.



Specifications

Product	Multi process trainer
Product code	326A
Control unit	ADAM-4022T Serial based dual loop PID controller; Analog input 4, Analog output 2, Digital input 2, Digital output 2. with RS485 communication.
Communication	USB port using RS485-USB converter
Differential pressure transmitter	Type Capacitance, two wire, Range 0–200 mm, Output 4–20 mA sq.root (2 Nos)
Level transmitter	Type Electronic, two wire, Range 0–250 mm, Output 4–20mA
I/P converter	Input 4-20mA, Output 3-15 psig
Control valve	Type: Pneumatic; Size: 1/4", Input: 3–15 psig, Air to close, Characteristics: linear
Rotameter	10-100 LPH(3 nos)
Pump	Fractional horse power, type submersible
Process tank	Transparent, Acrylic, with 0-100% graduated scale
Supply tank	SS304
Flow measurement	Orifice meter (3 Nos)
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	425Wx500Dx1750H mm
Optional	Mini Compressor

Shipping details

Gross volume 0.30m^3, Gross weight 110 kg, Net weight 80 kg

Packing slip

Shipping details

Gross volume 0.59m^3, Gross weight 150kg, Net weight 80kg

Box No.1/2	Size W1625xD625xH525 mm; Vol:0.53m^3	Gross weight:110 kg Net weight: 65 kg
1	Set up assembly	1 No
Box No.2/2	Size W750xD350xH225 mm; Vol:0.06m^3	Gross weight:40 kg Net weight: 25 kg
1	Communication cable	1 No
2	Tool kit	1 No
3	Set of instruction manuals consisting of: Instruction manual CD (Apex) DP transmitter manual I/P converter manual (ControlAir)	1 No

Installation requirements

Electric supply

Provide 230 +/- 10 VAC, 50 Hz, single phase electric supply with proper earthing. (Neutral – Earth voltage less than 5 VAC)

- 5A, three pin socket with switch (2 Nos.)

Water supply

Distilled water @16 liters

Air supply

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

Computer

Standard configuration

Installation Commissioning

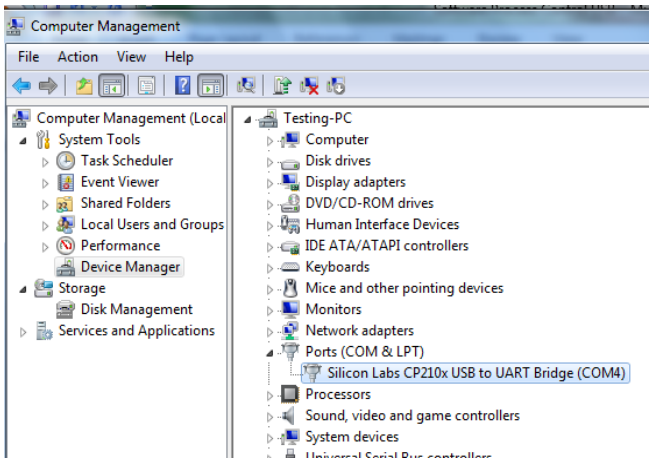
Installation

- 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 hard floor.
- Connect SS pipe to the process (level) tank outlet and clamp it to the structure frame.
- Pierce a hole in to the rubber cap fitted on pressure gauge(s) with pin or needle.
- Remove packing wire inserted in the rotameter.
- 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.
- Connect the set up to "USB" port of the computer.
- Electric supply: Before connecting electric supply ensure that supply voltage is 230 V AC and earth neutral voltage is less than 5 V Ac.

Commissioning

- Ensure that flow transmitter FT1 is connected to orifice meter placed in F1 line and FT2 to orifice meter placed in F3 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.
- Keep rotameters open and switch on pump. Ensure water circulation from rotameters F1, F3 to process tank. Remove air from the pressure signal connections of flow transmitters (Loosen vent plugs on flow transmitters slightly to remove air entrapped).
- Keep the valve at the outlet of process tank slightly closed.
- 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.
- 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.
- 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.

Troubleshootin

Note: For component specific problems refer components' manual

Problems	Possible causes
Incorrect flow reading	• Air trap in pressure signal line to flow transmitter • Reversed High-Low pressure signal connections from orifice to the flow transmitter
Control valve does not operate	• Valve diaphragm breakage • Faulty I/P converter • No output from the controller
I/P converter does not work	• Insufficient supply air pressure • Faulty electrical input signal • Clogged orifice
No communication with computer	• Improper USB port connection • Computer USB port not configured.

Components used

Product	Multi process trainer
Product code	326A
Control unit	ADAM-4022T, Serial based dual loop PID controller; Analog input 4, Analog output 2, Digital input 2, Digital output 2. with RS485 communication.
RS485-USB converter	Make Advantech, Model ADAM 4561, 1 Port USB to RS232/485/422 converter
Differential pressure transmitter	Make Yokogawa, Model EJA110E-JMS5J-912NN, Calibration range 0-200(SQ RT) mm H2O, Output square root
Level transmitter	Make Wika, Model SL-1-A-MAG-ND-ZA4Z-ZZZ, output 4-20 mA, supply 10-30 Vdc, conn. 1/2"NPT (M), Range 0-25 mbar.
I/P converter	Make Control air inc, Type T500-AC, Input 4-20 mA DC, output 3-15 psig, end connection 1/4 NPT
Power supply	Make Meanwell, model NES-15-24, O/P 24 V, 0.7 A
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

It is assumed that commissioning part of “Installation commissioning” is completed.

(Note: The experiment nos 1 thru 6 are to get feel of the process and PID settings.)

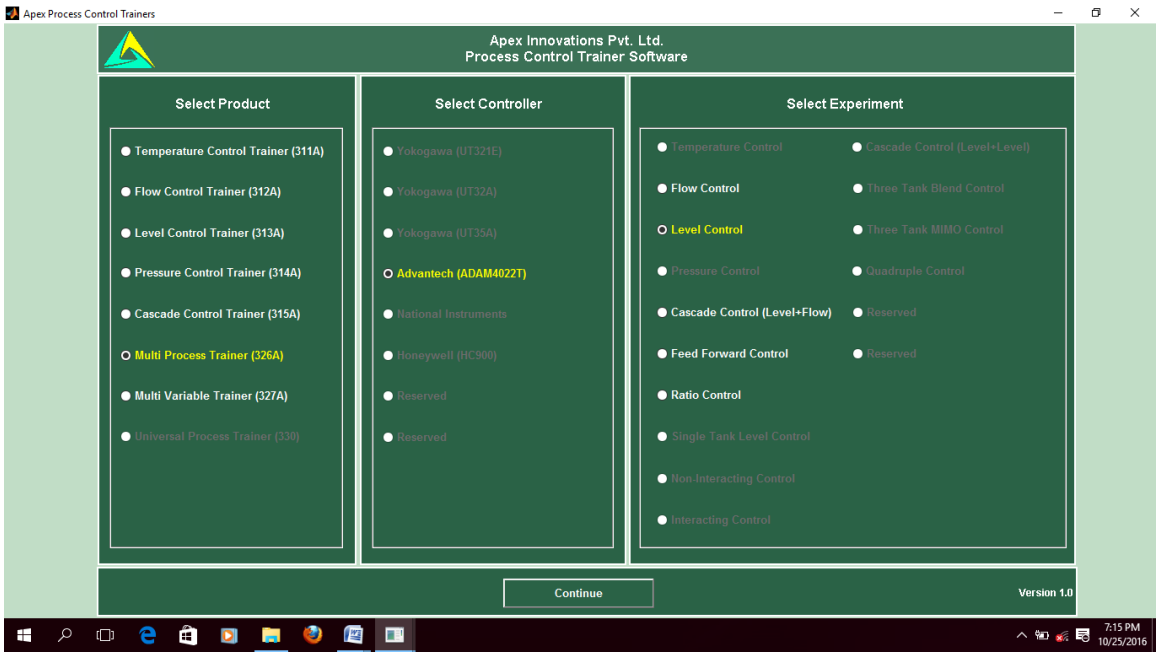
(Note: The experiment nos 1 thru 6 are to get feel of the process and PID settings.)

1. Study of open loop response (Manual control)

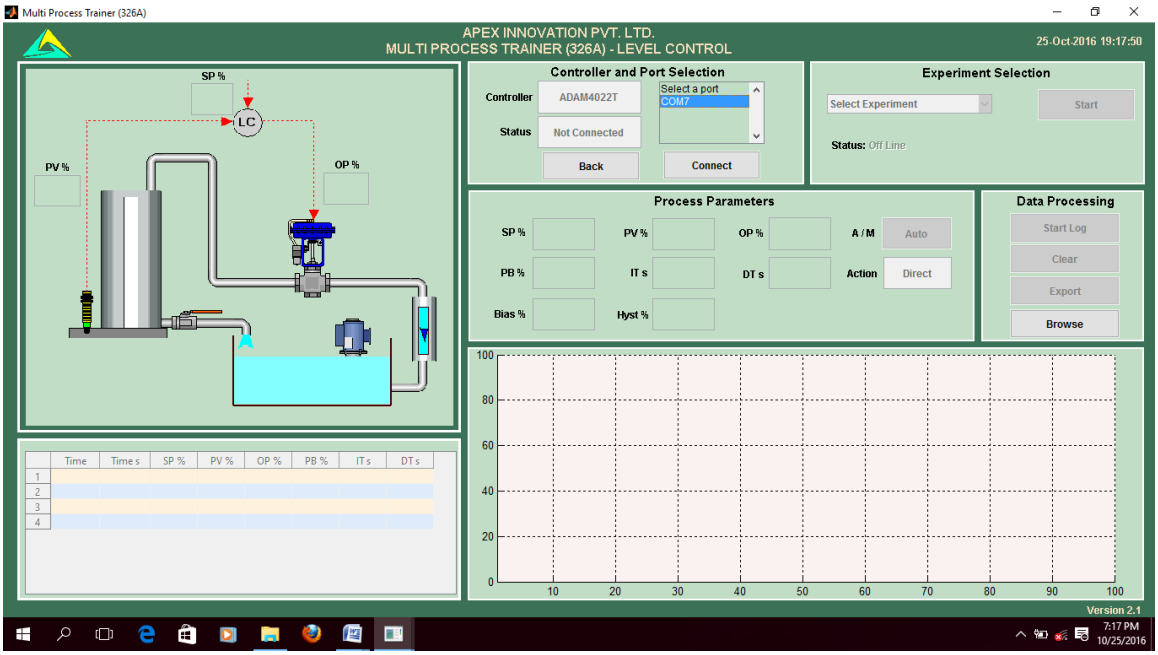
Procedure

For Level Control

- Start up the set up and adjust the Rotameter-1 (extreme right) to 100LPH.
- Provide air supply to the regulator and adjust it to 2 kg/cm^2
- Switch on the computer.
- Double click on Apex_Process_Trainers icon on the desktop



- Select product Multi Process Trainer (326A) and select experiment Level Control and Click Continue



- Select Port to which ADAM 4561 is connected.

  Click Connect
- Click Select Experiment, select **Open Loop** and click Start
- Close the Rotameter-2 (Extreme Left) and close the drain valve provided at the inlet of Rotameter-2.
- Open the control valve fully by decreasing the controller output to 0%.
- Adjust the tank drain valve such that the tank level shall remain between 90 and 100%
- 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 process value to reach the steady state value.

Observations

Tabulate the results as follows

Controller output in %	Process Value in %	
100		
90		
80		
70		

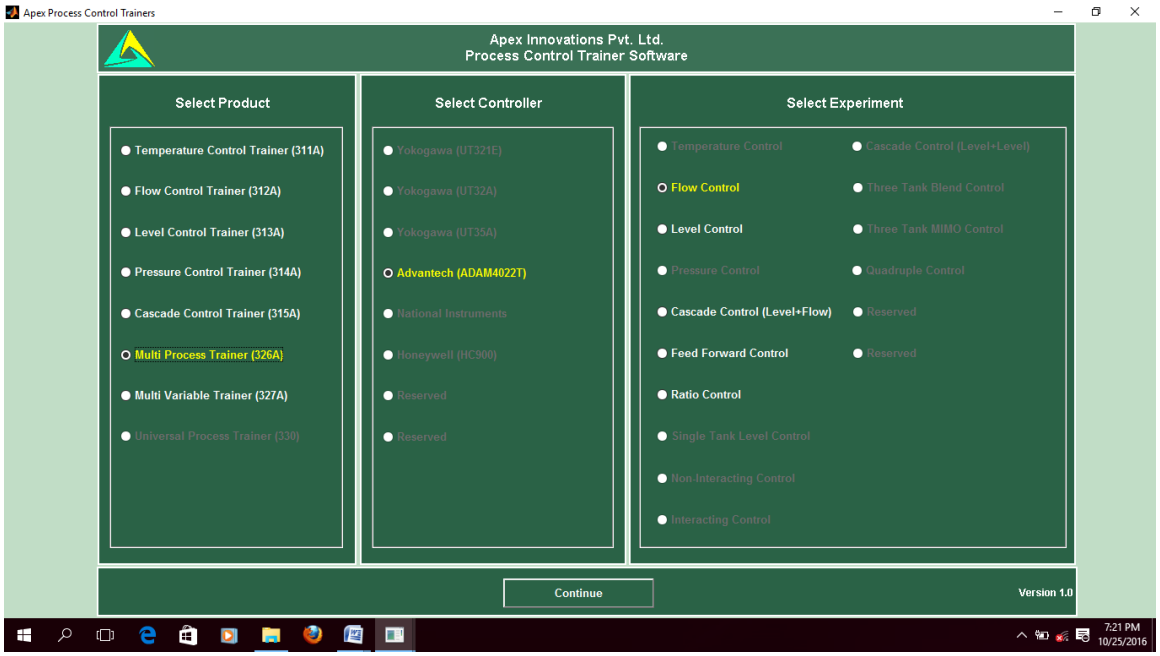
60		
50		
40		
30		
20		
10		
0		

For Flow Control

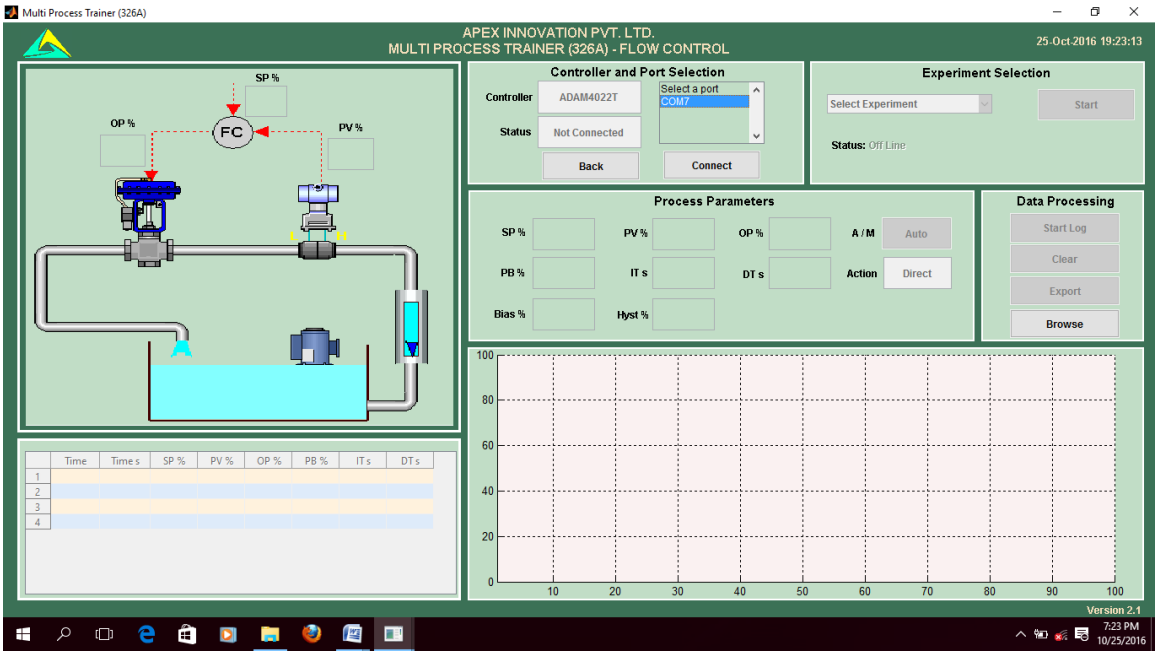
Procedure

(This experiment can be performed for both Level and Flow loops)

- Start up the set up and adjust the Rotameter-1 (extreme right) to 100LPH.
- Provide air supply to the regulator and adjust it to 2 kg/cm^2
- Switch on the computer.
- Double click on Apex_Process_Trainers icon on the desktop



- Select product Multi Process Trainer (326A) and select experiment Flow Control and Click Continue



- Select Port to which ADAM 4561 is connected.

  Click Connec
- Click Select Experiment, select **Open Loop** and click Start
- Open the control valve by decreasing the controller output to 0%.
- Remove entrapped air, if any from the FT1. For removing air open the vent valves on the DP transmitter.
- Apply the step change by 10% to controller output in manual mode, wait for the process value to reach the steady state value.
- Repeat the above step until the controller output reaches to maximum (100%)

Observations

Tabulate the results as follows

Controller output in %	Process Value in %	
0		
10		
20		
30		
40		
50		
60		
70		
80		
90		
100		

Calculations

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

Note: The scale on the process tank is provided only for general use. However rely on the screen data. It is not necessary to calibrate level transmitter with the scale on process tank.

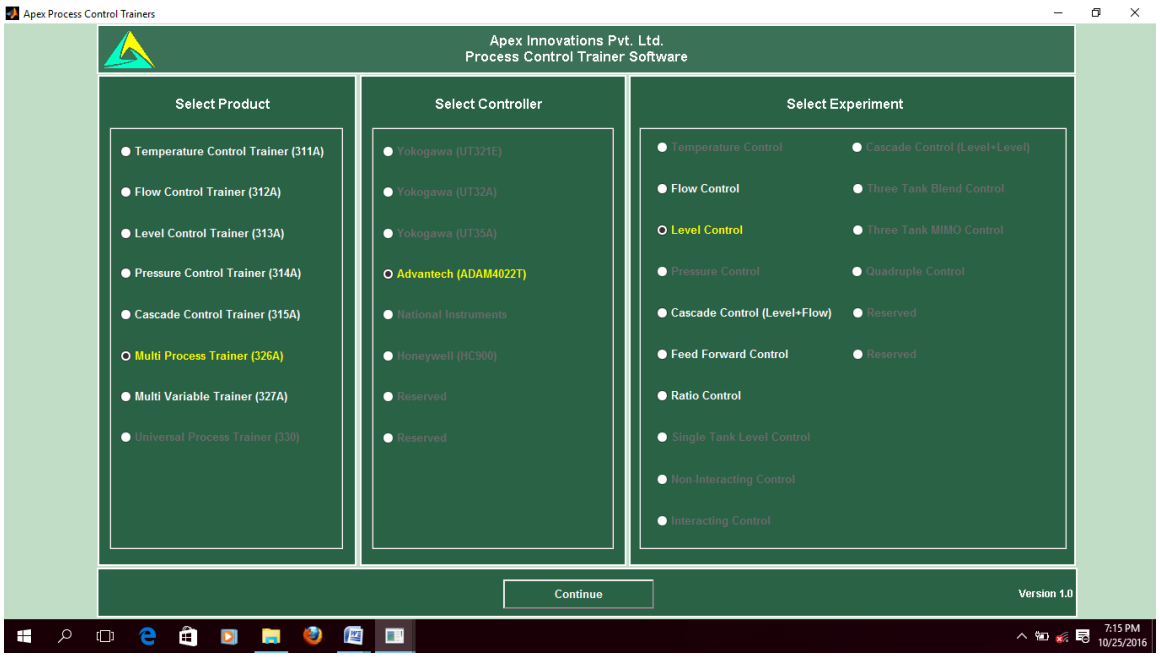
Similarly for flow loop the Rotameter float is only for general indication. However the on screen process data (flow readings) is to be relied upon.

2. Study of on/off controller

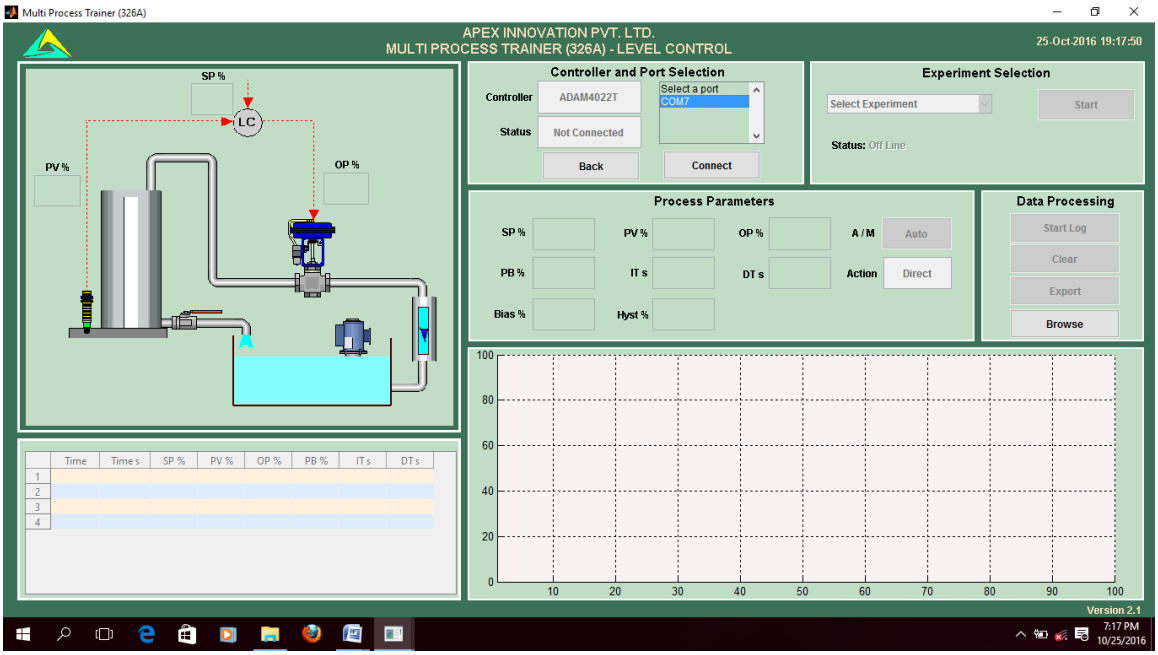
Procedure

For Level Control

- Start up the set up and adjust the Rotameter-1 (extreme right) to 100LPH.
- Provide air supply to the regulator and adjust it to 2 kg/cm^2
- Switch on the computer.
- Double click on Apex_Process_Trainers icon on the desktop



- Select product Multi Process Trainer (326A) and select experiment Level Control and Click Continue



- Select Port to which ADAM 4561 is connected.

  Click Connec
- Click Select Experiment, select **On-Off Mode** and click Start
- Close the Rotameter-2 (Extreme Left) and close the drain valve provided at the inlet of Rotameter-2.
- Open the control valve fully by decreasing the controller output to 0%.
- Adjust the tank drain valve such that the tank level shall remain between 90 and 100%
- Change Hystresis value to 1%.(Range 0.1-10%)
- Change the values of the set point and observe the On-Off control operation.

(Note: In case of level loop if the process value is not reaching set point, close the tank drain valve partially.)

Observations

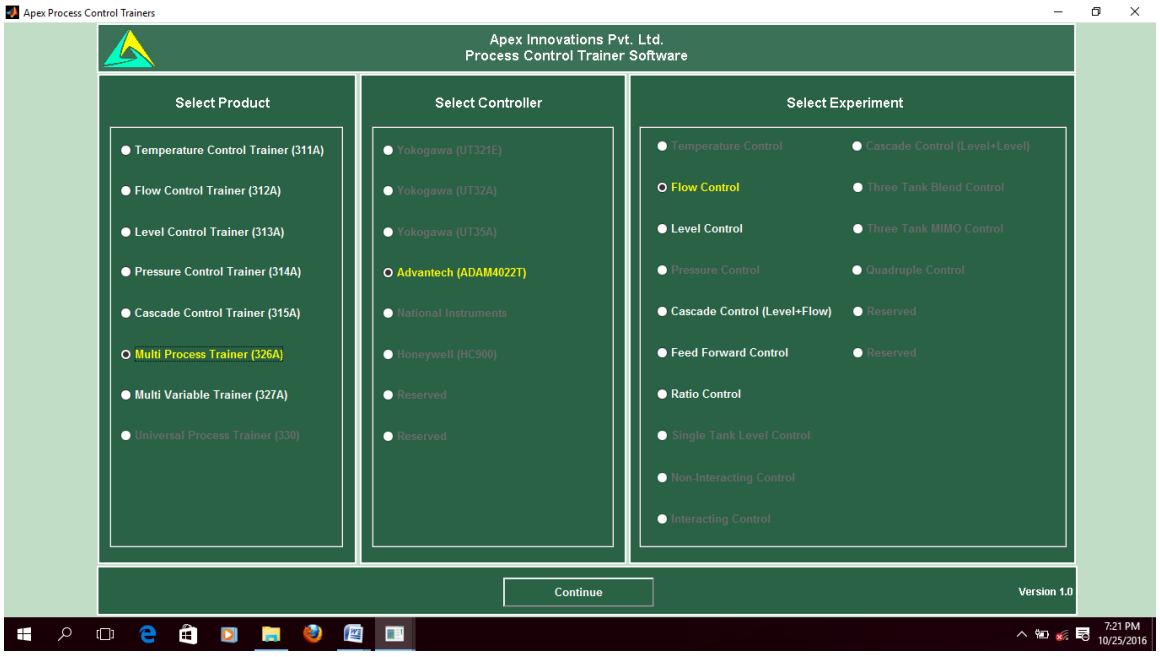
Observe that if process value exceeds the set point and increases than the value of (0.5x Hysteresis), controller closes the control valve and if process value decreases below the set point by (0.5 x Hysteresis), control valve opens (i.e. controller operates like On/Off switch). This can be better observed by increasing Hysteresis value.

For Flow Control

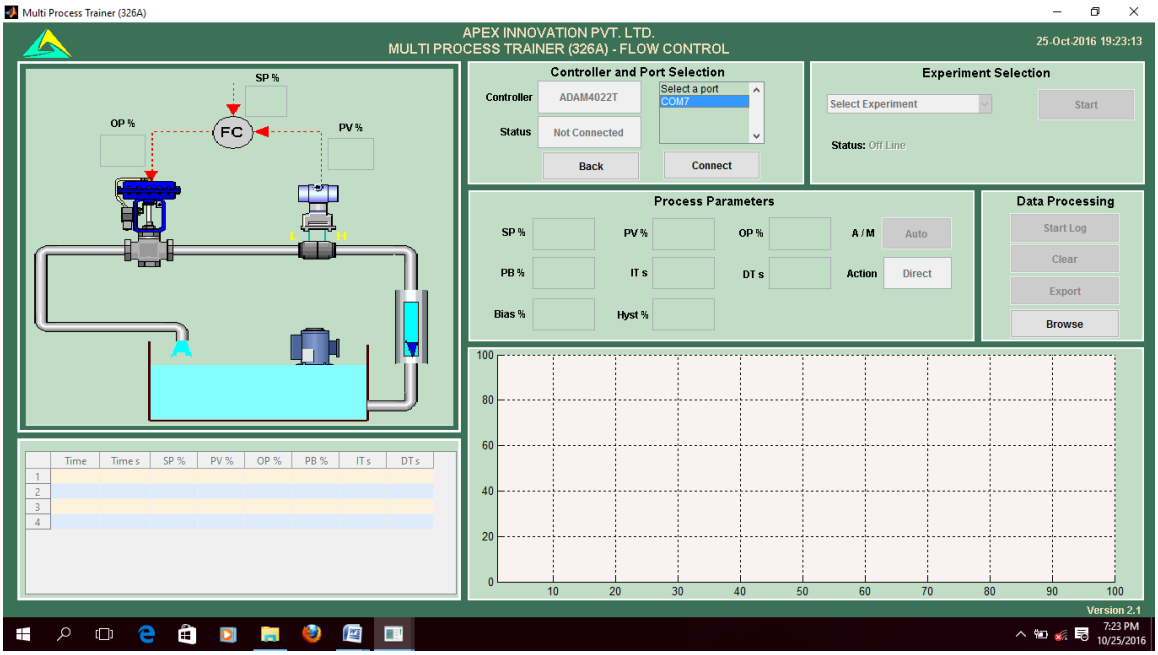
Procedure

(This experiment can be performed for both Level and Flow loops)

- Start up the set up and adjust the Rotameter-1 (extreme right) to 100LPH.
- Provide air supply to the regulator and adjust it to 2 kg/cm^2
- Switch on the computer.
- Double click on Apex_Process_Trainers icon on the desktop



- Select product Multi Process Trainer (326A) and select experiment Flow Control and Click Continue



- Select Port to which ADAM 4561 is connected.

  Click Connec

  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

1 Observe that if process value exceeds the set point and increases than the value of (0.5x Hysteresis), controller closes the control valve and if process value decreases below the set point by (0.5 x Hysteresis), control valve opens (i.e. controller operates like On/Off switch) This can be better observed by increasing Hysteresis value.

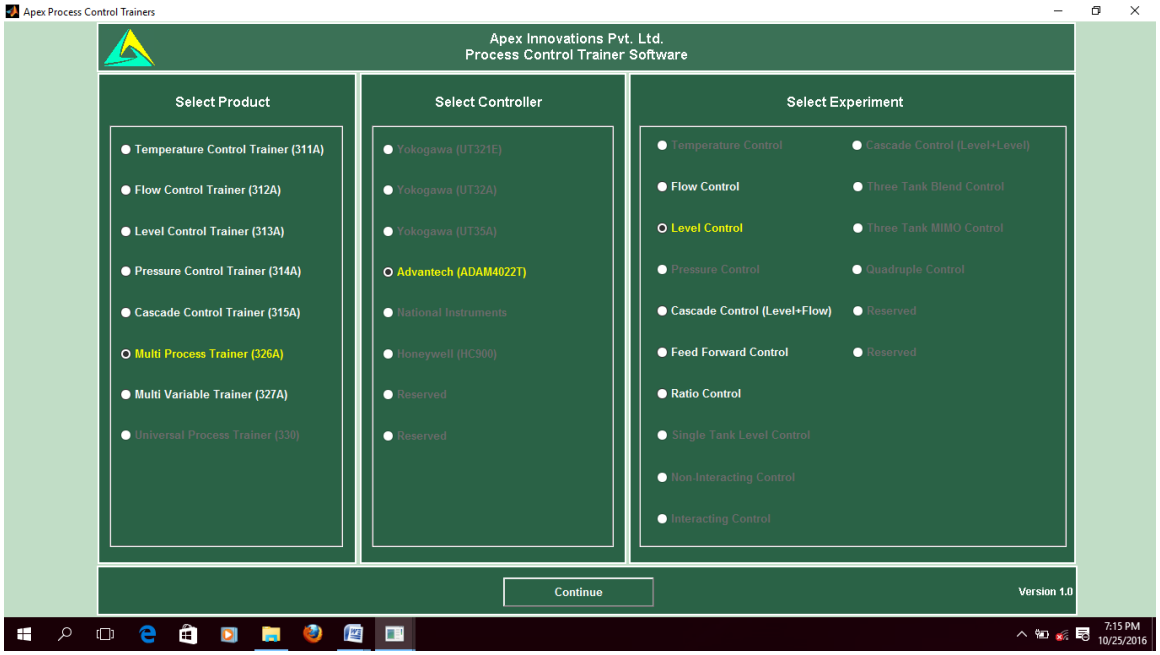
2 As the flow process is non-integrating type the process value keeps on oscillating with wide variation.

3. Study of proportional controller

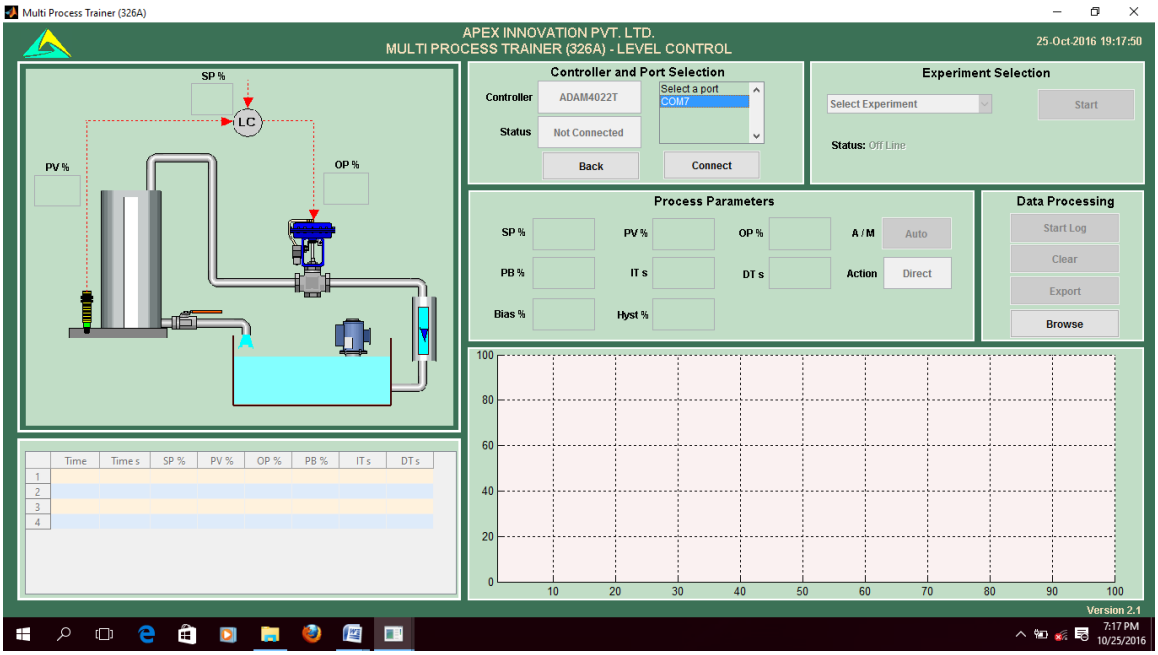
Procedure

For Level Control

- Start up the set up and adjust the Rotameter-1 (extreme right) to 100LPH.
- Provide air supply to the regulator and adjust it to 2 kg/cm^2
- Switch on the computer.
- Double click on Apex_Process_Trainers icon on the desktop



- Select product Multi Process Trainer (326A) and select experiment Level Control and Click Continue



- Select Port to which ADAM 4561 is connected.

  Click Connec
- Click Select Experiment, select **P Mode** and click Start
- Close the Rotameter-2 (Extreme Left) and close the drain valve provided at the inlet of Rotameter-2.
- 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
- From the default values of SP=50, PB=100, Bias=50, AM=Auto and Act =Direct; observe the process value PV. Check if there is any offset.
- Increase the SP to 60% and check the offset. Repeat the observation for SP=70. It will be observed that the process becomes steady with some offset.
- The offset can be eliminated by any of the following ways:

  a) By Increasing/decreasing the bias value gradually by 1% (in steps).

  b) By decreasing the PB. (Decrease the PB in steps of @10%. As the PB is decreased offset is reduced. Below certain PB the process will show oscillatory response.)

Observations

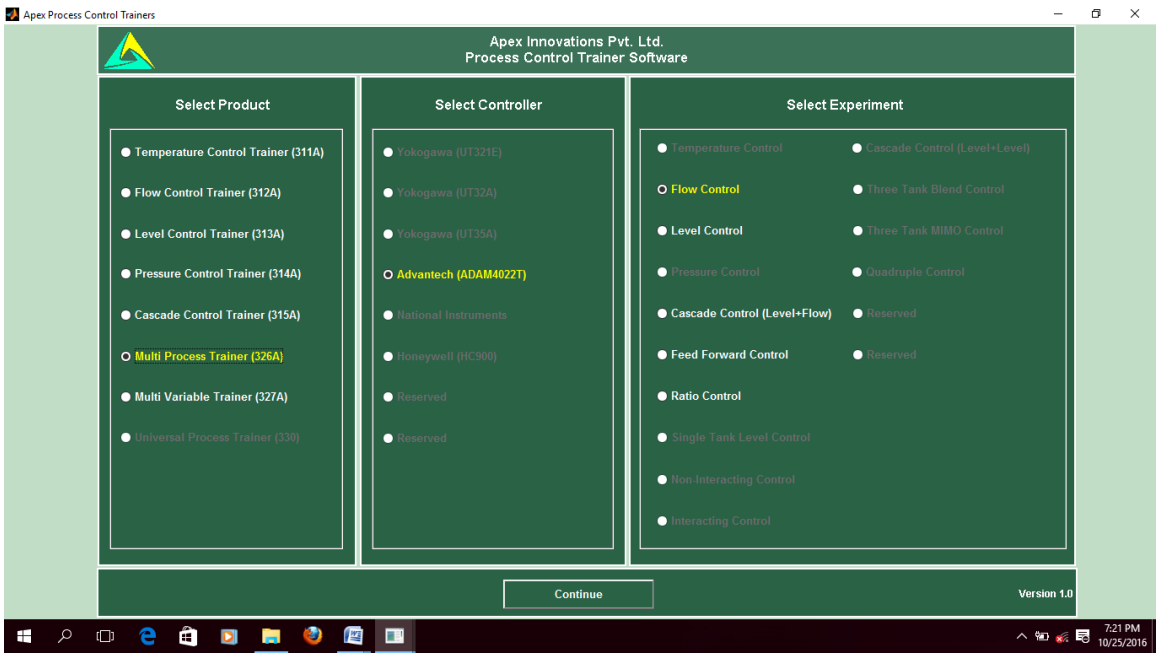
- With P only controller Offset is observed
- Offset can be eliminated by adjusting bias value.
- As Proportional band is reduced the offset value is reduced.
- At very low Proportional band process oscillates.

For Flow Control

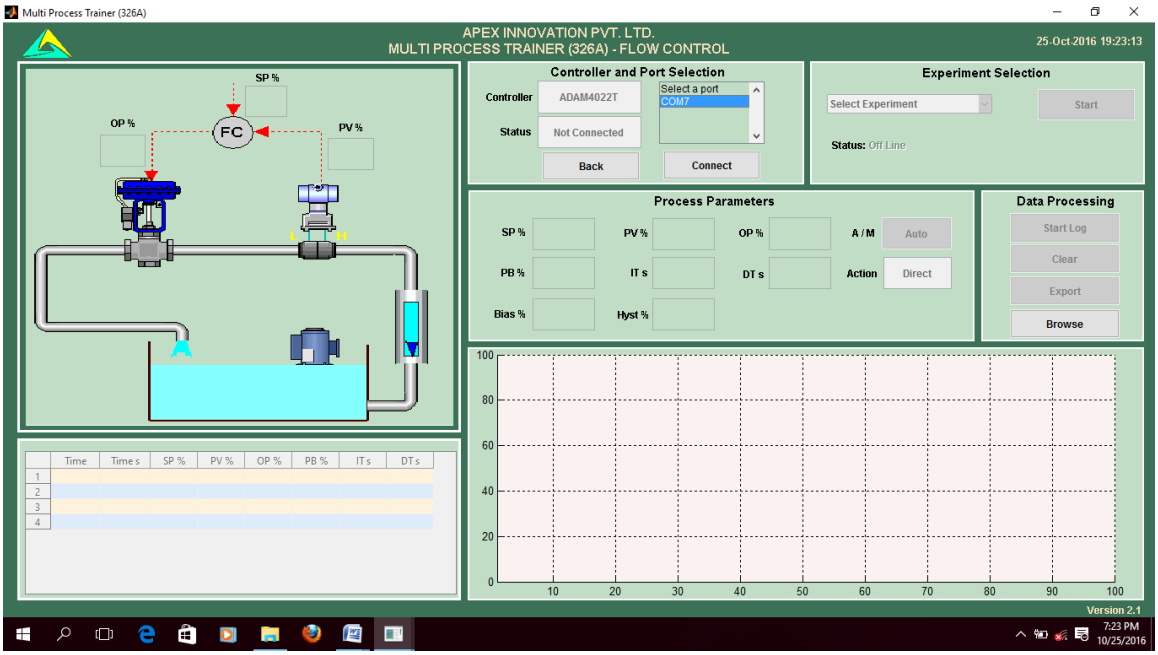
Procedure

(This experiment can be performed for both Level and Flow loops)

- Start up the set up and adjust the Rotameter-1 (extreme right) to 100LPH.
- Provide air supply to the regulator and adjust it to 2 kg/cm^2
- Switch on the computer.
- Double click on Apex_Process_Trainers icon on the desktop



- Select product Multi Process Trainer (326A) and select experiment Flow Control and Click Continue



- Select Port to which ADAM 4561 is connected.

  Click Connec
- Click Select Experiment, select **P Mode** and click Start
- From the default values of SP=60, PB=100, Bias=50, AM=Auto and Act =Direct; observe the process value PV. Check if there is any offset.
- Change the SP in steps of @10% and check the offset. It will be observed that the process becomes steady with different offset values.
- The offset can be eliminated by any of the following ways:

  a) By Increasing/decreasing the bias value gradually by 1% (in steps).

  b) By decreasing the PB. (Decrease the PB in steps of @10%. As the PB is decreased offset is reduced. Below certain PB the process will show oscillatory response.)

Observations

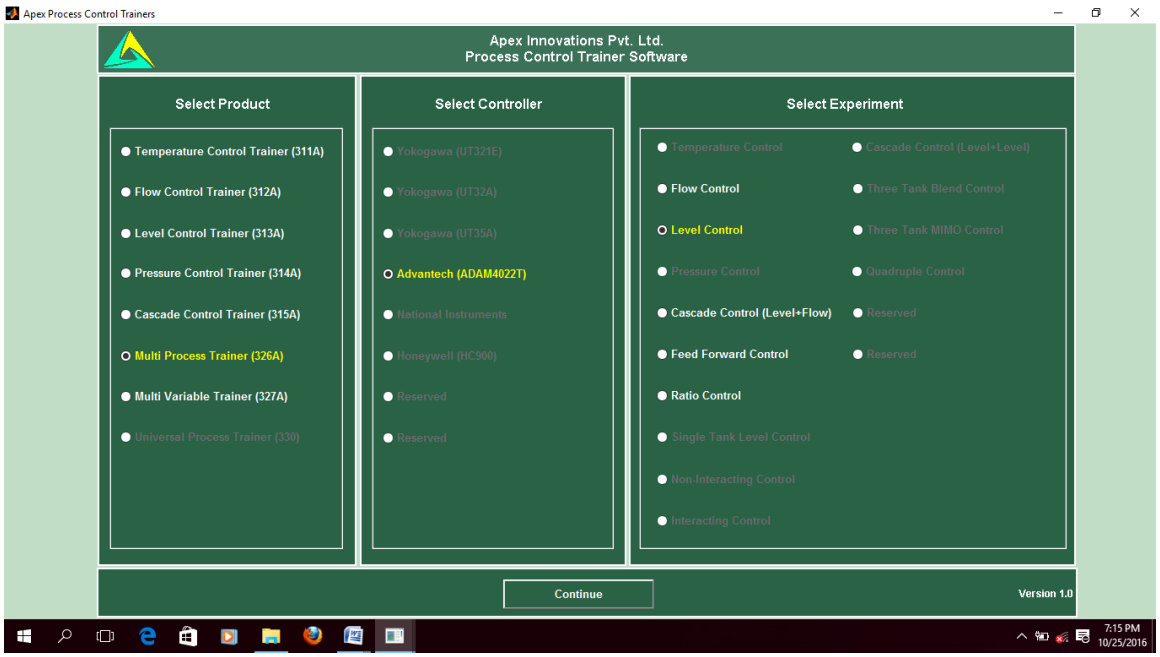
- With P only controller Offset is observed
- Offset can be eliminated by adjusting bias value.
- As Proportional band is reduced the offset value is reduced.
- At low Proportional band process oscillates.

4. **Study of proportional integral controller**

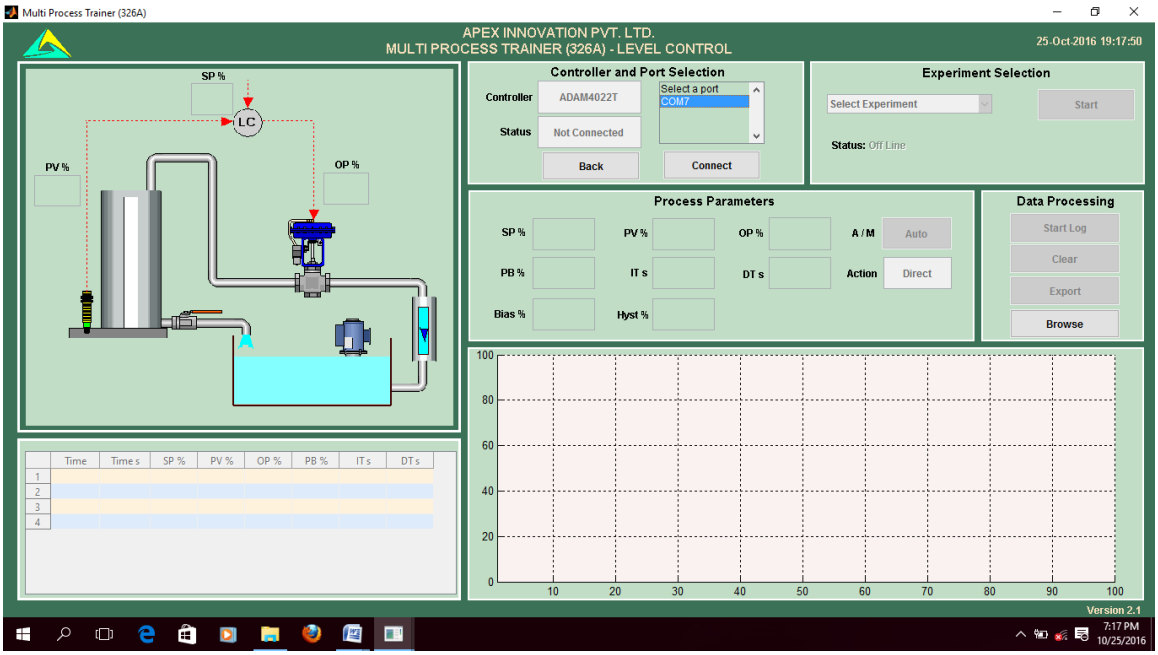
Procedure

For Level Control

- Start up the set up and adjust the Rotameter-1 (extreme right) to 100LPH.
- Provide air supply to the regulator and adjust it to 2 kg/cm^2
- Switch on the computer.
- Double click on Apex_Process_Trainers icon on the desktop



- Select product Multi Process Trainer (326A) and select experiment Level Control and Click Continue



- Select Port to which ADAM 4561 is connected.

  Click Connec
- Click Select Experiment, select **PI Mode** and click Start
- Close the Rotameter-2 (Extreme Left) and close the drain valve provided at the inlet of Rotameter-2.
- 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
- From the default values of SP=50, PB=50, IT=60, AM=Auto and Act =Direct; observe the process value PV. Observe that the output continuously changes till the process value matches with set point. Also note that the change in output due to integral action is more when error is more.
- Increase the SP to 60% and observe that process value matches with set point without any offset.
- Reduce the integral time to 30 seconds, change set point to 50%. Observe that the output change is faster and process value reaches set point in lesser time as compared with

previous setting. Repeat and confirm this observation for still lower values of integral time. Remember to apply step change of +/- 10% every time.

- Observe the oscillatory response of the process value at lower values of integral time.
- Repeat similar observations by keeping the integral time constant (default value) and reducing proportional band. (After every change in Proportional Band the integral value changes automatically which needs to be corrected to keep is constant.) At lower values of Proportional band the output value shows oscillatory response which in-turn oscillates process value.
- From above observations we can identify the need for controller tuning (i.e. finding optimum setting of Proportional band and integral time).

Observations

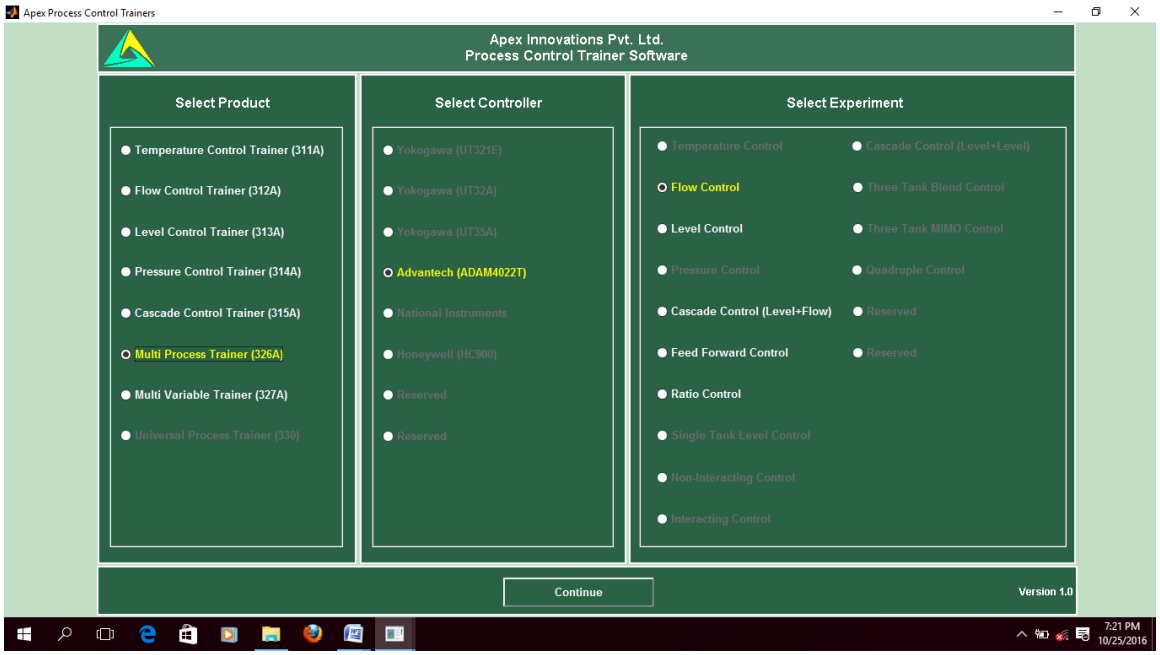
- Adding integral action in control helps in eliminating offset.
- At lower values of Integral time process shows oscillatory response.

For Flow Control

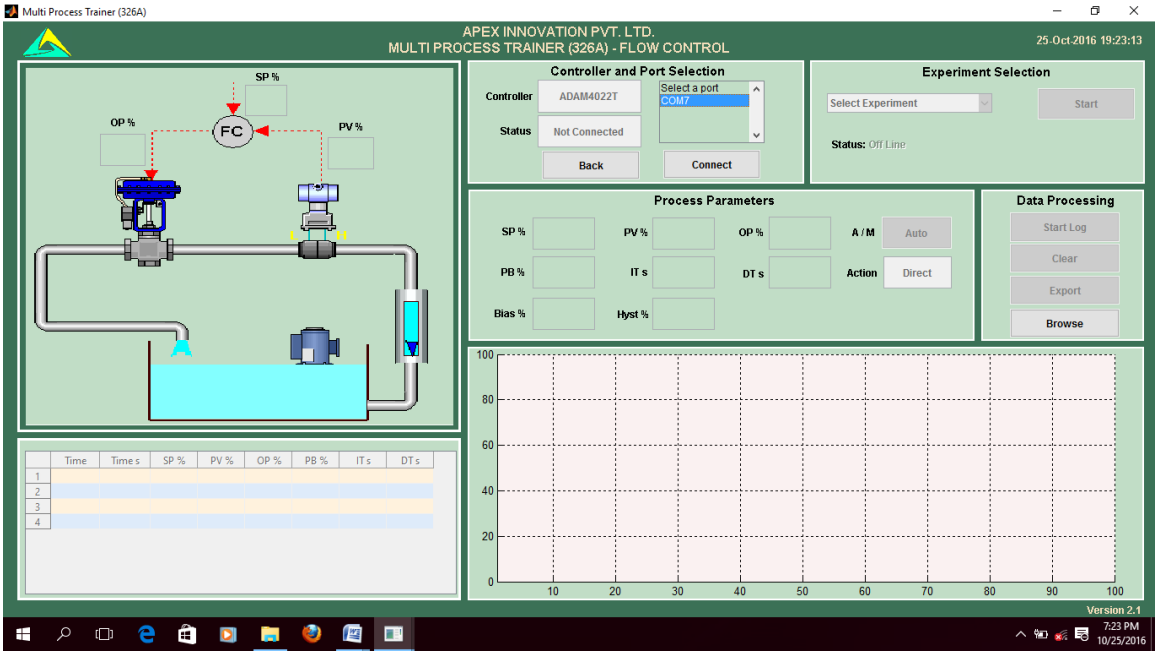
Procedure

(This experiment can be performed for both Level and Flow loops)

- Start up the set up and adjust the Rotameter-1 (extreme right) to 100LPH.
- Provide air supply to the regulator and adjust it to 2 kg/cm^2
- Switch on the computer.
- Double click on Apex_Process_Trainers icon on the desktop



- Select product Multi Process Trainer (326A) and select experiment Flow Control and Click Continue



- Select Port to which ADAM 4561 is connected.

  Click Connec

- Click Select Experiment, select **PI Mode** and click Start

- From the default values of SP=60, PB=50, IT=15, AM=Auto and Act =Direct; observe the process value PV. Increase the SP to 70%. Observe that the output continuously changes till the process value matches with set point. Also note that the change in output due to integral action is more when error is more.
- Reduce the integral time to lower values. Change the set point to 50%. Observe that the output change is faster and process value reaches set point in lesser time as compared with previous setting. Repeat and confirm this observation for still lower values of integral time. Remember to apply step change of +/- 10% every time.
- Observe the oscillatory response of the process value at lower values of integral time.
- Repeat similar observations by keeping the integral time constant (default value) and reducing proportional band. (After every change in Proportional Band the integral value changes automatically which needs to be corrected to keep it constant.) At lower values of Proportional band the output value shows oscillatory response which in-turn oscillates process value.

  From above observations we can identify the need for controller tuning (i.e. finding optimum setting of Proportional band and integral time).

Observations

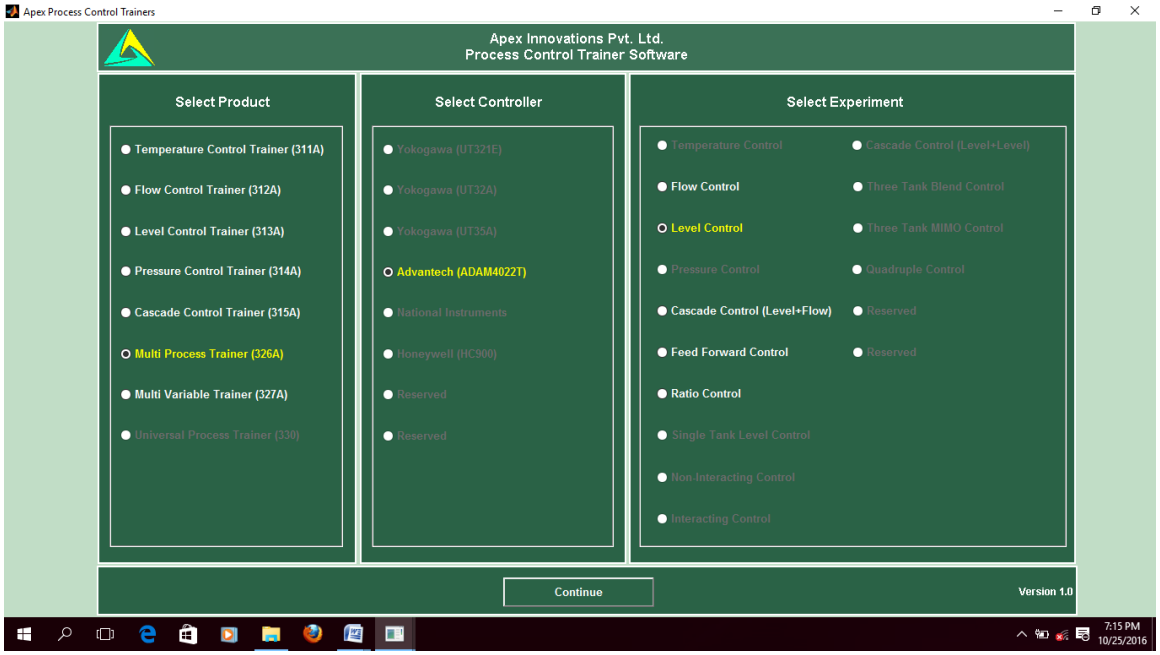
- Adding integral action in control helps in eliminating offset.
- At lower values of Integral time process shows oscillatory response.

5. **Study of proportional derivative controller**

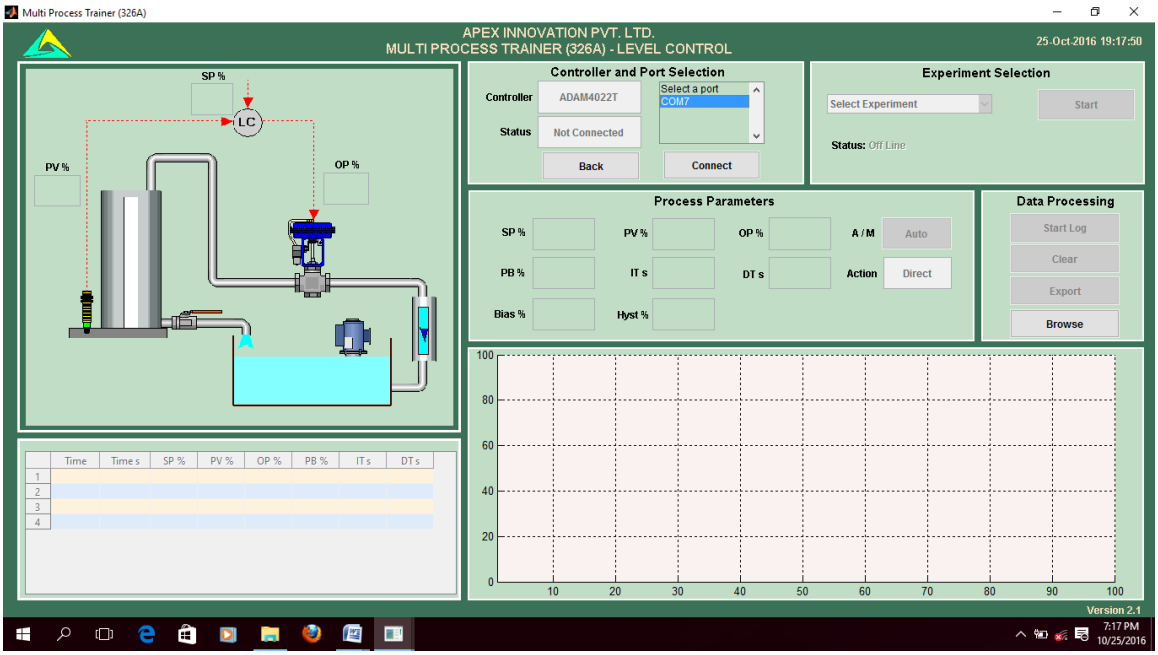
Procedure

For Level Control

- Start up the set up and adjust the Rotameter-1 (extreme right) to 100LPH.
- Provide air supply to the regulator and adjust it to 2 kg/cm^2
- Switch on the computer.
- Double click on Apex_Process_Trainers icon on the desktop



- Select product Multi Process Trainer (326A) and select experiment Level Control and Click Continue



- Select Port to which ADAM 4561 is connected.

  Click Connec
- Click Select Experiment, select **PD Mode** and click Start
- Close the Rotameter-2 (Extreme Left) and close the drain valve provided at the inlet of Rotameter-2.
- Open the control valve fully by decreasing the controller output to 0%.
- Adjust the tank drain valve such that the tank level shall remain between 90 and 100%
- From the default values of SP=50, PB=100, DT=1, AM=Auto, bias=50 and Act =Direct; observe the process value PV. Check if there is any offset.
- Set PB=50, DT=5 and change the SP to 60. Observe that the output changes in steps as observed in proportional control. Whenever the process value is changing the output value shows contribution of derivative effect also. As seen in proportional control the process value may not match with set point and offset is observed.

Observations

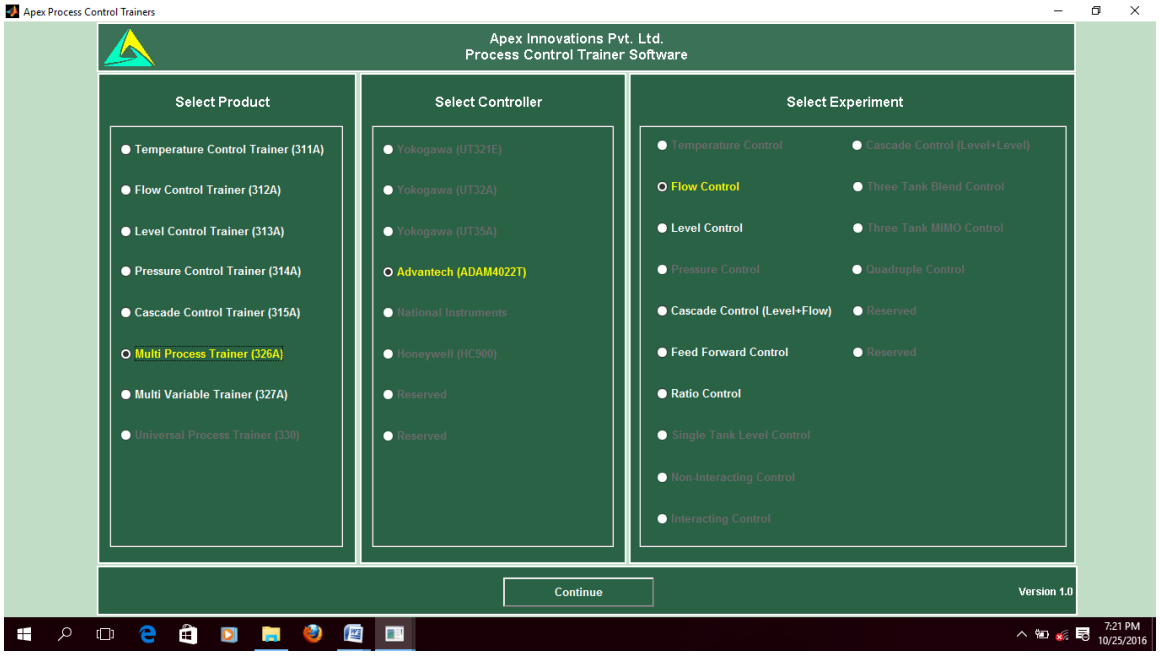
- Because of derivative action the output changes are more based on the rate of change of process vale. The offset can not be eliminated by derivative action.

For Flow Control

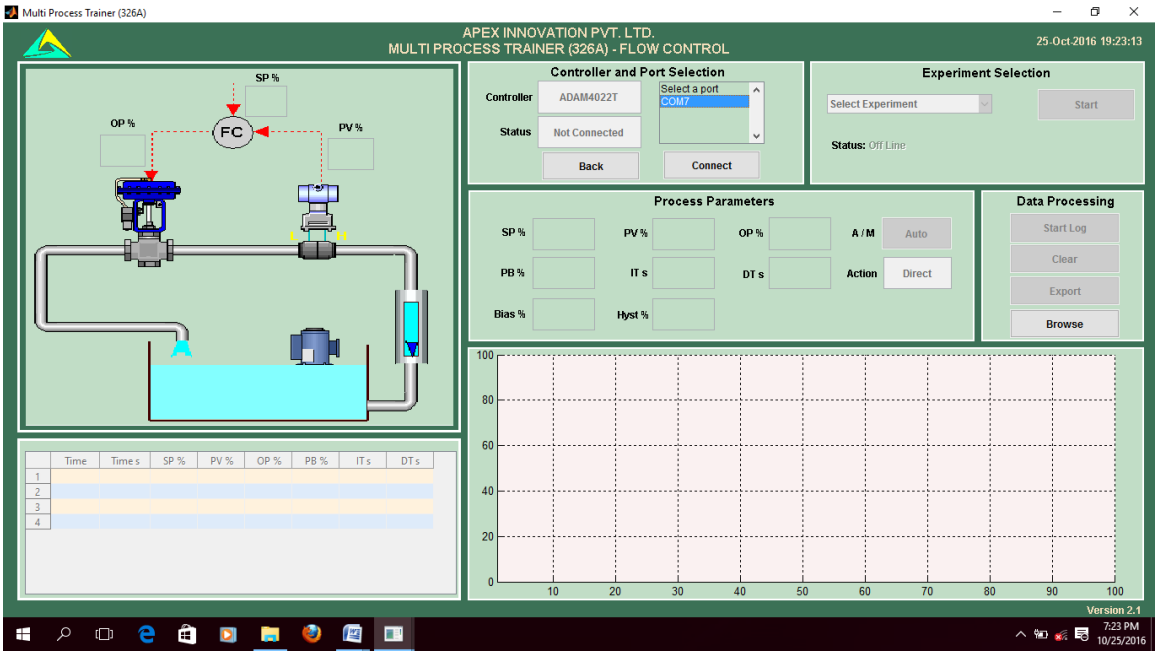
Procedure

(This experiment can be performed for both Level and Flow loops)

- Start up the set up and adjust the Rotameter-1 (extreme right) to 100LPH.
- Provide air supply to the regulator and adjust it to 2 kg/cm^2
- Switch on the computer.
- Double click on Apex_Process_Trainers icon on the desktop



- Select product Multi Process Trainer (326A) and select experiment Flow Control and Click Continue



- Select Port to which ADAM 4561 is connected.

  Click Connec

  Click Select Experiment, select **PD Mode** and click Start

  From the default values of SP=60, PB=100, DT=1, AM=Auto, Bias=50 and

  Act =Direct; observe the process value PV.

  Increase the SP to 70%.

- Set DT=2 and Increase the SP to 70%. Observe that the output changes in steps as observed in proportional control. Whenever the process value is changing the output value shows contribution of derivative effect also. As seen in proportional control the process value may not match with set point and offset is observed.

Observations

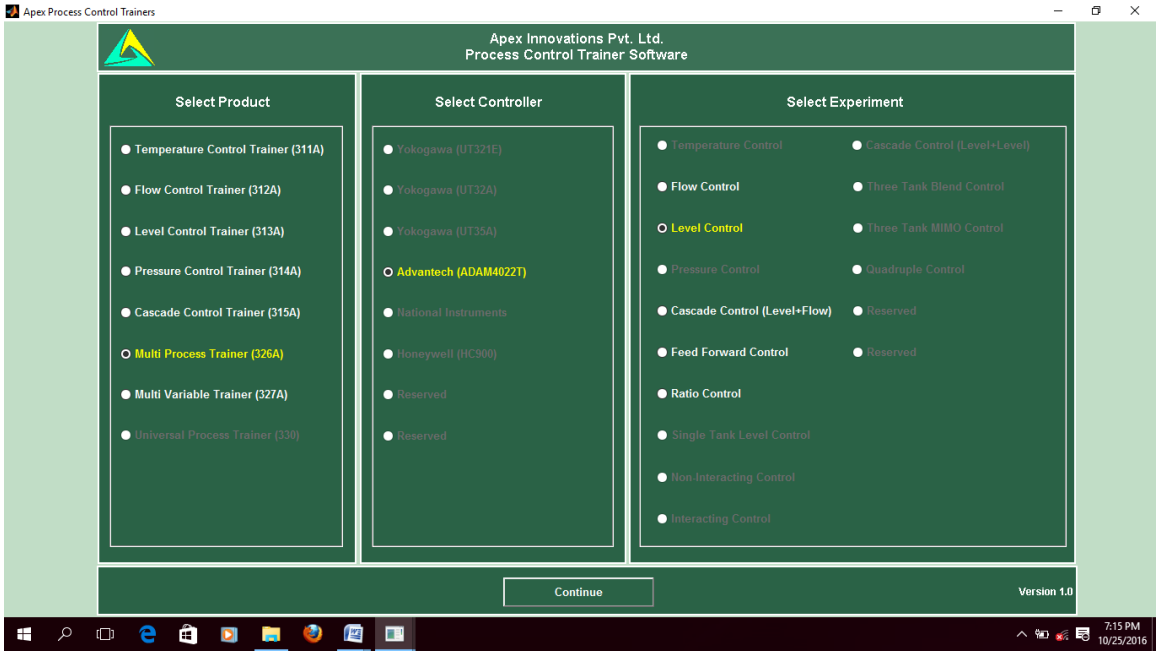
- Because of derivative action the output changes are more based on the rate of change of process vale. The offset can not be eliminated by derivative action.
- As the flow measurement is noisy the derivative action responds to the noise also.

6. **Study of proportional integral derivative controller**

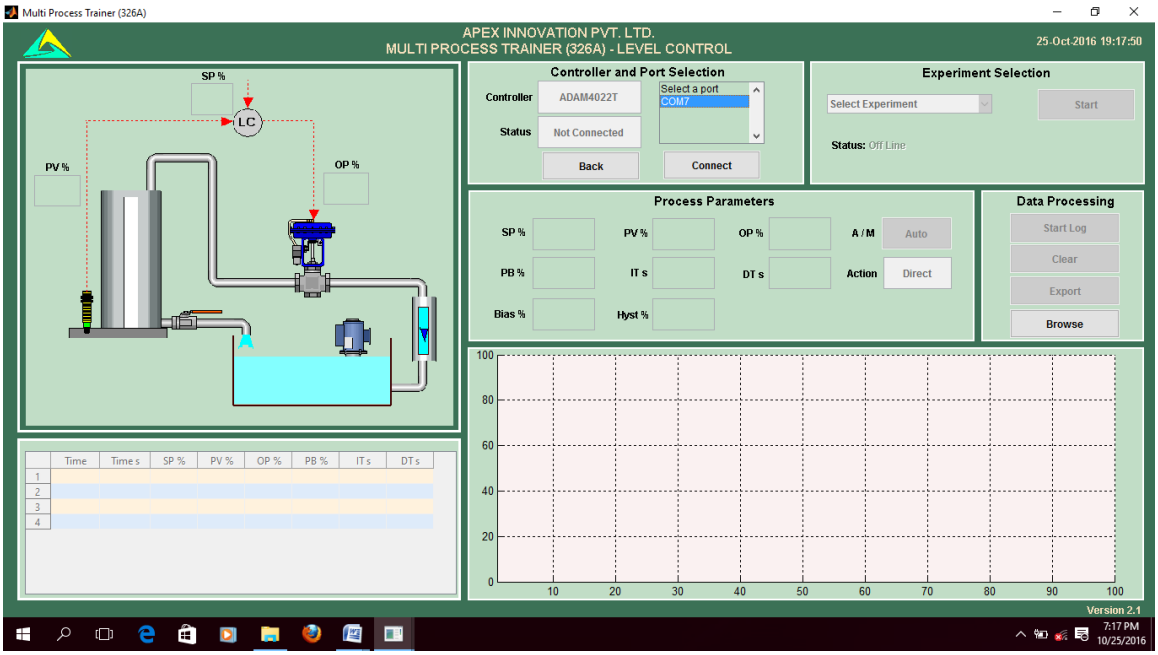
Procedure

For Level Control

- Start up the set up and adjust the Rotameter-1 (extreme right) to 100LPH.
- Provide air supply to the regulator and adjust it to 2 kg/cm^2
- Switch on the computer.
- Double click on Apex_Process_Trainers icon on the desktop



- Select product Multi Process Trainer (326A) and select experiment Level Control and Click Continue



- Select Port to which ADAM 4561 is connected.

  Click Connec
- Click Select Experiment, select **PID Mode** and click Start
- Close the Rotameter-2 (Extreme Left) and close the drain valve provided at the inlet of Rotameter-2.
- 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
- From the default values of SP=50, PB=20, IT=30, DT= 2, AM=Auto and Act =Direct; observe the process value PV. Change the set point by 10% and observe the response by varying values of PB, IT and DT.

Observations

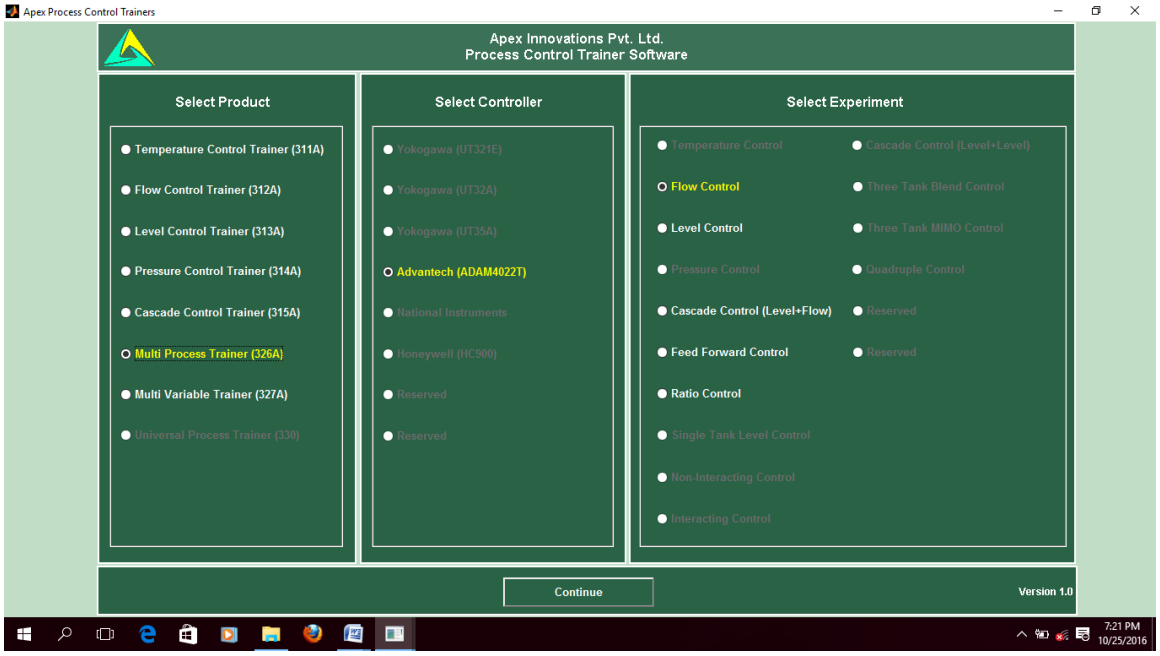
Compare the steady state response of the PID controller with P. PI and PD controller obtained in the above experiment.

For Flow Control

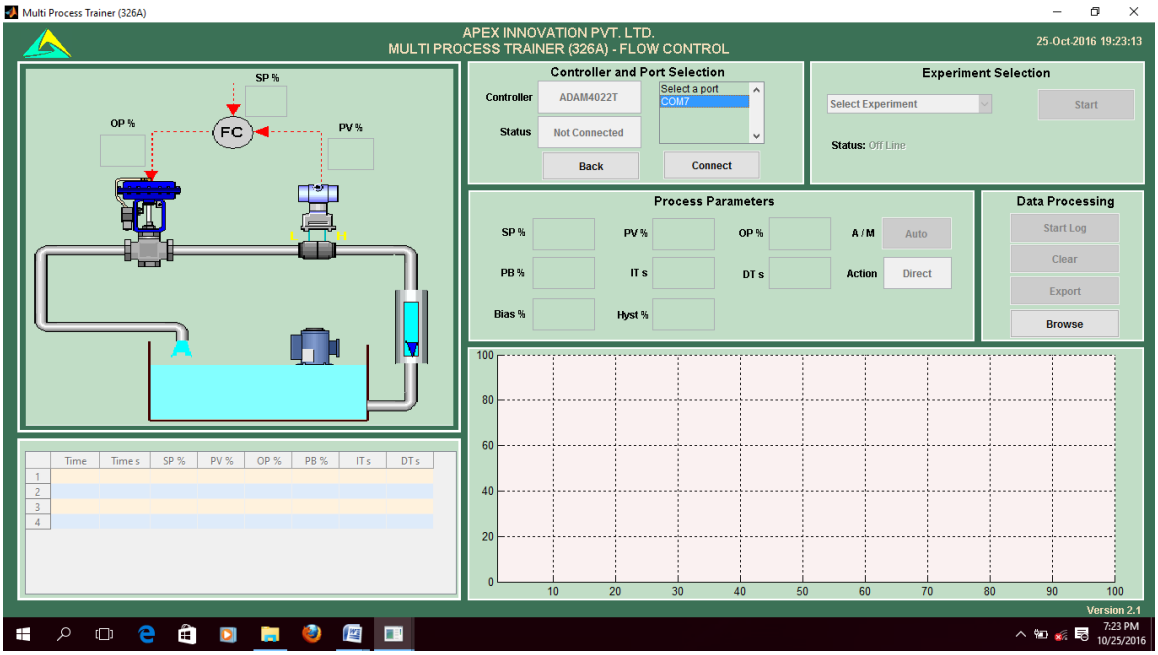
Procedure

(This experiment can be performed for both Level and Flow loops)

- Start up the set up and adjust the Rotameter-1 (extreme right) to 100LPH.
- Provide air supply to the regulator and adjust it to 2 kg/cm^2
- Switch on the computer.
- Double click on Apex_Process_Trainers icon on the desktop



- Select product Multi Process Trainer (326A) and select experiment Flow Control and Click Continue



- Select Port to which ADAM 4561 is connected.

  Click Connec

  Click Select Experiment, select **PID Mode** and click Start

- From the default values of SP=60, PB=50, IT=10, DT=1, AM=Auto and Act =Direct; observe the process value PV. Increase the SP to 70%. Change the set point by 10% and observe the response by varying values of PB, IT and DT.

Observations

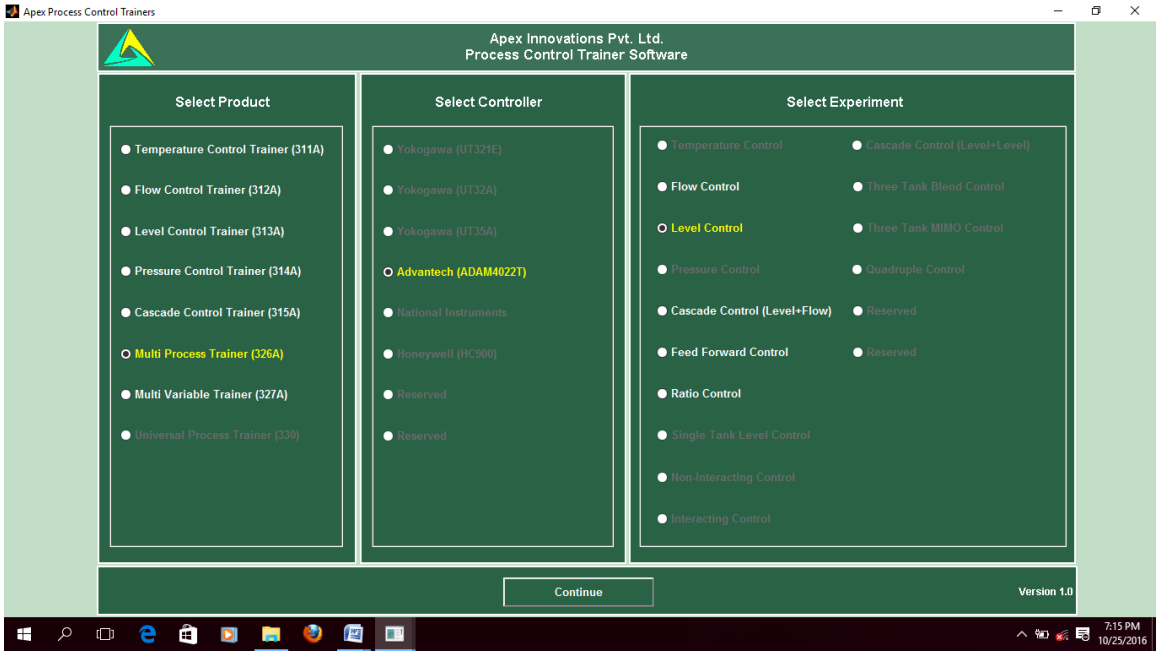
Compare the steady state response of the PID controller with P. PI and PD controller obtained in the above experiment.

4. Tuning of controller (Open loop method)

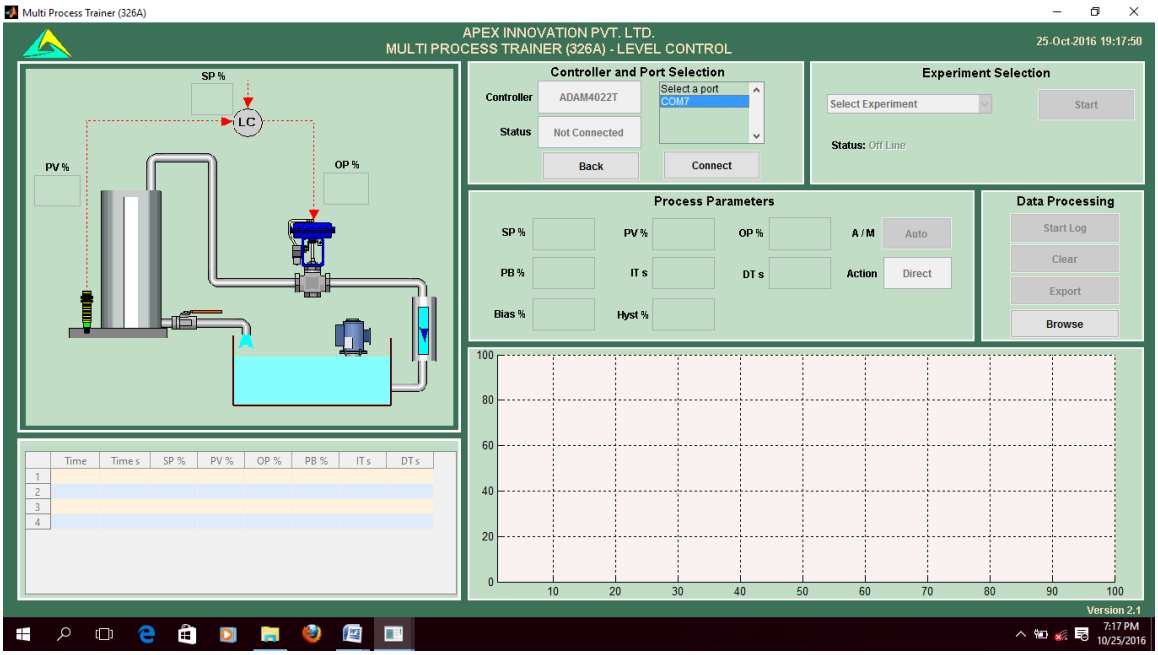
Procedure

For Level Control

- Start up the set up and adjust the Rotameter-1 (extreme right) to 100LPH.
- Provide air supply to the regulator and adjust it to 2 kg/cm^2
- Switch on the computer.
- Double click on Apex_Process_Trainers icon on the desktop



- Select product Multi Process Trainer (326A) and select experiment Level Control and Click Continue



- Select Port to which ADAM 4561 is connected.

  Click Connec
- Click Select Experiment, select **Process Reaction** and click Start
- Close the Rotameter-2 (Extreme Left) and close the drain valve provided at the inlet of Rotameter-2.
- 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
- From the default values change OP=50; observe the process value PV. Wait till it comes to steady state.
- Start data logging.
- Apply a 20 - 30 % change to controller output. (Change control valve output to 30%) Record the step response. Wait for the steady state.
- Stop data logging when the process value is fairly steady.
- Click the “HistData” to see the data. Plot the step response (Process reaction curve) from stored data. Find out the value of slope at the point of inflection and time lag.

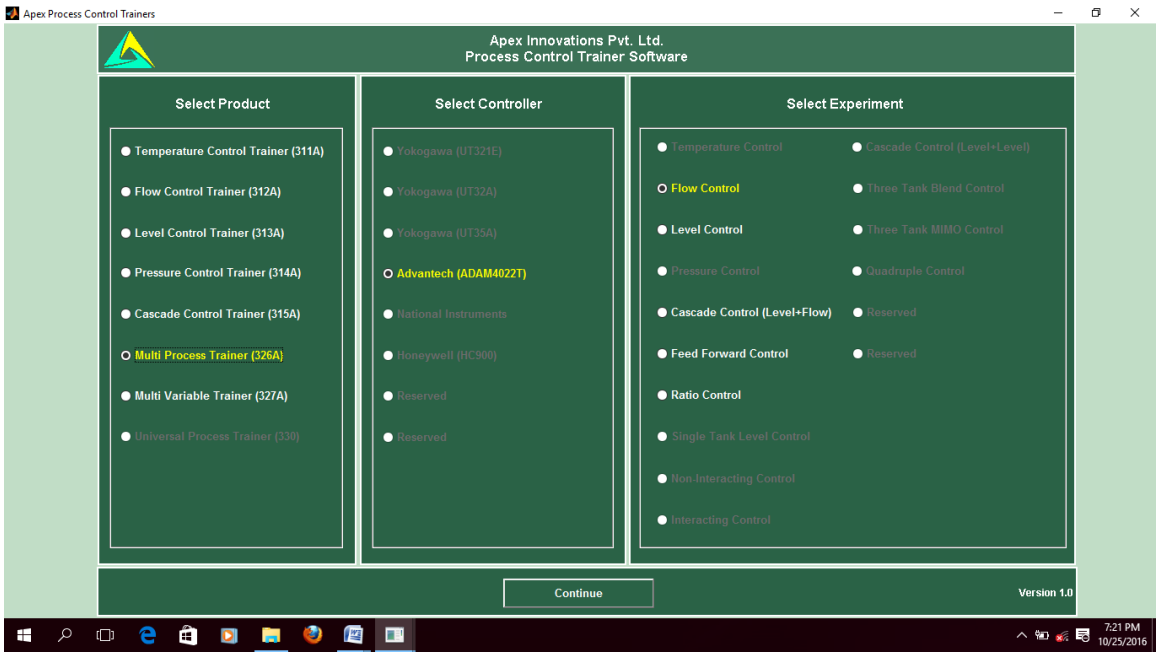
- Calculate P I D settings for different modes.
- Select **PID Mode.** Set the PID values obtained from the calculations. Apply the step change & observe the response of the system. Allow the system to reach steady state.

For Flow Control

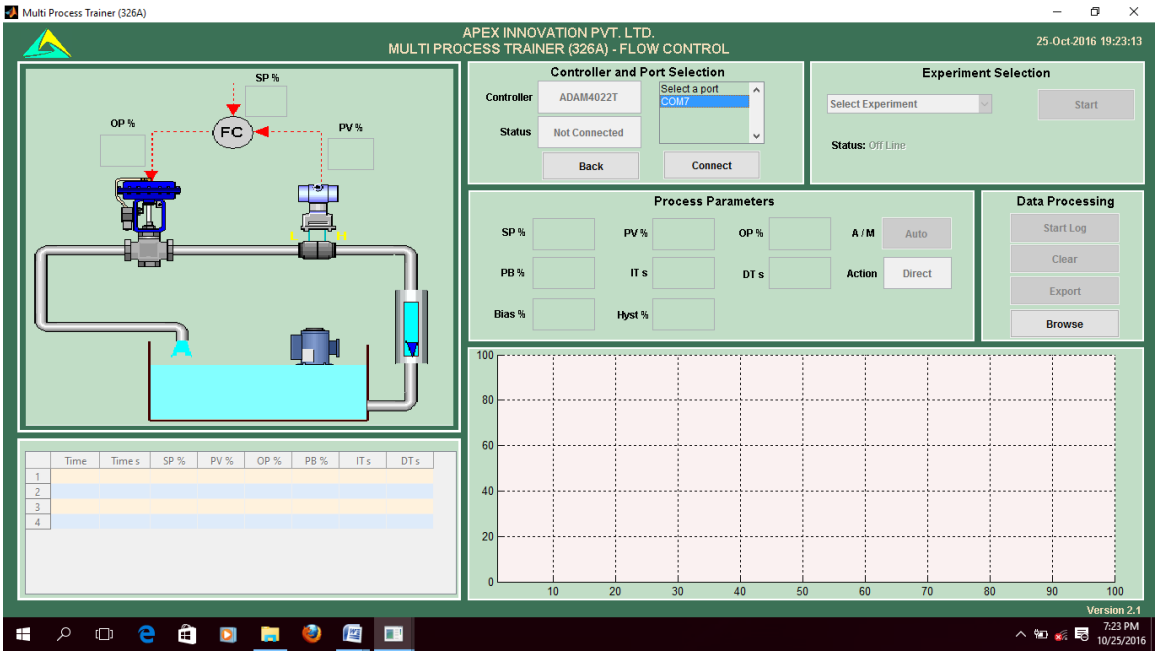
Procedure

(This experiment can be performed for both Level and Flow loops)

- Start up the set up and adjust the Rotameter-1 (extreme right) to 100LPH.
- Provide air supply to the regulator and adjust it to 2 kg/cm^2
- Switch on the computer.
- Double click on Apex_Process_Trainers icon on the desktop



- Select product Multi Process Trainer (326A) and select experiment Flow Control and Click Continue



- Select Port to which ADAM 4561 is connected.

  Click Connec
- Click Select Experiment, select **Process Reaction** and click Start
- From the default values change OP=50; observe the process value PV. Wait till it comes to steady state.
- Start data logging.
- Apply a 20 - 30 % change to controller output. (Change control valve output to 30%) Record the step response. Wait for the steady state.
- Stop data logging when the process value is fairly steady.
- Click the “HistData” to see the data. 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.** 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 for formulae.)

- Step change to the system ΔP = 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.

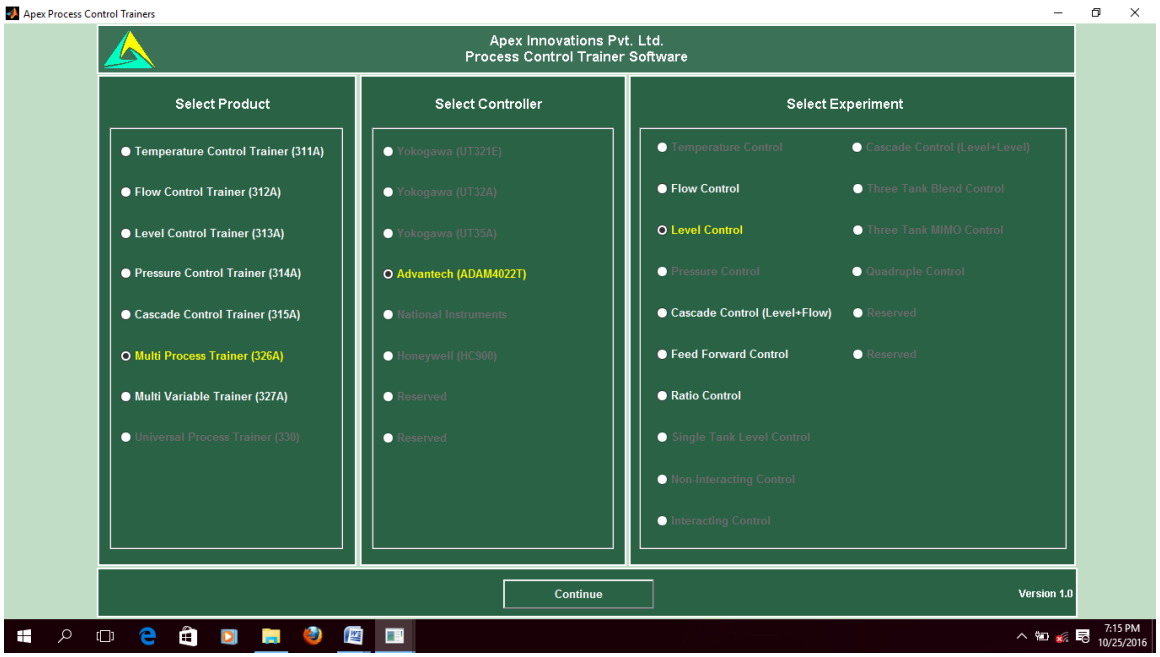
Observe response of the system for different PID settings.

8.**Tuning of controller (Closed loop method)**

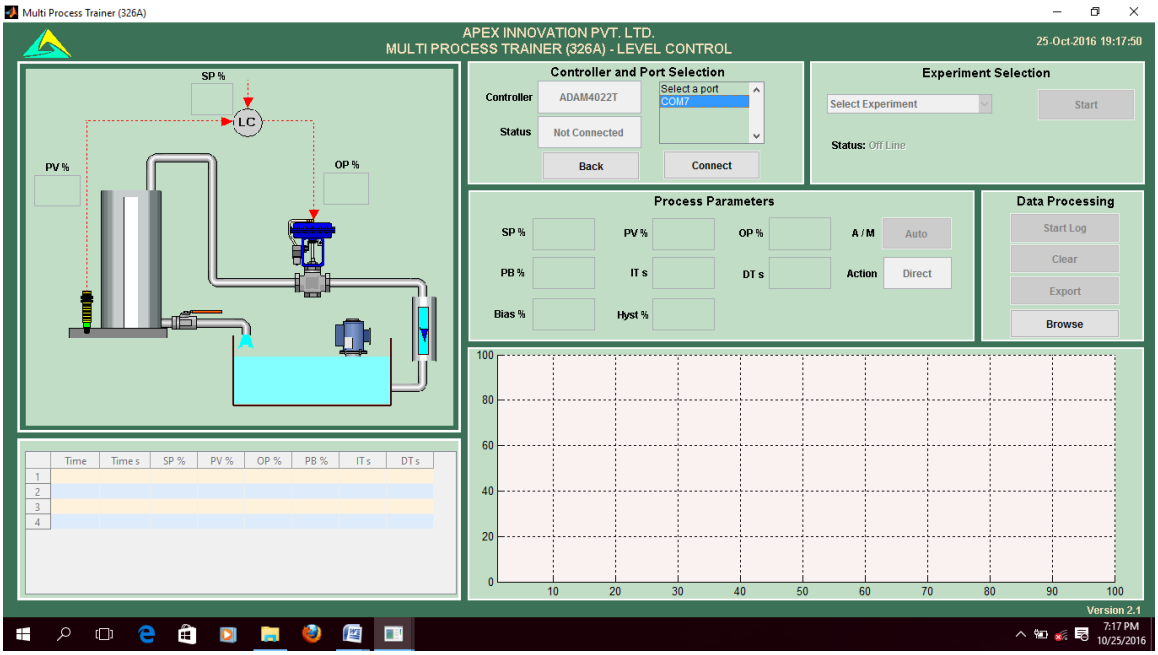
Procedure

For Level Control

- Start up the set up and adjust the Rotameter-1 (extreme right) to 100LPH.
- Provide air supply to the regulator and adjust it to 2 kg/cm^2
- Switch on the computer.
- Double click on Apex_Process_Trainers icon on the desktop



- Select product Multi Process Trainer (326A) and select experiment Level Control and Click Continue



- Select Port to which ADAM 4561 is connected.

  Click Connec
- Click Select Experiment, select **Close Loop** and click Start
- Close the Rotameter-2 (Extreme Left) and close the drain valve provided at the inlet of Rotameter-2.
- Open the control valve fully by decreasing the controller output to 0%.
- Adjust the tank drain valve such that the tank level shall remain between 90 and 100%
- From the default values of SP=50, PB=100, Bias=50, AM=Auto and Act= Direct; adjust bias value so that process value approximately matches with set point.
- Disturb the step change by providing step change of +2% to set point and observe the system response.
- If the PV is steady, reduce the PB by @ 10% and disturb the system by applying step change of -2%
- Repeat above steps and find out the PB for which the system shows continuous oscillatory response.
- Record this PB as ultimate proportional band and period of oscillation as ultimate period.

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

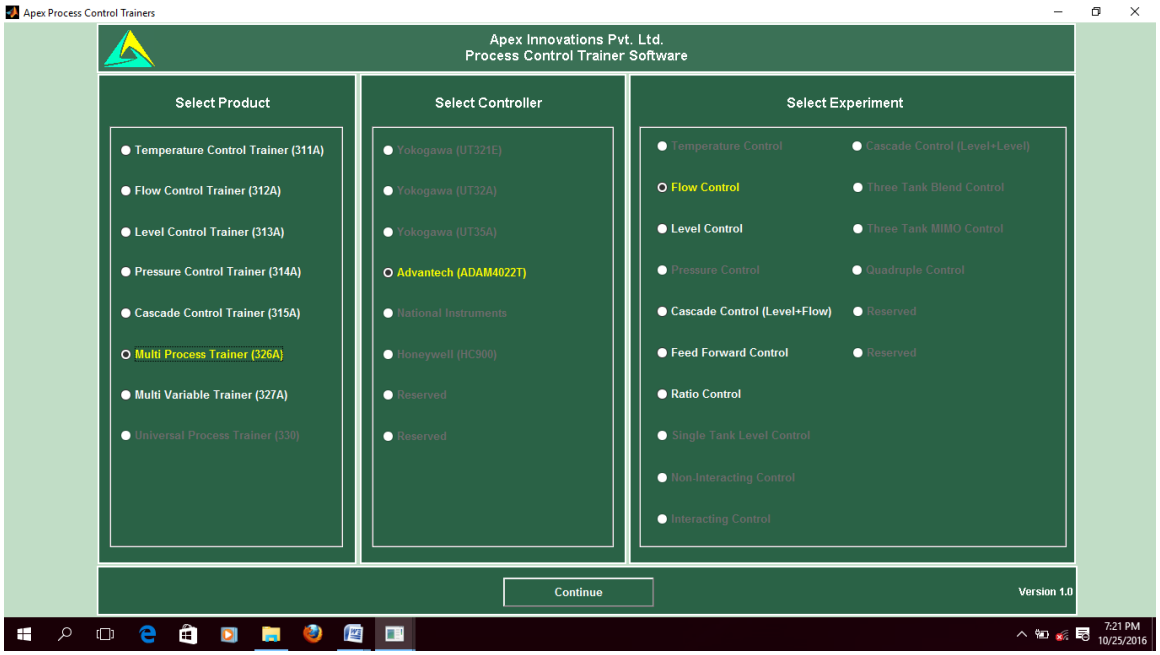
- Record the ultimate proportional band (***Pbu***) and ultimate period (***Tu***) from above experiment. (Typical value Pbu=4%, Tu = 17 sec.)
- Calculate PID values by referring theory part for different control actions.
- Observe the process response for these settings.
- Compare the values obtained with open loop response.

For Flow Control

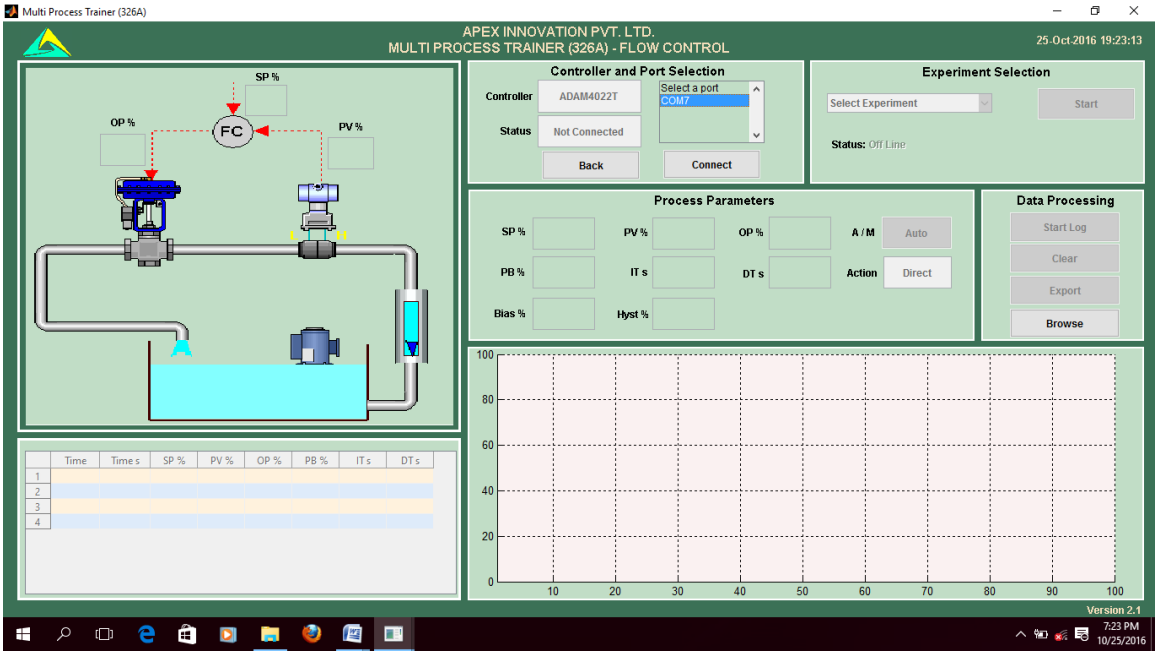
Procedure

(This experiment can be performed for both Level and Flow loops)

- Start up the set up and adjust the Rotameter-1 (extreme right) to 100LPH.
- Provide air supply to the regulator and adjust it to 2 kg/cm^2
- Switch on the computer.
- Double click on Apex_Process_Trainers icon on the desktop



- Select product Multi Process Trainer (326A) and select experiment Flow Control and Click Continue



- Select Port to which ADAM 4561 is connected.

  Click Connec

- Click Select Experiment, select **Close Loop** and click Start

- From the default values of SP=60, PB=100, Bias=50, AM=Auto and Act= Direct; adjust bias value so that process value approximately matches with set point.
- Disturb the step change by providing step change of +5% to set point and observe the system response.
- If the PV is steady, reduce the PB by @ 10% and disturb the system by applying step change of -5%
- Repeat above steps and find out the PB for which the system shows continuous oscillatory response.
- Record this PB as ultimate proportional band and period of oscillation as ultimate period.
- 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

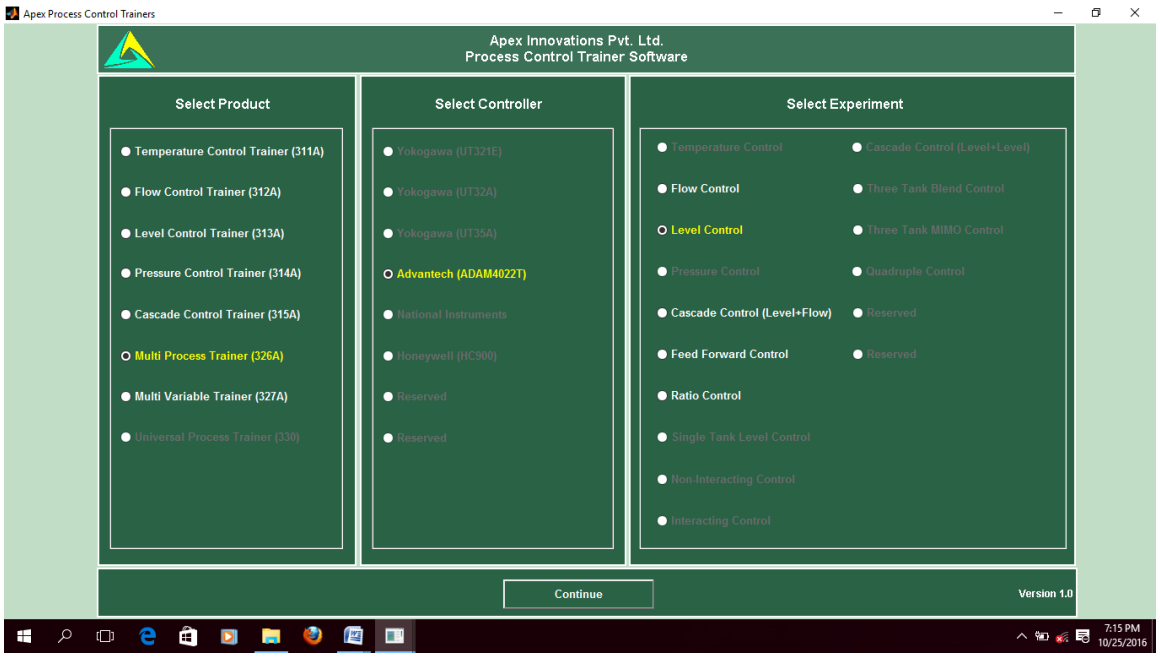
- Record the ultimate proportional band (***Pbu***) and ultimate period (***Tu***) from above experiment. (Typical value Pbu=35%, Tu = 7 sec.)
- Calculate PID values by referring theory part for different control actions.
- Observe the process response for these settings.
- Compare the values obtained with open loop response.

9. **To study stability of the system (Bode plot)**

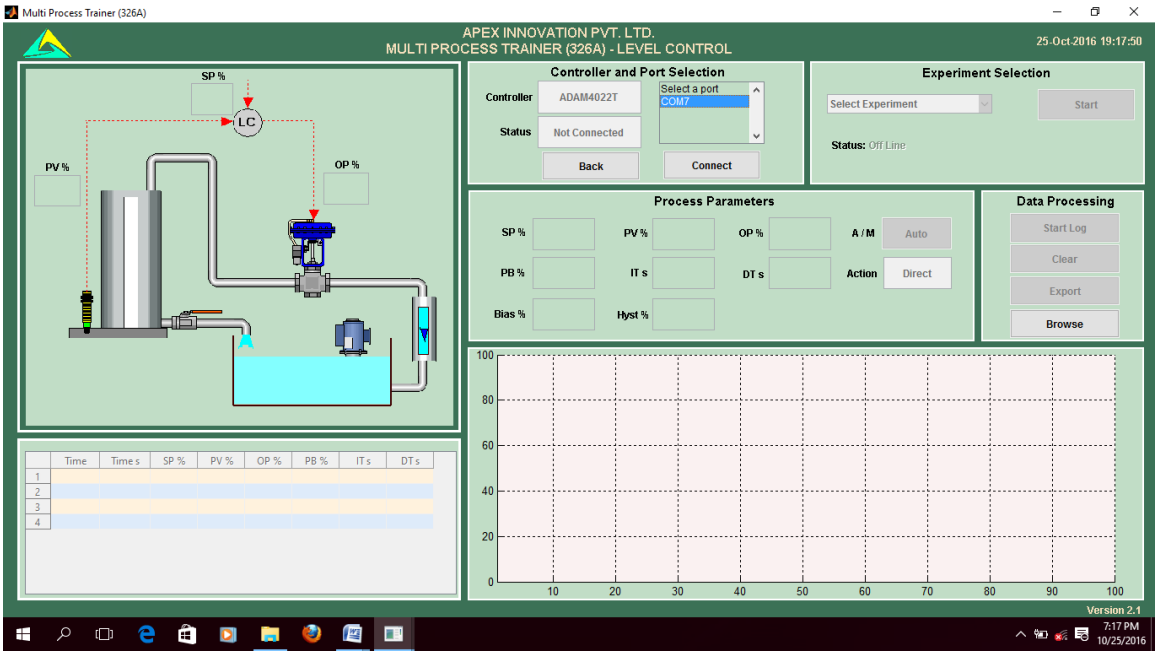
Procedure

For Level Control

- Start up the set up and adjust the Rotameter-1 (extreme right) to 100LPH.
- Provide air supply to the regulator and adjust it to 2 kg/cm^2
- Switch on the computer.
- Double click on Apex_Process_Trainers icon on the desktop



- Select product Multi Process Trainer (326A) and select experiment Level Control and Click Continue



- Select Port to which ADAM 4561 is connected.

  Click Connec
- Click Select Experiment, select **Stability Analysis** and click Start
- Close the Rotameter-2 (Extreme Left) and close the drain valve provided at the inlet of Rotameter-2.
- Open the control valve fully by decreasing the controller output to 0%.
- Adjust the tank drain valve such that the tank level shall remain between 90 and 100%
- From the default values of Ref point = 50%, Amplitude = 50% and period =10 sec. observe the output and process value variations.
- Change Reference point, Amplitude and Period so that continuous sinusoidal waveform is observed for process value.
- Log the data for records.
- Change the period and repeat the observation for 3-4 different values of the period.

(Note: Tf the process value is reaching zero, close the tank drain valve slightly.)

Observations

- From the data file stored observe the phase lag x, in sec. and process value amplitude in %

  Typical values: Ref Point 50%, Amplitude =50%, Period = 60 sec., Process value amplitude: 7.1%, Lag= 25 Sec. Hence Phase lag =150 Deg. Magnitude ratio= 14.2%.

  Repeat the observations for different period.

Obs. No.	Input amplitude A1 %	Output amplitude A2 %	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.

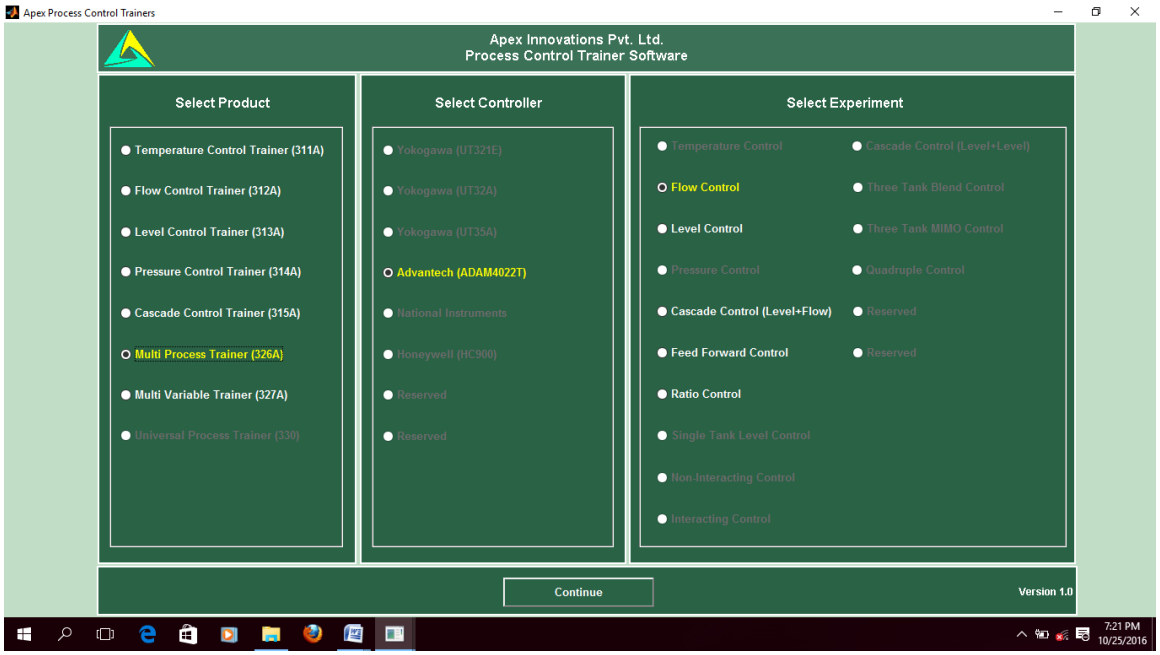
- Study the graph for stable conditions mentioned in theory.

For Flow Control

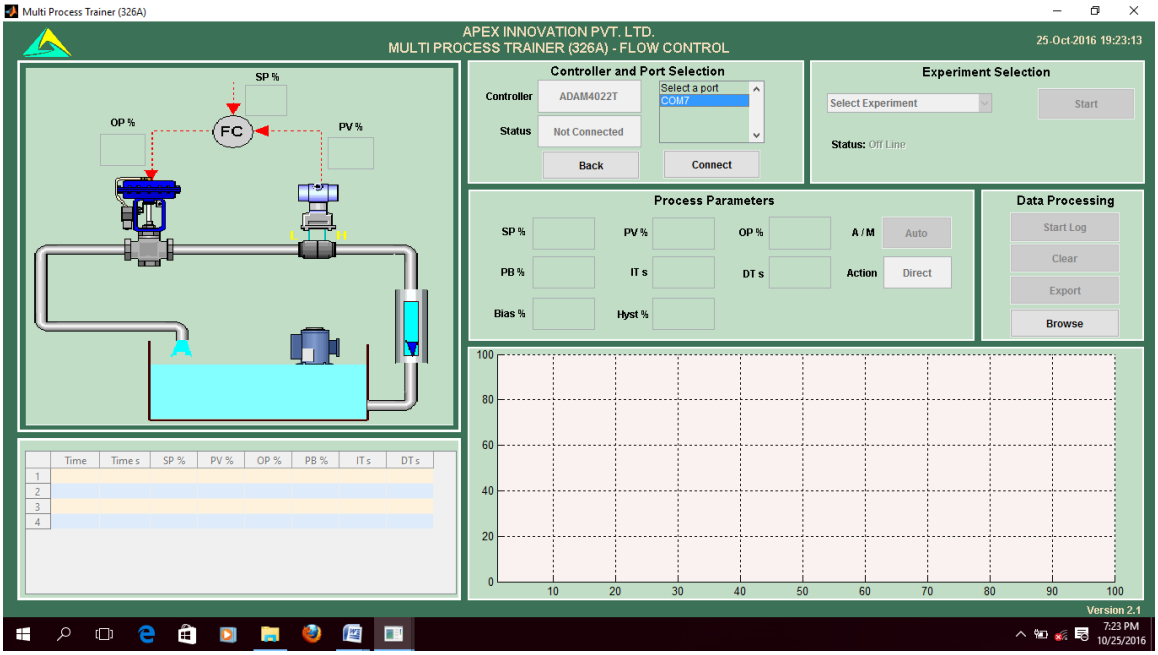
Procedure

(This experiment can be performed for both Level and Flow loops)

- Start up the set up and adjust the Rotameter-1 (extreme right) to 100LPH.
- Provide air supply to the regulator and adjust it to 2 kg/cm^2
- Switch on the computer.
- Double click on Apex_Process_Trainers icon on the desktop



- Select product Multi Process Trainer (326A) and select experiment Flow Control and Click Continue



- Select Port to which ADAM 4561 is connected.
- Click Connec
- Click Select Experiment, select **Stability Analysis** and click Start

- From the default values of Ref point = 50%, Amplitude = 30% and period =30 sec. observe the output and process value variations.
- Change Reference point, Amplitude and Period so that continuous sinusoidal waveform is observed for process value.
- Log the data for records.
- Change the period and repeat the observation for 3-4 different values of the period.

Observations

- From the data file stored observe the phase lag x, in sec. and process value amplitude in %
  Typical values: Ref Point 50%, Amplitude =30%, Period = 30 sec., Process value amplitude: 21%, Lag= 8 Sec. Hence Phase lag =96 Deg. Magnitude ratio= 70%.
  Repeat the observations for different period.

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

Calculations

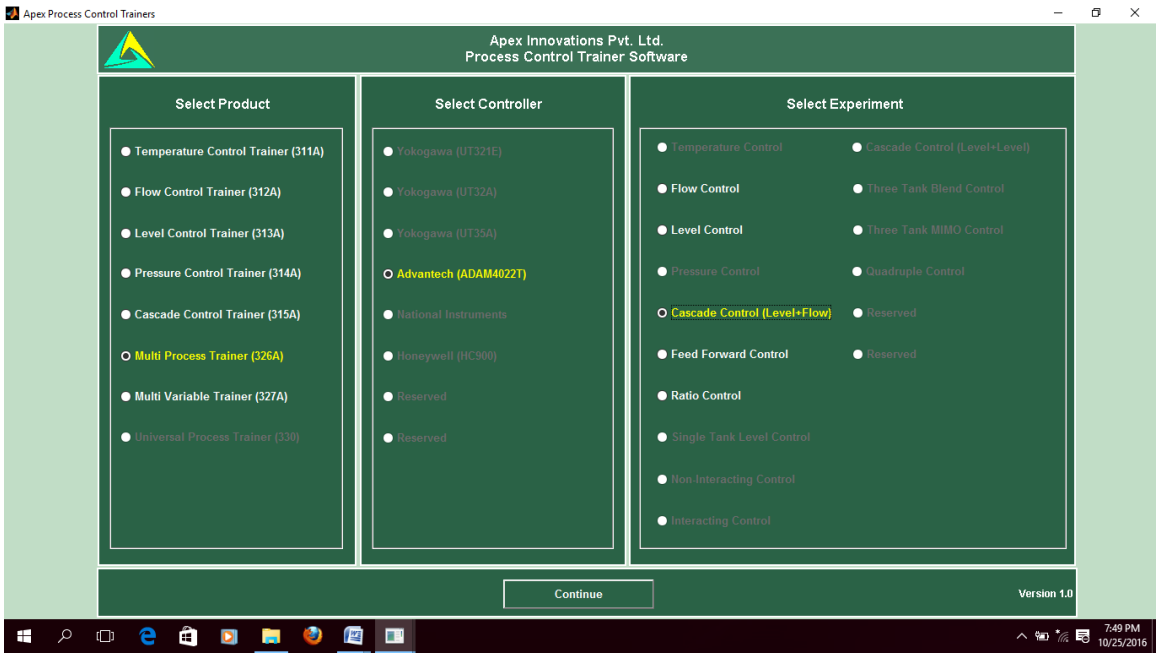
- Calculate for each observation
  Magnitude ratio as M = A2/A1
  Phase angle = (X/T) x 360
  Frequency = 1/T cycles / sec.
- Draw the graphs of:
  Magnitude Vs frequency on log - log scale
  Phase angle Vs frequency on semi-log coordinates.
  Study the graph for stable conditions mentioned in theory.

10. **To study cascade control system**

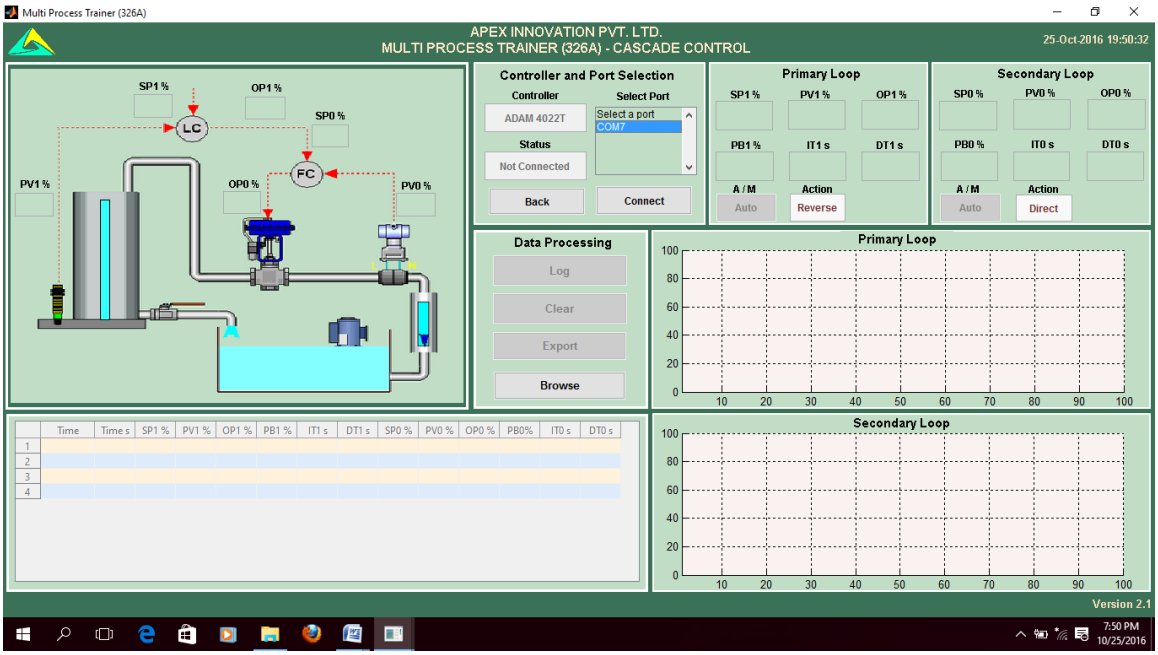
Procedure

For Cascade Control (Level+Flow)

- Start up the set up and adjust the Rotameter-1 (extreme right) to 100LPH.
- Provide air supply to the regulator and adjust it to 2 kg/cm^2
- Switch on the computer.
- Double click on Apex_Process_Trainers icon on the desktop



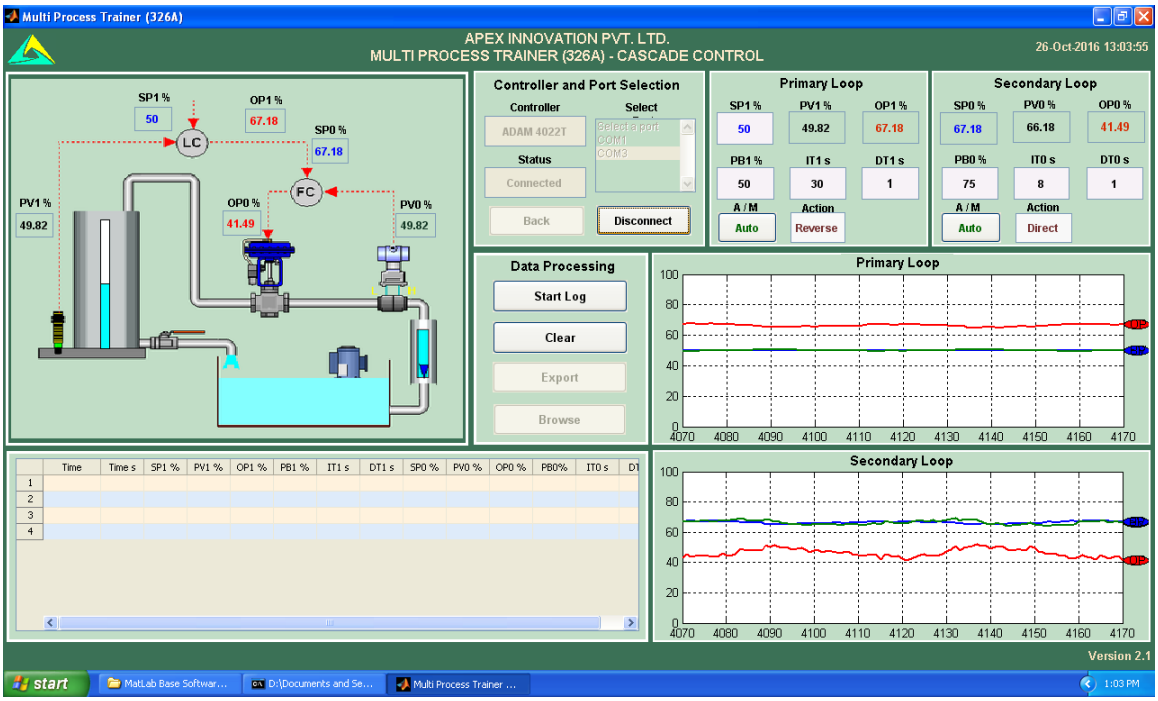
- Select product Multi Process Trainer (326A) and select experiment Level Control and Click Continue



- Select Port to which ADAM 4561 is connected.

  Click Connec
- Close the Rotameter-2 (Extreme Left) and close the drain valve provided at the inlet of Rotameter-2.
- Open the control valve by changing secondary loop to “Manual” mode and decreasing the controller output to 0%.
- Adjust the tank drain valve such that the tank level shall remain between 95 and 100% . Take Secondary loop to “Auto” mode.
- Default values of Primary loop are SP=50, PB=20, IT=30, DT=2, Act=Revese, and that of secondary loop are PB= 75, IT=8, DT=2, Act=Direct. Note that primary loop is “Level control” loop and secondary loop is “Flow Control” loop. The output of primary loop is connected to secondary loop as a set point.
- Wait till the Process is at steady state. Change the set point of primary loop and observe the response.
- For tuning cascade controller first tune **Secondary Controller.** Tune the controller independently by keeping the Primary controller in manual mode. The set point of secondary loop can be changed by changing output of primary loop.

- Tune the **Primary Controller** using trial and error approach, select the proportional band and integral time, which gives a satisfactory response to step change in set point.



Observations

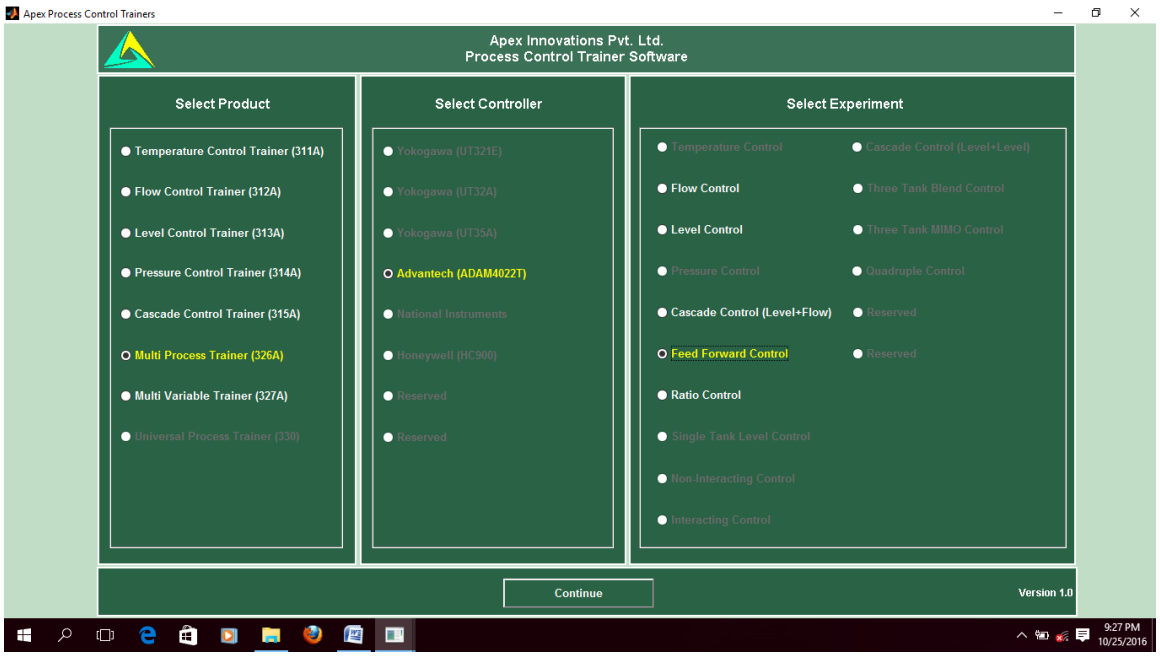
- It is observed that the speed of response of the level control system is improved. As the flow loop is fast responsive than the level control loop, for a small change in primary controller output, the secondary controller tries to achieve the set point.
- Time required to achieve the primary controller set point is less than that of single loop control.

11. **To study feed forward +feed back control system**

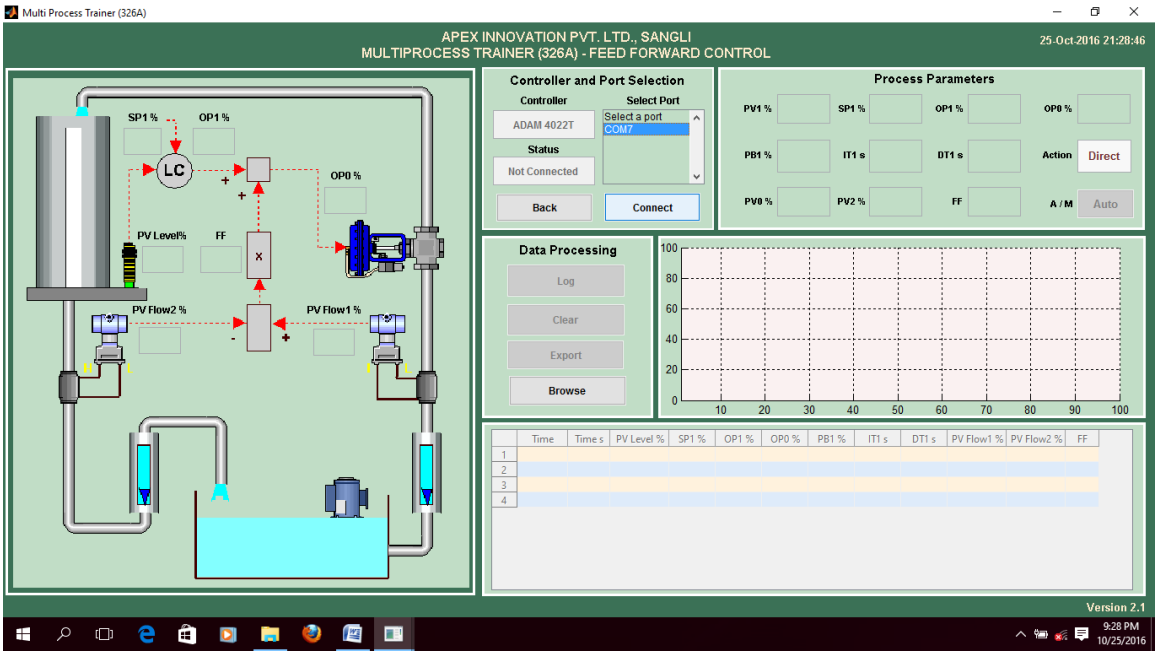
Procedure

For feed forward Control (feed back loop):

- If the tappings of orifice placed in the process tank outlet line are short circuited by a PU tube loop, remove the loop. Connect pressure signal tappings of this orifice to FT2 with proper polarity.
- Short circuit the pressure tappings of orifice placed in the line, at the outlet of the middle rotameter).
- Start up the set up and adjust the Rotameter-1 (extreme right) to 100LPH.
- Provide air supply to the regulator and adjust it to 2 kg/cm^2
- Remove entrapped air, if any from the FT2. For removing air open the vent valves on the DP transmitter.
- Switch on the computer.
- Double click on Apex_Process_Trainers icon on the desktop



- Select product Multi Process Trainer (326A) and select experiment Feed Forward Control and Click Continue



- Select Port to which ADAM 4561 is connected.

  Click Connec

- Close the drain valve of the tank and close the Rotameter drain valve provided at the inlet of Rotameter-2
- Open Rotameter-2 and adjust flow to 75 LPH.

  From the default values of SP=50, PB=20, IT=30, DT=2, FF=1 observe the response of the system. Note for FF=0 the loop is purely feed back loop.
- With Feed forward factor =1 apply load disturbance by changing the output flow rotameter. Observe the effect of feed forward on LIC output and on process variable.

Observations

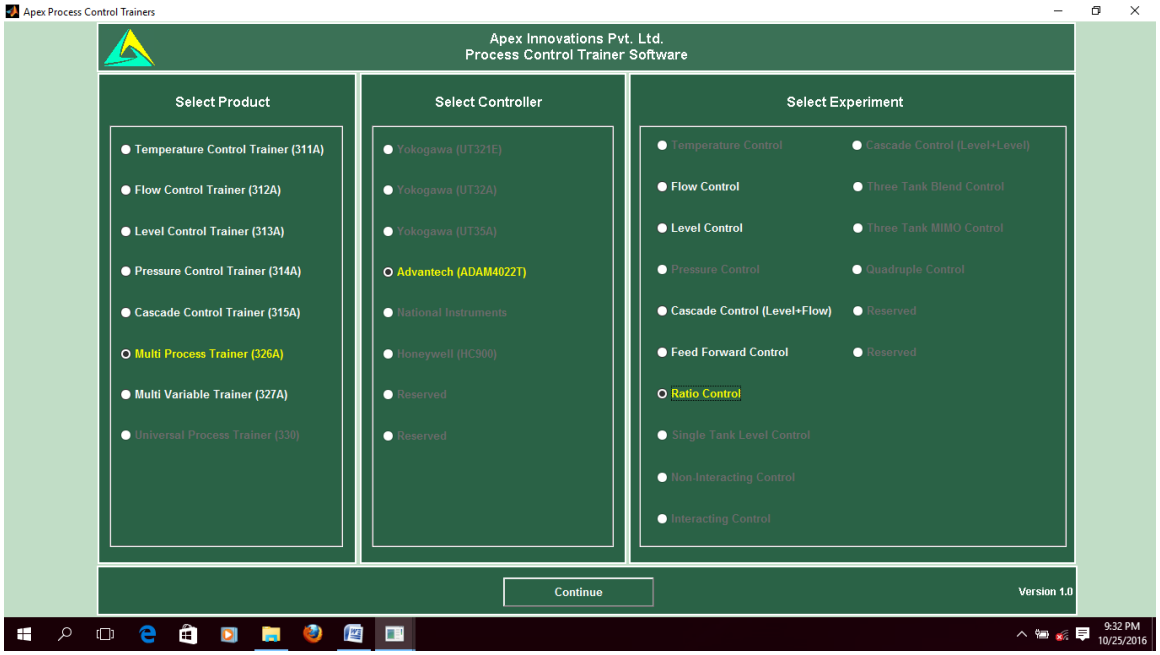
Because of the feed forward loop the controller responds immediately to the disturbance before the process value is affected. The final correction is done by PID control loop.

Any error observed in the flow measurement (due to manufacturing inaccuracies or air in signal lines or DP calibration) has no impact on controlling.

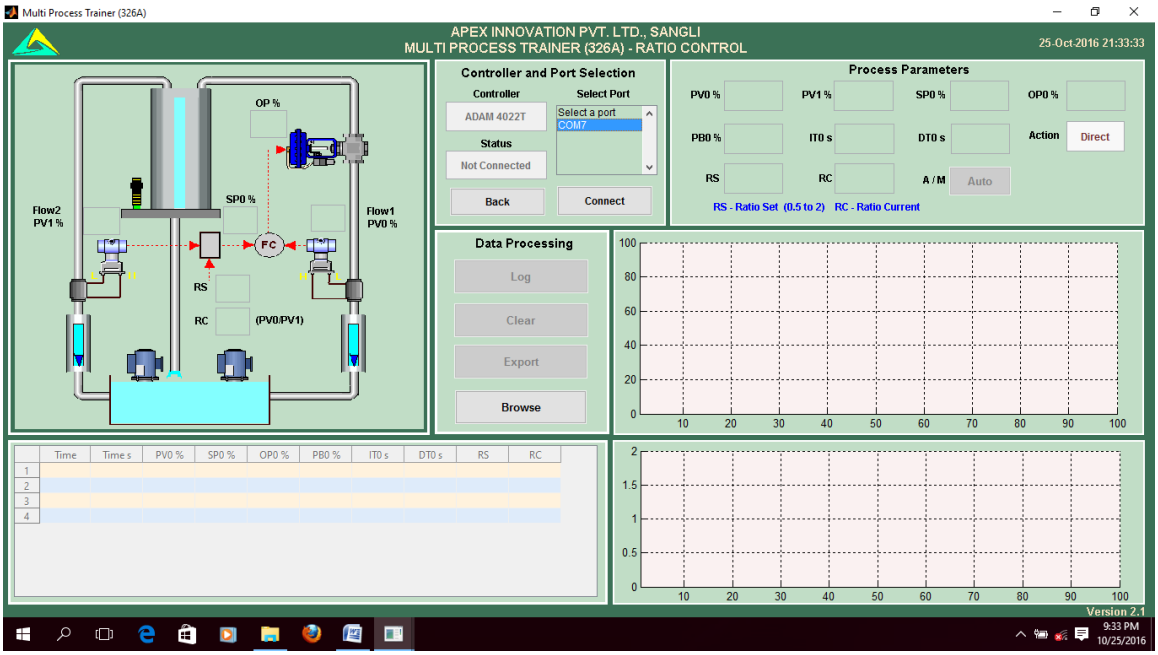
12.**To study ratio control system**

Procedure

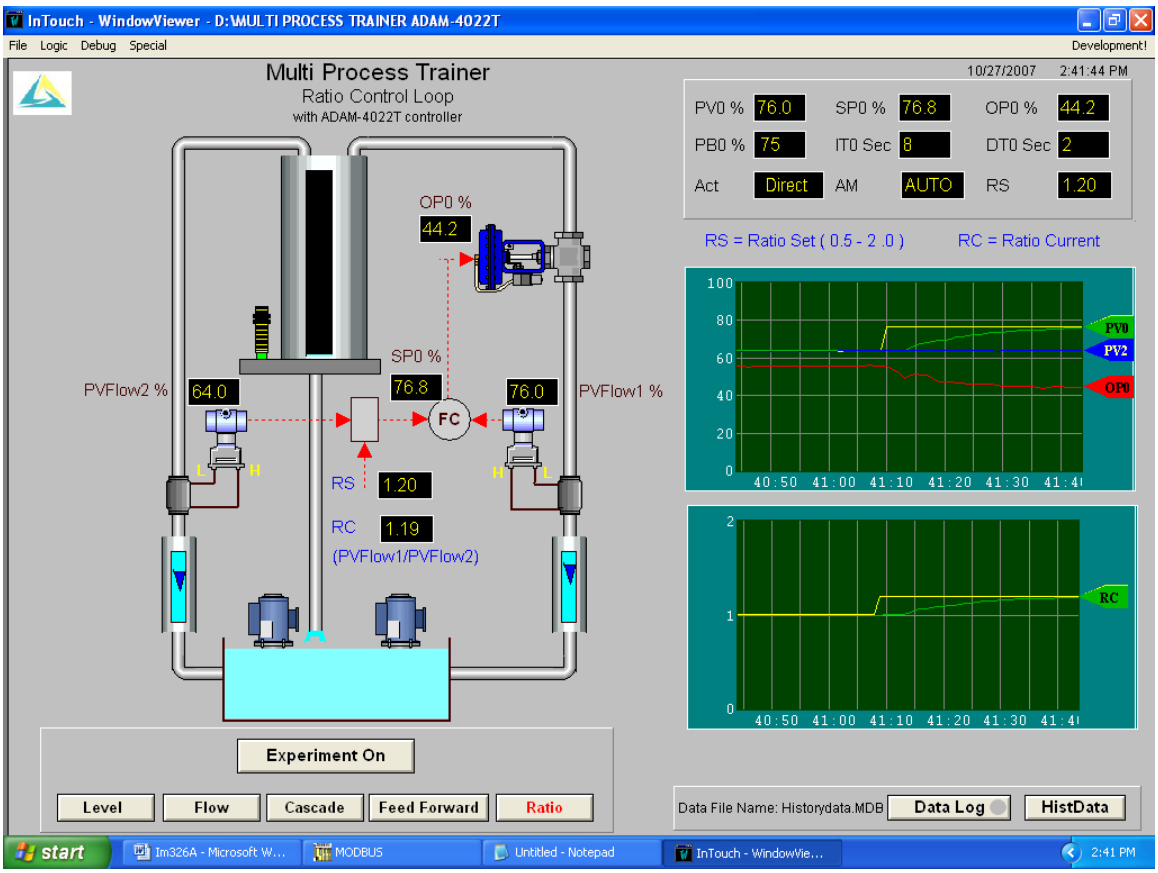
- If the tappings of orifice placed in the second inlet flow line to the process tank are short circuited by a PU tube loop, remove the loop. Connect pressure signal tappings of this orifice to FT2 with proper polarity.
- Short circuit the pressure tappings of orifice placed in the outlet line of the process tank. (i.e. at the inlet of the left rotameter).
- Start up the set up and adjust the Rotameter no. 3 (middle) and Rotameter-1 (extreme right) to 100LPH. Remove air entrapped, if any, from the FT2. For removing air open the vent valves on the DP transmitter.
- Provide air supply to the regulator and adjust it to 2 kg/cm^2
- Switch on the computer.
- Double click on Apex_Process_Trainers icon on the desktop



- Select product Multi Process Trainer (326A) and select experiment Ratio Control and Click Continue



- Select Port to which ADAM 4561 is connected.
- Click Connec
- Adjust Rotameter no.3 to @ 75 LPH.
- From the default values of PB=75, IT=8, DI=2, Ratio Set (RS)=1, observe that the flow in rotameter no.1 is automatically adjusted and become equal to that of rotameter no.3.
- Manipulate the flow in Rotameter no. 3 and observe the effect on Rotameter no. 1.
- Change the ratio (range 0.5-2) and observe the effect.



Observations

The ratio of controlled variable (Flow1) to wild variable (Flow2) can be set and Controlled.

Wiring diagram