AUTOMATION CONTROL LAB

ADVANCE PROCESS CONTROL TECHNIQUES

STUDENT MANUAL

Technology for designing the future

AUTOMATION CONTROL LABORATORY

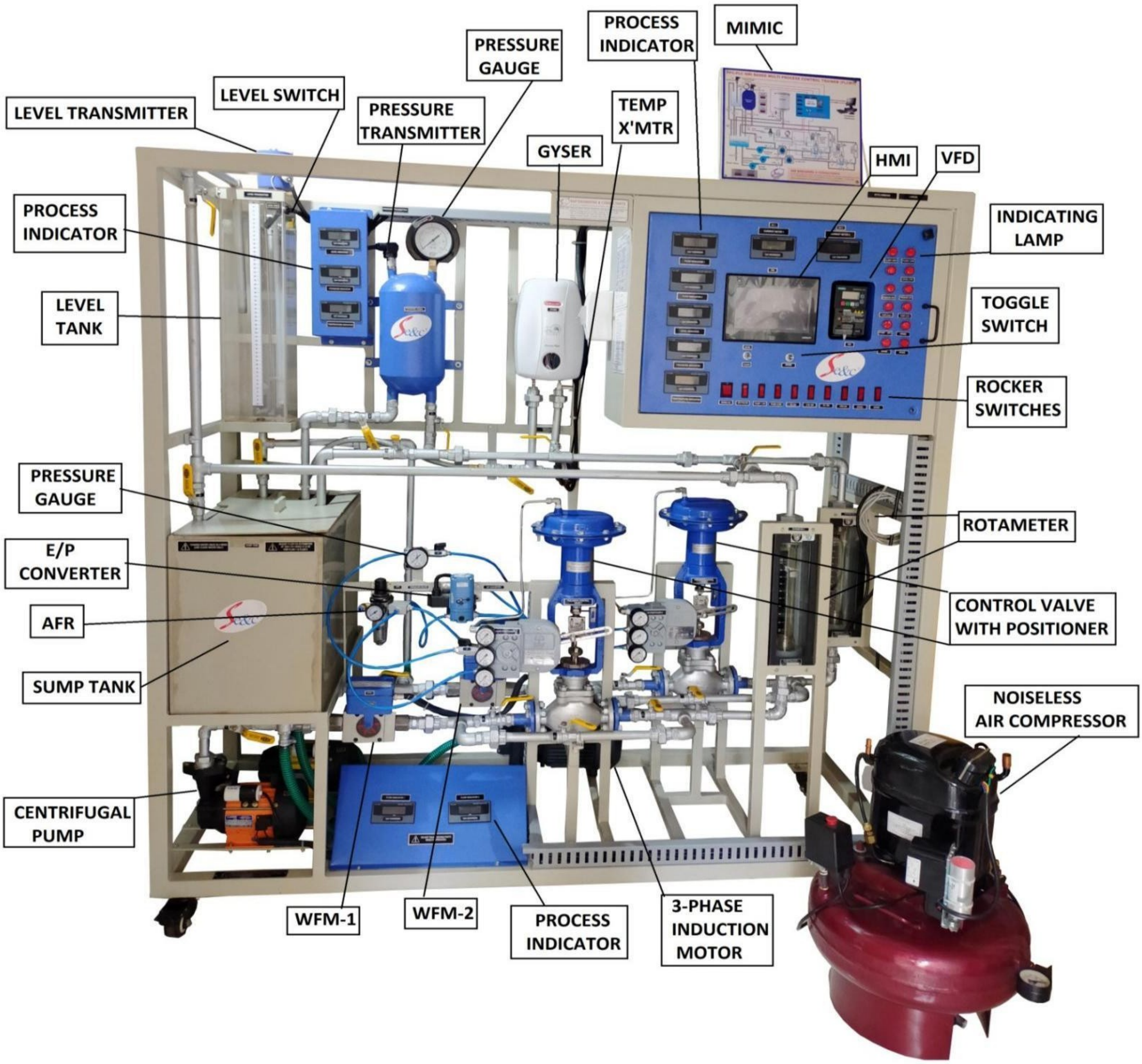
In this lab we use different types of Automation and control techniques, we will work on the different applications according to real-time industry scenarios. Understand the role of programmable logic controllers in complex mechatronic systems, modules, and subsystems.

COURSES OFFERED

S.No	NAME OF THE COURSE	DURATION
1.	Basics of PLC	50 Hours
2.	Basic SCADA	50 Hours
3.	Industrial Level control and Batch Process Reactor System	30 Hours
4.	Process Instrumentation Technology	30 Hours
5.	Advance Process Control Techniques	40 Hours
6.	Advanced Industrial Electro-Pneumatic System	40 Hours
7.	Industrial Electro-Hydraulic System	40 Hours

S.No	NAME OF THE COURSE	DURATION
1.	**Advanced Process Control Technique**	**40 Hours**

In this course students will learn about different process control techniques, feedback control systems for Temperature, Pressure, Level, Flow etc. Based on this student will learn manual and automatic control of processes. Study about cascade systems, ratio control, on/off control etc.



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Course Objectives:

Post successful Completion Advance Process Control Technique Course,

The Participant Should be able to,

- Understand Introduction of Process
- Understand Process Variable
- Understand Different Types of Process Symbols
- Understand P & ID Diagrams
- Understand PID Control
- Understand ON/OFF Control
- Understand Cascade Control
- Understand Split Range Control
- Understand Ratio Control
- Understand VFD Feedback Control

Session Format:

- Presentation
- Practice Session – Hands on Experience

Training Tips:

- Encourage Interactive Training
- Focus More Hands on Experience
- Active Questioning

Background:

Advance Process Control Techniques training course are designed for Engineering Students and working professionals who are aspirant to develop their careers in control engineering sector. Generally, the participants aren't having much professional background hence trainer is expected to narrate overview about basic of hydraulic and touch base the industry scenario during day 1. First session is dedicated to Basic control techniques and its terms

Objectives:

At the End of the Day, Participants should be able to

- Understand Introduction of Process
- Understand Process Variable
- Understand Different Types of Process Symbols
- Understand P & ID Diagrams
- Understand PID Control
- Understand ON/OFF Control
- Understand Cascade Control

INTRODUCTION OF PROCESS CONTROL

How to Control Process Variable?

- The differences between good control and bad control is a success and a failure. Process Control begins with understanding your process variables.
- In Manufacturing, a wide number of Variables from temperature to flow pressure can be measured simultaneously. All of these can be interdependent variables in a single process. Controlling each variable manually would be difficult, time consuming, prone to mistakes and potentially hazardous. Fortunately, Process control Simplifies complex tasks, reduce variability and ensures the safety of Workers and their Equipment.

All Process Control Loops Work in the same way, requiring three tasks to Occur:

- Measure : Measure the Right Parameters accurately and Quickly.
- Decide : What to Adjust by How much.
- Act : Quickly act on the decision before the process goes further Out of Control.

Let's look at a basic example.

- A Level of Sensor measures the level in a tank and transmits a signal associated with the level reading to a controller.
- The Controller Compares the Reading to a Predetermined Value. If the Level is Low, the Controller sends a signal to the valve on the feed line. The Valve opens to add Product to the tank and bring the level back to a correct position.
- Many different instruments and devices may be used in control loops (Transmitters, Sensors, Valves, Pumps etc.) but the three basic steps are always used.
- Good Control Decisions are made by applying your Process Knowledge. The Control loops needs to be "Turned" for the best response.
- Too Little Correction that we have no impact. Too much Correction may result in damage to the Controls, the Equipment or the Product.

Introduction of a Process:

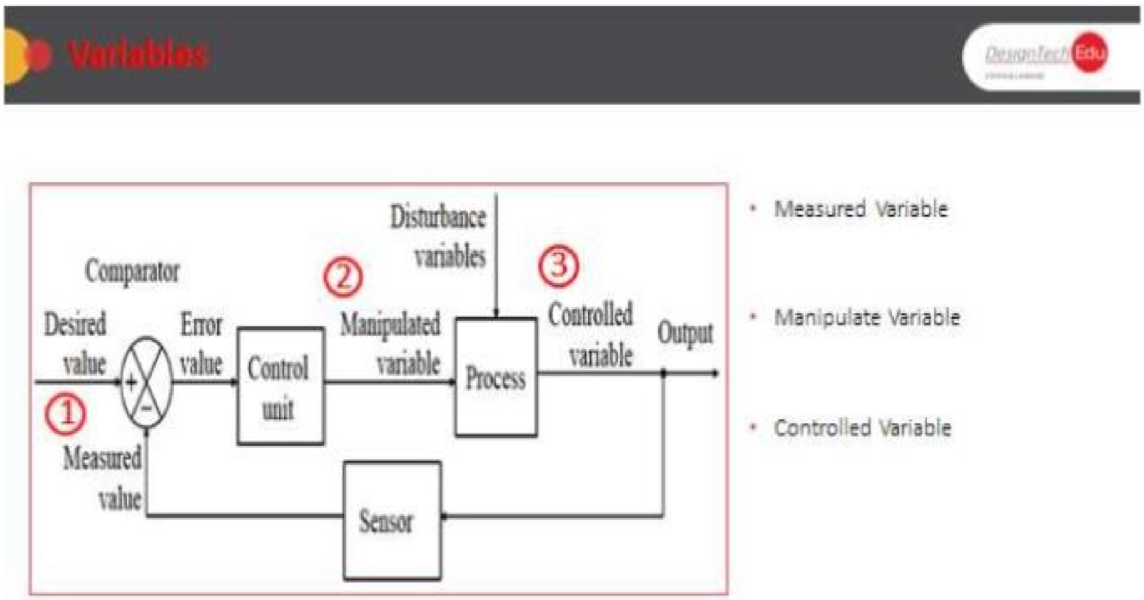
- Process Controls are generally used to maintain a process at a desired, Constant Operating Condition (Temperature, Pressure, Flow, Composition etc.) in the face of disturbances.

Process Variables:

- **Measured Variables** : Continues Measured Variable from the Process
- **Manipulate Variable**: The Input Variables are adjusted dynamically to keep the Controlled variables at their set-points.
- **Control Variable:** These are the variables which quantify the performance or quality of the final product, which are also called as output variables.
- **Set point** : The desired or Target value for process value of a system.

Variables:

- **Input Variables:** Affects the process independently; Change the Condition of the Process.
- The Input Variable can be adjusted manually or automatically to keep the Controlled Variables value constant at a set value.
- **Output Variables:** Gives Information about the state of the Process Controlled Variable.
- The Output Variable which is requested to be kept constant at a set value (Set Point) Manipulated Variable.



Classification of the variables:

Input variables

- Manipulated variable -which can be easily adjusted by a control mechanism or Operator
- Disturbance, load effect -Input variables which are effective on controlled variable but which cannot be easily manipulated.

Output Variables

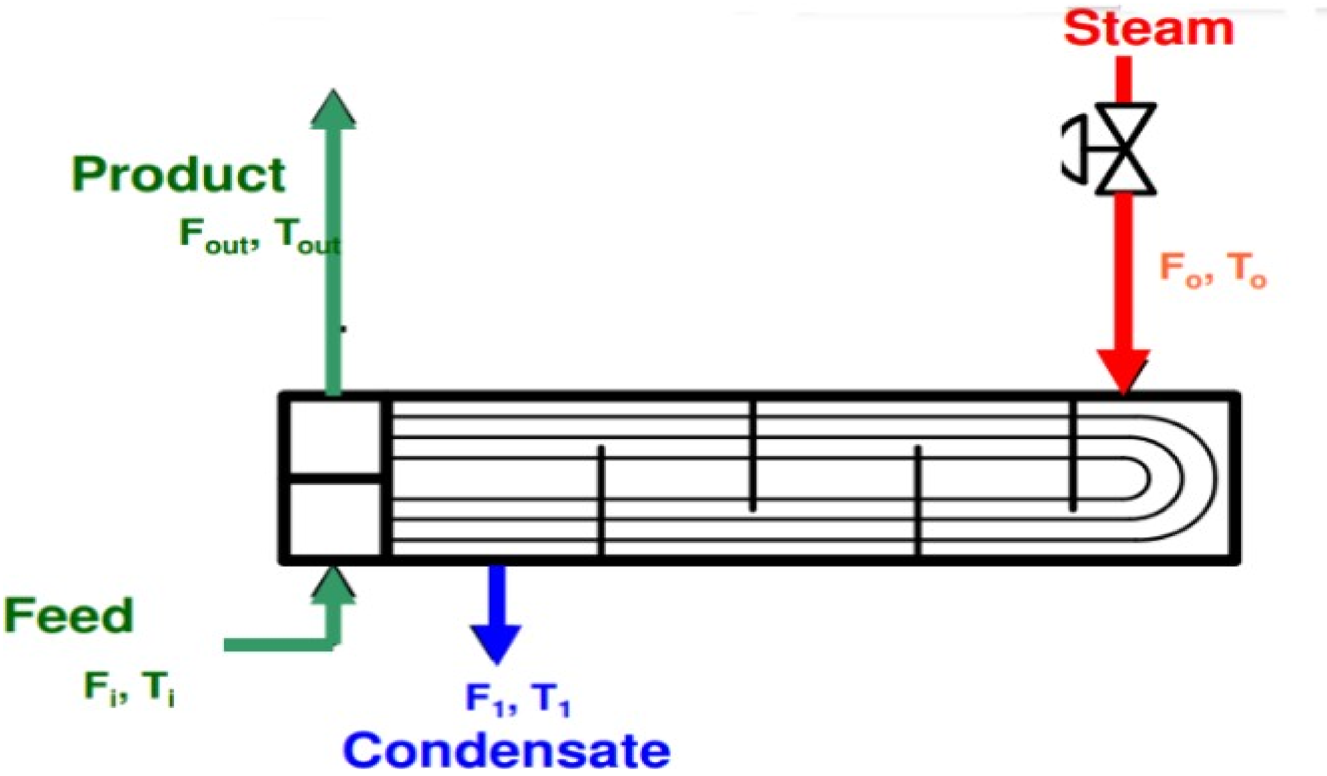
Measurable Variable or Controlled Variable

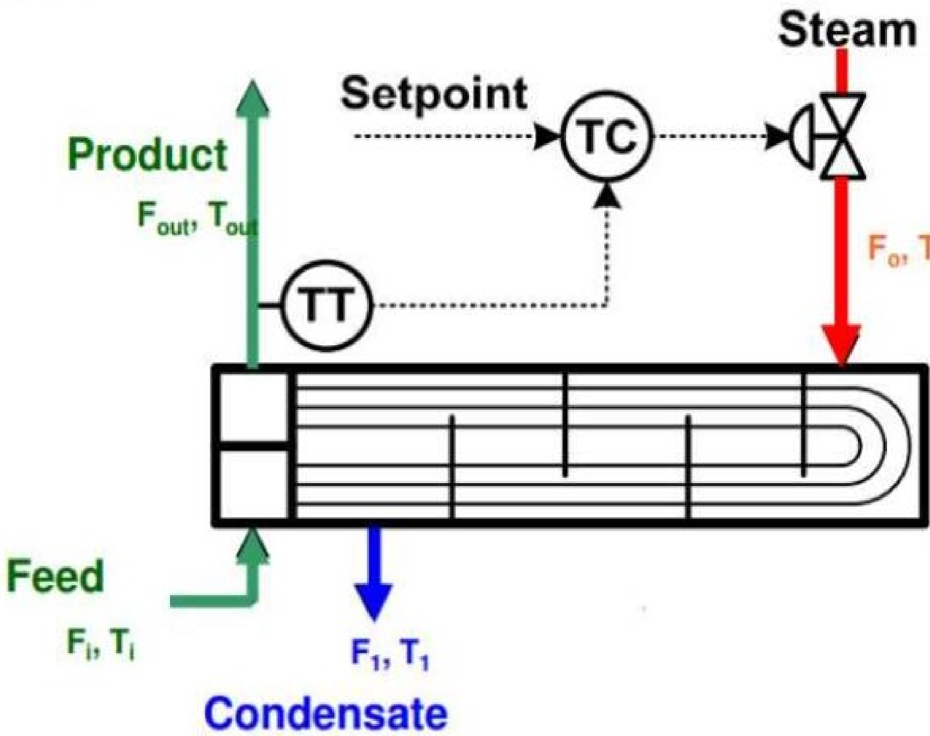
- Its value can be easily determined by measurement methods e.g. the temperature of the product in a pasteurizer.

Immeasurable output variable

- It cannot be measured directly.

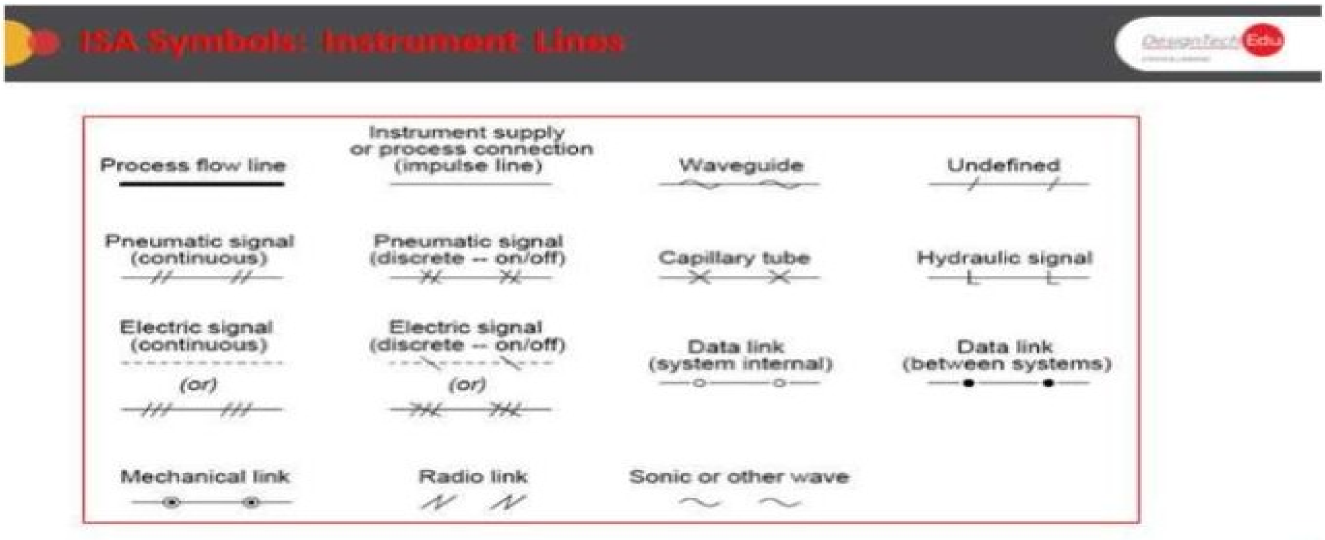
Temperature Control for a Heat Exchanger



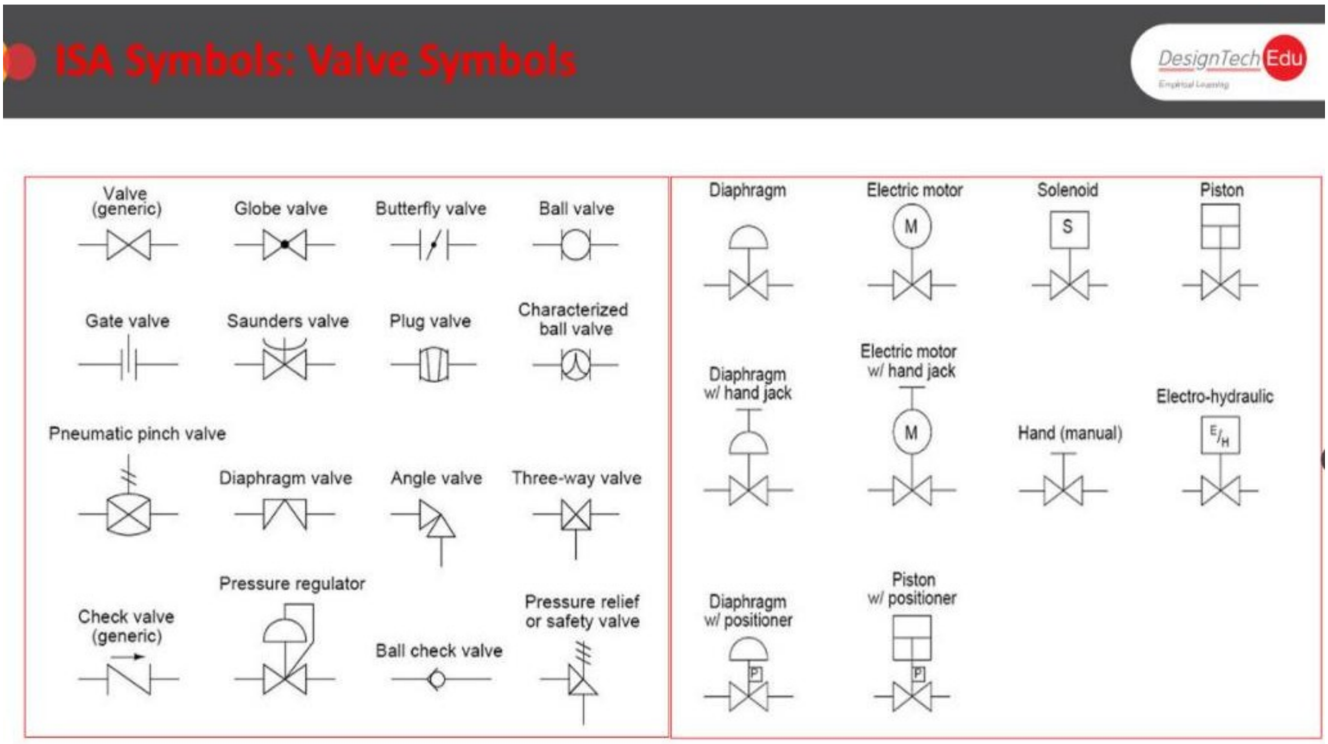


- Controlled Variable-Output temperature of product stream
- Measuring Instrument-Thermocouple on product stream
- Manipulated Variable-Flow rate of steam
- Final Control Element-Control valve on steam stream
- Disturbance (Noise)-Variation of feed temperature

ISA Symbols:



ISA Valve Symbols:



ISA Symbols: Valve Symbols

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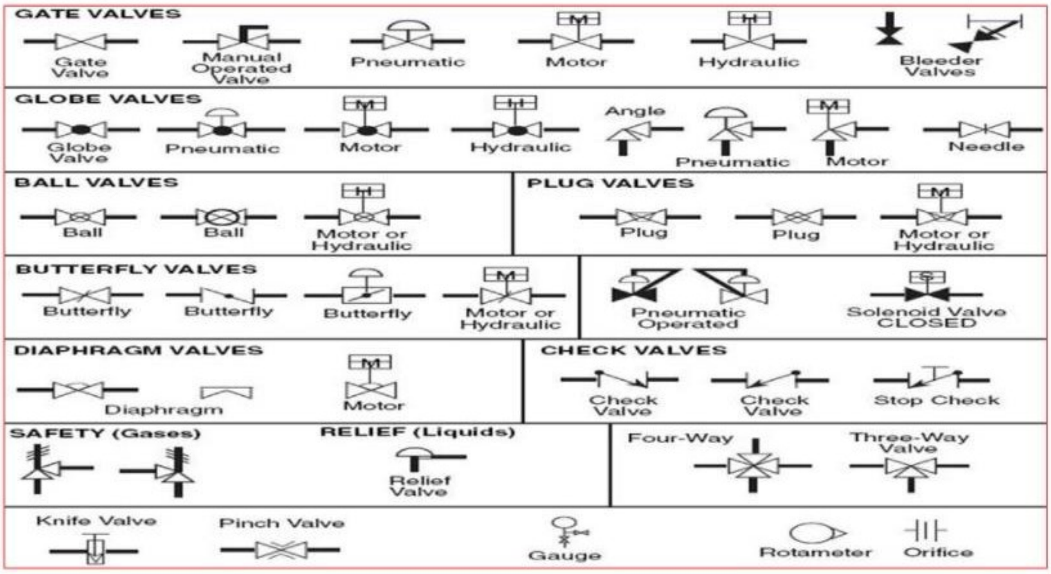

ISA Symbols: Process Equipment

ISA Symbols: Process Equipment

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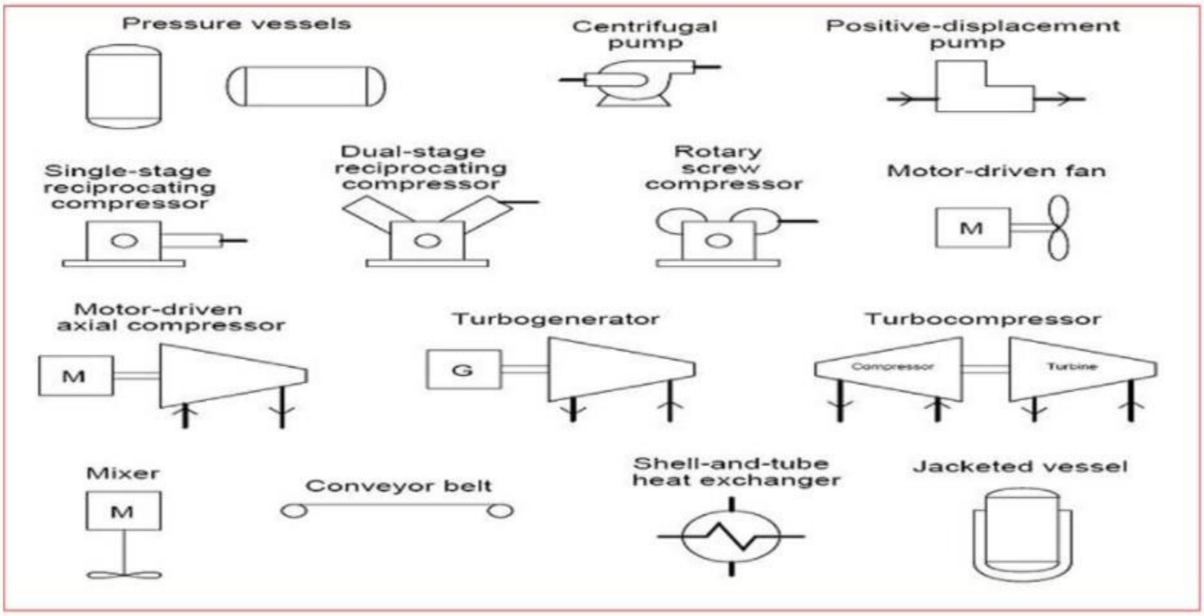
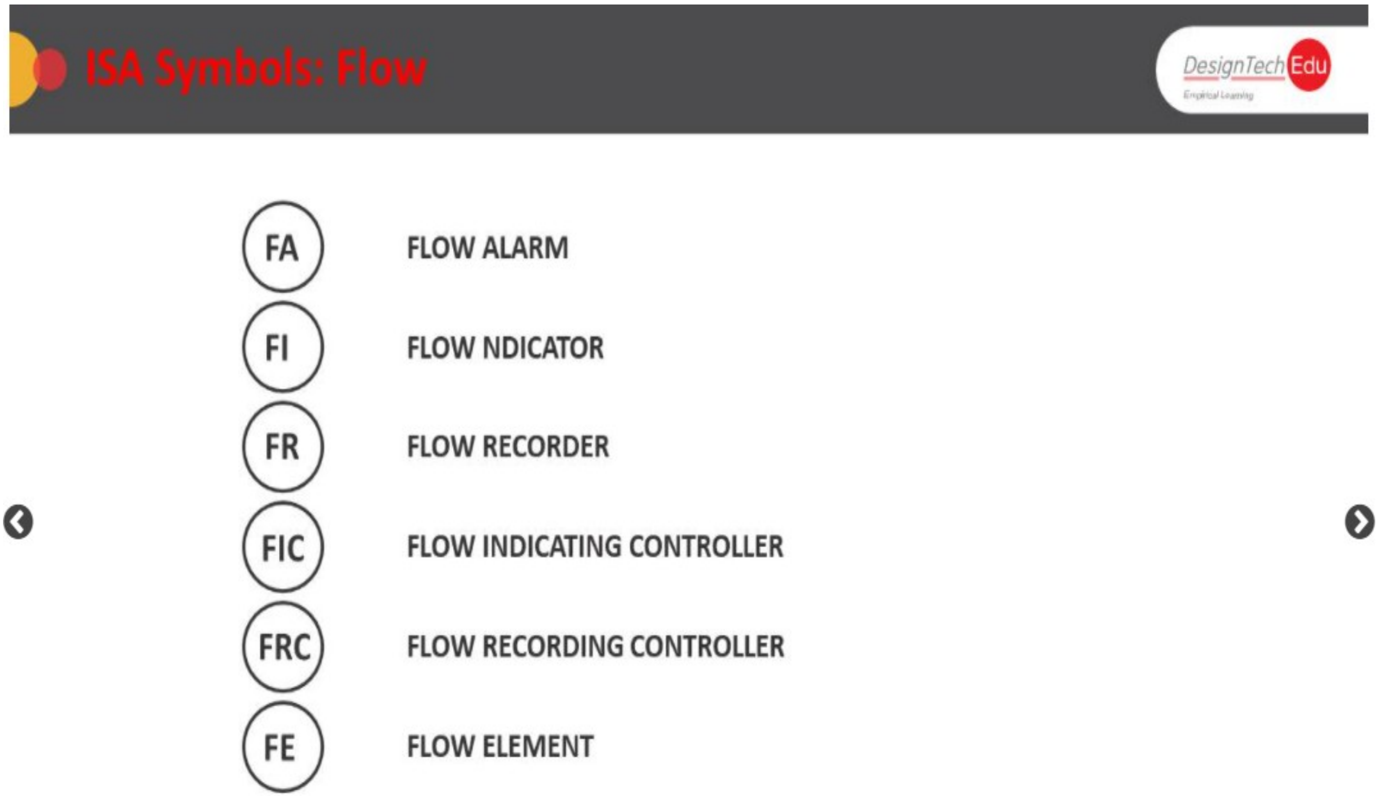
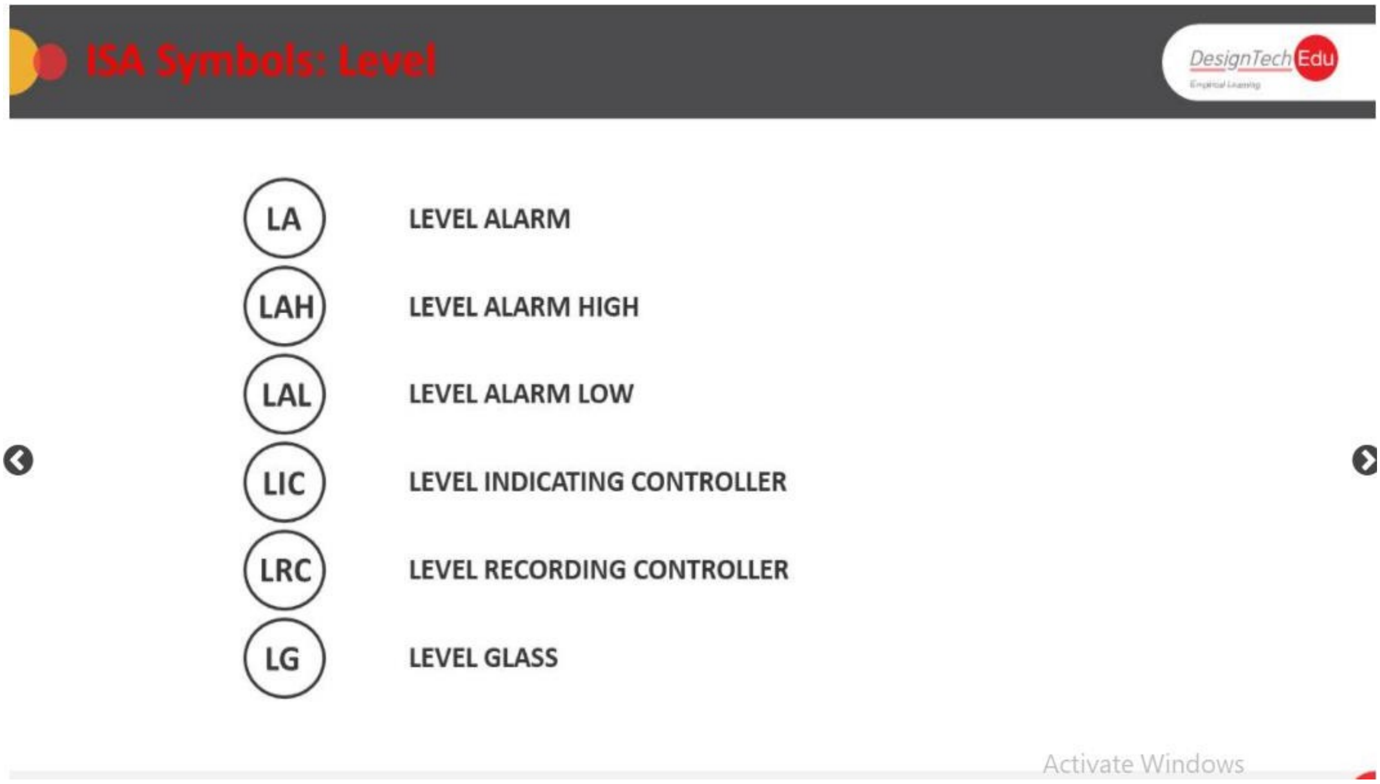


ISA Symbols: Pressure

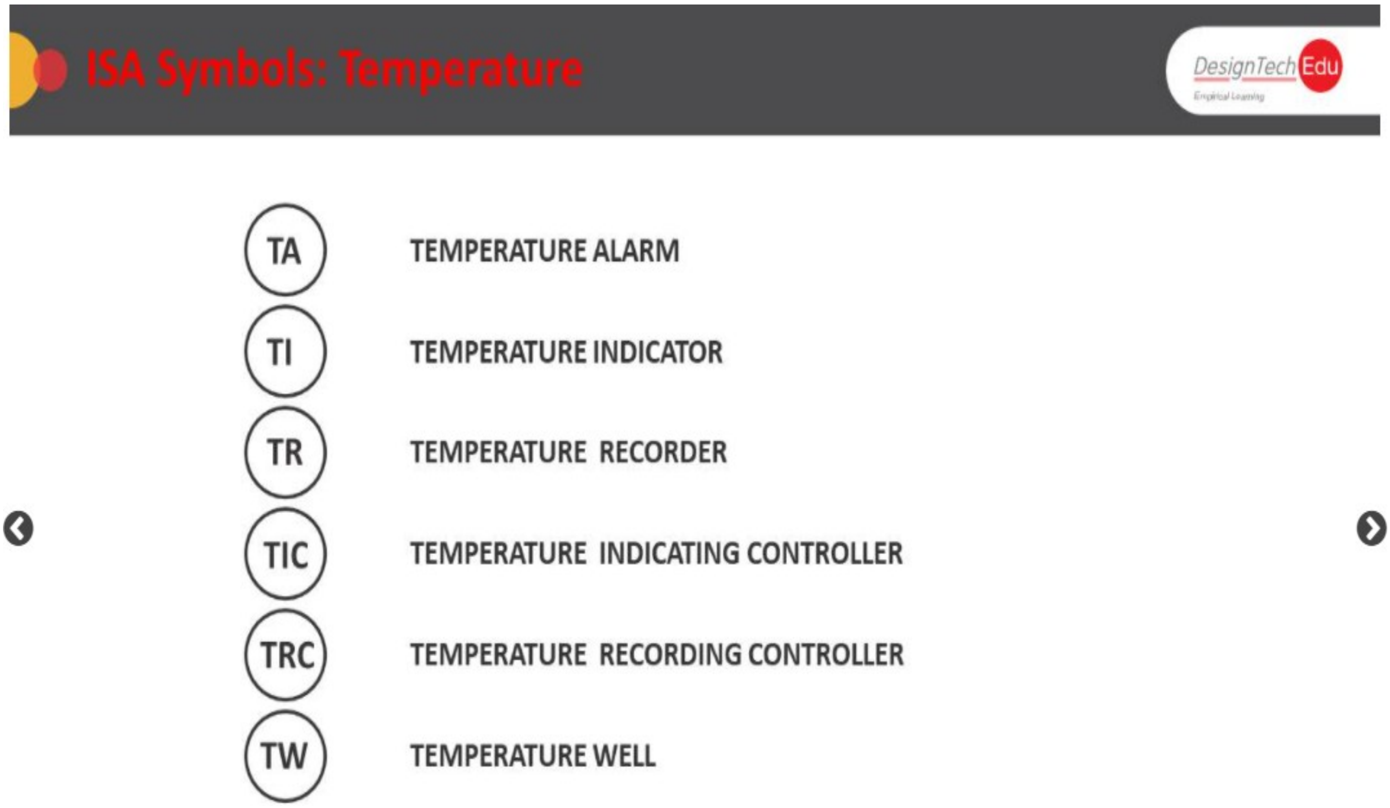
ISA Symbols: Flow



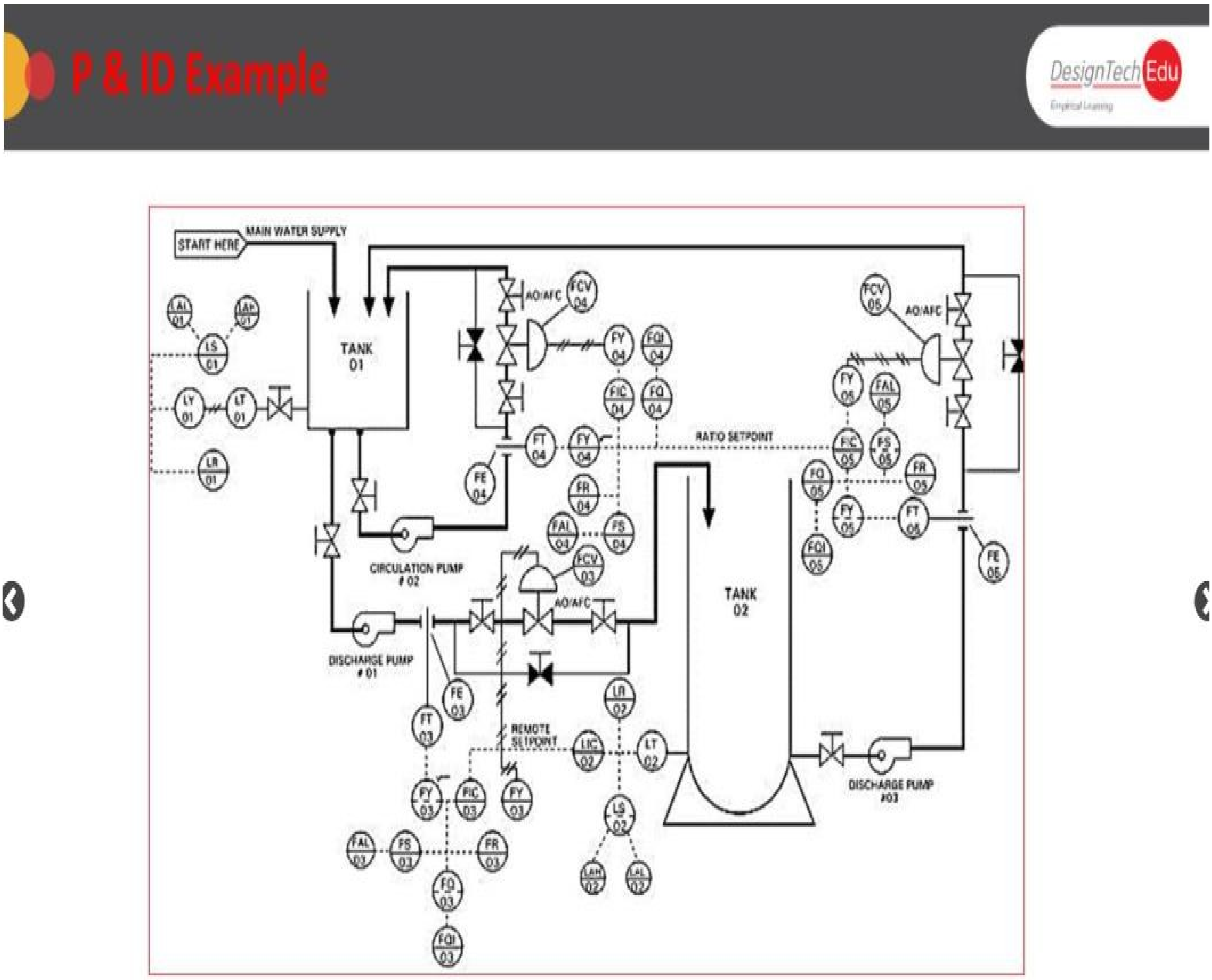
ISA Symbols: Level



ISA Symbols: Temperature



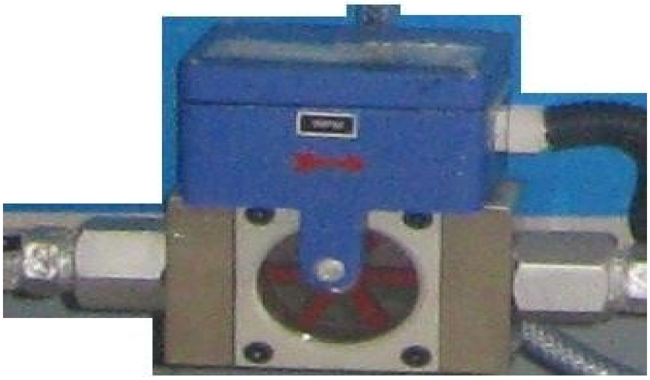
P & ID Examples:



TYPES OF CONTROLS:

SENSORS & ACTUATORS

FLOW SENSORS (WHEEL FLOW METER)



Photograph: Wheel Flow Meter

The measurement and control of flow can be said to vary heart of process industries, primarily the pressure that is forcing the liquid through the pipe determines the flow rate of liquids in pipes.

PRINCIPLE OF OPERATION:

The turbine type of flow meter is Composed of a freely Spinning turbine blade assembly in a flow path. The Rate of Rotation of the turbine is directly proportional to the flow rate of the Rotary Motion caused by the flowing medium is sensed by Infrared Sensors/ Hall Sensor to give pulses Proportional to flow rate. These Pulses are converted to give Standard Electrical output by circuitry Mounted in the Housing.

RESTRICTION TYPE FLOW SENSOR:

Common method of measuring flow of liquids in pipes is by introducing a restriction in the pipe and measuring the pressure drop that results across the restriction. When restriction is placed in the Pipe, velocity of fluid through increases and pressure in the restriction decreases. As flow Increases, the flow increases, the pressure drops.

Flow rate is given by $Q = K\sqrt{\Delta P}$

where, Q = volume flow rate

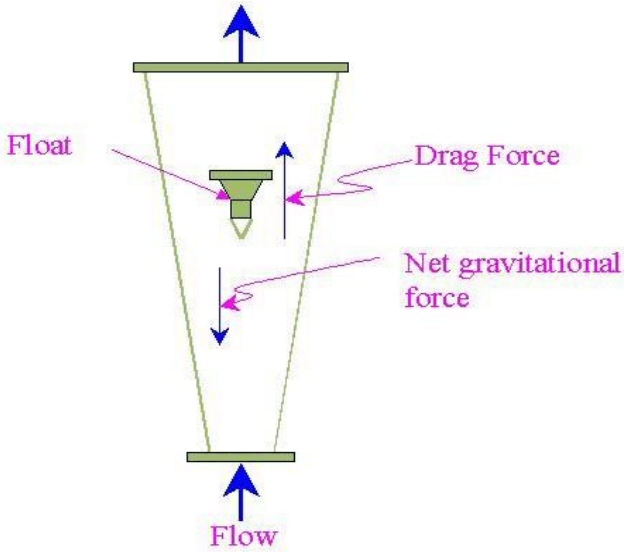
K = constant for pipe and liquid

ΔP = drop in pressure across the restriction.

The different types of restrictions commonly used are orifice, venturi, Pitot tube, nozzle etc. The most common method of measuring the pressure drop is to use DP transmitter.

OBSTRUCTION FLOW SENSOR

In this flow sensor an obstruction is placed in flow stream. In a Rotameter, the obstruction is float that rises in vertical tapered column. The lifting force and thus the distances to which the float rises in the column is proportional to the flow rate. The differential pressure that exists across that float, because it is a restriction in flow, produces the lifting force.



$$q = u_{max} \frac{\pi}{4} (D_t^{\,2} - D_f^{\,2})$$

where ,	q	- Volumetric flow rate
	u_{max}	- Maximum Velocity of the fluid
	D_t	- Tube Diameter
	D_f	- Float Diameter

The tube is marked in divisions, and the reading of the meter is obtained from the scale reading at the reading edge of the float, which is taken at the largest cross section of the float. This type of flow sensor is used for both liquids and gases.

TURBINE FLOW METER:

The turbine type of flow meter is composed of a Freely Spinning Turbine blade assembly in the flow path. The rate of rotation of the turbine is proportional to the Flow rate. If turbine is attached to tachometer, a convenient electrical signal can be produced which is flow rate in terms of current.

MAGNETIC FLOW METER:

If charged particles move across a magnetic field, a potential is established across the flow, perpendicular to the magnetic field. Thus if the flowing liquid is also a conductor, the flow can be measured by allowing the liquid to flow through a magnetic field and measuring the transverse Potential produced.

A) LEVEL SENSORS

The Measurement of a Solid or a Liquid level is a special class of displacement sensors. The level measured is most commonly associated with a material in a tank or Hopper. A great variety of measurement techniques exists are as follows:

MECHANICAL:

One of the most common techniques for level measurement particularly for Liquid measurement. In this float is used as level sensor. Float is connected by linkages to a Secondary displacement measuring system such as an LVDT core.

ULTRASONIC:

The use of ultrasonic reflection to measure level is favored because it is a "Non-Invasive Technique ". It does not involve placing anything in the material. The measurement depends on the length of time taken for reflections of an ultrasonic pulse from the surface of them Arterial.

ELECTRICAL:

There are several purely methods of measuring level. For example, one may use the inherent conductivity of a liquid or solid to vary the resistance seen by probes inserted into the material. Another common technique in this is use of capacitance type transmitter.

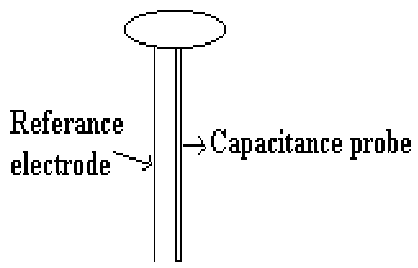
CAPACITIVE TYPE LEVEL TRANSMITTER:

It is a simple and reliable method for level measurement & indication. The capacitive type Level sensor is commonly used to measure the level of water in the level tank.

PRINCIPAL OF OPERATION:

Capacitance is formed between two parallels, which are separated by a distance and is given by,

$$C = \varepsilon A/D$$



where,

C = Capacitance in µf.

ε = Dielectric constants of material.

A = Area of plates.

As the area and the distance between two plates is constant, capacitance is directly proportional to the dielectric constant. In practice, for capacitance type level measurement, capacitance is formed by wall of the tank (if tank is conductive) and an insulated probe mounted in the tank.

For non-conductive tank, reference probe is used to serve the purpose of second probe consists of a sensing electrode with integral electronics housed in an enclosure on its upper end. The sensing electrode is provided with flanged or screwed process connections for mounting it on the tank. The sensing electrode is bare or insulated depending on dielectric of the material. The measuring principle is based on the value of capacitance formed between the electrode and tank Wall, which varies with the level of material. This capacitance is sensed and converted in to Voltage signal to actuate the output.

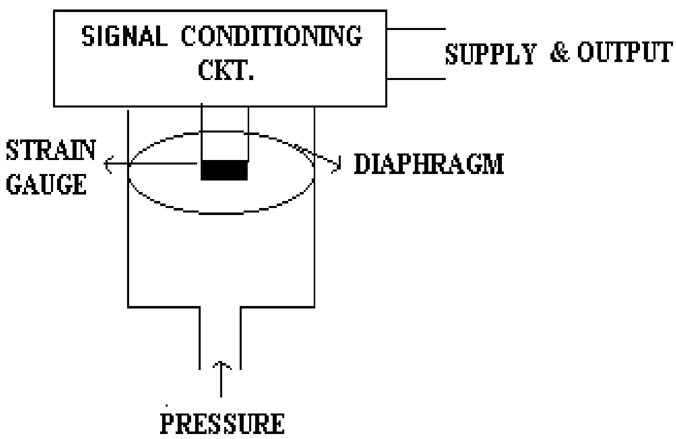
B) PRESSURE SENSORS

INTRODUCTION:

Power Transmitter is used to measure on line as well as off line Pressure in the Industries. It gives 4-20mA standard output for a specified range of pressure input.

PRINCIPLE OF OPERATION:

It is a very simple method to measure the pressure. It consists of a pressure inlet through which Pressure acts on the diaphragm and the diaphragm gets deformed. This causes

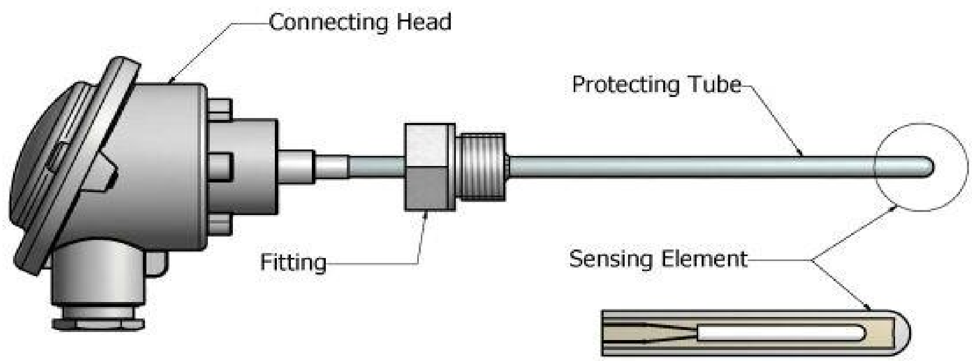


change in strain of the strain gauge mounted on the diaphragm this change causes unbalance in the bridge, which is further, processed by the signal conditioning circuit. Output of the signal conditioning circuit is Standard 4-20mA signal which is proportional to input pressure (0 to 4 Kg/cm^2).

DIAPHRAGM TYPE PRESSURE SENSOR:

They are either metallic with good spring Characteristics or Non-Metallic with no elastic characteristics– the latter, being limp in use, are opposed by a calibrated coil spring or any other Suitable elastic member. The latter is known as slack diaphragms. The force acts against a thin stretched diaphragm causes a deflection of the diaphragm with its centre deflecting the most.

Temperature Sensor



RTD Sensor

These sensors are mainly used in environments where the temperature reading out is separated from the measure taking area (ovens, pipes, etc.). The active part of the sensor is made of a sensing element protected by a metallic sheath. Connection is made by a terminal block or a transmitter situated inside a connecting head. A sliding or welded fitting allows a tight fixing.

TEMPERATURE CONTROL LOOP:

In process industries ON-OFF control of temperature is normally used. Thermostatic control of temperature is very commonly used method in the temperature control of dry air. In the temperature cabinet or oven temperature is controlled by varying the voltage applied across the heater coil thereby varying the current flowing through the coil i.e. Power = I^2*r is controlled. The temperature is sensed using the Temperature Transmitter (RTD based) & it is transmitted to the controller in the form of mA (current output) by signal condition circuit. PID controller compares the actual temperature with the Set Point & accordingly error is generated. Controller output is Calculated using the P, I, D values. That output is fed to the phase angle control unit whose output Voltage (0-230V) is the proportional to the output of PID controller. This voltage is given to N heating coil so that temperature is controlled.

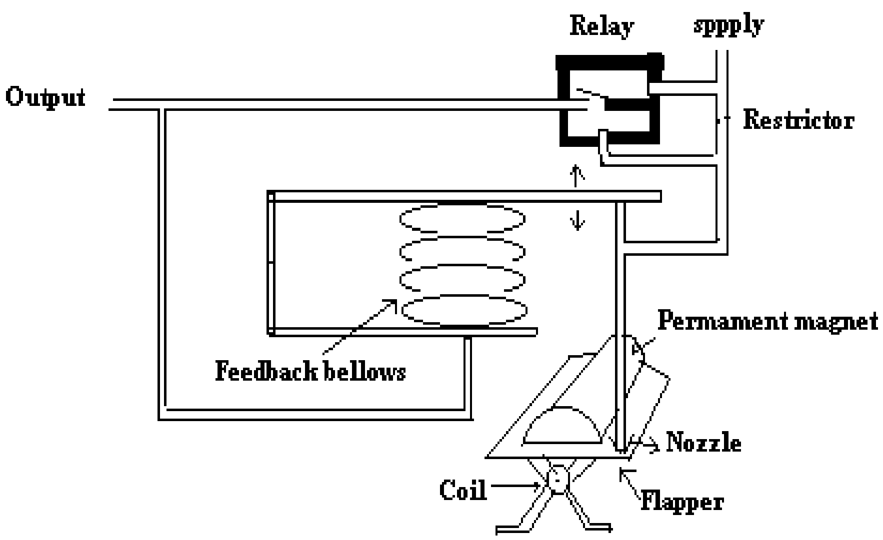
C) I TO P CONVERTOR

INTRODUCTION:

Current to pressure conversion is done by using current to pneumatic converter i.e. I/P Converter or E/P Converter. The current to pneumatic converter is a field-mounted instrument that transforms a DC Ma signal into pneumatic signal proportional to it. Electro-pneumatic transmitter is important because they form the link between electric measurement and pneumatic control System. They also convert electronic control outputs into air pressure for operations of pneumatic Control valves. Now a day's Electro-pneumatic transducers are widely used in the Process Industries. The input used for this transducer is electric that is direct supply of current and its range is 1 to 5mA, 4 to 20mA, and 10 to 50 mA. But mostly used in industries range is 4 to 20mA. The output range is 3 to 15psi, 0.2 to 1 Kg/cm².4

PRINCIPLE OF OPERATION:

A DC mA input signal is given to the coil shown in fig, which is kept in the permanent magnetic field. It produces thrust, which varies gap between flapper and nozzle. This causes a change in output pressure of the relay, which is also, converter output pressure. This pressure is fed to the feedback bellows which exerts a force on a feedback flexure to move the nozzle and establish a throttling relationship between the flapper and nozzle.



D) PNEUMATIC CONTROL VALVE

INTRODUCTION:

Pneumatic control valve is used to control flow of fluids in industrial processes. Normally close (Air to open) or normally open (Air to close) valves are used. The System consists of 2 Pneumatic Equal Percentage Characteristic Air to close type Control Valves with attached Positioner. These Control Valves operate on Pneumatic Signal of 3-15 psi (0.2 – 1 bar) pressure.

PRINCIPLE OF OPERATION:

The below figure self describes the working principle of pneumatic control valve. It consists of a Diaphragm, feedback spring, valve plug and seat ring. When controlling pneumatic supply (3-15 psi) Is given through inlet, it creates pressure from up side of the diaphragm and tries to Push it down. Due to this, the steam of the valve moves down and control valve starts closing. Same time the Feedback spring pulls the diaphragm up and balances it to some position required to control the flow.

SYSTEM PHILOSOPHY:

In our Flow system, following system components are incorporated:

1. Sump Tank
2. Centrifugal Pump
3. Equal Percentage Control Valve
4. Rota Meter
5. Air Filter Regulator
6. Electro Pneumatic Convertor
7. Pneumatic Fittings
8. PLC
9. Pressure Gauges

Centrifugal Pump – Pumps the water into a system through Pneumatic Control Valve. Flow Rate of the Water is monitored by Rota Meter. (0-1050LPH). with the help of MANUAL mode of the PID, we can vary the pressure (3-15 psi) input to the control valve so that its opening is varied & flow rate is observed for different percentage opening of the control valve. The Control valves are having equal % opening characteristics. Graph of % Flow Rate versus % Opening gives the characteristic plot of the respective control valve.

CONTROL VALVE SIZING:

Suggestions in Control valve sizing are given here:

One should first determine both the minimum & maximum C_v requirements for the valve, considering not only normal but also start-up & emergency conditions. The selected valve should perform adequately over a range of 0.8 [C_v (MIN)] to1.2 [C_v (MAX)]. If this results in a high range ability requirement, use two or more valves. Control valve should never operate below their minimum gain point. Properly scale points to the Fact that all “fat” settles in the control valve. In constant speed pumping systems, each Design Engineer will add his own safety margin in calculating pressure drops through pipes, Exchangers & finally in selecting the pump Therefore the control valve will end up with all these safety margins are added pressure drops, Resulting in a much over-sized valve. A highly oversized valve will operate in a nearly closed state, which is the most unstable & least desirable operating condition.

For the above reasons, the question of how much pressure drop should be assigned for a Control valve can usually be answered simply: None. This is because the various safety margins by themselves will usually contribute more than what necessary to satisfy the requirements are described. In variable speed pumping systems this approach does not apply, because there the pump speed is adjusted to keep the control valve differential constant & therefore the effect of accumulated safety margins is eliminated.

PROCESS FLUID CHARACTERISTICS:

In selecting control valves, the properties of the process fluid must be fully considered. The process data should be carefully & accurately determined because even small variations in Temperature or pressure can cause flashing or cavitation. These include such obvious variables as Pressure, temp, Viscosity, slurry or corrosive nature, or the less obvious factors of flashing, Cavitation’s, erosion, leakage, etc. These are discussed in the paragraphs below.

High Pressure or High Differential Pressure Services

The design pressures for each valve type are listed in the corresponding feature summaries in front of their sections. Design of high-pressure valves usually necessitates at least three Considerations:

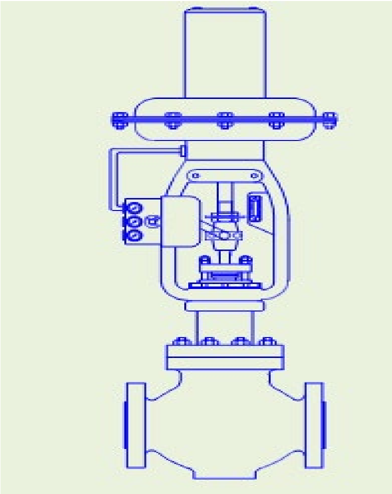
1. Increased physical strength.
2. Selection of erosion- resistant material.
3. Use of special seals

Valve bodies can usually withstand higher pressures than the piping. Valve bodies for high pressure.

Service are usually forged to provide homogeneous materials free of voids & with good Mechanical Properties. The loads & stresses on the valve stem are also high. For this reason, Higher-strength Materials are with increased diameter. High operating pressure frequently Involves high-pressure drops. This usually means erosion, abrasion, or cavitation's at the trim. Cavitation's & erosion resistance are usually not properties of the same metal. Materials Resistant to erosion & abrasion include 440C stainless steel, flame-sprayed aluminium oxide Coating & tungsten carbide. On the stem, where the unit pressure between it & the packing is high, it is usually sufficient to chrome plate the stem surface to prevent galling. Special "self-energizing" seals are used. With higher-pressure valves (above 10,000 PSIG or 69 M Pa service) so that the seal becomes tighter as pressure rises. Popular body seal designs for such service include the delta ring closure and the Bingham closure.

The self-energizing seals are used in connecting the high-pressure valves into the pipeline. These Designs depend on the elastic or plastic deformation of the seal ring at high pressures for Self- Energization. Special packing designs & materials are also required in high-pressure service, because Conventional packing would be extruded through the clearances. To prevent this, the clearance between stem & packing box bore is minimized & extrusion-resistant material, such as glass Impregnated Teflon, is used for packing.

VALVE POSITIONER DETAILS:



PRINCIPLE OF OPERATION:

Pneumatic Valve Positioner is force balance device which, ensure the position of the Plug, which is directly proportional to the controller output pressure. The Positioner compares the forces generated by the control signal and the control valve stem through the motion connector and the feedback cam, and accordingly it feeds or blades the air going to the valve actuator.

The Instrument Air signal is applied to the signal diaphragm. An increase in signal will drive the diaphragm and flapper- Connecting stem to the right. The Flapper-Connecting stem will then open the supply flapper admitting supply pressure into the output which is connected to the Actuator Diaphragm. The Exhaust flapper remains closed when the flapper connecting stem is deflected to right. The effect of increasing signal is to increase the pressure in the Actuator. This increased pressure in the actuator drives the valve stem downward and rotates the positioner level Clockwise. This Clockwise rotation of the lever results in a compression of Range spring through cam. When the Valve stem reaches the position called for by the Controller, the Compression the range spring will give a balance force resulting the closure of both the Flapper.

If the Control signal is decreased, the force exerted by the signal diaphragm will also decrease and the force from the range Spring will push the flapper-connecting stem to the left, Opening the Exhaust Flapper. This Causes a decrease actuator diaphragm pressure and allows the valve stem to move upward until a new force balance is established.

TECHNICAL SPECIFICATIONS:

MODEL	: PVP-1 Single Acting - Direct Action.
	: PVP-2 Single Acting - Reverse Action.
	: PVP-3 Double Acting - Direct Action.
SUPPLY CONNECTION	: 1 /4” NPT (F)
SUPPLY AIR PRESSURE	: 1.4 to 3.5 kg/cm² (Standard.) 5.0 kg/cm² (Maximum)
INPUT	: 0.2 – 1.0 kg/cm² (Standard)
	0.2 – 0.6 kg/cm² (Split Range)
	0.6 – 1.0 kg/cm² (Split Range)
HYSTERESIS	: Within □ 1% of FS.
LINEARITY	: Within □ 1% of FS.
DEAD BAND	: Within 0.1% of FS.
STROKE SPEED (Max)	: 10mm/sec
STROKE	: 14 mm to 100mm

MATERIAL CONSTRUCTION:

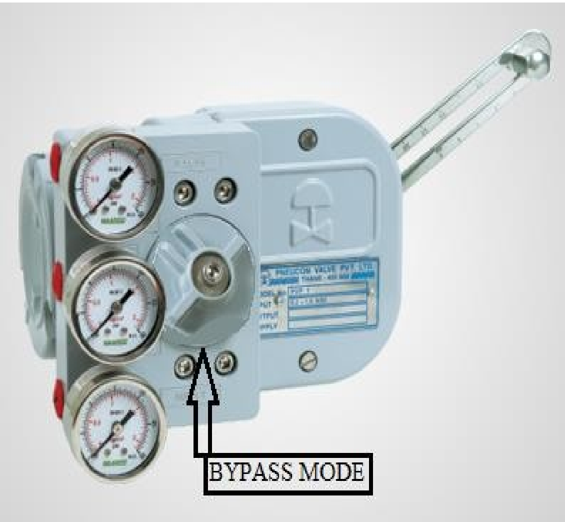
HOUSING	: Die Cast Aluminum to LM - 6
INTERNALS & LINKAGE	: AISI 304
DIAPHRAGM	: Nitrile / Neoprene with Nylon Fabric Reinforcement.

DESIGN AND PERFORMANCE FEATURES:

- High Sensitivity and Stability
- Simple Zero and Span Adjustments
- Field Reversibility
- Large Port Pilot relay eliminates the air passage blockage
- Internal components are of Stainless Steel

Both Control Valves of the system are supplied with a connected positioner. The Positioners are used for split Range Control Process. The Positioner attached to Pneumatic Control Valve -1 has input of 3-9 psi (0.2-0.6 bar) and its output is 3-15 psi (0.2-1.0 bar). Whereas, Pneumatic Control Valve -2 has input of 9-5 psi (0.6-1.0 bar) and its output is 3-15 psi (0.2-1.0 bar). In case of Bypass Mode, the Positioner will pass on the input signal of 3-15 psi (0.2-1.0 bar) Coming from electro-Pneumatic Converter to the control valve.

These Positioners have a Bypass Switch. For this Multi Process System, Split Range Control is the only Experiment which involves action of valve Positioner. Rest of the Experiment do not need positioner. Hence, keep these Positioner in Bypass Mode for Feedback –Cascade-Ratio Control Experiment and turn it into positioner mode, whenever you want to perform the split range. Use the supplied Allen Key (of 3/16 no.) for Turning Bypass switch into Positioner mode/Bypass Mode.



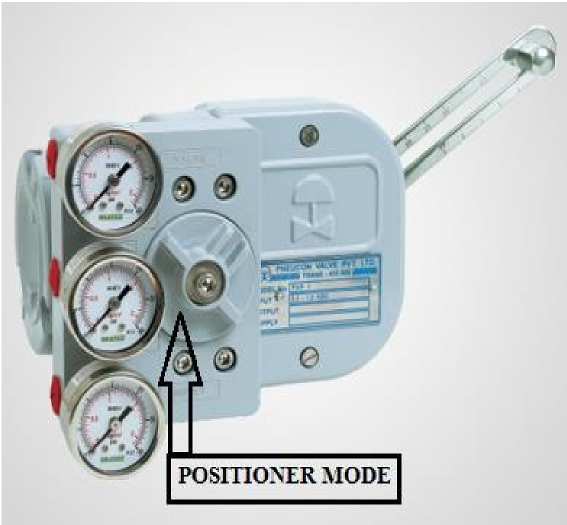


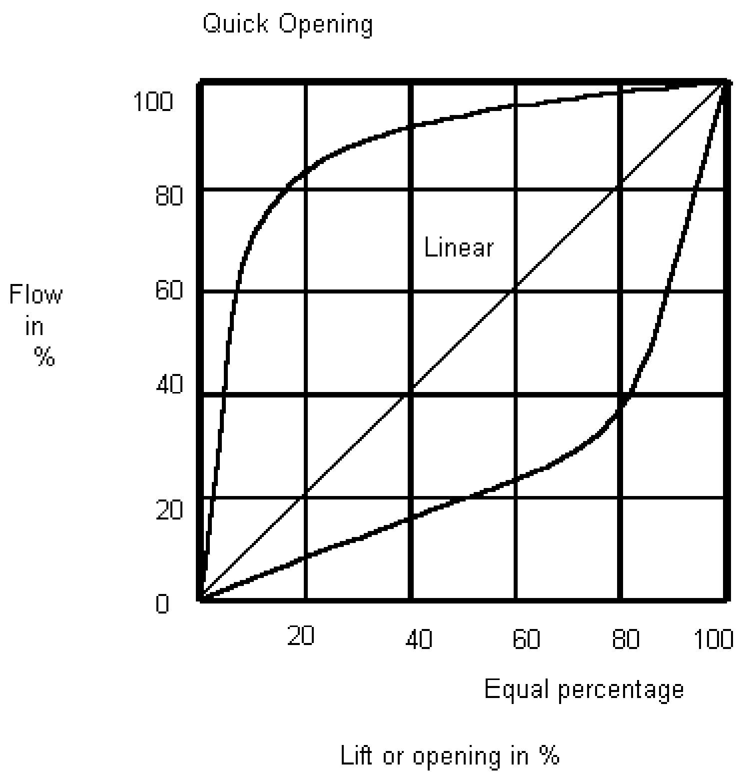
Fig: Knob Positions for Positioner Mode & Bypass Mode

E) CONTROL VALVE

CHARACTERISTICS Flow Characteristics:

It is the relationship between the changes in valve opening to the change in flow through the valve with constant pressure drop.

Most Control Valves used in the process industries have one of three characteristics. Linear, Equal Percentage and Quick Opening.

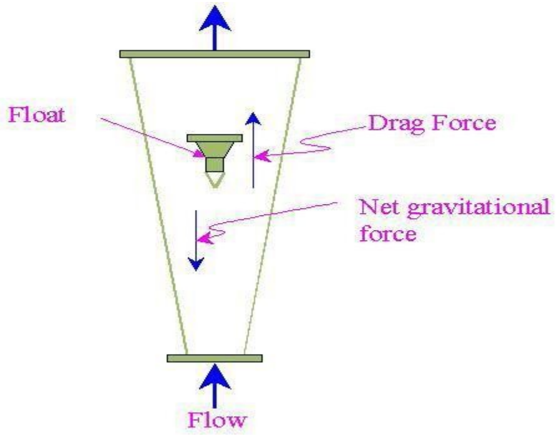


A Linear Valve gives approximately equal increments of flow per increment of travel. An equal Percentage valve gives equal percentage changes in flow per increment of travel. A quick opening valve has an approximately Straight – line characteristic near its seat (to about 60% flows at 30% travel), after which it is of little use as a flow-proportioning device.

DESCRIPTION OF THE COMPONENTS USED IN THE SYSTEM:

A) ROTAMETER

This Rotameter is an Obstruction type flow sensor. In a Rotameter, the obstruction is float that rises in vertical tampered column. The Lifting force and thus the distances to which the float rises in the column and proportional to the flow rate.



$$Q = \mu_{max}\ \pi/4\ (D_t^2 - D_f^2)$$

where, Q -Volumetric Flow Rate

μ_{max} - Maximum Velocity of the Fluid

D_t - Tube Diameter

D_f - Float Diameter

The Tube is marked in divisions, and the reading of the meter is obtained from the scale reading at the reading edge of the float, which is taken at the largest cross section of the float. This type of flow sensor is used for both liquid and gases.

B) AFR UNIT

The air that is sucked by the air compressor is evidently not clean because of the presence of various types of contaminants in the atmosphere; Moreover, the air that is supplied to the system from the compressor is further contaminated by virtue of generation of Contaminants downstream. Hence, to enable supply of clean pure and contamination free compressed air, the air requires to be filtered. The three main elements of an AFR Unit are as follows.

1. Air Filter
2. Pressure Regulator
3. Pressure Gauge

AFR UNIT

AIR FILTER

It is used in a pneumatic system to perform the following main functions:

1. To Prevent the Entrance of Solid Contaminants to the system.
2. To Condense & remove the water Vapour that is present in the air passing through it.
3. To arrest any Submicron Particles that may pose a problem in the system components.

PRESSURE REGULATOR

The main function of this valve is to regulate the incoming pressure to the system so that the desired pressure is capable of flowing at a steady condition. The Valve has a metallic body with the two openings – primary and secondary openings. The Pressure regulation is achieved by opening the poppet valve to a measured amount commensurate with the desired pressure level to be achieved. This is done by an adjustable screw. The adjusting screw will move the diaphragm upward and thus will make the poppet unseat, thereby creating an opening to allow air from the primary to secondary side.

PRESSURE GAUGE

In pneumatic circuits, Pressure gauge is used to measure the pressure of compressed air. The pointer rotates on a calibrated scale whose readings gives the amount of Air Pressure. Today Pressure gauge is among the most commonly used instruments. We can see numerous applications using Pressure Gauges such as Pumps, Hydraulic & Pneumatic circuits, Boilers and Pressurized Vessels.

PROCESS CONTROL SYSTEM

Meaning of Process Control is to control different parameters of the system. Parameters may be temperature, level, flow, pressure, humidity, pH etc. Our aim is to keep them at desired value or within specified limit. There are different methods to apply control. Different Types of control loops are as follows – Feedback, Feed-Forward, ON-OFF and Cascade.

In Process Control Systems, the automatic controller uses the difference between the set point and measurement signals to develop the output signal to valve. The accuracy and responsiveness of these signals is a basic limitation on ability of the controller to control the measurement correctly. If the transmitter does not send an accurate signal, or if there is a lag in measurement signal, the ability of the controller to manipulate process will be degraded. At the same time, the Controller must receive an accurate set point signal.

In controller using pneumatic or electronic set point signals generated within the controller, Miscalibration of set point transmitter will develop the wrong value. The ability of the controller to position the valve accurately is yet another limitation. If there is friction in the valve, the Controller may not be able to move the valve to specific stem position to produce a specific flow, and this will appear as a difference between measurement and set point. Repeated attempt to position the valve may lead to hunting in the valve and in the measurement. Or, if controller is able only move the valve very slowly, the ability of the controller to control process will be degraded. This necessitates the use of the Positioner, which acts as a feedback controller to position the valve at the exact position corresponding to the controller output signal.

SELECTING THE CONTROL ACTION

Depending on the action of the valve, increases in measurement may require either increasing or decreasing outputs for control. All controllers can be switched between direct and reverse action. Direct action means that, when the controller sees an increasing signal from the transmitter, its output will increase. For reverse action, increasing measurement signal cause the controller-to-controller output to decrease. To determine which of this response is correct, an analysis of the Loop is required. The first step is to determine the action of the valve, and the second to consider the Effect of the change of change in measurement.

Two concepts provide the basis for most automatic process control strategies: feedback (Closed – loop) control. And feed-forward (open – loop) control. Feedback control is the more commonly used technique of the two and is the underlying concept on which much of today Automatic control theory is based.

Feedback Control is a strategy designed to achieve and maintain a desired process condition by measuring the process condition, comparing the measured condition with the desired and initiating corrective action based on the difference between the desired and actual condition. Feedback control has definite advantages over feed-forward control in relative simplicity and potentially successful operation in the face of unknown contingencies. In general, it works Well as a regulator to maintain a desired operating point by compensating for various disturbances That affect the system, and it works equally well as a servo system to initiate and follow changes demanded in the operating point.

Feed-Forward Control system in another basic technique used to compensate for uncontrolled disturbances entering the system. In this technique the control action is based on the state of a disturbances input without reference to the actual system condition. In concept, Feed-Forward Control yields much faster correction than feedback control, and in the ideal case compensation is applied in such manner that the effect of the disturbances is never seen in the process output.

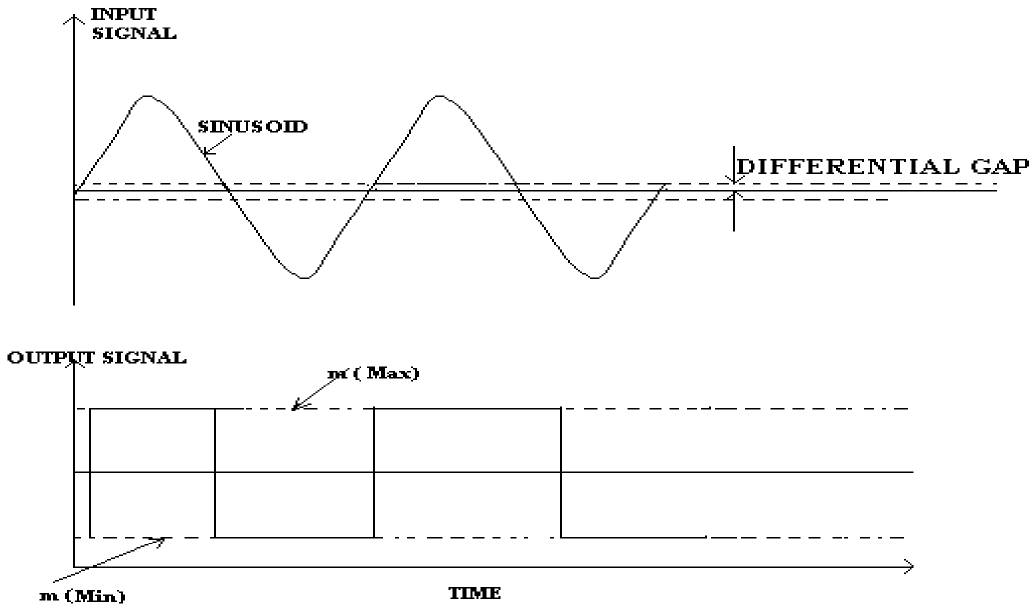
The Concept of Feed-Forward Control is very powerful, but unfortunately it is difficult to implement in pure form in most process control application. In many cases disturbances cannot be accurately measured, and therefore pure feed-forward control cannot be used. The main limitation of feed-forward is due to our inability to generate perfect models or to make perfectly accurate measurements. Because of this limitations, pure feed- forward would accumulate the errors in its models and would eventually “Self-Destruct”. The main limitation of feedback control is that it cannot anticipates upsets but can only make corrections after the upsets have occurred, and that it makes its correction in an oscillating Cyclic Manner.

It has been found that the proper industrial use of feedback and feed-forward is to combine in such a way that the imperfect feed-forward model corrects for about 90% of the upset as it occurs, while the task of correcting for the remaining 10% is left for the bias generated by the feedback loop. With this approach, the feed-forward component is not pushed beyond its abilities, while the load on the feedback loop is reduced by an order of magnitude, allowing for much tighter control.

PROCESS CONTROL LOOPS

ON-OFF CONTROL LOOP:

The oldest Control Strategy is to use a switch for control for example, if the controlled process is the room temperature, the switch would turn on the heat source when the temperature is low, and turn it off when the desired comfort level is reached.



A Perfect ON-OFF Controller is ON when the measurement is below the set point and under such condition the manipulated variable is at its maximum value. When the measured Variable is above the set point, the Controller is OFF and the manipulated variable is at its minimum value.

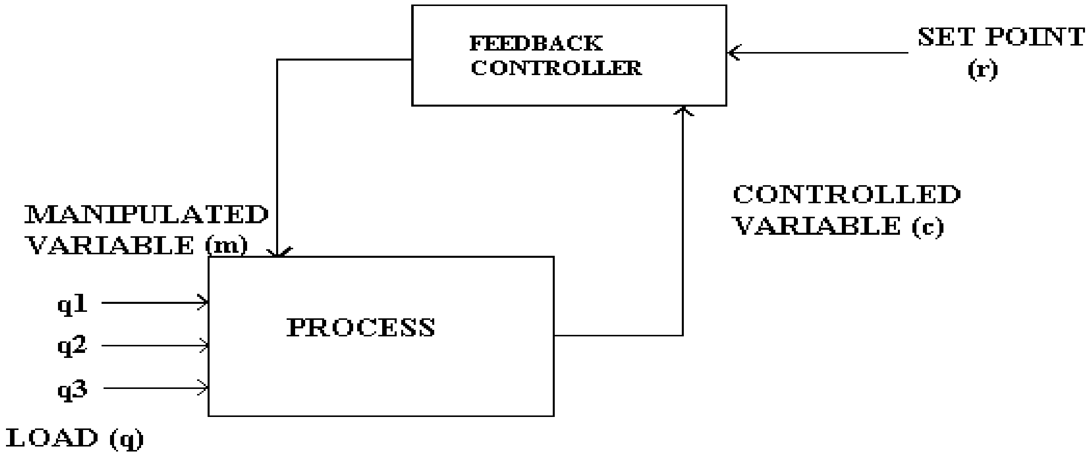
E >0m = Minimum Value

E <0m = Maximum Value

In Most Practical Applications, due to mechanical friction or arcing of electrical contacts, there is a narrow band (around zero error) that the error must pass through before a change will occur. This band is known as the differential gap, and its presence is usually desirable to minimize the cycling of the process. Figure shows the response of ON – OFF Sinusoidal input.

FEEDBACK CONTROL LOOP:

Regulation through feedback control is achieved by acting on the change in the controlled variable that was induced by change in load. Deviation in the controlled variable are converted into changes in the manipulated variable and sent back to the process to restore the balance. Figure shows the backward flow of information from the output of the process back to its manipulated input. The Load can be divided into various components such as feed rate, feed composition, and temperatures. These may be balanced by a single manipulated variable. Feedback, by its nature, is incapable of correcting a deviation in controlled variable at the time of detection. In any process, a finite delay exists between a changing of the manipulated variable and the effect of the change on the controlled variable. Where this delay is substantial and the process is subject to many frequent disturbances, considerable difficulty can be encountered in maintaining the control. Perfect control is not even theoretically obtainable, because a deviation in the Controlled variable must appear before any corrective action can begin. In addition, the value of the manipulated variable needed to balance the load must be sought by trial and error, with the feedback controller observing the effect of its output on the controlled variable.

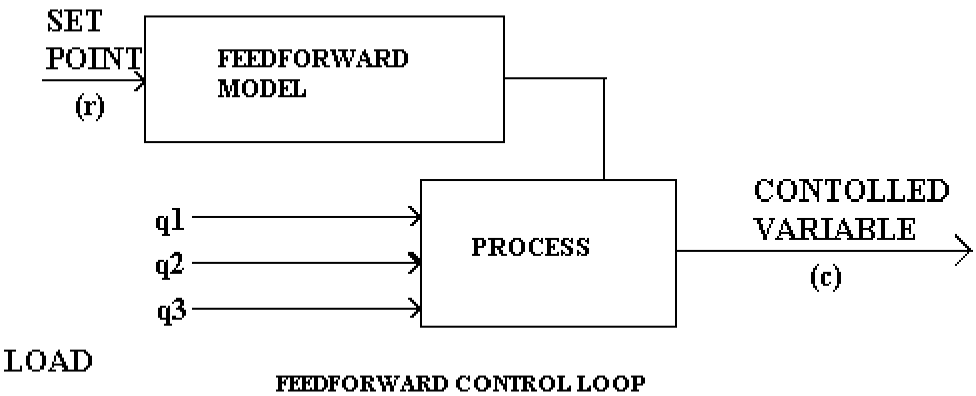


THE FEEDBACK CONTROL LOOP

The Effectiveness of the feedback control depends on the dynamic gain of the controller in relation to the frequency and magnitude of the disturbances encountered.

FEED FORWARD CONTROL LOOP:

Feed – forward provides a more direct solution to control than finding the correct value of the manipulated variable by trial and error, as occurs in the feedback control. In the feed forward system, the major components of load are entered into a model to calculate the value of the manipulated variable required to maintain control at the set point.



FEEDFORWARD CONTROL LOOP

Figure shows how information flows forward from the load to the manipulated variable input process. The set point used to give the system a command. A dynamic balance is achieved for The Process by solving its material and/or energy balance equation continuously. When a change in Load is sensed the manipulated variable is automatically adjusted to the correct value at a rate that keeps the process continuously in balance. While it is theoretically possible to achieve such Perfect control, in practice the system cannot be made to duplicate the process equation exactly.

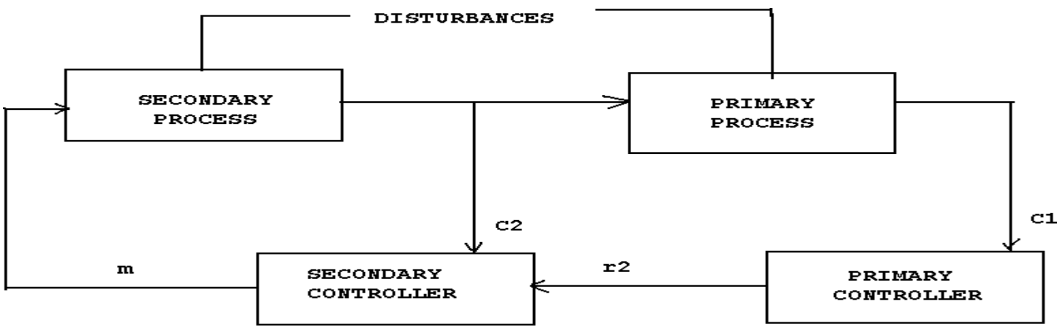
CASCADE CONTROL LOOP:

An intermediate process variable that responds both to the manipulated variable and to some disturbances can be used to achieve more effective control over the primary process variable. This technique is called cascade control. Two controllers are used, but only one process variable(m) is manipulated. The primary controller maintains the primary variable c1 at its set point by adjusting The set point r2 of the secondary controller. The secondary controller in turns responds both the Output of the primary controller and to the secondary controller variable c2.

There are distinct advantages gained with cascade control:

1. The Secondary Controller can correct disturbances affecting the secondary variable before the Secondary Controller feels a pronounced influence before a pronounced influence is felt by the Primary Controller.
2. Closing the Control Loop around the secondary part of the process reduces the phase lag seen by the Primary Controller, resulting in increased speed of response.
3. Gain Variation in the secondary part of process, are overcome within its own loop.

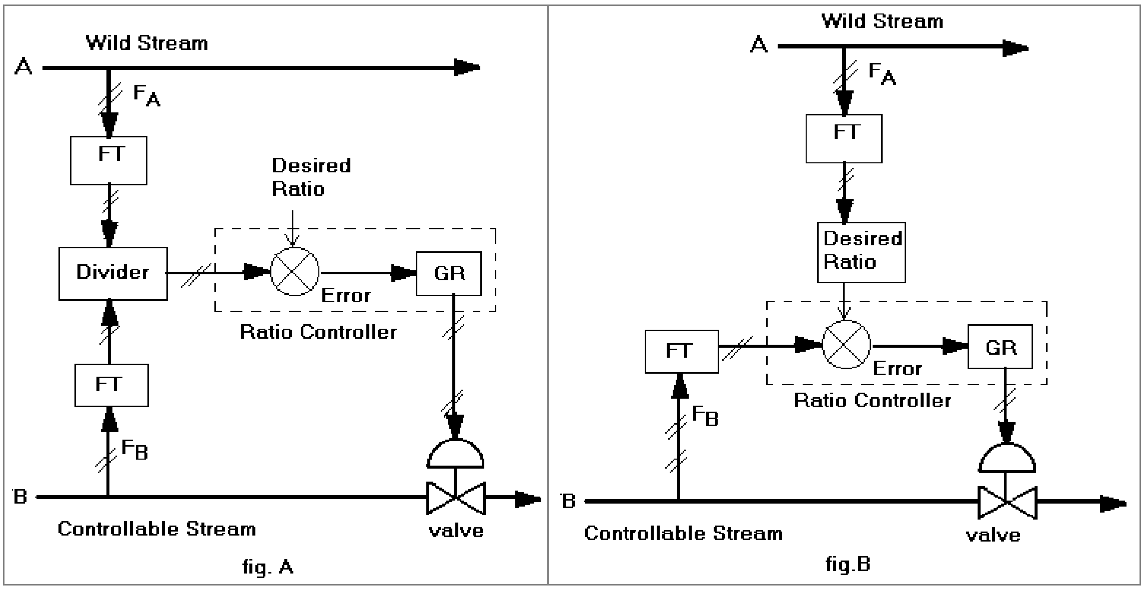
4. The Secondary loop permits an exact manipulation of the flow of mass or energy by the Primary Controller.



5. Cascade Control is of great value where high performance is mandatory in the face of random disturbances or where secondary part of the process contains an undue amount of phase shift. Eg: A Secondary Loop should be closed around an integrating element whenever practicable, to overcome its Inherit 90 lag. On the Other hand, flow is used by the secondary variable whenever disturbances in the line pressure must prevented from affecting the prime variable. It must be recognized. However, the cascade control cannot be employed unless a suitable intermediate variable can be measured. Many Processes are so arranged that they cannot be readily be broken apart in this way.

RATIO CONTROL LOOP:

It is special type of feed forward control loop where two disturbances (Flow 1 & Flow 2) are measured and held in constant ratio to each other. It is mostly used to control the ratio of the flow rate of two streams. Both flow rates are measured but only one can be controlled. The Stream whose flow rate is not under control is usually referred as a WILD Stream.



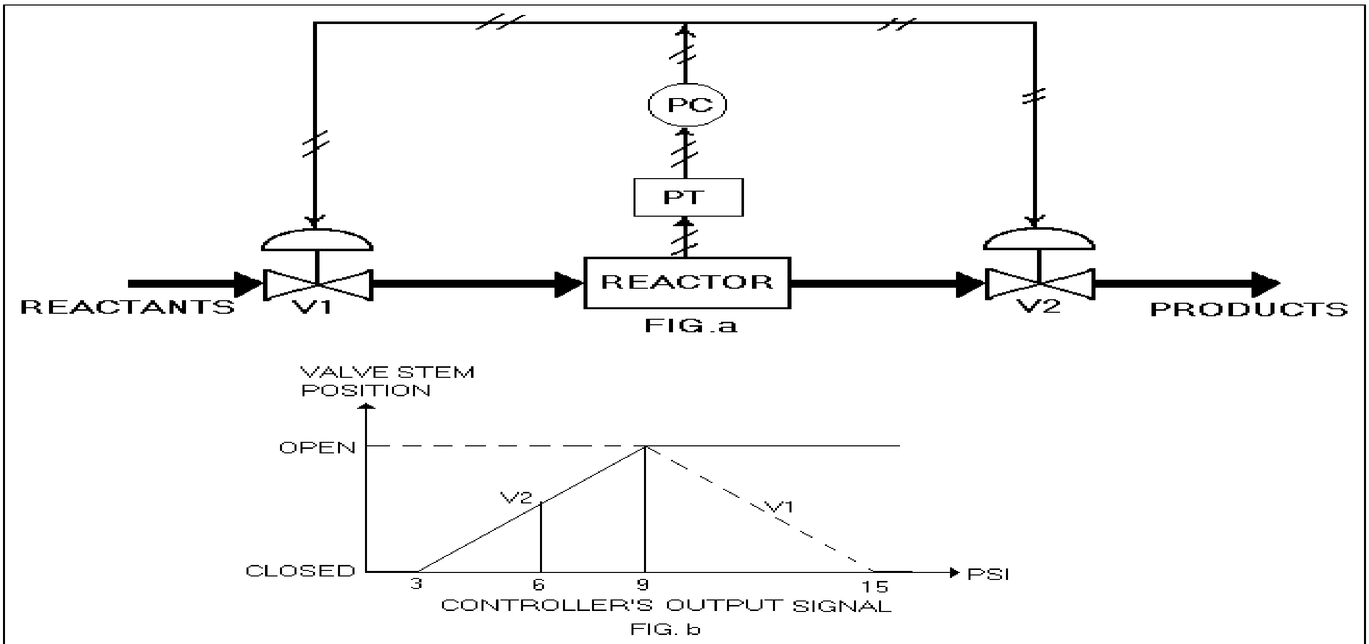
RATIO CONTROL LOOP

Fig. A & B shows two different ratio control configuration for two streams. Stream A is the wild stream.

1. Compared to the desired ratio (set point) and the deviation (error) between the measured and desired ratio constitutes the actuating signal for the ratio controller.
2. In configuration two (fig. B) we measured the flow rate of the wild stream 'A' and multiply it by the desired ratio. The result is the flow rate that the stream 'B' should have and constitute the set point value which compares to the measured flow rate of stream 'B'. The deviation constitutes the actuating signal for the controller, which adjust appropriately the flow of stream 'B'.

SPLIT RANGE CONTROL LOOPS:

Unlike cascade control scheme the split-range control configuration has one measurement Only (controlled output) and more than one manipulated variable. Since there is only one controlled output, we have only one control signal, which is thus Split into several parts, each affecting one of the available manipulations. In other words, we can control a single process output by coordinating the actions of several manipulated Variables, all of which have the same effect on the controlled output. Such systems are not Very common in chemical processes but provide added safety and operational optimally Whenever necessary as the following examples demonstrate. Consider a reactor as shown in Fig: **A** at where a gas phase reaction takes place. Two control Valves manipulate the flow of feed and the reaction product. It is clear that in order to control the Pressure in the reactor. The two valves cannot act



OUTPUT SIGNAL AND VALVE COORDINATION

CONTROLLER'S OUTPUT SIGNAL	VALVE V1 STEM POSITION	VALVE V1 STEM POSITION
3 psig	OPEN	CLOSED
9 psig	OPEN	OPEN
15 psig	CLOSED	OPEN

independently but should be coordinated. Fig: **B** Indicates the coordination of the two valves actions as a function of the controller's output signal

(Also see the table). Let the controller's output signal corresponding to the desired operation of the Reactor be 6psi. From fig. b we see that valve **V2** is partly open while valve **V1** is completely open. When for various reasons the pressure in the reactor increases, the controller's output signal also increases. Then it is split into two parts, affects the two valves simultaneously, and following actions takes place:

1. As the controller output increases from 6 psig to 9 psig, valve **V2** opens continuously while **V1** remains completely open. Both actions lead to a reduction in the pressure.
2. For large increases in the reactor's pressure, the control output may exceed 9 psig. In such a case, as we can see from fig. b valve **V2** is completely open while **V1** starts closing. Both actions Again lead to a reduction in pressure until the reactor has returned to the desired operation.

THEORY OF PID

CONTROLLER PROPORTIONAL ACTION

Proportional response is basis of three-mode controller. It is characterized by a continuous linear relationship between the controller input & output. If the other two integral & derivative are present, they are added to the proportional response. “Proportional” means the percent change in output of the controller is some multiple of the percent change in the measurement. This multiple is called the “Proportional Gain” of the controller. For some controllers, proportional action is adjusted by such a gain adjustment, while for others a “proportional band” adjustment is used. Both have the same purposes & effect. The proportional gain, Kc is frequently expressed in terms of percent proportional band, PB as,

KC=100/PB

“Wide bands “(high percentage of PB) corresponds to less “sensitive “controller settings, & “narrow bands” (low percentages) correspond to more “sensitive “controller settings. As the name “proportional” suggests the correction generated by the proportional control mode is proportional to the error. The following equation describes the operation of the proportional controller:

$M = (Kc)(e)+b = (100/PB)(e)+b$

where, M = the output signal to the manipulated variable (valve)

Kc = the proportional sensitivity or gain of the controller

e = the deviation from set point or error

PB=the proportional band (100/Kc)

b= the bias of the output

One consequence of the application of proportional control to the basic control loop is “Offset”. Offset means that the controller will maintain the measurement at a value different from the set point. The acceptability of proportional only control depends on whether this offset can be tolerated. Since the error necessary to produce any output decreases with the proportional band, the narrower the proportional band, the less the offset. For large capacity, small dead time applications accepting a very narrow proportional band, proportional only control will probably be satisfactory, since the measurement will remain within a small percentage band around the set point.

INTEGRAL ACTION (Reset):

As long as the measurement remains at the set point, there is no change in the output due to the integral mode in the controller. However, when any error exists between measurement & set point, the integral action will cause the output to begin to change & continue to change as long as the error exists. This function then causes the output to change until the proper output is achieved in order to hold the measurement at the set point at various loads. This mode is also called reset mode, because after a load change it returns the controlled variable to set point & eliminates the offset, which the plain proportional controller would leave. The mathematical expression of the integral (I) controller:

$M = (1/Ti) \int e \, dt + b$

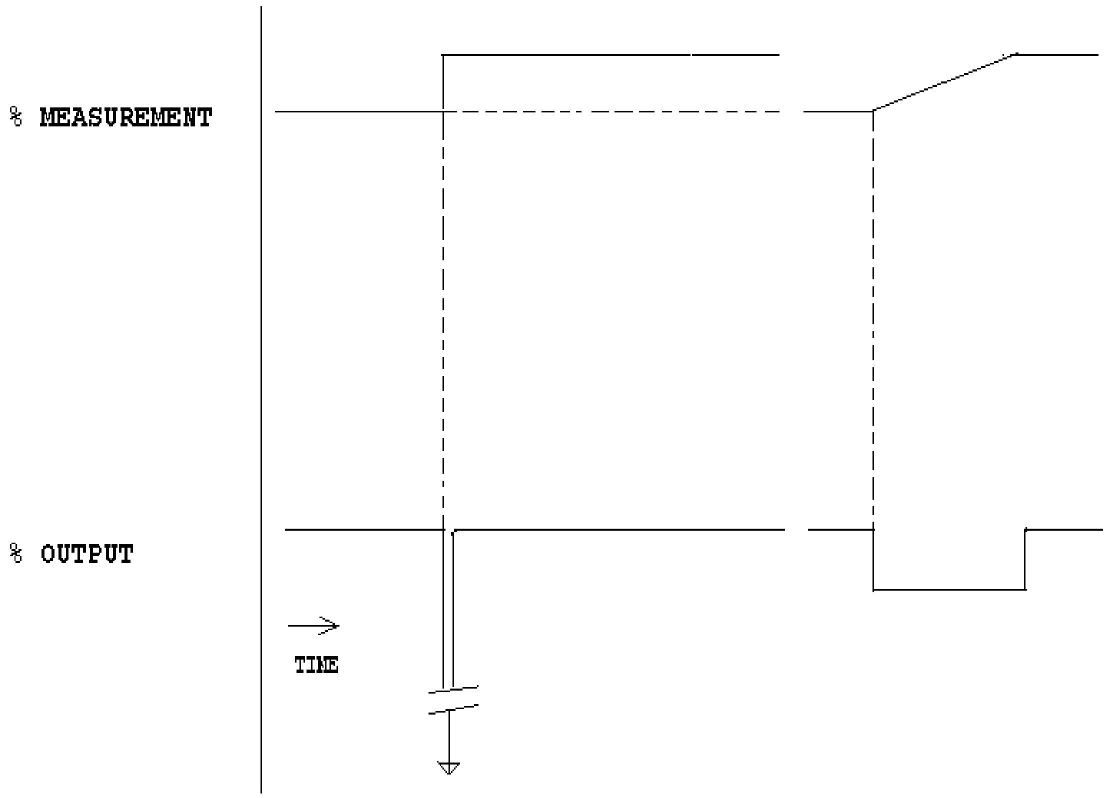
The Term "Ti" is the integral time setting of the controller. It is also called reset time & is sometimes designed as R or I instead of the more common Ti. The open loop response of the integral mode is shown in above figure, which indicates a step change in the artificial measurement away from the set point at some instant in time & the response of the integral controller output. The more integral action there is in the controller, the more quickly the output changes due to the integral response. The integral adjustment determines how rapidly the output changes as a function of time. Among the various controllers manufactured, the amount of integral action is measured in one of two ways-either in minutes per repeat, or the number of repeats per minute. The smaller integral time, the greater the action of the integral mode. The proper amount of integral action depends on how fast the measurement can respond to the additional valve travel it causes. The controller must not drive the valve faster than the dead time in the process allows the measurement to respond or the valve will reach its limits before the measurement can be brought back to the set point. The valve then remain in the extreme position until the measurement crosses the set point, where upon the controller will drive the valve to its opposite extreme, where it will remain until the measurement crosses the set point in the opposite direction. The result will be an integral cycle in which the valve ravels from one extreme to another as the measurement oscillates around the set point. The integral mode continuously looks at the total past history of the error by continuously integrating the area under the error curve & eliminates the offset. This is useful when the loop is operational but it can be a problem when the loop is idle. When the plant is shut down for night the controllers do not need to integrate the error under the error curves because if it does, it will eventually saturate & its output will either drop to zero or its Maximum value. Once saturated the controller will not be able to control when called upon to do so but will actually upset the process by trying to introduce an equal & opposite area of error, which it has introduced during its idle state. This is called as integral windup. Including a "batch function" in The controller, a function specially designed to prevent “wind-up”, can prevent this problem.

DERIVATIVE ACTION:

The third response found on controllers is the derivative mode. Whereas the proportional mode responds to the size of the error & the integral mode responds to size & time duration of the error the derivative mode responds to how quickly the error is changing. That is the proportional considers the present state of the process error & the integral mode looks at its past history while the derivative mode anticipates its future state & acts on the prediction. This third control mode became necessary as the size of processing equipment increased & correspondingly them as & the thermal inertia of such equipment. For such large process it is not good enough to respond to respond to an error when it has already evolved because the flywheel effect (the inertia or momentum) of these large processes Makes it very difficult to stop or reverse a trend once it has evolved. The purpose of derivative mode is to predict process errors before they have evolved & take corrective action in advance of that occurrence. The mathematical expression for derivative (D) controller:

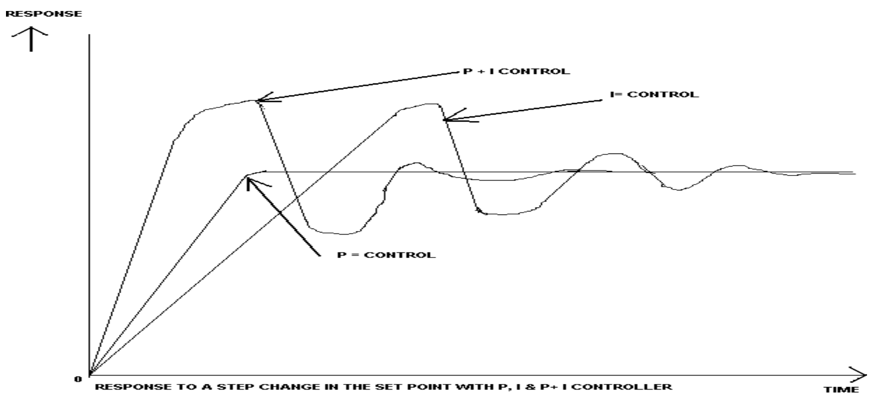
$M = Td\ (de/dt) + b$

where, Td is the derivative time in seconds



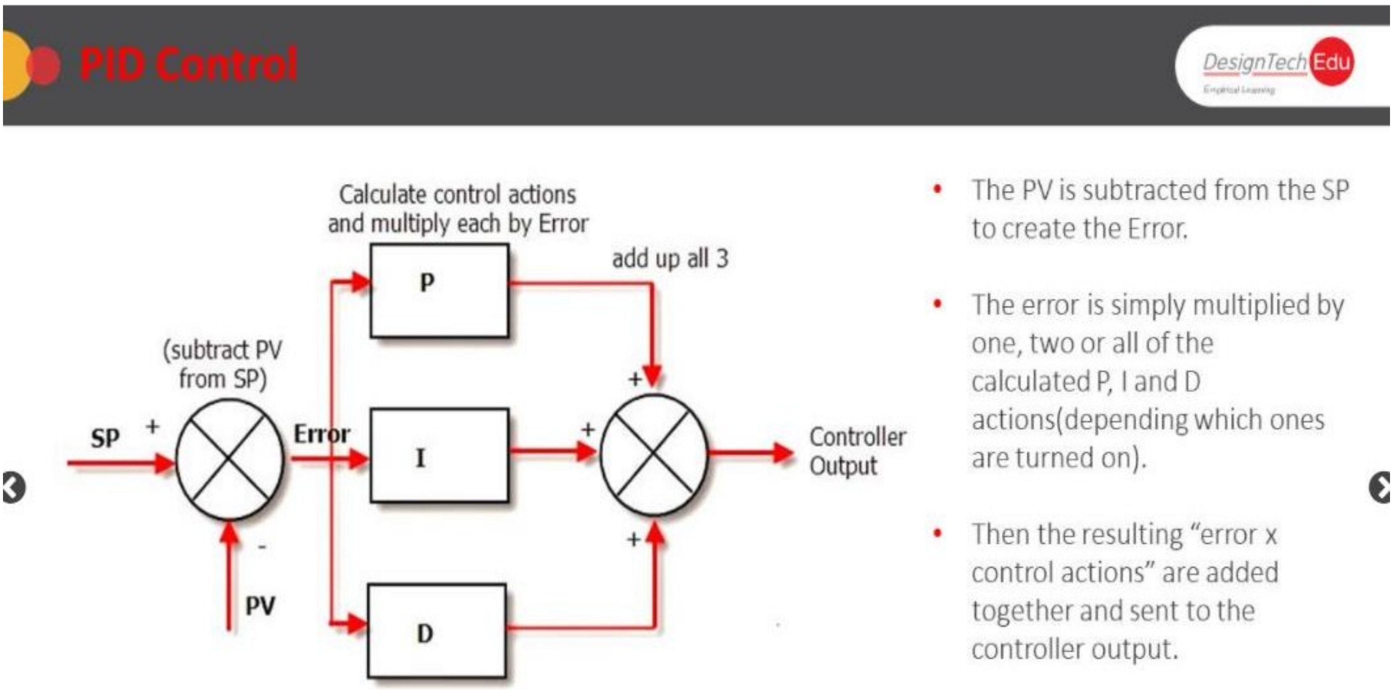
As shown in fig is the response to a change of measurement away from set point. For a step the measurement is changing infinitely fast & the derivative mode in controller causes a considerable change or spike in the output, which dies immediately because the measurement has stopped changing after the step. The second response shows the response of the derivative mode to a measurement that is changing at a constant rate. The derivative output is proportional to the rate of change of this error. Greater the rate of change, greater the output due to derivative response. The derivative holds this output as long as the measurement is changing. As soon as the measurement stops changing, regardless of whether it at the set point above or below it the response due to the derivative action will cease. The derivative response is commonly measured in minutes. The derivative time in minutes is the time that the open loop proportional plus derivative response is ahead of the response due to proportional action alone. Thus, the greater the derivative no, Greater the derivative response. To avoid large output spikes caused by step changes in the set point most modern controllers apply derivative action only to changes in the measurement. Derivative action in controllers helps to control processes that respond to the rapid changes in the measurement it sees in the noise this will cause large & rapid variations in the controller output, which will keep the valve constantly moving up & down wearing the valve & causing the measurement to cycle.

Because the derivative mode acts on the rate at which the error signal changes it can also because unnecessary upsets it will react to a sudden set point change by the operator, it will amplify Noise & it will cause upsets when the measurement signal changes in steps in steps. In such situations special precautions are recommended. For example, in order to make sure that the derivative contribution to the output the valve will respond only to the rate at which the measurement changes but will disregard the rate at which the operator changes the set point the control equation need to be changed.



PID ACTION:

When the measurement begins to deviate from the set point the first response from the Controller is derivative response proportional to the rate of change of measurement that opposes the movement of the measurement away from the set point. This derivative response is combined with the proportional response. In addition, as the integral mode in the controller sees the error increase it drives the valve further still. This action continues until the measurement stops changing at which point the derivative response ceases. Since there is still an error the measurement continues to change due to integral action until the measurement begins to move back towards the set point, there is a derivative response proportional to the rate of change in the measurement opposing the return of the measurement towards the set point. The integral response continues because there is still error although its contribution decreases with the error. Also the output due to proportional is changing. Thus the measurement comes back towards the set point. As soon as measurement reaches the set point & stops changing, the derivative response again ceases & the Proportional output returns to 50%. With the measurement back at the set point there is no Longer any changing response due to integral action. However, the output is at a new value. This new value is the result of the integral action during the time that the measurement was away from the set point & compensates for the load change the original offset.



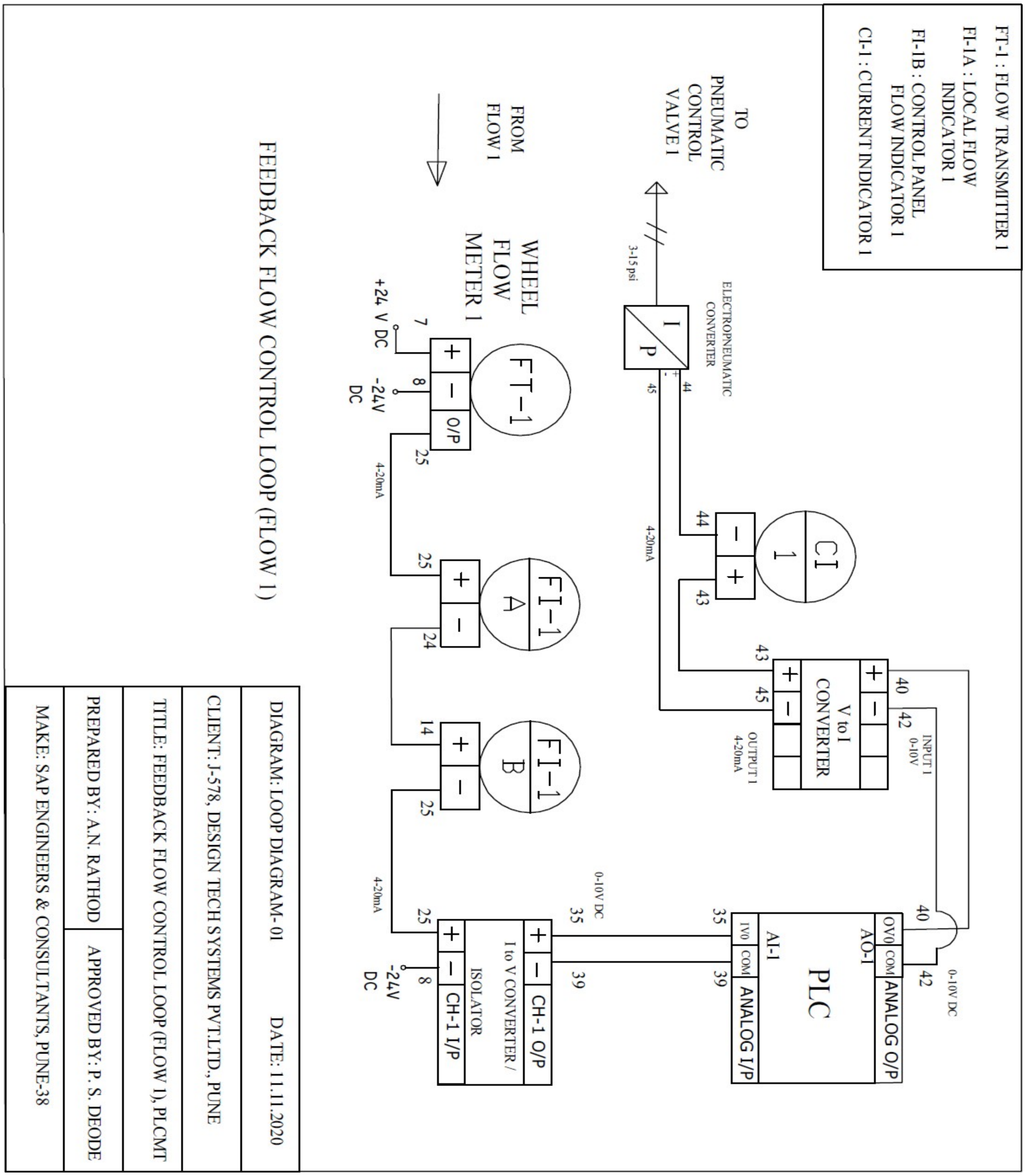
FEEDBACK FLOW CONTROL SYSTEM

In the feedback flow experiment the water is pumped through the wheel flow meter, Pneumatic control valve & circulated in the pipeline. It closed loop flow control system. The wheel flow meter senses the flow & gives out the electrical signal (4-20mA) proportional to the flow. This signal is transmitted to the controller (PID-1). PID-1 controller compares the Input signal (measured variable Mv) with the set point value (SP) & calculates error signal (e). The output value of PID-1 controller is proportional to the error & PID settings such as proportional band (PB) derivative time (Td) integral time (Ti). The output of controller (4-20mA) is given to the electro-pneumatic converter, which converts electrical signal into the pneumatic one (3-15 psi). This pneumatic signal is fed to the pneumatic actuator (diaphragm) which activates the final control element i.e. control valve by controlling its opening according to the input given & the flow is manipulated or controlled (manipulated variable). This process goes on till the error becomes zero & output stabilizes that means actual flow or measured Variable matches with the set value of flow or set point. The system becomes stable until the disturbances is inserted manually or generated by default the MANUAL disturbance Generation means changing the set point & observing the response of the system for same settings.

COMPONENT SPECIFICATION:

Pneumatic control valve 1 equipped Positioner (with bypass mode)	Type : equal % NO Type, Operating Pressure: 3 to 15 psig,
E TO P Converter	Input: 4 to 20mA , Output: 3 to 15 psig
Wheel flow meter 1	Range: 0 to 1000 LPH Output: 4 to 20mA, Input: +24 VDC
Rotameter 1	Range: 0 to 1000 LPH
AFR Unit with gauge	Range: 0 to 10 kg/cm2
Centrifugal Pump 1	Input: 230 VAC , HP: 0.5, Flow: 1050 LPH
Sump Tank	Capacity: 50 lit.Aprrox.

LOOP WIRING DIAGRAM:



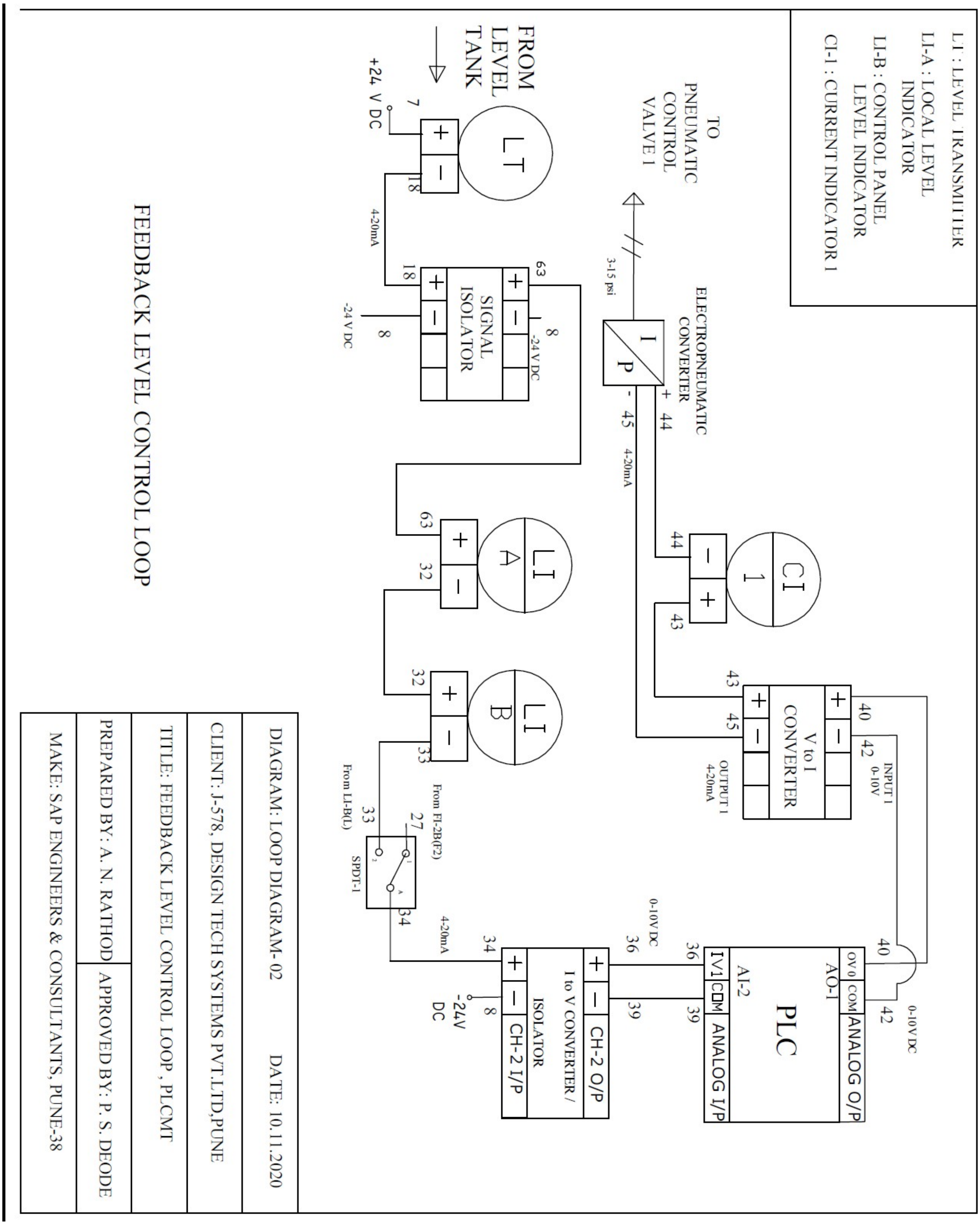
FEEDBACK LEVEL CONTROL LOOP:

In the feedback level experiment, the water from sump tank is pumped into the level tank through the pneumatic control valve. A capacitance level probe is inserted into the level tank where the change in capacitance takes place as the water level in the tank changes. A suitable signal conditioning circuit converts the change in capacitance into current signal (4-20mA), which is fed to the Programmable Logic controller via level transmitter. PID controller compares the input signal measured variable (mv) with the set point value (sp) & calculates error signal (e). The output value of PID controller is proportional to the error & PID settings such as proportional band (PB), derivative time (D), integral time (I). The output of the controller (4-20mA) is given to the electro-pneumatic converter, which converts electrical signal into the pneumatic one (3-15 psi). This pneumatic signal is fed to the pneumatic actuator (diaphragm) which activates the final control element i.e. control valve by controlling its opening according to the input given & the flow is manipulated (manipulated variable). As per the manipulation of flow the level in the tank is controlled. This process goes on till the error becomes zero & output stabilizes that means actual level or measured variable matches with the set value or set point. The system becomes stable until the disturbances is inserted manually or generated by default. The MANUAL disturbance generation means changing the set point & observing the response of the system for same settings.

COMPONENT SPECIFICATIONS:

Pneumatic control valve 1 equipped Positioner (with bypass mode)	Type : equal % NO type, Operating pressure: 3 to 15 psig,
E TO P Converter	Input: 4 to 20mA , Output: 3 to 15 psig
Wheel flow meter 1	Range: 0 to 1000 LPH Output: 4 to 20mA, Input: +24 VDC
Rotameter 1	Range: 0 to 1000 LPH
AFR Unit with gauge	Range: 0 to 10 kg/cm2
Centrifugal Pump 1	Input: 230 VAC HP: 0.5 , Flow: 1050 LPH
Sump Tank	Capacity: 50 lit. Approx.
Level tank	Range 0 To 500 mm
Level Transmitter	Input: +24 VDC , Range 0 To 500 mm Output: 4 To 20mA
Level Switch (FLOAT TYPE)	NO Type

LOOP WIRING DIAGRAM:



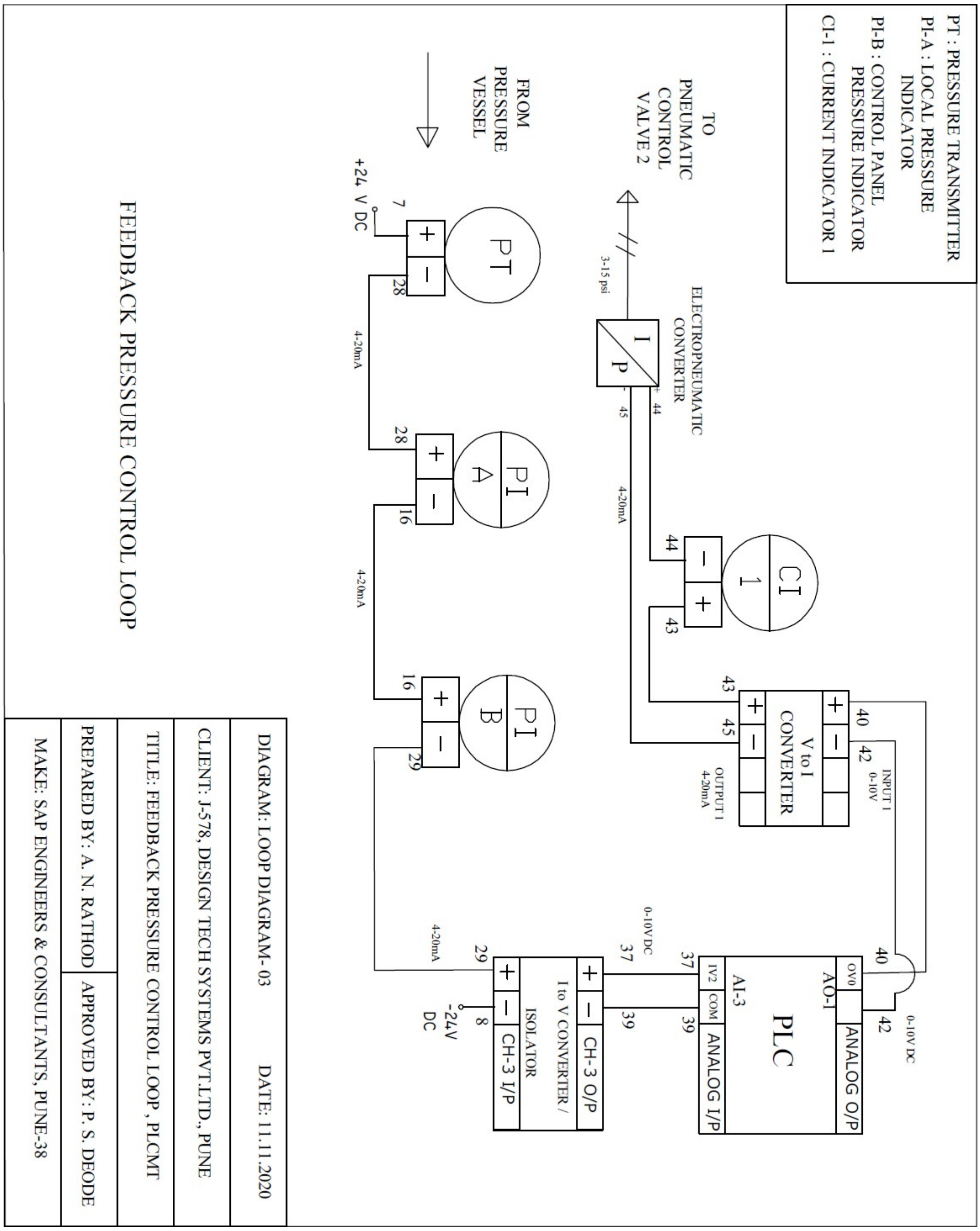
FEEDBACK PRESSURE CONTROL LOOP:

In the feedback pressure experiment, the water from sump tank is pumped into the pressure vessel/pressure tank through the pneumatic control valve. A Piezo-resistive pressure transmitter is mounted on the pressure vessel to sense the pressure of air trapped between the surface of water level & diaphragm of pressure transmitter. A suitable signal conditioning circuit converts the change in pressure into current signal (4-20mA), which is fed to the controller via pressure transmitter. PID controller compares the input signal measured variable (Mv) with the set point value (sp) & calculates error signal (e). The output value of PID controller is proportional to the error & PID settings such as proportional band (PB), derivative time (D), integral time (I). The output of the controller (4-20mA) is given to the electro-pneumatic converter, which converts electrical signal into the pneumatic one (3-15 psi). This pneumatic signal is fed to the pneumatic actuator (diaphragm) which activates the final control element i.e. control valve by controlling its opening according to the input given & the volumetric flow is manipulated (manipulated variable). As per the manipulation of volumetric flow the pressure in the tank is controlled. This process goes on till the error becomes zero & output stabilizes that means actual pressure or measured variable matches with the set value or set point pressure. The system remains stable until the disturbances is inserted manually or generated by default. The MANUAL disturbance generation means changing the set point & observing the response of the system for same settings.

COMPONENT SPECIFICATIONS:

COMPONENT	SPECIFICATIONS
Pneumatic control valve 2 equipped Positioner (with bypass mode)	Type : equal % NO type, Operating pressure: 3 to 15 psig,
E TO P Converter	Input: 4 to 20mA , Output: 3 to 15 psig
Wheel flow meter 2	Range: 0 to 1000 LPH Output: 4 to 20mA, Input: +24 VDC
Rotameter 2	Range: 0 to 1000 LPH
AFR Unit with gauge	Range: 0 to 10 kg/cm²
Centrifugal Pump 2	Input: 230 VAC , HP: 0.5, Flow: 1050 LPH
Sump Tank	Capacity: 50 lit.
Pressure transmitter (Mounted on vessel)	Input: +24 VDC Output: 4 to 20mA, Range: 0 To 2.5 kg/cm^2
Pressure Gauge (Mounted on vessel)	Range:0 to 4 kg/cm², Bottom Connections
Pressure vessel	Capacity: 15 kg/ cm²

LOOP WIRING DIAGRAM:



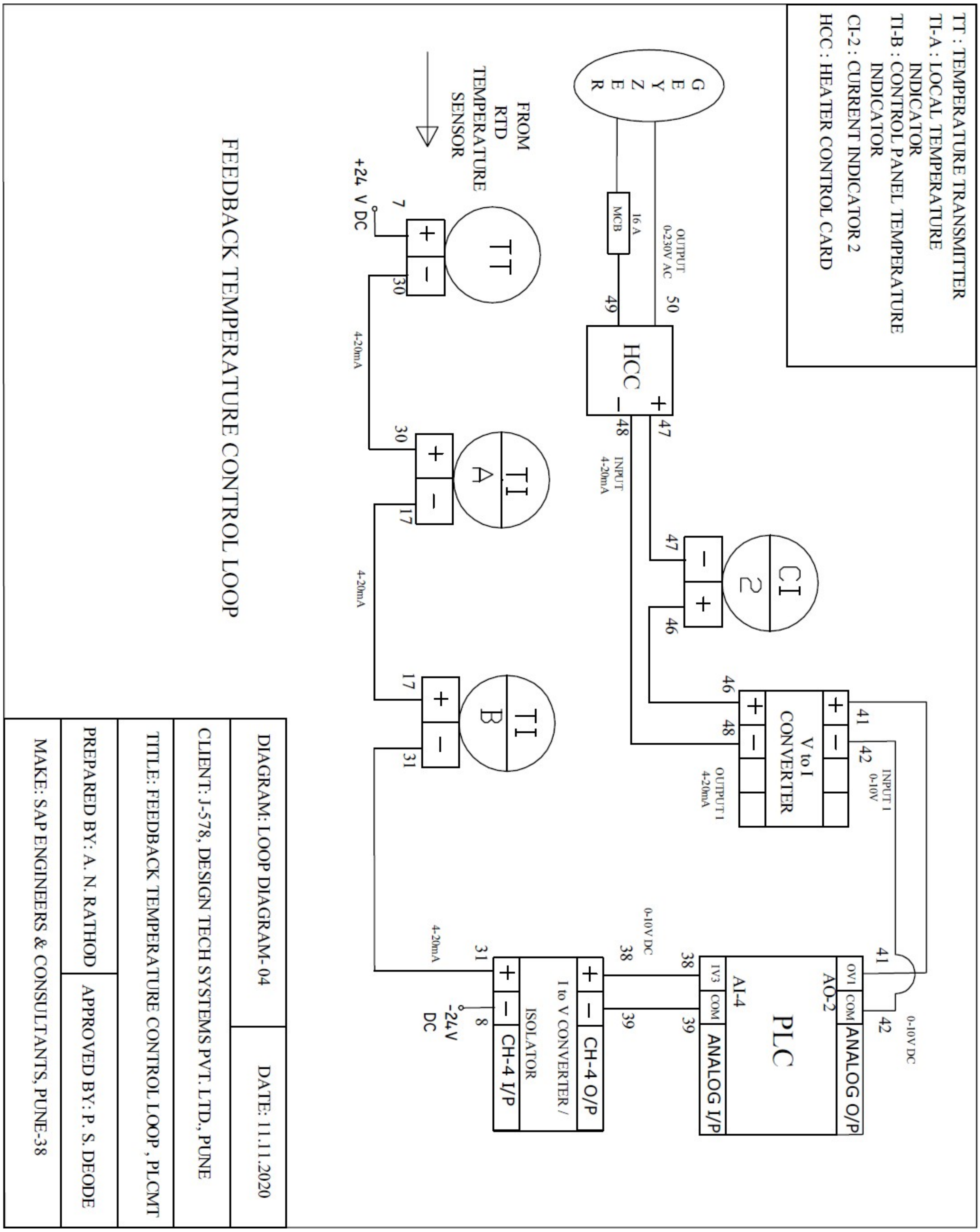
FEEDBACK TEMPERATURE CONTROL LOOP:

In process industries ON-OFF control of temp is normally used. Thermostatic control of temperature is the very commonly used method in the temp control of dry air. In the temperature cabinet or oven temp is controlled by varying the voltage applied across the heater coil thereby varying the current flowing through the coil i.e. Power = I^2*r is controlled. In the temperature control loop, the objective of the experiment is to control the temperature of water flowing inside the Flow line at the desired set point. A 3Kw heater/ Geyser is used to heat the water flowing inside the pipeline. Temperature transmitter(RTD) is used to sense the temperature, which is given to the PID controller as measured variable (M.V.). This input is compared with Set point (S.P.) and error signal (E) is generated. The error signal (E) generated is fed to the arithmetic PID block & output is computed as controller output. This controller output (0-100% = 4-20mA) is given to the thyresterized phase angle control card (HEATER CONTROL CARD) which converts the electrical input signal (4-20mA) in to corresponding electrical power output signal (0-230VAC, 10A). This power output is fed to the heater element of the Geyser.

COMPONENT SPECIFICATIONS:

COMPONENT	SPECIFICATIONS
Rotameter 2	Range: 0 to 1000 LPH
Centrifugal Pump 2	Input: 230 VAC, HP: 0.5, Flow: 1050 LPH
Sump Tank	Capacity: 50 lit. Approx.
Temperature Transmitter-1	Input: +24 VDC, Output: 4 to 20mA
Heater	Range: 0 To 50°C
Temperature Analog SSR	Input: 4 to 20mA , Output: 0 To 230 VAC

LOOP WIRING DIAGRAM:



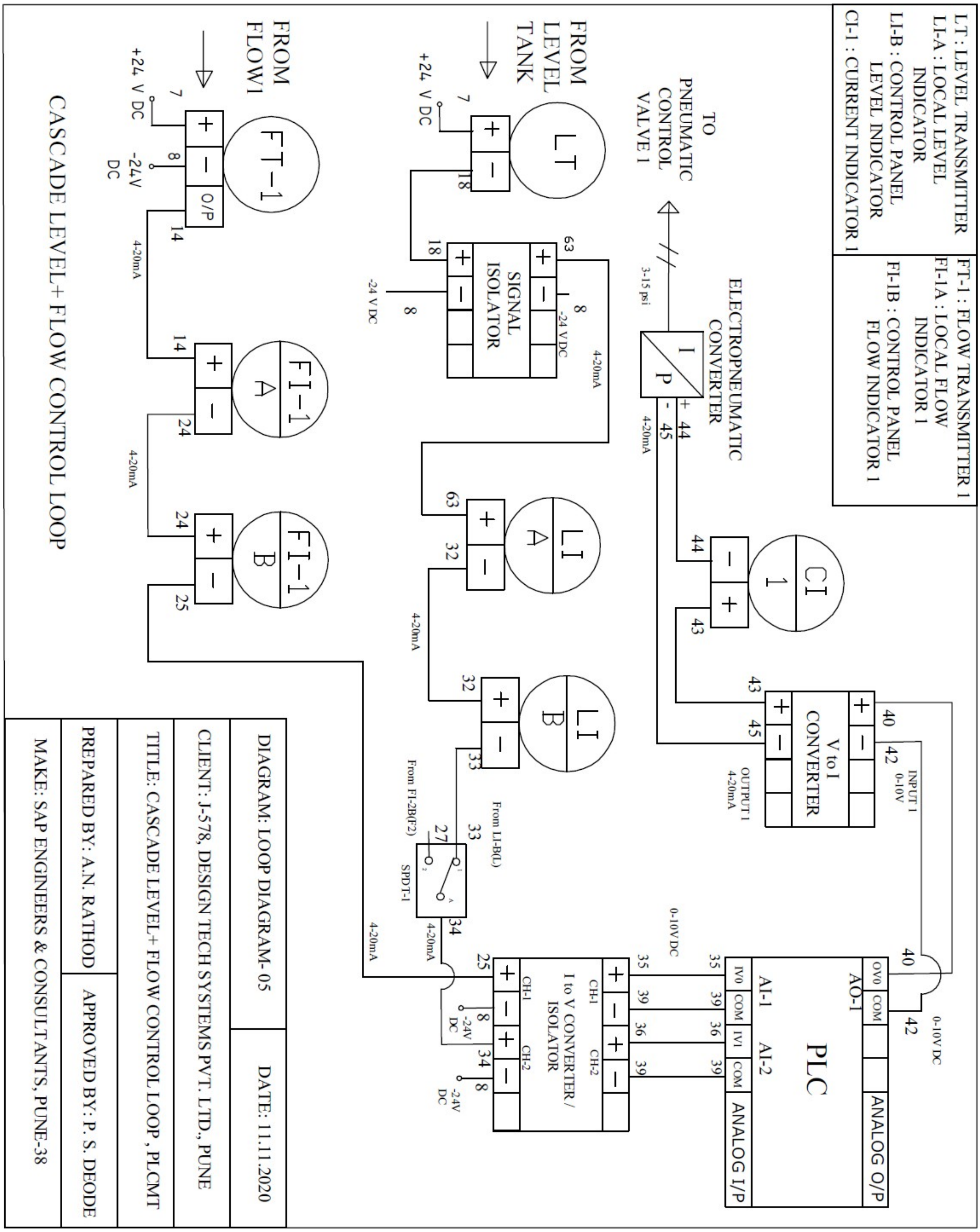
CASCADE CONTOL LEVEL FLOW:

In cascade control system final control element is manipulated through an intermediate or secondary control variable whose value is dependent on the primary. The output of one controller can be used to manipulate the set point of another. The controllers are said to be cascade. Each controller has its own set measurement input but only the primary controller has its own set point & only the secondary controller has an output to process. The manipulated variable, the secondary controller, & its measurement constitutes close loop within the primary loop. Here the primary loop is level control loop & the secondary loop is the flow one. The purpose of the cascade control is to get a faster response of level control loop. The level transmitter transmits the level input (4-20mA) to the primary PID controller where it is compared with the set point level of primary controller & output is calculated as per the error generated & set values of PI, & D for primary controller. This output is given to the secondary flow Programmable logic controller as the set point where it is compared with the actual flow (secondary loop measured variable) & error signal is generated. The output of the secondary loop controller is calculated according to this error signal generated & PID values for the secondary loop. The output of the secondary controller (4-20mA) is given to the electro -pneumatic converter, which converts electrical signal into the Pneumatic one (3-15 psi). This pneumatic signal is fed to the pneumatic actuator (diaphragm), which activates the final control element i.e. control valve by controlling its opening according to the input given & the flow 1 is manipulated (manipulated variable). As per the manipulation of flow 1 the level in the tank is controlled. This process goes on till the error becomes zero & output stabilizes that means actual level or measured variable matches with the set value of level or set point. The system becomes stable until the disturbances is inserted Manually or generated by default The MANUAL disturbance generation means changing the set point & observing the response of the system for same settings.

COMPONENT SPECIFICATIONS:

COMPONENT	SPECIFICATIONS
Pneumatic control valve 1 equipped Positioner (with bypass mode)	Type : equal % NO type, Operating pressure: 3 to 15 psig,
E TO P Converter	Input: 4 to 20mA, Output: 3 to 15 psig
Wheel flow meter 1	Range: 0 to 1000 LPH, Output: 4 to 20mA, Input: +24 VDC
Rotameter 1	Range: 0 to 1000 LPH
AFR Unit with gauge	Range: 0 to 10 kg/cm^2
Centrifugal Pump 1	Input: 230 VAC, HP: 0.5, Flow: 1050 LPH
Sump Tank	Capacity: 50 lit.
Level tank	Range 0 To 500 mm
Level Transmitter	Input: +24 VDC , Output: 4 To 20mA
Level Switch (FLOAT TYPE)	NO Type

LOOP WIRING DIAGRAM:



CASCADE CONTROL PRESSURE FLOW:

In cascade control system final control element is manipulated through an intermediate or secondary control variable whose value is dependent on the primary. The output of one controller can be used to manipulate the set point of another. The controllers are said to be cascade. Each controller has its own set measurement input but only the primary controller has its own set point & only the secondary controller has an output to process. The manipulated variable, the secondary controller, & its measurement constitutes close loop within the primary loop.

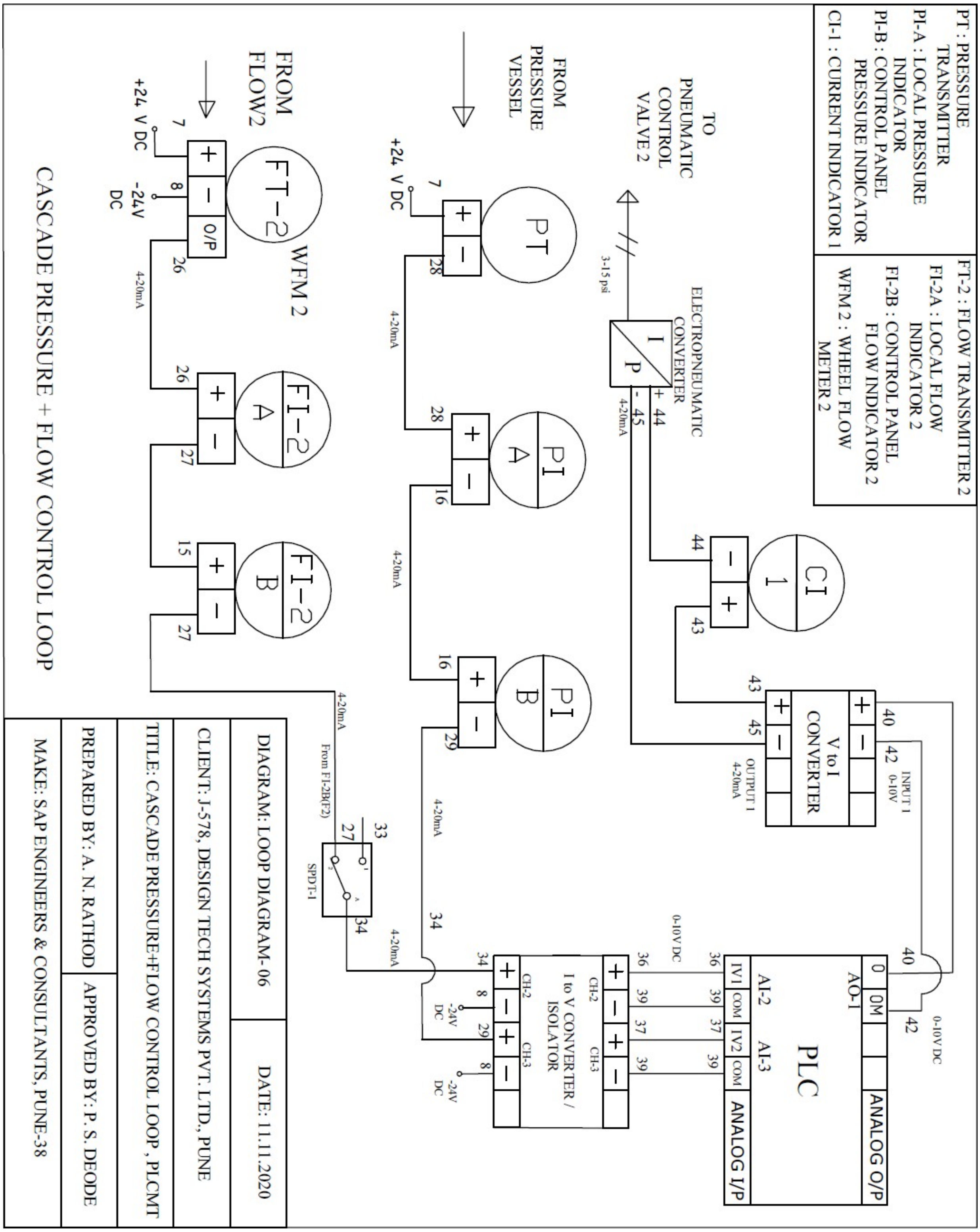
Here the primary loop is pressure control loop & the secondary loop is the flow two. the purpose of the cascade control is to get a faster response of pressure control loop. The pressure transmitter transmits the pressure input (4-20mA) to the primary PID controller where it is compared with the set point pressure & output is calculated as per the error generated & set values of P, I, & D for primary controller. This output is given to the secondary flow PID controller as the set point where it is compared with the actual flow 2 (secondary loop measured variable) & error signal is generated. The output of the secondary loop controller is calculated according to this error signal generated and PID values for the secondary loop. The output of the controller (4-20mA) is given to the electro-pneumatic converter, which converts electrical signal into the pneumatic one (3-15 psi). This pneumatic signal is fed to the pneumatic actuator (diaphragm), which activates the final control element
i.e. control valve by controlling its opening according to the input given & the flow is manipulated (manipulated variable).

As per the manipulation of flow the pressure in the tank is controlled. This process goes on till the error becomes zero & output stabilizes that means actual pressure or measured variable matches with the set value of pressure or set point. The system becomes stable until the disturbances are inserted manually or generated by default the MANUAL disturbance generation means changing the set point & observing the response of the system for same settings.

COMPONENT SPECIFICATIONS:

COMPONENT	SPECIFICATIONS
Pneumatic control valve 2 equipped Positioner (with bypass mode)	Type : equal % NO type, Operating pressure: 3 to 15 psig,
E TO P Converter	Input: 4 to 20mA, Output: 3 to 15 psig
Wheel flow meter 2	Range: 0 to 1000 LPH, Output: 4 to 20mA, Input: +24 VDC
Rotameter 2	Range: 0 to 1000 LPH
AFR Unit with gauge	Range: 0 to 10 kg/cm2
Centrifugal Pump 2	Input: 230 VAC, HP: 0.5, Flow: 1050 LPH
Sump Tank	Capacity: 50 lit.
Pressure transmitter (Mounted on vessel)	Input: +24 VDC , Output: 4 to 20mA Range: 0 To 2.5 kg/cm2
Pressure Gauge (Mounted on vessel)	Range:0 to 4 kg/cm2, Bottom Connections
Pressure vessel	Capacity: 15 kg/cm2

LOOP WIRING DIAGRAM:



RATIO CONTROL OF FLOW:

In Ratio Control System, there are two flow streams: Flow1 (Controlled flow) & Flow2 (Wild flow). Wheel flow meter 1 is used to measure the flow in flow1 which is i/p1 to the PID Controller. Wheel flow meter 2 with local indicator is used to measure flow in flow2 which is i/p2 to the PID Controller. In ratio control operation, wild flow2 is kept constant at some flow rate. Two flow meters transmit the output to the RATIO PID CONTROLLER. Ratio of the two flows is calculated in the arithmetic logic ratio block by **R=FLOW2/FLOW1**. This calculated ratio is compared with the set point & error signal is generated. The output of the Ratio loop PID controller is calculated according to this error signal generated & PID values for the Ratio loop.

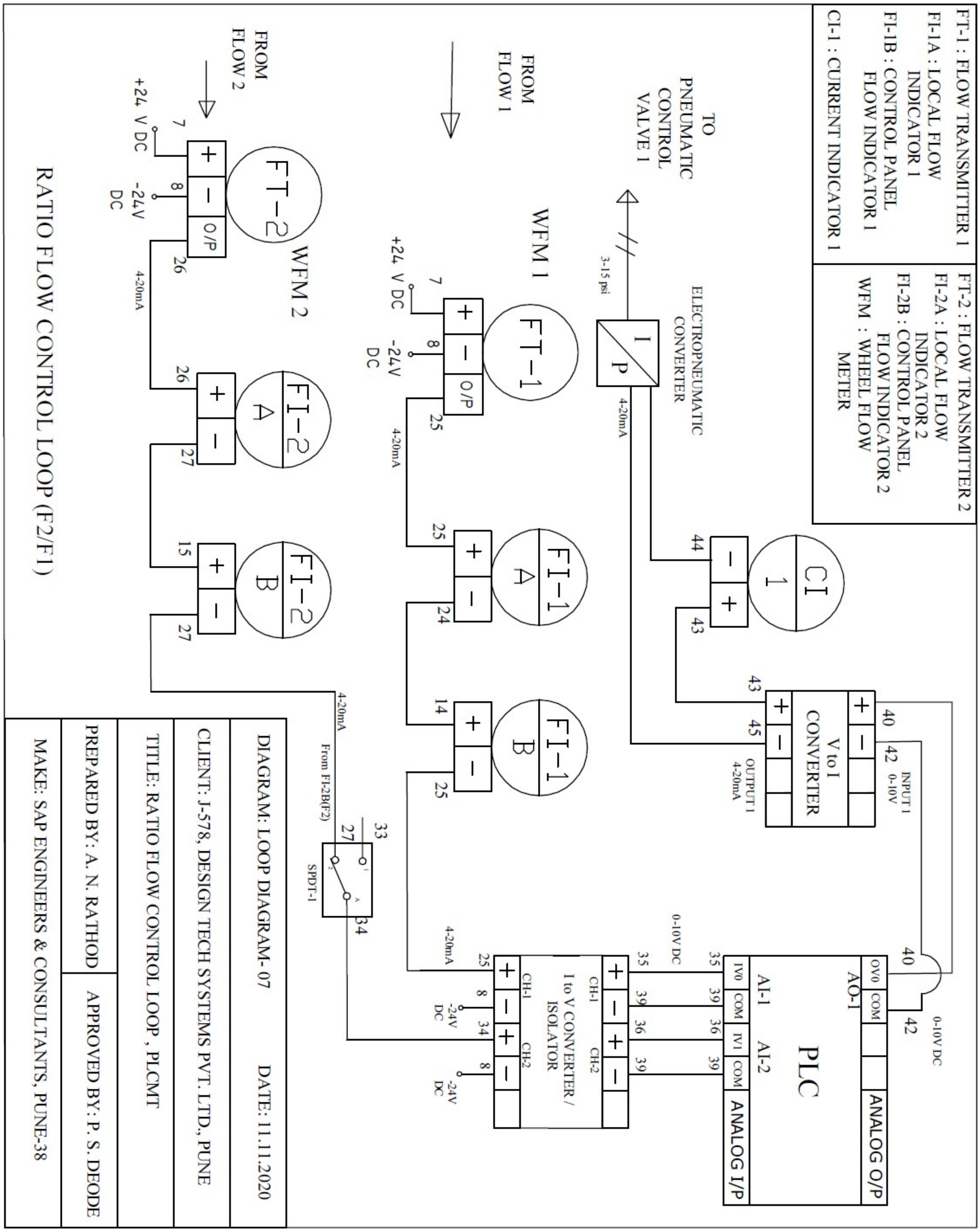
The output of the controller (4-20mA) is given to the electro-pneumatic converter, which converts electrical signal into the pneumatic one (3-15 psi). This pneumatic signal is fed to the pneumatic actuator (diaphragm), which activates the final control element i.e. control valve by controlling its opening according to the input given & the flow1 is manipulated (manipulated variable).

As per the manipulation of flow1 the ratio in the loop is controlled. This process goes on till the error becomes zero & output stabilizes that means actual ratio or measured variable matches with the set value of ratio or set point. The system becomes stable until the disturbances is inserted manually or generated by default. The MANUAL disturbance generation means changing the set point & observing the response of the system for same settings.

COMPONENT SPECIFICATIONS:

COMPONENT	SPECIFICATIONS
Pneumatic control valve 1 equipped Positioner (with bypass mode)	Type : equal % NO type, Operating pressure: 3 to 15 psig,
E TO P Converter	Input: 4 to 20mA, Output: 3 to 15 psig
Wheel flow meter 1	Range: 0 to 1000 LPH , Output: 4 to 20mA, Input: +24 VDC
Rotameter 1	Range: 0 to 1000 LPH
AFR Unit with gauge	Range: 0 to 10 kg/cm2
Centrifugal Pump 1	Input: 230 VAC , HP: 0.5, Flow: 1050 LPH
Sump Tank	Capacity: 50 lit.
Wheel flow meter 2	Range: 0 to 1000 LPH, Output: 4 to 20mA, Input: +24 VDC
Pneumatic control valve 2 equipped Positioner (with bypass mode)	Type : equal % NO type, Operating pressure: 3 to 15 psig,
Centrifugal Pump 2	Input: 230 VAC, HP: 0.5, Flow: 1050 LPH
Rotameter 2	Range: 0 to 1000 LPH

LOOP WIRING DIAGRAM:



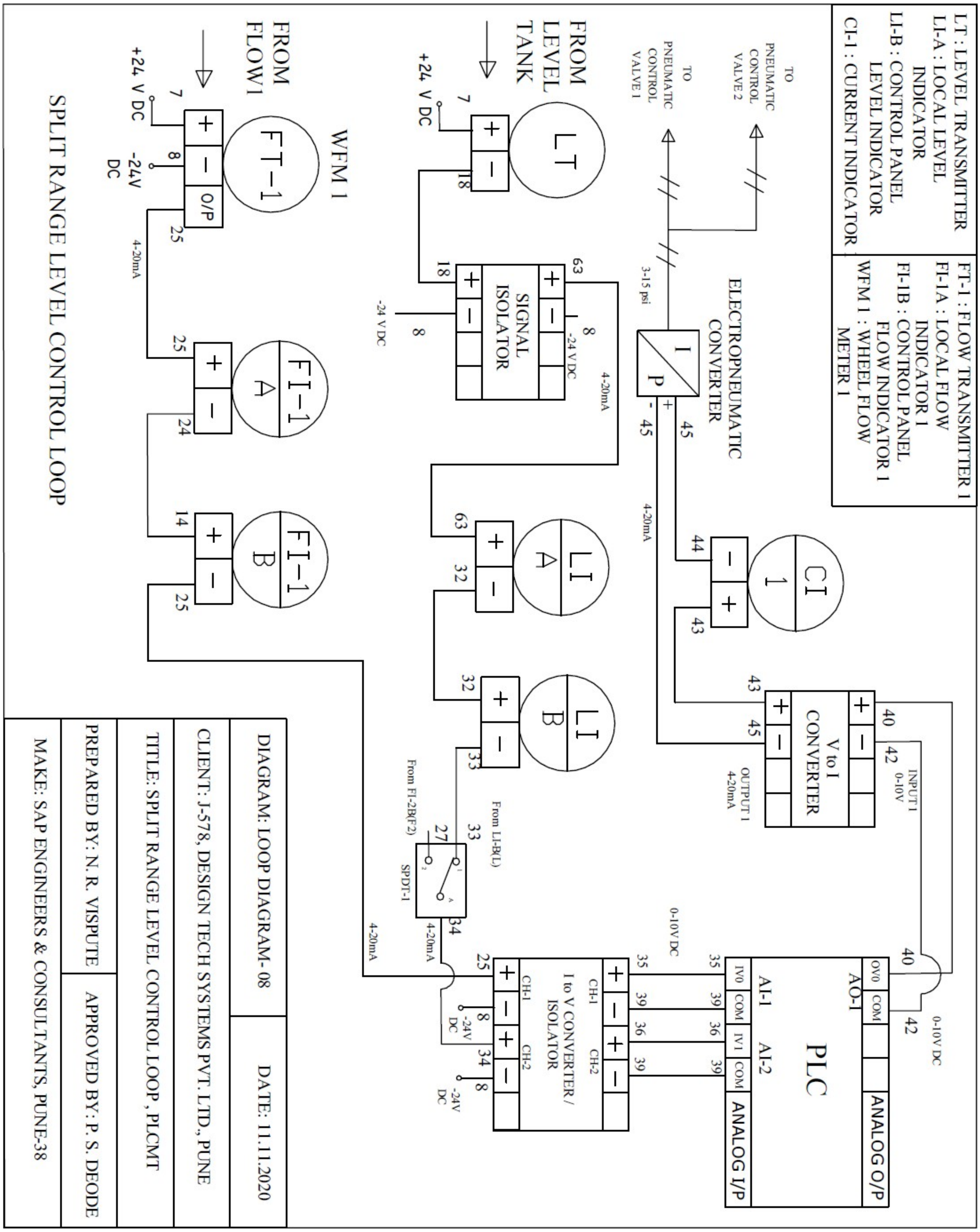
SPLIT RANGE CONTROL SYSTEM:

In the split range control system pneumatic control valve in line one is act as an input valve and pneumatic control valve in second line as an output valve by using the positioner we can change these to valve to operate in the range of 3-9psi and 9-15psi respectively. Now we arrange the ball valve such that water will flow through line-1 (input valve), LEVEL TANK, line-2 (output valve) and back to the sump. Level in the pressure tank is fed to the PID-1 (PLC ALGORITHM) by using LEVEL transmitter same as in the level control loop and output of PID-1 controller is fed to the E/P converter the o/p pressure of E/P converter is then fed to the positioner of two (input & output) pneumatic control valve. According to output of the positioner both valves will operate.

COMPONENT SPECIFICATIONS:

COMPONENT	SPECIFICATIONS
Pneumatic control valve 1 equipped Positioner (with Positioner mode)	Type : equal % NO type, Operating pressure: 3 to 9psig,
Pneumatic control valve 2 equipped Positioner (with Positioner mode)	Type : equal % NO type, Operating pressure: 9 to 15 psig,
E TO P Converter	Input: 4 to 20mA ,Output: 3 to 15 psig
Wheel flow meter 1	Range: 0 to 1000 LPH, Output: 4 to 20mA, Input: +24 VDC
Rotameter	Range: 0 to 1000 LPH
AFR Unit with gauge	Range: 0 to 10 kg/cm2
Centrifugal Pump 1	Input: 230 VAC, HP: 0.5, Flow: 1050 LPH
Sump Tank	Capacity: 50 lit. Approx.

LOOP WIRING DIAGRAM:



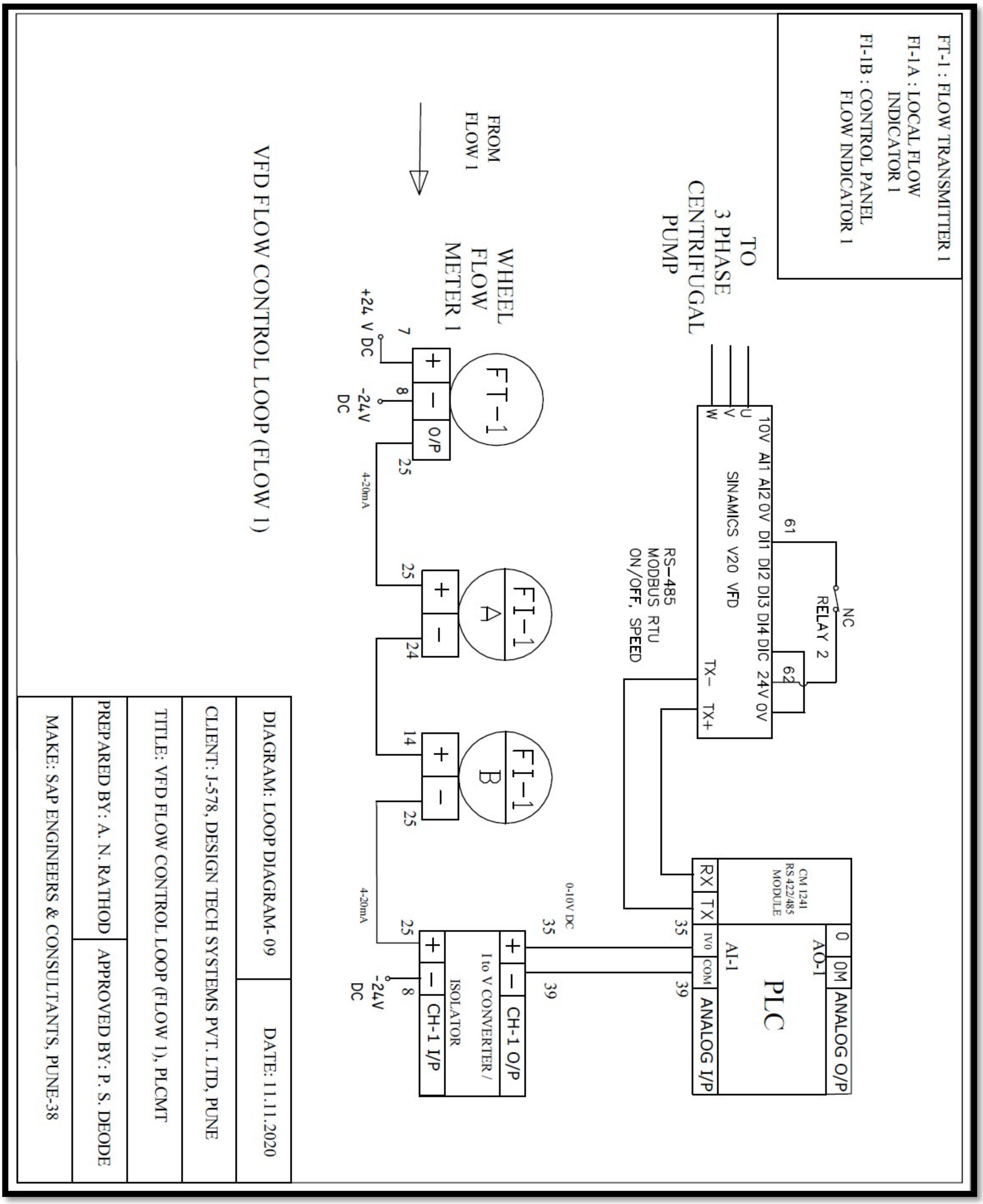
VFD (FEEDBACK) – FLOW CONTROL LOOP:

In the feedback flow experiment the water is pumped through the wheel flow meter, circulated in the pipeline. It closed loop flow control system. The wheel flow meter senses the flow & gives out the electrical signal (4-20mA) proportional to the flow. This signal is transmitted to the controller (PID-1). PID-1 controller compares the input signal (measured variable Mv) with the set point value (SP) & calculates error signal (e). The output value of PID-1 controller is proportional to the error & PID settings such as proportional band (PB) derivative time (Td) integral time (Ti). The output of controller (0-10VDC) is given to the VFD, which provides electrical signal to Control the rpm Speed of Pump 3, This process goes on till the error becomes zero & output stabilizes that means actual flow or measured variable matches with the set value of flow or set point. The system becomes stable until the disturbances is inserted manually or generated by default the MANUAL disturbance generation means changing the set point & observing the response of the system for same settings.

COMPONENT SPECIFICATIONS:

COMPONENT	**SPECIFICATIONS**
VFD	230VAC input, Output : 220VAC, 3Phase 1HP,
Pump 3	1HP, 220VAC, 3Phase , RPM : 2880
Wheel flow meter 1	Range: 0 to 1000 LPH Output: 4 to 20mA, Input: +24 VDC
Rotameter 1	Range: 0 to 1000 LPH
Sump Tank	Capacity: 50 lit.Aprrox.

LOOP WIRING DIAGRAM:



VARIABLE FREQUENCY DRIVE:

The AC drive industry is growing rapidly and it is now more important than ever for technicians and maintenance personnel to keep AC drive installations running smoothly. AC drives change the speed of ac motor by changing voltage and frequency of the power supplied to the ac motor. In order to maintain proper power factor and reduce excessive heating of the motor, the name plate volts/hertz ratio must be maintained. This is the main task of VFD. AC drives basic working principle,

1. AC drives are used to step-less speed control of squirrel cage induction motors mostly used in process plants due to its ruggedness and maintenance free long life.

2. AC drive control speed of ac motor by varying output voltage and frequency through Sophisticated microprocessor controlled electronics device.

3. AC drive consists of Rectifier and inverter units. Rectifier converts AC in DC voltage and Inverter converts DC voltage back in AC voltage.

FIG: VFD