Basics of Instrumentation & Control

Resistance temperature detectors (RTDs)

An RTD sensing element consists of a wire coil or deposited film of pure metal. The element's resistance increases with temperature in a known and repeatable manner. RTDs exhibit excellent accuracy over a wide temperature range and represent the fastest growing segment among industrial temperature sensors.

Application of Instruments in Excel:-

Application of RTD:-

For Profenofos Expansion we ordered Temperature Transmitter with below details.
Type:- PT-100 (PT- Platinum) 02 wired RTD Type

Temp. Range of Platinum:- -200 to 850 °C

Proposed application Temp. Range to measured:- 0-120 °C

Application of Level Transmitter:-

For Profenofos Expansion we ordered two different types of Level Transmitter with below details.

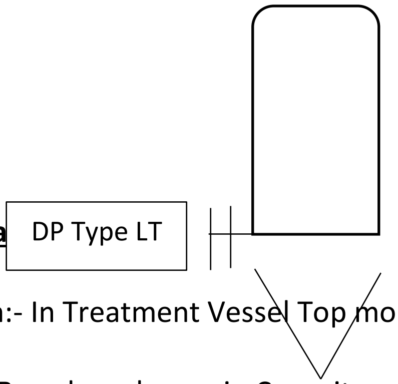
1. **Type:- Differential Pressure Type**

   Application:- In Batch Tank bottom mounting

Principle:- Based on Pressure difference P=ρ*g*h Level can be measured

Mounting:- Bottom

Limitation:- Sp. Gr of Fluid inside Tank must be constant in order to get max. Accuracy



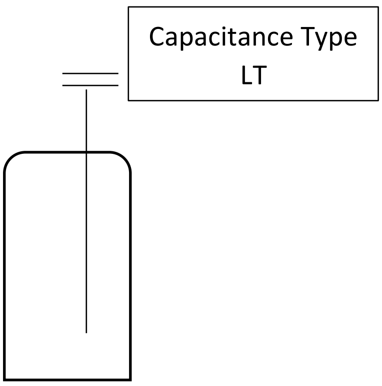
2. **Type:- Capa**

Application:- In Treatment Vessel Top mounting

Principle:- Based on change in Capacitance of rod/ sensor of height equivalent to Vessel Ht. Level can be measured

Mounting:- Top with Rod/ Sensor to be deep inside vessel

Limitation:- Dielectric Constant of stored fluid must be known & should be constant



3. **Type:- Radar Type = Continuous Level measurement device**

Application:- Level measurement in storage Tank of Clean Fluid- TMA

Principle:- They use Radar waves which is electromagnetic waves in nature. This device actually measure Distance between Source to the upper surface of Tank fluid level by measuring the time of flight of wave.

Types:-

1. Guided Wave Radar= Contact type use probe inside tank to guide the radio waves into process fluid inside tank.

2. Non Contact Type which will guide radio waves outside tank.

Mounting:- Top with Rod/ Sensor to be deep inside vessel

Application of Flow Transmitter:-

1. **Magnetic Flow Meter = Mag Flow Meter = Volumetric Flow Meter**

Application:- To measure Volumetric Flow Rate of Liquid/ Slurry

Principle:- Farady's Law which states that when electrically conductive Liquid passes via magnetic field it will induce voltage proportionate to Strength of Magnetic Field, Velocity of Liquid via pipe & Length of Pipe. This voltage is proportional to Velocity of liquid. So basically measuring velocity through voltage & convert to Flow Rate by equation Q= A * V

Mounting:- Between Pipe where Flow is to be measured

Limitation:- Liquid which Flow is to be measured must be conductive enough, Conductivity must be > 10 microsemence/cm

Can’t use to measure vol. Flow of Steam/ Gases

Remarks:- We have given order to Yokogawa special made Mag Flow Meter to measure conductivity < 1 microsemence/cm because in our case conductivity of liquid is 1.5 microsemence

2. **Vortex Type Flow Meter = Mass Flow Meter**

Application:- To measure Mass Flow Rate of Steam

Principle:- When an object for obstruction is installed in the way of fluid it will cause vortex due to lowering the pressure & increase in velocity. So Meter will measure the frequency of formation of vortex, the mass flow rate can be obtained. Governing equations are as per below.

St= (Frequency*Width of Obstruction)/ (Avg. Velocity of Fluid)

Q=A*V= (A*Frequency*Width of Obstruction)/ St

Mounting:- Between Pipe where Flow is to be measured line should always be flooded

Limitation:-

1. Fluid must be able to produce sufficient pressure so it must be having sufficient velocity to produce vortex for flow measurement
2. Fluid must be free of solid must be clean doesn’t contain slurry
3. Fluid should be free of solid so clogging of bluff body/ obstruction can be prevented
4. Should be single phase

3. **Coriolis Type Flow Meter = Mass Flow Meter**

Application:- To measure Mass Flow Rate of Liquid

Principle:- When an object for obstruction is installed in the way of fluid it will cause vortex due to lowering the pressure & increase in velocity. So Meter will measure the frequency of formation of vortex, the mass flow rate can be obtained. Governing equations are as per below.

St= (Frequency*Width of Obstruction)/ (Avg. Velocity of Fluid)

Q=A*V= (A*Frequency*Width of Obstruction)/ St

Mounting:- Between Pipe where Flow is to be measured line should always be flooded

Limitation:-

5. Fluid must be able to produce sufficient pressure so it must be having sufficient velocity to produce vortex for flow measurement
6. Fluid must be free of solid must be clean doesn't contain slurry
7. Fluid should be free of solid so clogging of bluff body/ obstruction can be prevented
8. Should be single phase

Thermocouples

A thermocouple consists of two wires of dissimilar metals welded together into a junction. At the other end of the signal wires, usually as part of the input instrument, is another junction called the reference junction, which is electronically compensated for its ambient temperature. Heating the sensing junction generates a thermoelectric potential (emf) proportional to the temperature difference between the two junctions. This millivolt-level emf, when compensated for the known temperature of the reference junction, indicates the temperature at the sensing tip.

Thermocouples are simple and familiar. Designing them into systems, however, is complicated by the need for special extension wires and reference junction compensation.

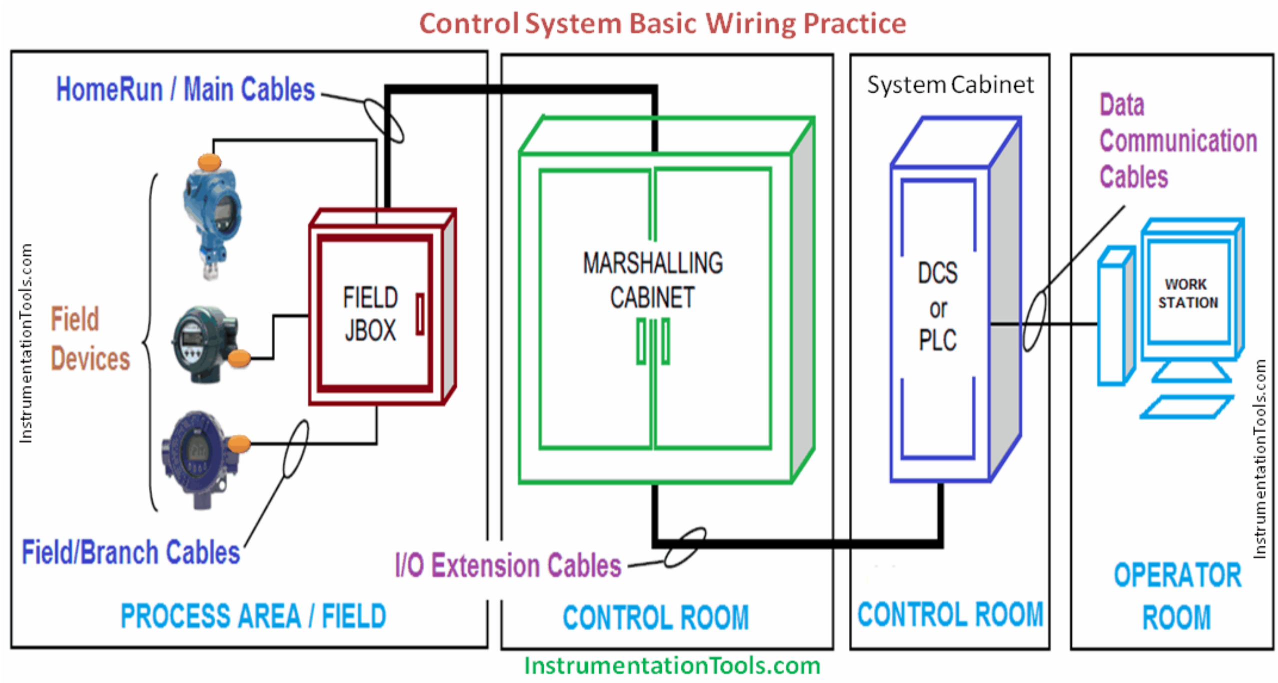
Thermistors

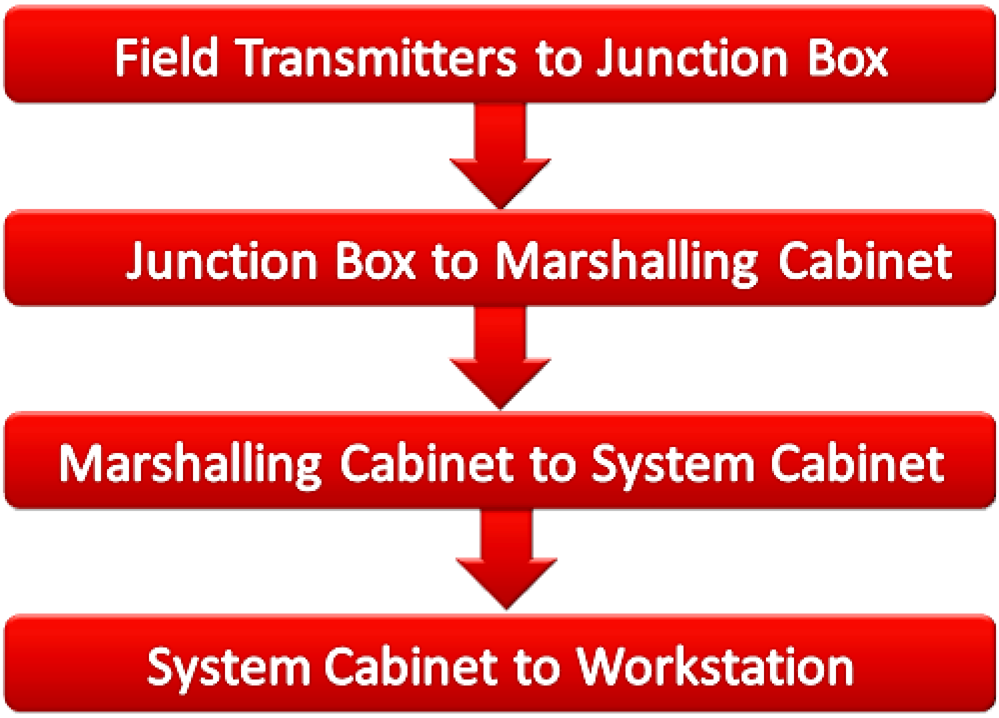
- A thermistor is a resistive device composed of metal oxides formed into a bead and encapsulated in epoxy or glass.

- A typical thermistor shows a large negative temperature coefficient. Resistance drops dramatically and non-linearly with temperature. Sensitivity is many times that of RTDs but useful temperature range is limited. Some manufacturers offer thermistors with positive coefficients. Linearized models are also available.

	RTD	Thermocouple	Thermistor
Temp. range	-260 to 850°C (-436 to 1562°F)	-270 to 1800°C (-454 to 3272°F)	-80 to 150°C (-112 to 302°F) (typical)
Sensor cost	Moderate	Low	Low
System cost	Moderate	High	Moderate
Stability	Best	Low	Moderate
Sensitivity	Moderate	Low	Best
Linearity	Best	Moderate	Poor
Specify for:	• General purpose sensing • Highest accuracy • Temperature averaging	• Highest temperatures	• Best sensitivity • Narrow ranges (e.g. medical) • Point sensing

DCS/PLC Flow Diagram Animation :





- We have thousands of field transmitters installed in a process plant. So it is practically difficult to lay straight individual cables from each field transmitter to control room for displaying the process variables on the workstation. As per design standards, particular number of field devices / transmitters are wired and terminated in a Field Junction box. Cable used for connecting the field device to Junction box are called as Branch cables or field cables. Generally we use one pair cables for branch cables.

- The below figure shows 5 field devices are connected to a Junction Box using individual Branch cables. In this example, for carrying out these five signals to control room we need minimum 5 pair cable (means one cable have 5 pairs) and also we have to consider spare cable requirement for future purpose. so at least 6 pair cable or better a 12 pair cable best suits the below requirement. Say we choose 12 pair cable and is nothing but a Main Cable or Home run cable as it interfaces the field junction box and marshalling cabinet in the control room. so finally one big main cable is required and serves our purpose.

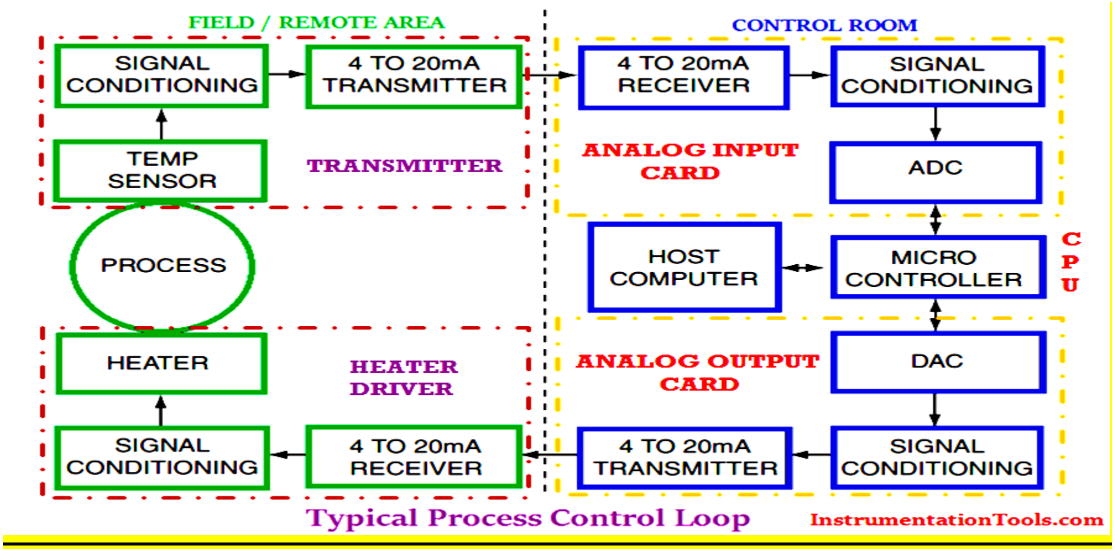
In a Process plant, we have so many Junction boxes installed and connected with number of field devices. Say we have 100 no's of Junction boxes installed that means we have 100 no's main cables are there which are coming from field to control room. so practically it not possible to directly wire these main cables to analog input/output cards. To avoid these problems we use Marshalling cabinet for terminating these 100 no's main cables.

- Marshalling cabinet main purpose is to provide main cables termination and then re-distribute the field devices to respective Analog Input/Output card using internal wiring. Internal wiring will be used to connect from Marshalling cabinet to system cabinet.

- System cabinet consists of Processor card (CPU), Analog Input Cards, Analog Output Cards, Communication cards etc. Once Main cables are terminated in Marshalling cabinet, we have to take these field devices to the respective Analog input card channel. so we use internal wiring to route these main cables/field devices from marshalling to system cabinet.

- Once the main cables are connected to the Analog Input card via internal wiring and it converts the 4-20mA which is coming from field devices into equivalent Digital signal i.e. in Binary codes and the same will be communicated to Processor card. The processor card performs as per the predefined or programmed instructions. The processor card may have inbuilt or separate Ethernet communication link which is used to display the measured process variables on the workstation.

How a Process Control Loop Works



A typical process control system is shown in Figure. Assume the physical variable to be controlled is the temperature.

Basically Industrial process control loop consists of sensors, transmitters, Control systems (PLC/DCS), control valves, Electrical drives etc. These all equipment's installed in different areas of plant.

The Basic Plant areas classified as follows :

1.Field : Sensors, Transmitters, Control valves, on/off valves, local control panels etc.

2.Control Room : PLC, DCS, Microcontroller based controllers etc.

3.Substation : Variable Frequency Drives, Smart Feeders, Softstarters etc.

Basic Process Control Loop Example:

Now we are discussing about a basic temperature process control loop using a heater.

A Temperature Transmitters is required to measure the process variable i.e. process temperature. The transmitters have consists of sensors, signal conditioning circuit and 4-20mA converter. The transmitters basically measures the temperature and provides an output in 4-20mA current which is equivalent to measured temperature.

The transmitter output will goes to the PLC/DCS which is installed in control room. The transmitter wiring is terminated in Marshalling cabinet of PLC/DCS and an internal wiring is provided so that this transmitters output will be routed from marshalling cabinet to system cabinet. The system cabinet have Analog Input cards, Analog Output cards, Communication cards, CPU etc. As transmitters is an input to the system so it will be connected to Analog input card. The Analog input card converts the received 4-20mA into equivalent 1-5v DC using a standard 250 ohms resistor. Then an Analog to Digital Converter (ADC) converts this 1-5V DC into equivalent Binary Codes.

The Analog input card output will be connected to the Processor (CPU). The Processor converts this binary codes into operator readable format i.e. say temperature in degrees and it will be displayed in Graphics.

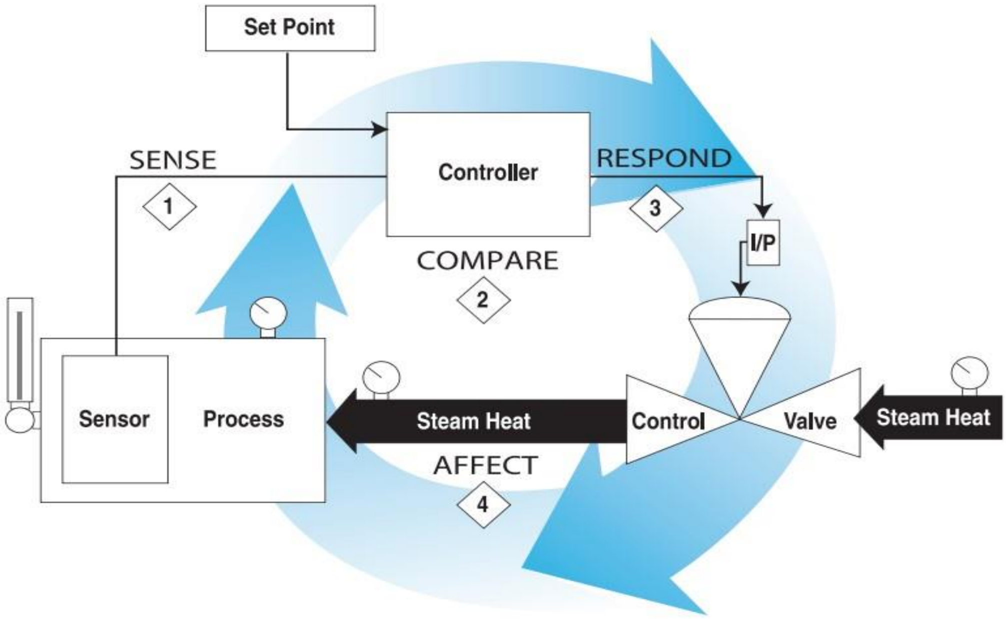
Say, Now the measured temperature value found little bit high when compared to setpoint. If the loop in auto mode then PID controller will takes the necessary action automatically as per predefined program. If the loop in Manual mode then the operator has to take action manually. Note for easy discussion consider loop in auto mode.

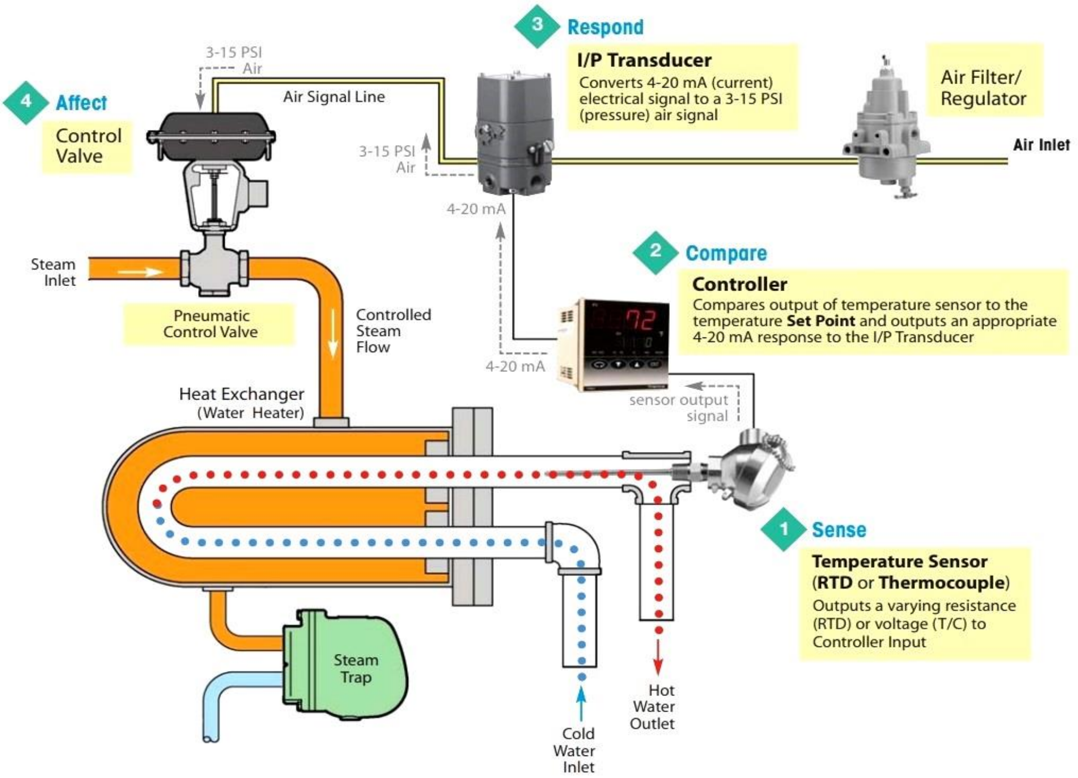
Here in our example we have an heater which is controlling the temperature. heater have standard 4-20mA input which is used for controlling the temperature from 0 to 100% of heater range. As assumed the measured temperature is high so PID controller decides to reduce the temperature.The Analog Output card is connected to the heater, so Processor (CPU) sends a equivalent Binary coded signal to the Analog Output card. The Analog Output card converts the Binary coded signal using a Digital to Analog converter (DAC) which is recieved from Processor and sends an equivalent 4-20mA signal to the heater. The heater receives the 4-20mA from the PLC then takes the necessary action and finally controls the temperature to the desired value.

The Human Machine Interface (HMI) nothing but a computer used for displaying the graphics to the operator. The graphics receives all the signals from the Processor and displays to the operator.

Notice that the interface between the control room and the substation, remote process area or field is via the industry standard 4–20mA loop.

What is a Control Loop ?





Control Loop : A control loop is a process management system designed to maintain a process variable at a desired set point. Each step in the loop works in conjunction with the others to manage the system. Once the set point has been established, the control loop operates using a four-step process.

The Control Loop Steps :

Sense : Measure the current condition of the process using a sensor, which can be a thermocouple or RTD transmitter.

Compare : Evaluate the measurement of the current condition against the set point using an electronic PID controller.

Respond : Reacts to any error that may exist between the measured temperature value and the temperature set point by generating a corrective pneumatic signal.

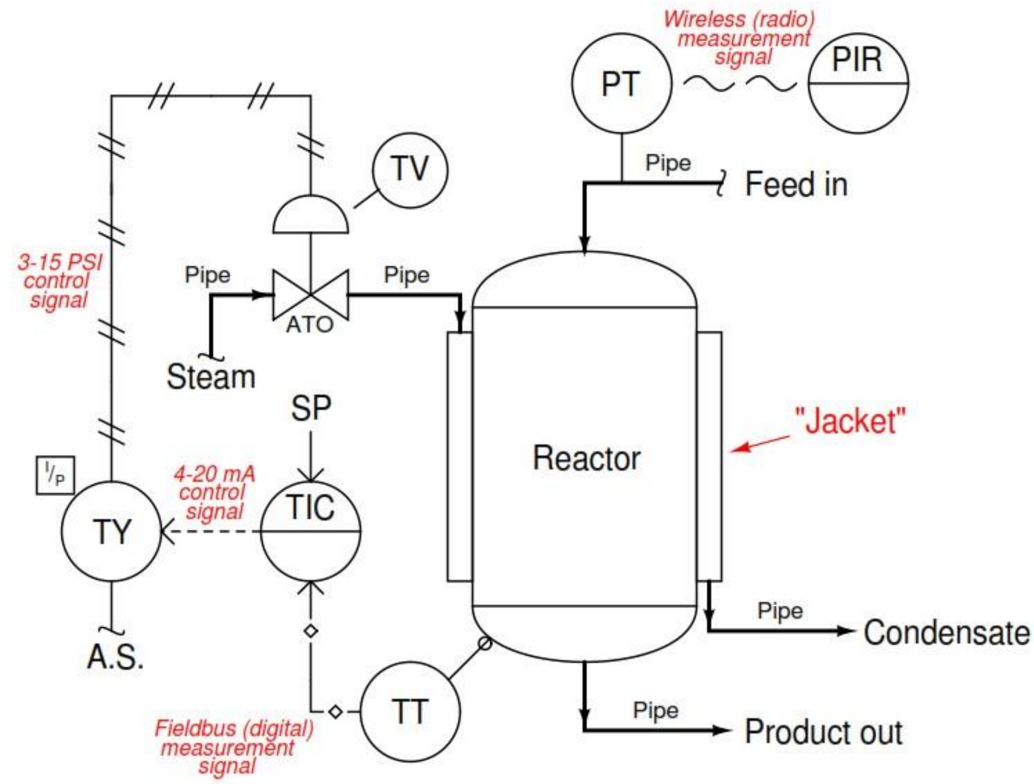
Affect : Actuate the control valve that will produce a change in the process variable.

The loop continually cycles through the steps, affecting the process variable (water temperature) in order to maintain the desired temperature set point.

Principle :

An electronic sensor (thermocouple, RTD or transmitter) installed at the measurement location continuously sends an input signal to the controller. At set intervals, the controller compares this signal to a predefined set point. If the input signal deviates from the set point, the controller sends a corrective electric output signal to the control element. This electric signal must be converted to a pneumatic signal when used with an air operated valve. Using a I/P Transducer, which converts a 4 to 20 mA electric signal to a 3 to 15 PSI air signal and sends the respective air supply to the Control Valve Positioner. The valve positioner adjusts the control valve stem position and regulates the flow through the control valve, accordingly the temperature controls. This loop repeats until controller achieves setpoint.

Reactor Control Principle



The purpose of this control system is to ensure the chemical solution inside the reactor vessel is maintained at a constant temperature. A steam-heated “jacket” envelops the reactor vessel, transferring heat from the steam into the chemical solution inside. The control system maintains a constant temperature by measuring the temperature of the reactor vessel, and throttling steam from a boiler to the steam jacket to add more or less heat as needed.

We begin as usual with the temperature transmitter, located near the bottom of the vessel. Note the different line type used to connect the temperature transmitter (TT) with the temperature indicating controller (TIC): hollow diamonds with lines in between. This signifies a digital electronic instrument signal – sometimes referred to as a fieldbus – rather than an analog type (such as 4 to 20 mA). The transmitter in this system is actually a digital (fieldbus), and so is the controller. The transmitter reports the process variable (reactor temperature) to the controller using digital bits of information. Here there is no analog scale of 4 to 20 milliamps, but rather electric voltage/current pulses representing the 0 and 1 states of binary data.

Digital instrument signals are capable of transferring multiple data points rather than single data points as is the case with analog instrument signals. This means digital instrument signals may convey device status information (such as self-diagnostic test results) as well as the basic measurement value. In other words, the digital signal coming from this transmitter not only tells the controller how hot the reactor is, but it may also communicate to the controller how well the transmitter is functioning.

The dashed line exiting the controller shows it to be analog electronic: most likely 4 to 20 milliamps DC. This electronic signal does not go directly to the control valve, however. It passes through a device labeled “TY”, which is a transducer to convert the 4 to 20 mA electronic signal into a 3 to 15 PSI pneumatic signal which then actuates the valve. In essence, this signal transducer acts as an electrically-controlled air pressure regulator, taking the supply air pressure (usually 20 to 25 PSI) and regulating it down to a level commanded by the controller’s electronic output signal.

At the temperature control valve (TV) the 3 to 15 PSI pneumatic pressure signal applies a force on a diaphragm to move the valve mechanism against the restraining force of a large spring. The construction and operation of this valve is the same as for the feedwater valve in the pneumatic boiler water control system. The letters “ATO” immediately below the valve symbol mean “AirTo-Open,” referring to the direction this valve mechanism will move (wider open) as more air signal pressure is applied to its actuator.

A detail not shown on this diagram, yet critically important to the operation of the temperature control system, is the direction of action for the controller while in automatic mode. It is possible to configure general-purpose controllers to act either in a direct fashion where an increasing process variable signal automatically results in an increasing output signal, or in a reverse fashion where an increasing process variable signal automatically results in a decreasing output signal. An effective way to identify the proper direction of action for any process controller is to perform a “thought experiment ” whereby we imagine the process variable increasing over time, and then determine which way the controller’s output needs to change in order to bring the process variable value back to setpoint based on the final control element’s influence within the process.

In this process, let us imagine the reactor temperature increasing for some reason, perhaps an increase in the temperature of the feed entering the reactor. With an increasing temperature, the controller must reduce the amount of steam applied to the heating jacket surrounding the reactor in order to correct for this temperature change. With an air-to-open (ATO) steam valve, this requires a decreased air pressure signal to the valve in order to close it further and reduce heat input to the reactor. Thus, if an increasing process variable signal requires a decreasing controller output signal, the controller in this case needs to be configured for reverse action.

We could easily imagine reasons why the temperature controller in this process might have to be configured for direct action instead of reverse action. If the piping were altered such that the control valve throttled the flow of coolant to the reactor rather than steam, an increasing temperature would require a further-open valve, which would only happen if the controller were configured for direct action. Alternatively, if the steam valve were air-to-close (ATC) rather than air-to-open (ATO), an increasing reactor temperature (requiring less steam be sent to the reactor) would necessitate the controller outputting an increased signal to the valve, so that more air signal pressure pushed the valve further closed.

Electromagnetic Flow Meters Working Principle

Magnetic flow meter, simply known as mag flow meter is a volumetric flow meter which is ideally used for wastewater applications and other applications that experience low pressure drop and with appropriate liquid conductivity required. The device doesn’t have any moving parts and cannot work with hydrocarbons and distilled water. Mag flow meters are also easy to maintain.

Magnetic flow meters works based on Faraday's Law of Electromagnetic Induction. According to this principle, when a conductive medium passes through a magnetic field B, a voltage E is generated which is proportional to the velocity v of the medium, the density of the magnetic field and the length of the conductor.

In a magnetic flow meter, a current is applied to wire coils mounted within or outside the meter body to generate a magnetic field. The liquid flowing through the pipe acts as the conductor and this induces a voltage which is proportional to the average flow velocity. This voltage is detected by sensing electrodes mounted in the Magflow meter body and sent to a transmitter which calculates the volumetric flow rate based on the pipe dimensions.

Mathematically, we can state Faraday's law as

E is proportional to V x B x L

[E is the voltage generated in a conductor, V is the velocity of the conductor, B is the magnetic field strength and L is the length of the conductor].

It is very important that the liquid flow that is to be measured using the magnetic flow meter must be electrically conductive. The Faraday's Law indicates that the signal voltage (E) is dependent on the average liquid velocity (V), the length of the conductor (D) and the magnetic field strength (B). The magnetic field will thus be established in the cross-section of the tube.

Basically when the conductive liquid flows through the magnetic field, voltage is induced. To measure this generated voltage (which is proportional to the velocity of the flowing liquid), two stainless steel electrodes are used which are mounted opposite each other. The two electrodes which are placed inside the flow meter are then connected to an advanced electronic circuit that has the ability to process the signal. The processed signal is fed into the microprocessor that calculates the volumetric flow of the liquid.

Limitations of electromagnetic Flow Meters

(i) The substance being measured must be conductive. Therefore, it can't be employed for metering the flow rate of gases and steam, petroleum products and similar liquids having very low conductivity.

(ii) To render the meter insensitive to variations in the resistance of liquid, the effective resistance of the liquid between the electrodes should not exceed 1% of the impedance of the external circuit.

(iii) It is a very expensive device.

(iv) As the meter always measures the volume rate, the volume of any suspended matter in the liquid will be included.

(v) To avoid any trouble which would be caused by entrained air, when the flow tube is installed in a horizontal pipe-line, the electrodes should be on the horizontal diameter.

(vi) As a zero check on the installation can be performed only by stopping the flow, isolating valves are required and a bypass may also be necessary through which the flow may be directed during a zero check.

(vii) The pipe must run full, in case regulating valves are installed upstream of the meter.

Applications of Magnetic Flow Meters

This electromagnetic flow meter being non intrusive type, can be used in general for any fluid which is having a reasonable electrical conductivity above 10 microsiemens/cm. Fluids like sand water slurry, coal powder, slurry, sewage, wood pulp, chemicals, water other than distilled water in large pipe lines, hot fluids, high viscous fluids specially in food processing industries, cryogenic fluids can be metered by the electromagnetic flow meter.

Differential Pressure Flow Meters

Differential pressure flowmeters are a type of inferential flowmeter where the flowrate is calculated from a non-flow measurement. In this case various methods of obstructing flow are used to create a pressure drop across a section of pipe. The flow rate is then easily calculated from the measured pressure drop using Bernoulli's prinicple.

Differential pressure meters account for approximately 30% of all flowmeters. They are easily adaptable to a wide variety of applications and are good for handling high temperatures and pressures. They are however, expensive to install relative to other types of flowmeters.

Differential pressure flowmeters, also known as DP flowmeters, create a cross sectional change in the flow tube, which causes the velocity of the flowing fluid to change. A change in velocity occurs whenever there is a change in flow cross-section; i.e., with a decrease in velocity, an increase in pressure occurs.

Differential pressure flowmeters can be used as liquid flowmeters or gas flowmeters; however, a single flow meter may not be configured to measure both liquid and gas phases.

Types of Differential Pressure Flowmeters

Orifice Flowmeters: flat metal plate with an opening in the plate, installed perpendicular to the flowing stream in a circular pipe. As the flowing fluid passes through the orifice, the restriction causes an increase in velocity and decrease in pressure.

A differential pressure transmitter is used to measure pressure between the orifice and the pipe flow stream. There is always a permanent pressure loss. No dirty liquids allowed. Orifice differential pressure flowmeters can be constructed to measure gas, liquid or steam. Orifice plates are primary flow elements which measure flow as a function of differential pressure

Venturi Flowmeters: a restriction with a relatively long passage having a smooth entry and exit. A venturi produces less permanent pressure loss than an orifice but is more expensive.

They are often used in dirty streams because there is no build-up of the foreign material. Venturi flow meters can be constructed to be either gas flowmeters or liquid flow meters.

Nozzle Flowmeters: smooth entry and sharp exit. Permanent pressure loss is on the same level as an orifice, with the added ability to handle dirty and abrasive fluids.

A differential pressure transmitter is used to measure pressure between the nozzle and the pipe flow stream. This type of differential pressure flowmeter technology can be constructed to measure either gas or liquids.

Pitot-static tube Flowmeters: a device consisting of a Pitot tube and an annular tube combined with static pressure ports. The differential pressure between the two ports is the velocity head.

A differential pressure transmitter is used to measure pressure differential between the two ports. This indication of velocity combined with the cross-sectional area of the pipe provides an indication of flow rate. Pitot tube flow meters, can measure either liquids or gases.

Ultrasonic Flowmeters Work

Ultrasonic flowmeters use sound waves to determine the velocity of a fluid flowing in a pipe. At no flow conditions, the frequencies of an ultrasonic wave transmitted into a pipe and its reflections from the fluid are the same. Under flowing conditions, the frequency of the reflected wave is different due to the Doppler effect. When the fluid moves faster, the frequency shift increases linearly. The transmitter processes signals from the transmitted wave and its reflections to determine the flow rate.

Transit time ultrasonic flowmeters send and receive ultrasonic waves between transducers in both the upstream and downstream directions in the pipe. At no flow conditions, it takes the same time to travel upstream and downstream between the transducers. Under flowing conditions, the upstream wave will travel slower and take more time than the (faster) downstream wave. When the fluid moves faster, the difference between the upstream and downstream times increases. The transmitter processes upstream and downstream times to determine the flow rate. They represent about 12% of all flowmeters sold.

How to Use Ultrasonic Flowmeters

Ultrasonic flowmeters are commonly applied to measure the velocity of liquids that allow ultrasonic waves to pass, such as water, molten sulfur, cryogenic liquids, and chemicals. Transit time designs are also available to measure gas and vapor flow. Be careful because fluids that do not pass ultrasonic energy, such as many types of slurry, limit the penetration of ultrasonic waves into the fluid. In Doppler ultrasonic flowmeters, opaque fluids can limit ultrasonic wave penetration too near the pipe wall, which can degrade accuracy and/or cause the flowmeter to fail to measure. Transit time ultrasonic flowmeters can fail to operate when an opaque fluid weakens the ultrasonic wave to such an extent that the wave does not reach the receiver.

Industries Where Used

The industries in order of higher to lower are oil and gas, water and wastewater, power, chemical, food and beverage, pharmaceutical, metals and mining, and pulp and paper.

Application Cautions for Ultrasonic Flowmeters

For transit time ultrasonic flowmeters, be sure that the fluid can adequately conduct ultrasonic waves, because the flowmeter will not measure when the ultrasonic waves cannot penetrate the flow stream between the transducers. Similarly, ultrasonic waves must be able to penetrate the fluid for Doppler flowmeters to operate accurately. When the fluid is relatively opaque and does not penetrate the fluid, Doppler flowmeters tend to measure the velocity of the fluid at or near the pipe wall, which can cause significant measurement error and/or cause the flowmeter to fail.

For Doppler ultrasonic flowmeters, be sure that the fluid adequately reflects ultrasonic waves, because the flowmeter will not operate without a reflected ultrasonic signal. Depending upon design, reflections can occur due to small bubbles of gas in the flow stream or the presence of eddies in the flow stream. If not already present in the flowing stream, generating these sources of reflection can be difficult in practice. Fortunately, some combination of bubbles of gas and/or eddies are present in most applications.

The velocity of the solid particles in slurry can be different than its liquid carrier fluid. Be careful applying ultrasonic technology when the solid particles can become concentrated in one part of the flowing stream, such as in a horizontal pipe flowing at a relatively low velocity. Be careful when applying Doppler ultrasonic flowmeters in slurry applications because the solid particles can produce strong signals that can cause the Doppler flowmeter to measure the velocity of the solids and not the velocity of the liquid.

Avoid fluids that can coat wetted transducers or coat the pipe wall in front of non-wetted transducers because the flowmeter will not measure when the ultrasonic waves cannot enter the flow stream. Be sure to maintain reliable clamp-on transducer connections to the pipe wall because the flowmeter will not measure when the ultrasonic waves are not able to reach the fluid.

Be sure to understand the process and apply these flowmeters properly. For example, a periodic cleaning process upstream may cause the flowmeter to stop working because the dirt may not allow ultrasonic energy to pass through the fluid. Further, if the dirt coats wetted transducers, the flowmeter may fail to operate until it is cleaned.

Magnetic Flowmeter Technonogy

Magnetic flowmeters use Faraday's Law of Electromagnetic Induction to determine the flow of liquid in a pipe. In a magnetic flowmeter, a magnetic field is generated and channeled into the liquid flowing through the pipe. Following Faraday's Law, flow of a conductive liquid through the magnetic field will cause a voltage signal to be sensed by electrodes located on the flow tube walls. When the fluid moves faster, more voltage is generated. Faraday's Law states that the voltage generated is proportional to the movement of the flowing liquid. The electronic transmitter processes the voltage signal to determine liquid flow.

In contrast with many other flowmeter technologies, magnetic flowmeter technology produces signals that are linear with flow. As such, the turndown associated with magnetic flowmeters can approach 20:1 or better without sacrificing accuracy. They represent about 23% of all flowmeters sold.

Plusses and Minuses

Mags are intermediate in accuracy therefore not commonly used for commodity transfer except for some special cases where the fluid is not expensive like water. Can be adapted for sanitary uses. They have large line sizes available. No pressure drop induced. Dirty liquids and even slurries OK. Very reliable. On the other hand, don't work on nonconductive fluids such as oils. Steam or gas flows don't register. Electrodes can become coated.

How to Use Magnetic Flowmeters

Magnetic flowmeters measure the velocity of conductive liquids in pipes, such as water, acids, caustic, and slurries. Magnetic flowmeters can measure properly when the electrical conductivity of the liquid is greater than approximately 5µS/cm. Be careful because using magnetic flowmeters on fluids with low conductivity, such as deionized water, boiler feed water, or hydrocarbons, can cause the flowmeter to turn off and measure zero flow.

This flowmeter does not obstruct flow, so it can be applied to clean, sanitary, dirty, corrosive and abrasive liquids. Magnetic flowmeters can be applied to the flow of liquids that are conductive, so hydrocarbons and gases cannot be measured with this technology due to their non-conductive nature and gaseous state, respectively.

Magnetic flowmeters do not require much upstream and downstream straight run so they can be installed in relatively short meter runs. Magnetic flowmeters typically require 3-5 diameters of upstream straight run and 0-3 diameters of downstream straight run measured from the plane of the magnetic flowmeter electrodes.

Applications for dirty liquids are found in the water, wastewater, mining, mineral processing, power, pulp and paper, and chemical industries. Water and wastewater applications include custody transfer of liquids in force mains between water/wastewater districts. Magnetic flowmeters are used in water treatment plants to measure treated and untreated sewage, process water, water and chemicals. Mining and mineral process industry applications include process water and process slurry flows and heavy media flows.

With proper attention to materials of construction, the flow of highly corrosive liquids (such as acid and caustic) and abrasive slurries can be measured. Corrosive liquid applications are commonly found in the chemical industry processes, and in chemical feed systems used in most industries. Slurry applications are commonly found in the mining, mineral processing, pulp and paper, and wastewater industries.

Magnetic flowmeters are often used where the liquid is fed using gravity. Be sure that the orientation of the flowmeter is such that the flowmeter is completely filled with liquid. Failure to ensure that the flowmeter is completely filled with liquid can significantly affect the flow measurement.

Be especially careful when operating magnetic flowmeters in vacuum service because some magnetic flowmeter liners can collapse and be sucked into the pipeline in vacuum service, catastrophically damaging the flowmeter. Note that vacuum conditions can occur in pipes that seemingly are not exposed to vacuum service such as pipes in which a gas can condense (often under abnormal conditions). Similarly, excessive temperature in magnetic flowmeters (even briefly under abnormal conditions) can result in permanent flowmeter damage.

Industries Where Used

In order of usage, water/wastewater industry, chemical, food and beverage, oil and gas (although not for oil and gas fluids but in support of the processes), power, pulp and paper, metals and mining, and pharmaceutical.

Application Cautions for Magnetic Flowmeters

Do not operate a magnetic flowmeter near its electrical conductivity limit because the flowmeter can turn off. Provide an allowance for changing composition and operating conditions that can change the electrical conductivity of the liquid.

In typical applications, magnetic flowmeters are sized so that the velocity at maximum flow is approximately 2-3 meters per second. Differential pressure constraints and/or process conditions may preclude application of this general guideline. For example, gravity fed pipes may require a larger magnetic flowmeter to reduce the pressure drop so as to allow the required amount of liquid to pass through the magnetic flowmeter without backing up the piping system. In this application, operating at the same flow rate in the larger flowmeter will result in a lower liquid velocity as compared to the smaller flowmeter.

For slurry service, be sure to size magnetic flowmeters to operate above the velocity at which solids settle (typically 1 ft/sec), in order to avoid filling the pipe with solids that can affect the measurement and potentially stop flow. Magnetic flowmeters for abrasive service are usually sized to operate at low velocity (typically below 3 ft/sec) to reduce wear. In abrasive slurry service, the flowmeter should be operated above the velocity at which solids will settle, despite increased wear. These issues may change the range of the flowmeter, so its size may be different than the size for an equivalent flow of clean water.

The closest technology to Mag that could possibly handle similar applications more cost effectively would be vortex shedding. They can handle light particulate, have a higher pressure drop, lower rangeability and are slightly less accurate

Differential Pressure Flowmeter Technology

Differential pressure flowmeters use Bernoulli's equation to measure the flow of fluid in a pipe. Differential pressure flowmeters introduce a constriction in the pipe that creates a pressure drop across the flowmeter. When the flow increases, more pressure drop is created. Impulse piping routes the upstream and downstream pressures of the flowmeter to the transmitter that measures the differential pressure to determine the fluid flow. This technology accounts for about 21% of the world market for flowmeters.

Bernoulli's equation states that the pressure drop across the constriction is proportional to the square of the flow rate. Using this relationship, 10 percent of full scale flow produces only 1 percent of the full scale differential pressure. At 10 percent of full scale flow, the differential pressure flowmeter accuracy is dependent upon the transmitter being accurate over a 100:1 range of differential pressure. Differential pressure transmitter accuracy is typically degraded at low differential pressures in its range, so flowmeter accuracy can be similarly degraded. Therefore, this non-linear relationship can have a detrimental effect on the accuracy and turndown of differential pressure flowmeters. Remember that of interest is the accuracy of the flow measurement system --- not the accuracy of the differential pressure transmitter.

Different geometries are used for different measurements, including the orifice plate, flow nozzle, laminar flow element, low-loss flow tube, segmental wedge, V-cone, and Venturi tube.

Plusses and Minuses

The upside of this technology is low cost, multiple versions can be optimized for different fluids and goals, are approved for custody transfer (though it is being used less and less for this), it is a well understood way to measure flow, and it can be paired up with temperature/pressure sensors to provide mass flow for steam and other gasses. Negatives are that rangeability is not good due to a non-linear differential pressure signal (laminar flow elements excepted), accuracy is not the best and can deteriorate with wear and clogging.