AUTOMATIC PROCESS CONTROL

CHAPTER - 1

SCIENCE OF AUTOMATIC CONTROL

Automatic process control is a principle part of the industrial progress during what is now termed as 'Second Industrial Revolution'. The industrial revolution witnessed the development of process industries when machines were substituted for human physical power. The early production processes were natural scale-up versions of the traditional manual practices. They were designed as batch process and later replaced by continuous processes which resulted in economic and technological benefits. There has been an increasing trend over the years towards larger and more complex plants and processes to take advantage of the economies of scale and technological developments.

The industrial process automation (or control) also came into existence since industries started. . The increase use of science of automatic control has come about through evolution rather than revolution. The engineers and designers of process industries always tried to automate the processes as much as possible, based on the available instruments. There has been a continuous development of industrial process which required the development of better instrumentation and automatic control. Conversely, the advancement in instrumentation and control contributed to the development on larger and more complex processes, bringing numerous new technologies an economic benefit made possible from the old. Automatic control is concerned with maintaining process variable i.e. temperature, pressure, flow, composition etc. at the desired operating value. Processes are dynamic in nature, changes are always occurring and if actions are not taken, the important process variable those related to safety, production quality, and production rate will not achieve desired condition. Elimination of human error is another positive contribution of the use of automatic control.

Automatic control devices are used in almost every phase of industrial operation. They are commonly used in –

1. Processing industries such as – petroleum, chemical, steel, power, paper pulp and paper mills, pharmaceuticals, foods and beverages, etc. For the control of temperature, pressure, flow and similar variables.
2. Goods manufacturers such as automobile parts, refrigerator, radios etc. for the control of assembly operations, work flow, heat treating and similar operations.
3. Transportation system such as railways, airplanes and ships.
4. Power machines such as machine tools, compressors and pumps, prime movers and electric power supply units for the control of position, speed and power.
5. Water and sewage treatment plants.

Advantages of Automatic Control :

1. Increase in quality of products.
2. Increase in quantity or no. of products.
3. Improvement in uniformity of products.
4. Saving in processing materials.
5. Saving in energy and power equipment.
6. Saving in plant equipment.
7. Decrease in human negligence as well as elimination of human error.

These factors generally lead to an increase in productivity.

Process Variables:

1. Controlled variable – It is that variable which directly or indirectly indicate the form or state of the product. e.g. temperature in a chemical reactor, outlet temperature of water in a water heater.
2. Manipulated variable – It is that variable which is selected for adjustment by the controller so as to maintain the controller variable at the desired value. Examples are cooling by changing cooling water flow rate of steam for heating in chemical reactors.
3. Load variable – All other independent variables except controlled and manipulated variables are called load variable. For e.g. inlet concentration and temperature of reactors in a chemical reactor, inlet temperature of cooling water or cold water in water heater.

Definitions:

Some important terms commonly used in APC are given below –

1. Process – It is a physical or chemical change of matter or conversion of in the widest sense.
2. Controlled condition – It is the condition of the process which is the direct purpose of the system to control.
3. Measuring element – The element which response to the signal from the detecting element and gives the measured value of the controller condition is known as measuring element.
4. Comparing element – It is that part of the controller which generates a signal proportional to the deviation.

5. Desired value – The specified value of a controlled condition or an agreed value is known as the desired value.
6. Set value – The value of the controlled condition to which the automatic controller mechanism is set is known as the set value or set point.
7. Deviation – The differences between the set value and the measured value of the controlled condition is known as deviation.

   A positive sign means the set value is greater than the measured value and negative sign means the measured value is greater.
8. Controlling element – It is the element which provides the controlled signal a support, which is depending upon the deviation of the correcting unit.
9. Automatic controller – It is a device which compares a signal from the detecting element with a signal representing the set value and which operates in such a way so as to reduce the deviation.
10. Offset – A sustained deviation due to an inherent characteristic of proportional controller action is known as offset.

Controlled System:

A controlled system consists of a controller and a plant which may be a machine, vehicle or process that is to be controlled. The controller is the system that is required to produce satisfactory result for the plant.

A ‘manual controlled system’ is one where the controller is a person. The alternative to this is an ‘automatic controlled system’ where the controller is a device, usually implemented electronically, either using analogue circuits or a digital computer (microprocessors).

There are two types of controlled systems –

a) Manual Control – In the given situation, the shower is cold. To start the heating process, the value in the hot water line is open. The operator (person) can determine the temperature by standing in the shower. If the water is too hot, the valve should be closed accordingly.

b) Automatic Control – In this type of control the person or operator only has to pre-set the temperature of water and the process is automatically control by –

- A temperature measurement device.
- A special kind of valve called as controlled valve for comparison and computation; it can also give orders.

Definition of Automatic Control:

Automatic control is the maintenance of a desired value of a quantity or condition by measuring existing value, comparing it to the desired value and employing the difference to initiate action for reducing this difference

Examples of Automatic Process Control Systems:

1. **Temperature Control in Heat Exchanger.**

Let us consider a heat exchanger in which a process steam is heated by condensing steam as shown in Fig. below.

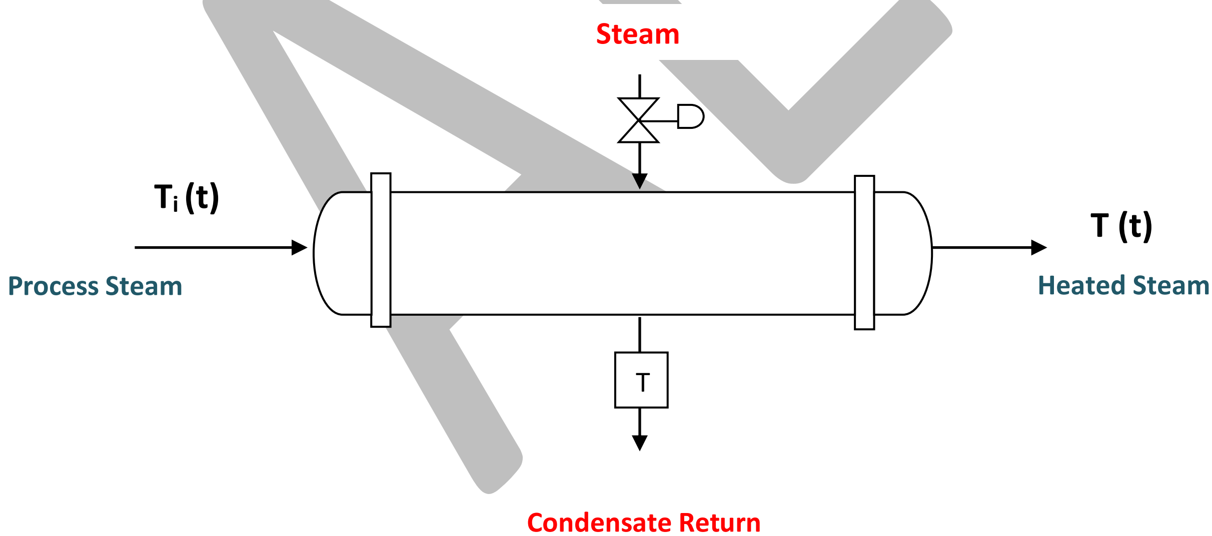


Fig: Heat Exchanger

This heat exchanger is used to heat the process fluid from some inlet temperature T_i (t) up to a desired outlet temperature T(t). The energy gained by the process fluid is provided by the latent heat of condensation of the steam. There are number of variables in this process that can change causing the outlet temperature to deviate from its desired value. Therefore, action must be taken to correct any deviation so as to maintain the outlet process temperature at its desired value T(t).

This objective can be achieved by measuring the outlet temperature T(t) and correcting any deviation by comparing it to the desired (set point) value. The steam valve can be manipulated (by throttling and opening the steam flow) to correct the deviation. The above can be done by manual control in which the operator has to frequently monitor the temperature to take corrective action to maintain the desired (set) value by opening or closing of steam flow valve. This type of manual control system will be operator dependent and vary from operator to operator. Also, it would be extremely difficult for operator to monitor hundreds of variables and take corrective action to maintain the desired value. Therefore, this manual control can be replaced with an automatic process control by designing and implementing a suitable control system as shown in Fig below.

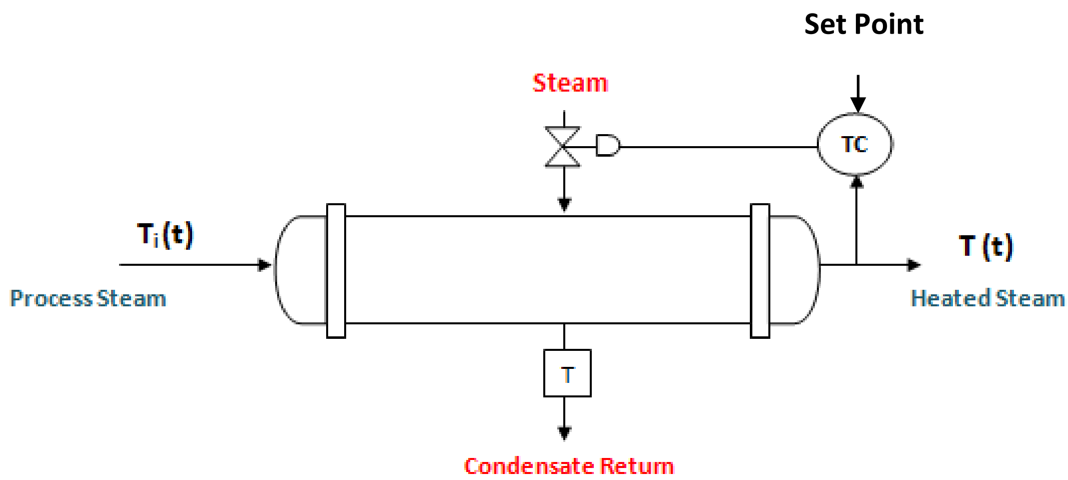


Fig: Heat Exchanger Control System

The outlet temperature T(t) is measured by a sensor and transmitted to the temperature controller TC. Temperature controller compares this measured value with the desired value and depending upon the difference it sends the signal to final control element which manipulates the steam flow by opening or closing the valve.

2. Home heating system :

In the below figure depending upon the difference in temperature between the required value and the measured value, a valve is operated to adjust the fuel gas supply to the furnace to bring the home temperature to the wanted value

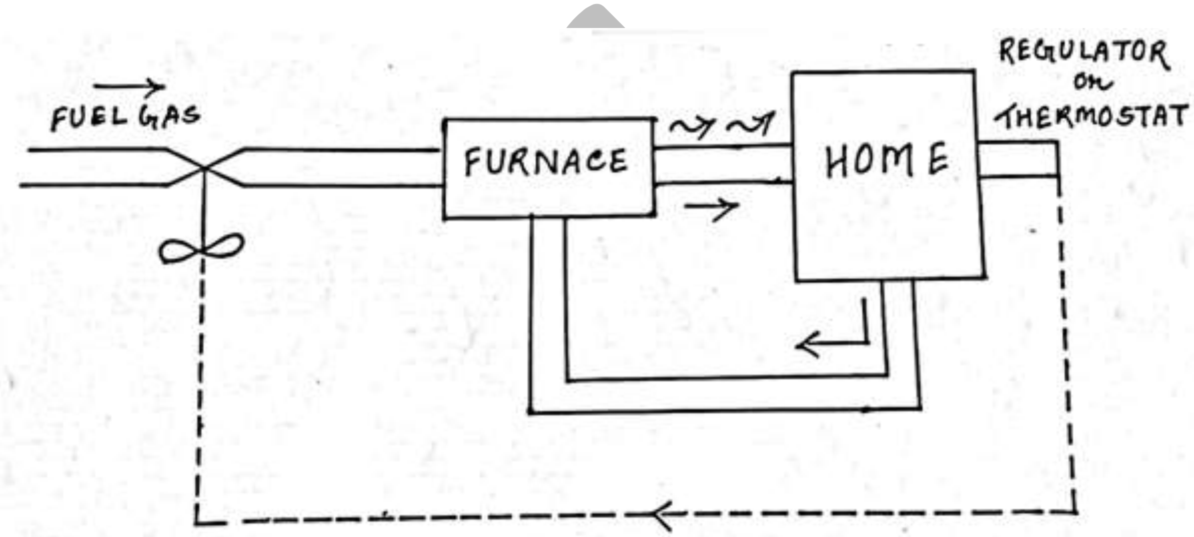


Fig: Home heating system

3. Temperature control in exothermic reactor.

In the next figure the temperature in the reactor is measured by the TIC (temperature indicating controller) and changes the inlet cooling fluid flow rate depending upon the error i.e. the difference between the measured value and the desired value.

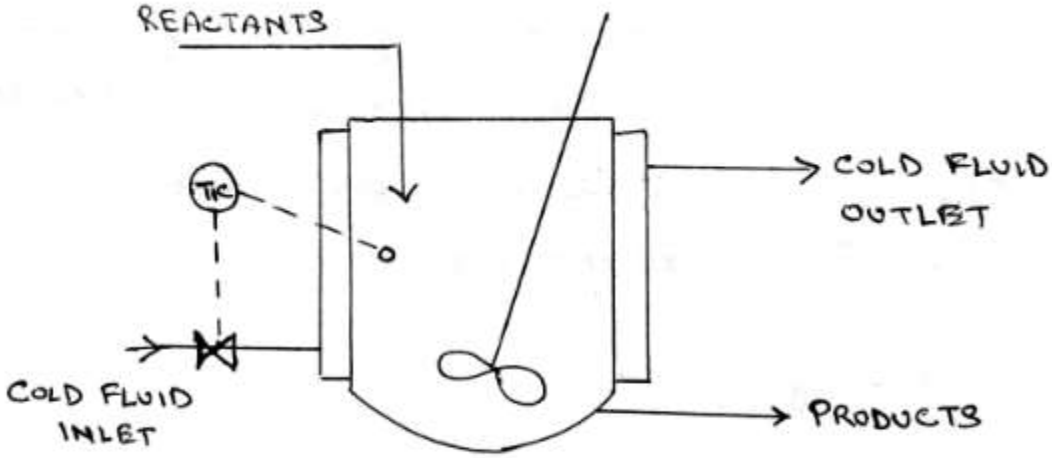


Fig : Exothermic Reactor

Types Of Control Systems:

There are different types of process control systems that are useful in the analysis and design of modern process control systems. We will study here two types of control system, they are:-

1. Open Loop Control System
2. Closed Loop Control System

1. Open Loop Control System :

An open loop control system is one in which the control action is independent of the output. In other words, the input has no control over the output (controlled variable). An example of the chemical addition pump with variable speed control is given in the figure. The feed rate of the chemicals that maintain proper chemistry of the system determined by an operator who is not part of the system. If the chemistry of the system changes, the pump cannot respond by adjusting its feed rate (speed) without operator's action.

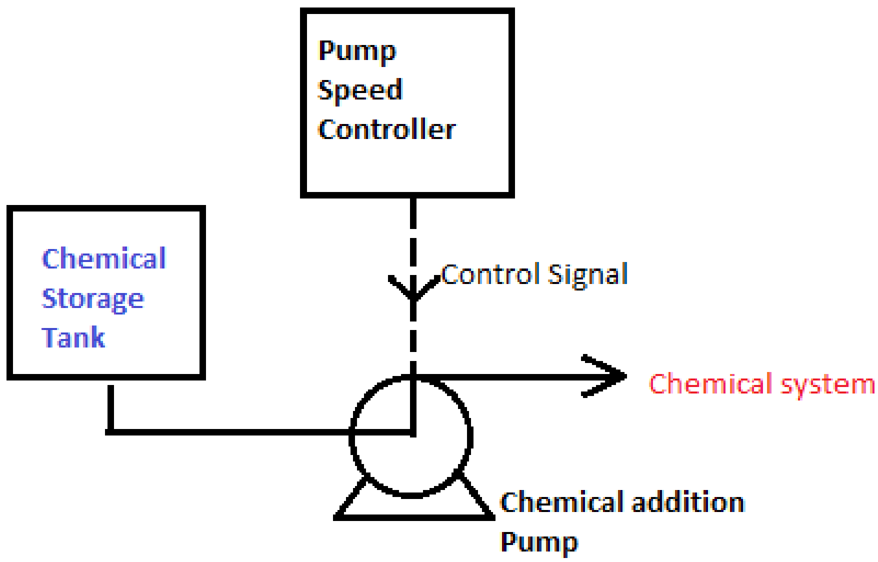


Fig: Open Loop Control System

Advantages : It is very simple system to design.

Disadvantages : In an open-loop control system, the input has no control over the output (controlled variable).

2. Closed-loop or Feedback Control System:

In a closed-loop (or feedback) control system, the input has control over the output (controlled variable). In this system, the controlled variable (the output quantity to be controlled) is measured and fed back to the controller through a path (or loop). The controller then compares a desired (Set value) plant value with the actual measured output value and acts to reduce the difference between the two to zero value.

A strong motivation for using feedback control is to correct the error between the controlled output and its desired value corresponding to the Set value. Feedback also affects other system performance characteristics such as stability, sensitivity and overall performance of the process. . Thus automatic control requires a closed loop of action and reaction operating without human aid. Some examples of Closed Loop control are given below –

a. Home Heating System :

To illustrate the closed loop action, we consider the example of home heating system as given in the figure below –

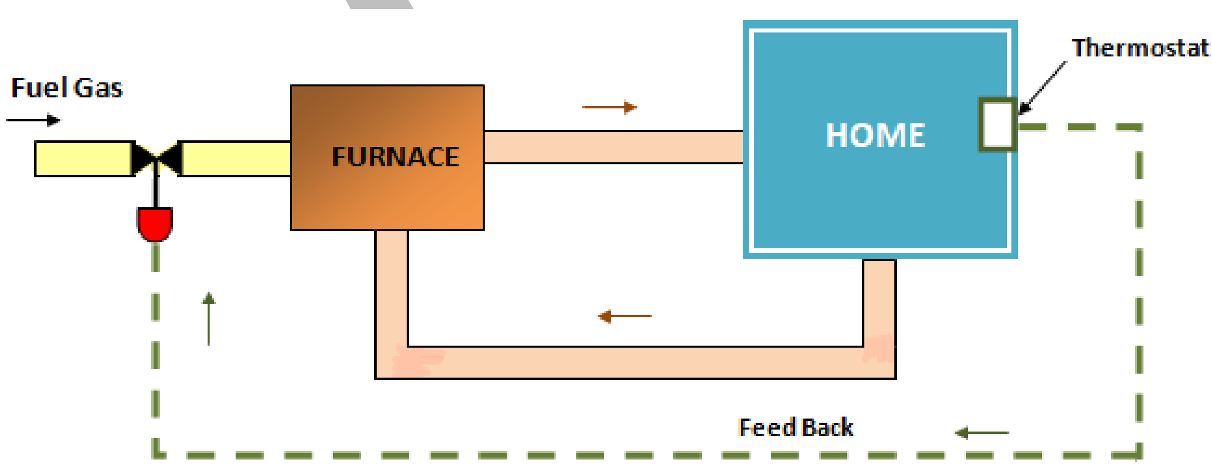


Fig: Home Heating System.

Suppose it is desired to maintain the temperature of a home at 21°C. This temperature is the desired value or set point. A thermostat (thermometer, regulator) is installed on an inside wall of the home and measures the existing room temperature. The temperature of the room is the controlled variable. But the thermometer notes that the temperature is 18°C which is less than the desired value. The actuating signal is 3°C. An action is then taken to reduce this difference by opening a valve that turns on the fuel gas to the furnace burners. The flow of fuel gas is the manual manipulated variable. As the furnace heats, warm air is delivered to the room (home) and the temperature will increase. In a short time, the temperature becomes too high and the whole sequence must be repeated in the opposite direction.

The control action is characterized by the closed loop from control variable to deviation to manipulated variable then again to control variable and the cycle repeats as shown in the figure.

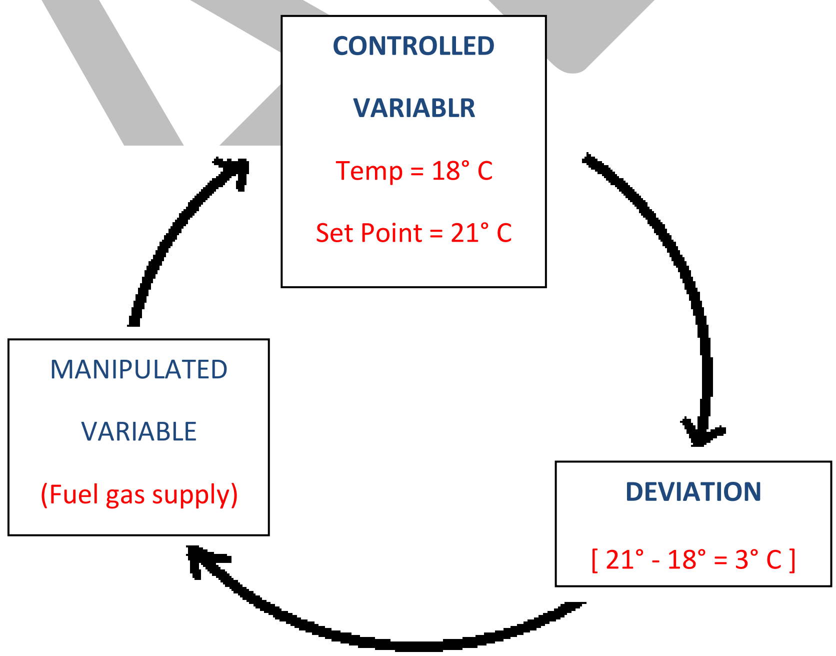


Fig: Control Action in Closed loop

b. Water tank closed loop control (level control):

A closed loop control is one in which the control action is dependent on the output. In the given figure, the control system maintains the water level in a storage tank. The system performs this task by continuously sensing the level in the tank and adjusting a supply valve to add more or less water to the tank. The desired level is pre-set by an operator, who is not a part of the system.

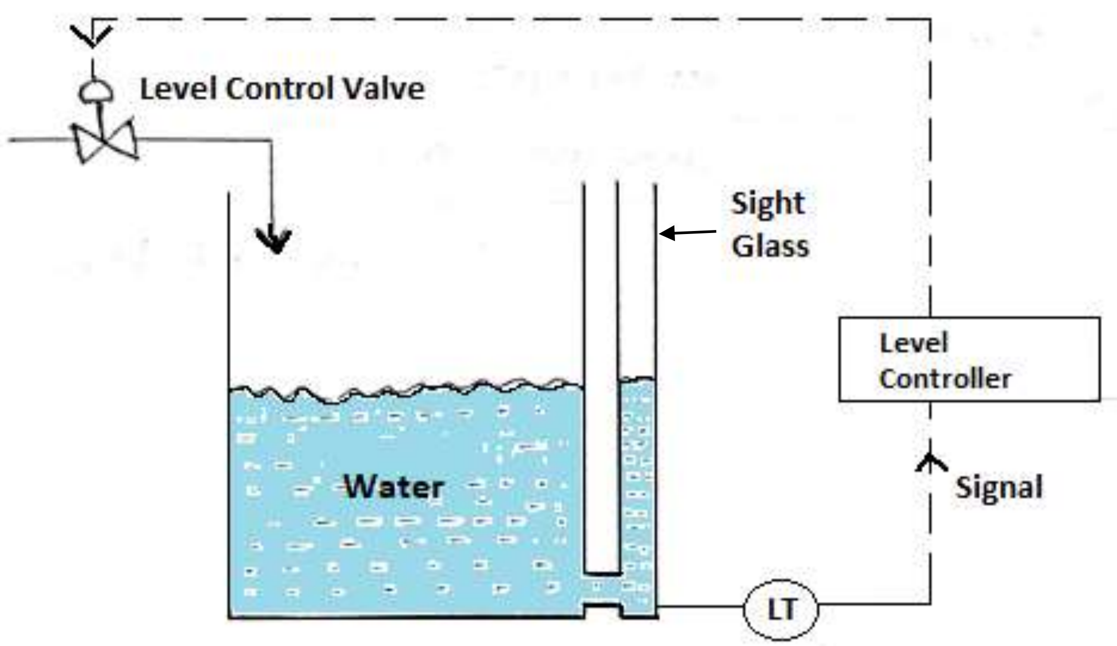


Fig : Water tank Level Control (Close loop)

<u>Advantages of feedback control system are:</u>

(i) The controller adjusts the controlled variable with the set point

(ii) The feedback control loop does not care for the disturbances entering into the process. It tries only to maintain the controlled variable at set point.

<u>Disadvantage :</u> The feedback controllers continue changing its output until measurement and set point are in agreement.

AUTOMATIC CONTROLLERS

Most industrial processes require that certain variables such as flow, pressure, temperature and level should remain at or near some reference value, called a set point (SP). The device that serves to maintain a process variable value at the set point is called a controller. The basic functions of an automatic controller are –

i. Receive the actual measured value of the variable being controlled.
ii. Compare that value with a reference or desired value (set-point).
iii. Determine the magnitude and direction of any error or deviation.
iv. Provide an output control signal as some function of the deviation which will reduce the deviation to zero or to a small value.

Industrial automatic controllers may be classified into two broad groups i.e.-

A. According to their control action.
B. Depending upon the actuating medium

A. Different Modes of Control Action

The method by which the automatic controller produces the counter action to eliminate or reduce error is called the mode of control or control action.

The simplest type of control action is **'proportional control'** why the output 'y' of the controller is directly proportional to the error 'e'.

In case of **'integral control'** the output is proportional to the integral 'e' and in the case of **'derivative control'** the output is proportional to $\frac{de}{dt}$.

Another type of control action is the **'on & off'** control where the output has only two states.

Proportional Control:

A proportional (P) action is a mode of control action which continuously adjusts the manipulated variable so that the input to the process is approximately in balanced with the process demand. In proportional control, the output of the controller is proportional to the error.

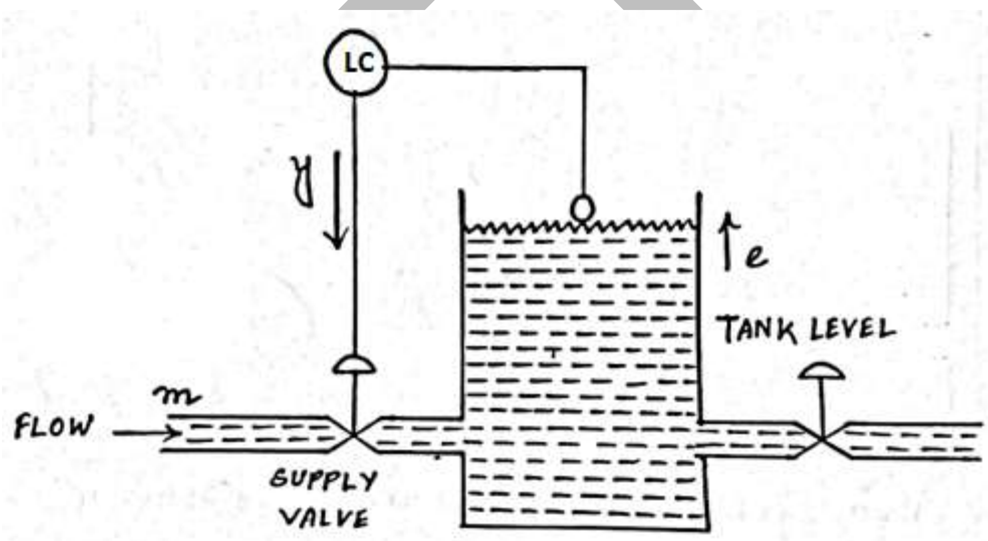


Fig: Proportional Control on a Level Process

The given figure shows the proportional type of control action as applied to a level process. Controlled variable is the level of the liquid in the tank 'e' represents change in the level or error or deviation in the level (i.e. e = set point-measured variable),'y' represents the movement of the control valve. If the level tends to change from the set point example it increases as shown, y tends to move downward, the valve closes the inflow 'm' i.e. the manipulated variable is reduced as the level decreases to the set point or till steady state is achieved. Thus –

$$m \propto e$$

$$m = K.e$$

where, m= manipulated variable

e= error = set point - measured variable

K= proportional sensitivity

The proportional sensitivity (K) is the change of manipulated variable caused by unit change of deviation /error.

Proportional control is essentially an amplifier with an adjustable gain. It is used where the error signal is weak and need some amplification.

The main limitation of a Proportional control is that it cannot keep the controlled variable on set point. Therefore controlled variable will increase or decrease from set point creating offset.

Integral Control:

In Integral Control output is proportional to the integral of e. An integral control is illustrated in the below figure. A set point mechanism is omitted in the diagram. A variable ratio speed reducer consisting of two parallel disks with a friction drive roller which operates control valve through gears. The left-hand disk is driven at constant speed by an electric motor. The piston of the friction driven roller is set by the float and arm. The controller action is as follows: -

A rise in level in the tank causes driver roller to move up from the neutral point. The speed of the valve stem is proportional to the change in level. A fall of levels move the drive roller below the neutral point and the valve is moved at a proportional speed in the opposite direction.

Integral control follows the following law: -

$$m = \frac{1}{Ti} e \text{ .... } (1)$$

or in integral form

$$m = \frac{1}{Ti} \int edt + M \text{ .... } (2)$$

where, m = manipulated variable

Ti = integral time

e = deviation

M = constant of integration

The integral time (Ti) is defined as the tie of change of the manipulated variable caused by a unit change or deviation.

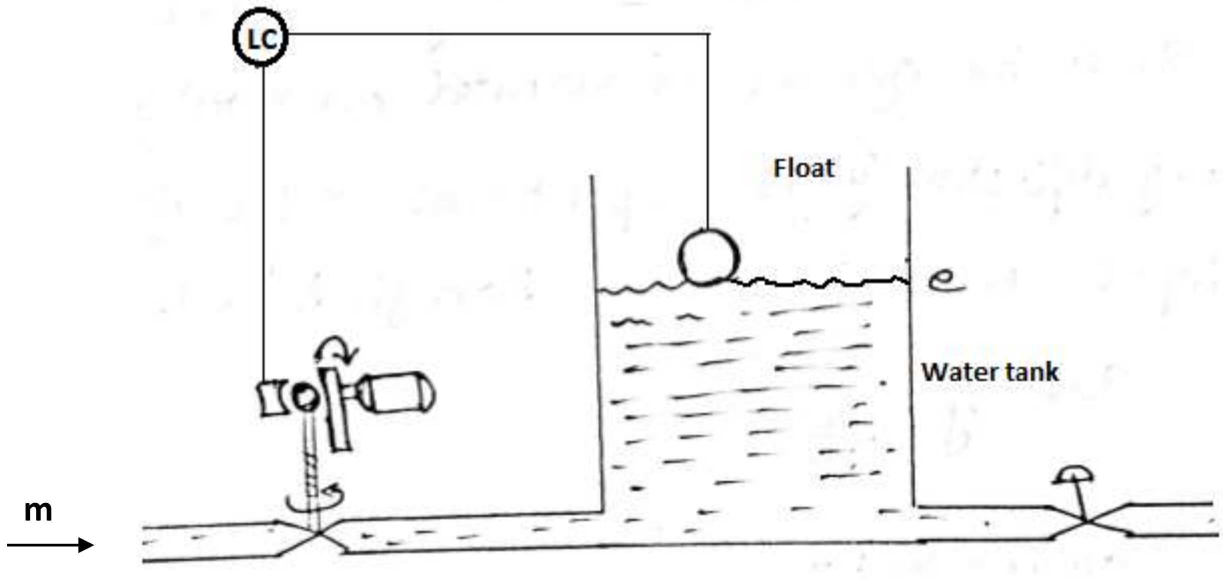


Fig : Integral Control on a Level Process

For a step change of deviation –

$$e = 0,\ t < 0$$

$$e = E,\ t \geq 0$$

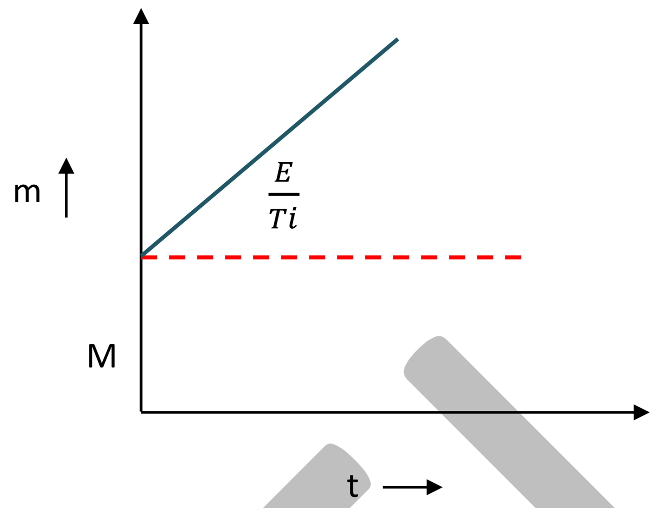
Where, E is a constant

Then from equation (2) we have –

$$m - M = \frac{Et}{Ti}$$

$$\text{or } m = \frac{Et}{Ti} + M$$

$$\text{or } m = \frac{E}{Ti}t + M$$



Integral control is also called reset control or proper floating mode of control.

ADVANTAGES:

- Even for zero error the value of output remains stationary.
- Offset of a Proportional Control is removed in Integral Control

Derivative Control

In derivative type of control, output signal 'y' is proportional to the derivative of error signal or the control action is proportional to the rate of change of control variable.

Referring to the below figure if 'x' were to rise, the piston was moved down with a velocity producing of force proportional to it, due to shearing action in the viscous oil. Since the cylinder is mounted on springs, the spring deflection 'y' is proportional to the force developed and transmitted through the oil, so

$$y \propto \frac{dx}{dt}$$

$$\text{or } y = K_2 Dx$$

Where, $D = \frac{d}{dt}$

K_2 = constant

In this type of control, the controller output is more if the rate of change of 'x' is more. If 'x' is constant or the float stops at any position away from the set point, the piston could also stop and the spring could restore the cylinder to its initial position. Derivative control action provides the means of obtaining a controller with high sensitivity. An advantage of using derivative control action is that it responds to the rate of change of the actuating error and can produce a significant correction before the magnitude of the actuating error becomes too large.

Since the derivative control mode acts on the rate at which the error signal changes and not on the error itself, thus derivative control is always used along with proportional control or proportional plus integral control so that the controller output is proportional to a deviation as well as its rate of change.

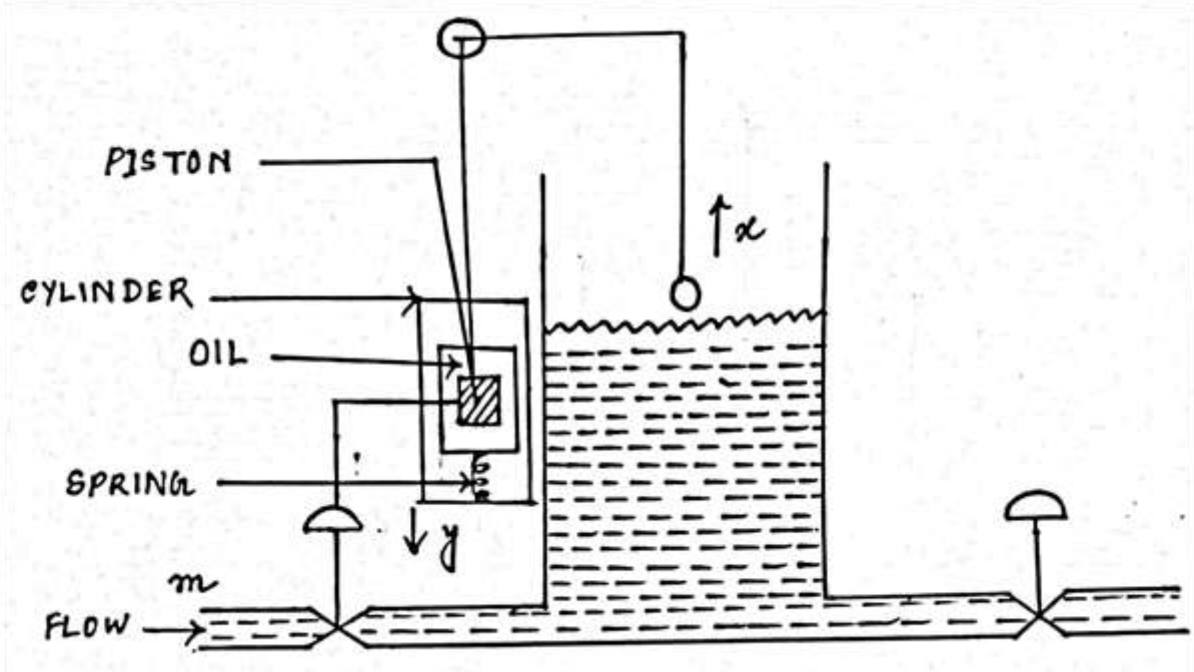
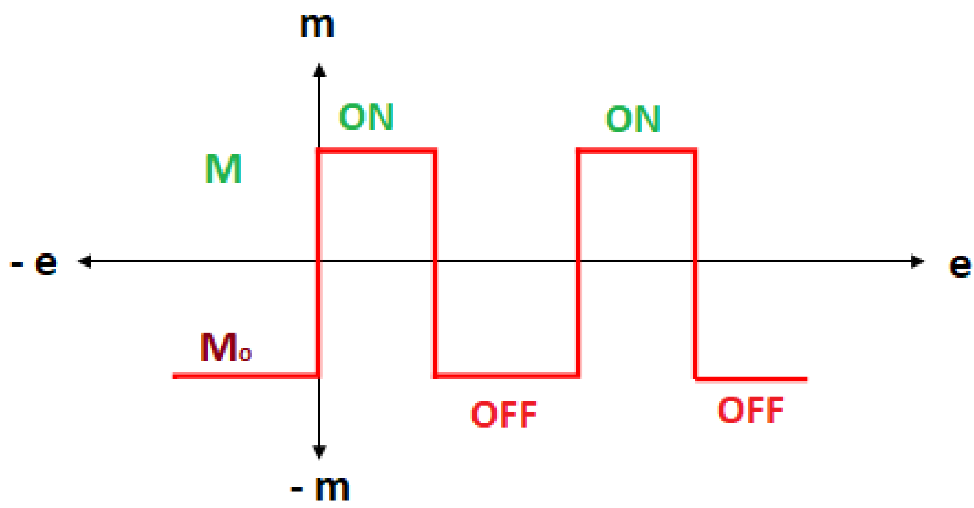


Fig : Derivative Control on a Level Process

Two Position Or On –Off Control:

In ON-OFF control action the output has only two states; fully ON or fully OFF i.e. the manipulated variable is changed either to maximum or minimum value depending upon the controlled variable, whether it is greater or less than the set point. On-off controller is normally used for low loads. A differential gap makes the manipulated variable to maintain its previous value till the controlled variable moves beyond the set point slightly. The working of this action is shown in this figure:-



Graph: m Vs e of Two Position Control

The equation for two positions is:-

$m = M_1$ when $e > 0$

$m = M_0$ when $e \leq 0$

Where, m = manipulated variable

M_1 = maximum value of manipulated variable (ON)

M_0 = minimum value of manipulated variable (OFF)

CHAPTER - 2

CONTROLLING ELEMENTS

The automatic control may operate through purely mechanical means but after through an auxiliary source of fluid or electric power is employed to actuate the control mechanism and to drive a final control element. The controlling means is usually classified according the kind of power employed in operation. They may be self operated, pneumatic, hydraulic and electronic.

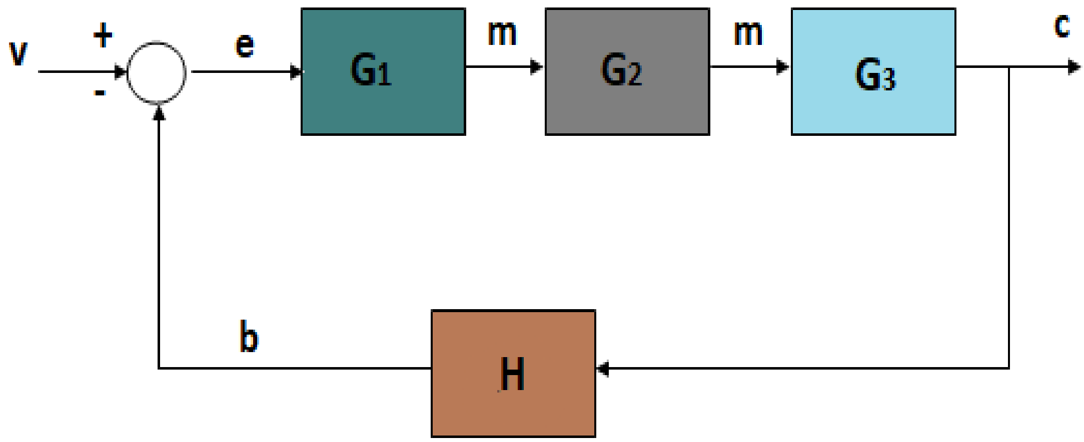


Fig: The controlling Elements

G_1=Controlling element

G_2=Final control element

G_3=Process

H=Measuring element

The automatic controller consist of the measuring element H, the actuating signal element, the control element G_1 and the final control element G_2, G_3 is the process or system, b is the feedback signal and e is the error , m actuating signal.

SELF –OPERATED CONTROLLERS:

In self operated controllers, the controlling element and final control element are present in one assembly. Thus Final Control Element is not present unlike in other analog controllers. They work by the power developed by the measuring means. The working and construction of some of the self operated controllers are given below:

1. **PRESSURE REGULATOR:**

Pressure regulator or pressure reducing valve may be either a ‘flow type’ or a ‘dead-end type’. The only difference between the two types is that the ‘dead-end’ type incorporates a relief valve, indicated by the opening through the diaphragm.
The set point is determined by the adjustment of spring compression. The diaphragm ‘measures’ the outlet pressure and the actuating signal is the net force acting on the valve plug. The manipulated variable is the flow rate past the valve plug.

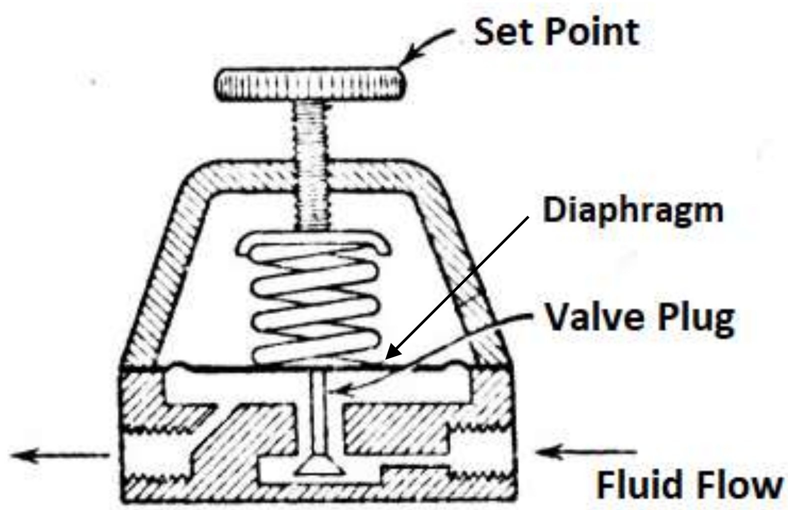


Fig: "Flow" Type Pressure Regulator

The operation is as follows; when the outlet pressure is too low, the diaphragm moves downward because downward spring force is greater than the upward force, to due to the pressure acting against the area of the diaphragm. This increases the flow into the outlet and raises the outlet pressure so that the upward pressure force equals the downward spring force. Conversely, if the outlet pressure is high, the valve plug reduces the flow at the outlet.

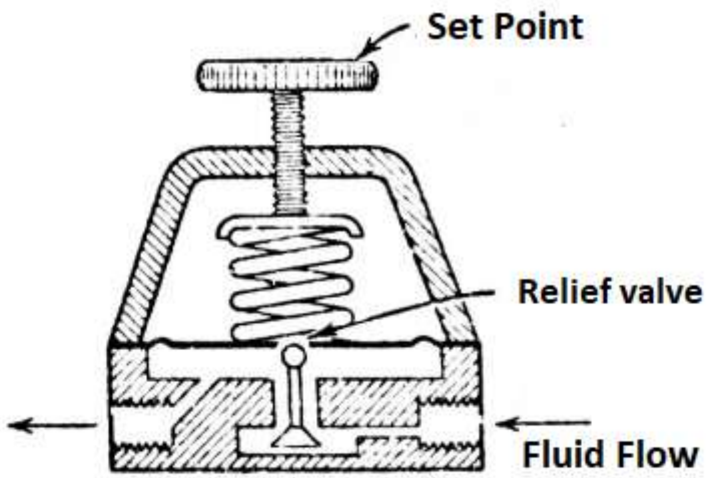


Fig: "Dead end" Type Pressure Regulator

The 'dead-end' type regulator releases fluid from the outlet through the relief valve when the outlet pressure is too high. Therefore, it may be used only on fluids such as air that may be released to the atmosphere.

2. FLOAT LEVEL CONTROLLER :

Flow type can be used for water, fuel control. His is used for control of liquid level in open and closed vessel. A float level controller is shown in the figure below. It is used for liquid level control in open and closed vessels. The stem of the valve is connected to an arm of the shaft. The shaft runs through sealed bearings to the interior of the tank or vessel. A float is fastened to the arm on the inside end of the shaft and the valve is operated by direct mechanical power from the float. The valve plug is designed for minimum fluid forces. The control action is proportional and the proportional sensitivity can be changed through adjustable linkage.

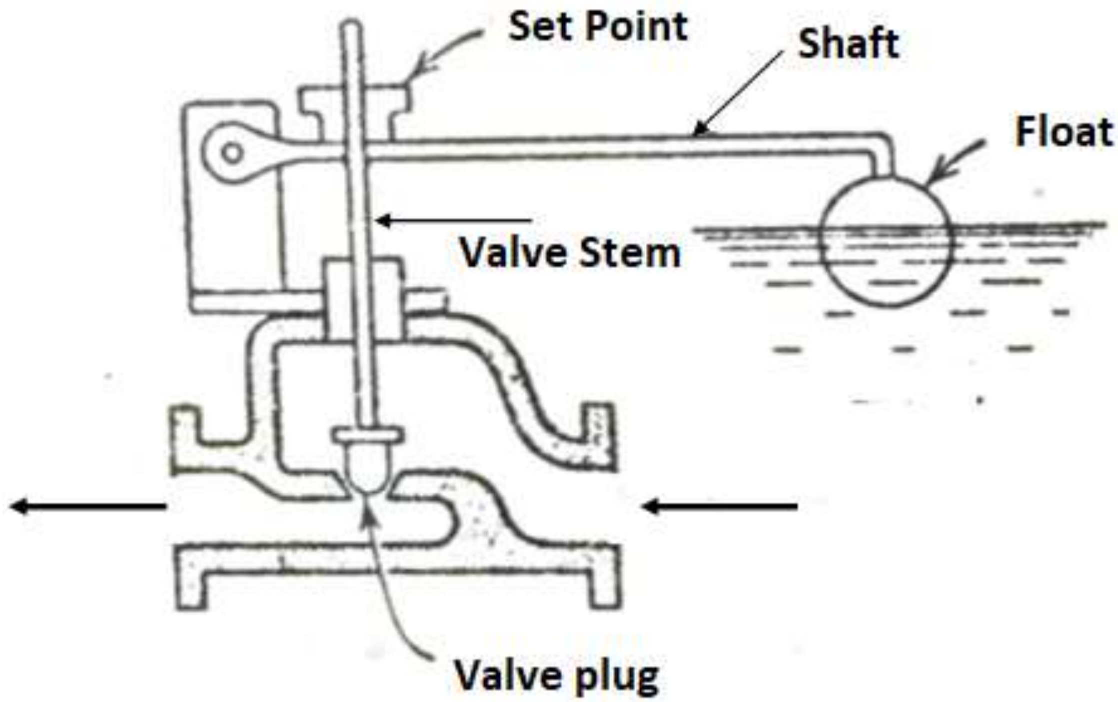


Fig: Liquid Tank Float level controller

3. THERMOSTATIC VALVE:

In the below figure temperature is measured by a vapour-pressure thermometer and the expansion of liquid or vapour operates on the bellows and then on the valve plug. A set-point mechanism is arranged to raise or lower the bellow position. The control action is of proportional type. Almost all self-operated controllers are of proportional type and the proportional sensitivity is fixed.

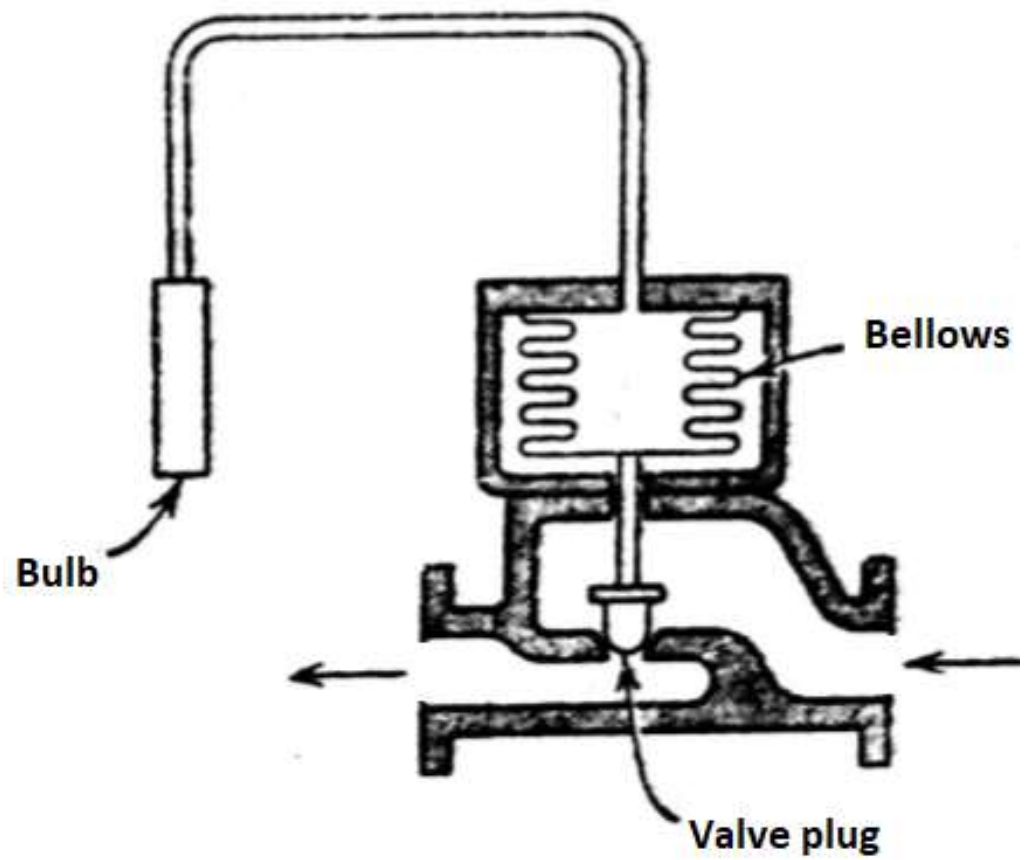


Fig: Thermostatic Valve

CLASSIFICATION OF CONTROLLERS BASED ON THE ACTUATING MEDIUM

The three types of controllers depending upon the actuating medium are now described below.

1) PNEUMATIC CONTROLLER:

Pneumatically operated controllers are used extensively in industrial processes due to their explosion-proof characteristics, their simplicity and maintained. They provide high power amplification using compressed air as a source of auxiliary power. They are used to control up to a distance of 300m.

The pneumatic controller consists of two parts:

a. A controller mechanism incorporating the control action and providing an air pressure output, and
b. A final control valve in accordance with the air pressure output of the controller.

- **Air supply in pneumatic system**

The greatest problem connected with pneumatic controllers is the maintenance of a clean, dry air supply at constant pressure. Moisture, oil, corrosive liquids or foreign particles carried into the pneumatic system from the air supply coil eventually cause trouble.

- **Advantages Of Pneumatic Controllers:**
    i. It is cheaper than hydraulic controller.
    ii. There is no fire hazard.
- **Disadvantages of Pneumatic Controllers:**
    i. Condensate in the instrument air causes chocking action of the nozzle.
    ii. It is not practicable to keep the actuators at a long distance.
    iii. It creates problem during the leakage of impulse lines (or tubings).

2) <u>HYDRAULIC CONTROLLER:</u>

Hydraulic controllers use a liquid control medium to provide an output signal which is a function of an input error signal. Previously water was used as an operating medium but presently petroleum oil or fire resistant liquids are used. If fire hazard is not a major concern, petroleum oil is preferred because of its lubricating and corrosion protecting features. Hydraulic controllers are used to control up to a distance of 30m.

- **Advantages of Hydraulic Controllers:**
    i. Their speed of response is high.
    ii. Small sizes of power units are required in these controllers.
    iii. It has a long life.
    iv. Usually high amplification or gain is possible in a minimum of amplifier.

- **Disadvantages of Hydraulic Controllers:**
  1. More space is required.
  2. Two lines are usually necessary for control, since the control medium must be recirculated.
  3. Dependent upon the types of fluid used, filtration is required to keep the fluid clean. If Fire-resistant fluids are used because of poor lubrication and corrosive effects require careful maintenance.
  4. Care must be taken with seals and connections to prevent leakage of the hydraulic fluid.

Applications of Hydraulic Controllers:

Hydraulic controllers are used where both high power and fast speed of response are required. They are used for the control and regulation of pressure, flow, mainly in steel plants, gas plants and other branches of heavy industry

3) ELECTRONIC CONTROLLER

These controllers use electric power to actuate the final control element. These types of controller have a wide range of applications in the modern process industries. They can be classified as follows:-

i. Self-operated controller
ii. Relay operated controller

- **Advantages of electronic controllers:**
  1. These controllers are fast in action.
  2. They are handy and occupy very small space.
  3. They are very cheap.
- **Disadvantages of electronic controllers:**
  1. Chances of fire-hazard are bold in these controllers.
  2. They are less reliable.
  3. Stray magnetic field may affect the transmitted signal, therefore shielding of cable is required in these controllers

CHAPTER - 3

TRANSMISSION SYSTEM

Transmission is a process of sending propagating and receiving an analogue or digital information signal over a physical point to multi-point transmission medium, either wired or unwired. Transmission of a digitalized analogue signal is known as data transmission or digital transmission.

Transmission lines are used to carry the measurement signal to the controller and the control signal to the final control element. There are three types of transmission lines, namely

1. Pneumatic Transmission
2. Hydraulic Transmission
3. Electrical (or Electronics) Transmission

1. Pneumatic Transmission

It is often required to measure the value of a controlled variable, where the location of the point of measurement is at a considerable distance from the location of the controller .Most measuring devices such as Hg in glass thermometer, pressure gauge or flow rate meter would then require fluid line connection of great length. This can't be done because excessive measuring lag would result. Therefore some transmission or telemetering means must be employed and pneumatic transmission is one method of transmitting the value of the controlled variable.

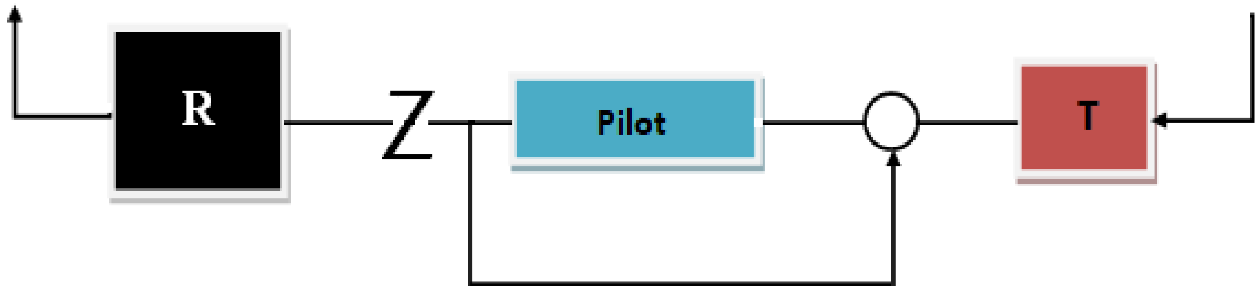


Fig: Pneumatic Transmission System

R = RECEIVER

T = TRANSMITTER

The above figure , shows the pneumatic transmission system which may be used for distance up to many feet. The controlled variable is converted to an air pressure at the transmitter T. The air pressure is then conducted through a single tube to the receiver R. where it is transduced to a position or force for operation of the controller. The pilot is provided to increase the flow air if required.

2. Electric Transmission

An Electric Transmission system is a system that transmits a signal from one place to another. The signal can be electrical, optical fiber or radio signal. Some transmission systems contain multipliers which amplify a signal prior to retransmission or re-generation, which attempt to reconstruct the coded message before the retransmission.

CHAPTER - 4

FINAL CONTROL ELEMENT

Any process control consist of three elements; measurement, evolution and final control. Final control is probably the most important because it exerts a direct effect in the process. Final control elements are not present in self operated controller.

Final control elements are the hardware components of the control loop that implement the control action. It may be defined as the mechanism which receive the output signal from the automatic control device (actuating signal) and adjust accordingly the value of the manipulated variable. Final control element consist of two parts-

- First, an actuator which is used to translate the output signal of the Automatic Control into a position of a member exerting large power and,
- Second, a device to adjust the value of the manipulated variable.

The most common final control element is the pneumatic valve, details of its mechanism is given below:

Pneumatic Valve:

The different parts of the single seat pneumatic control valve are given as per the figure.

- **Seat –** It is where the plug sits or rests..

- **Plug** – It is that component which can close or open the valve by its movement. In the given valve, when the plug sits on the seat then it is fully closed. The shape of the plug can be different.
- **Cage** – It is the part which surrounds the plug and seat.
- **Diaphragm** – It is a flexible, pressure responsive element that transmits force to the stem and it is at the top of the control valve.

OPERATION: The pneumatic valve is an air-operated valve, which controls the flow through an orifice by positioning a plug appropriately. The plug is attached at the end of a stem which is supported on a diaphragm at the other end. As the air pressure (controller output) above the diaphragm increases, the stem moves down and consequently the plug restricts the flow through the orifice.

FAIL OPEN :

In air-to-close pneumatic valve, if the air supply above the diaphragm is lost, the valve will fail open since the spring would push the stem and the plug upward.

FAIL CLOSED:

A valve condition in which the valve closer member moves to the closed position when the actuating energy source fails. In case of pneumatic valve where the actuating signal condition is air-to-open. If the air supply below the diaphragm is lost the valve will 'fail close' since the steam would push the plug downwards.

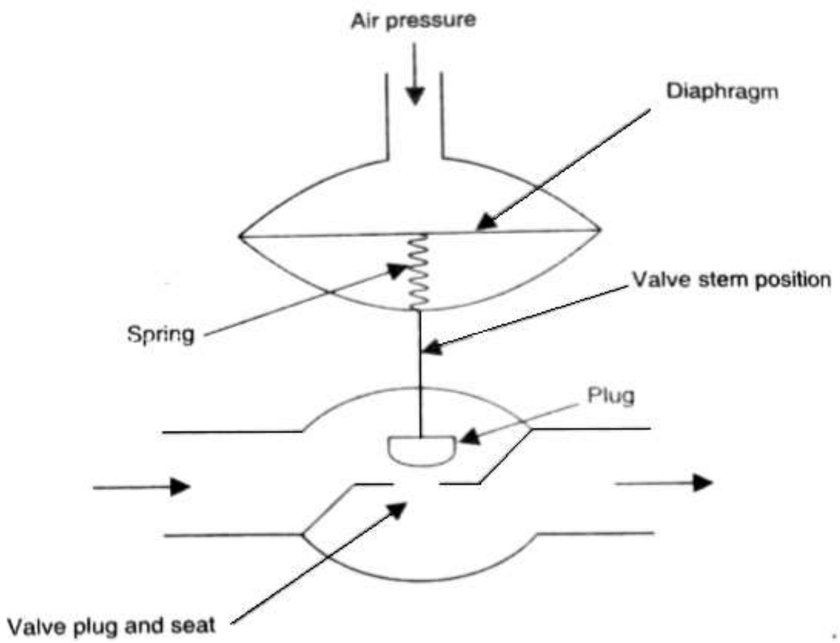


Fig: Pneumatic Valve

Different types of automatic control valves:

A control valve in a pipeline acts as a variable restriction. The vertical movement of the plug and stem changes the area of opening of the port. The flow rate passing through the port is thus proportional by positioning the valve stem. The stem is returned to position by the actuator. The different types of automatic control valves are-

1. **Sliding stem control valves:**
   a) **Single seat valve**

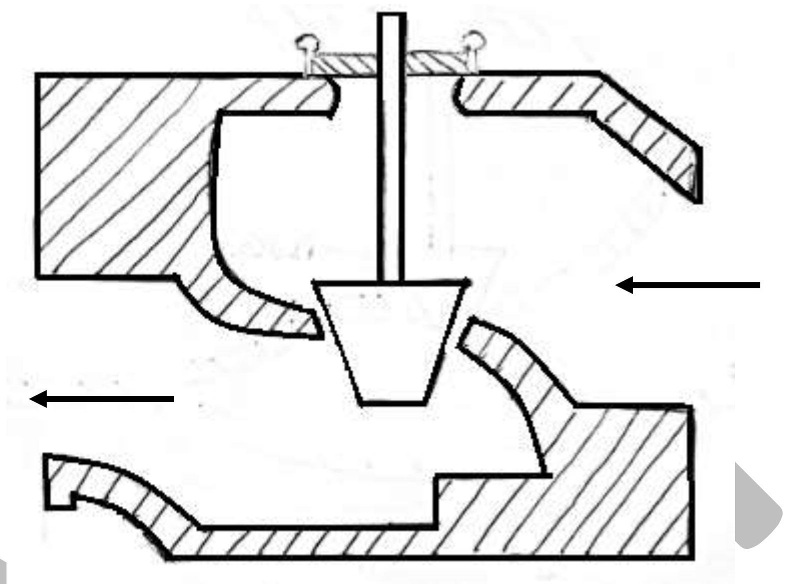


Fig: Single Seat Valve

A single-seat valve consists of only one part opening between seat ring and plug. It can be shut off to produce zero flow. There is a lot of force as the valve stem.

b) Double seat valve

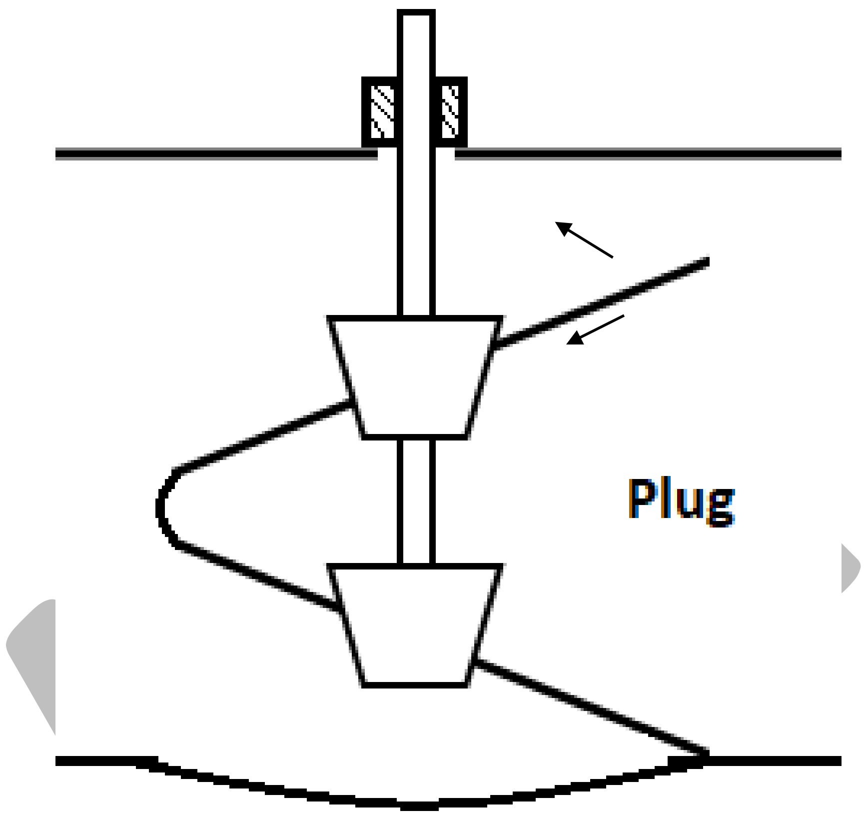


Fig : Double Seat Valve

Double seat valve consist of two part opening two seats and two plugs. These valves cannot be shut off tightly. Force acting as valve stem is small.

c) Diaphragm valve

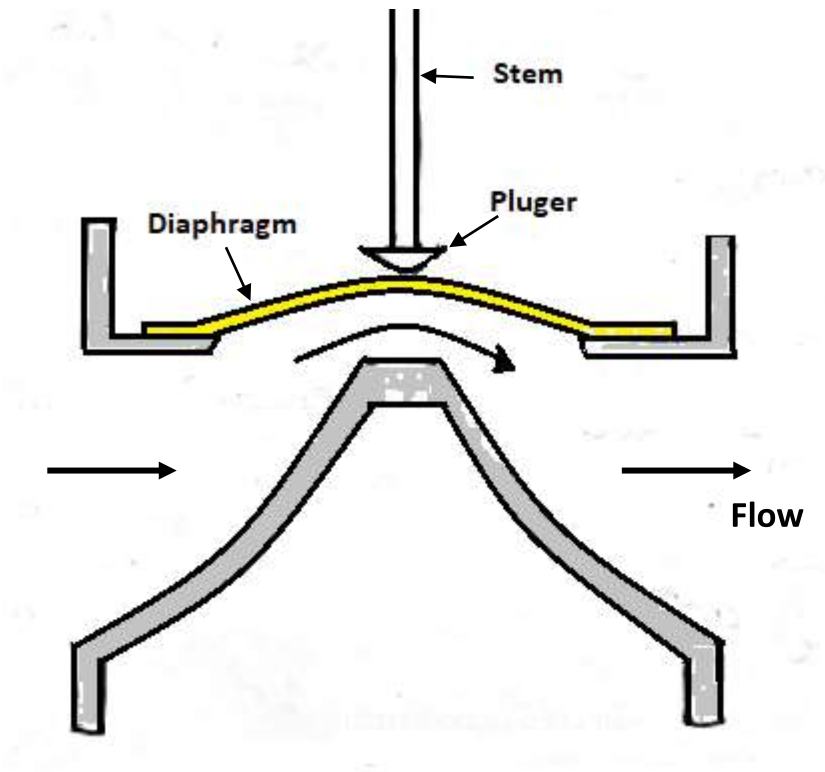


Fig : Diaphragm Valve

This valve is used for slurries. There is no packing-glove around the stem. The diaphragm made of rubber or other non-metallic substance is positioned by the stem and pluger.

2. Rotating Shaft Control Valves:

There is a wide range of rotary shaft control valves available in market. An important advantage of rotary control valves over slide-stem designs is that it virtually obstructs less path for fluid when the valve is wide-open. A Rotating Plug Valve is explained below:

<u>Rotating Plug Valve</u> :

Rotating plug valve is illustrated in figure. The plug is a cylindrical or conical element with a transverse opening. It is rotated in the valve body by an external lever so that the opening on one side of the plug is gradually covered or uncovered. The shape of the opening or port may be circular, V-shaped, rectangular or any form that is desired to produce a given flow-angle characteristic. A rotating plug valve having a conical plug can gradually e closed tightly and has high range ability. This type of valve is often employed for throttling the flow of oil to burner systems.

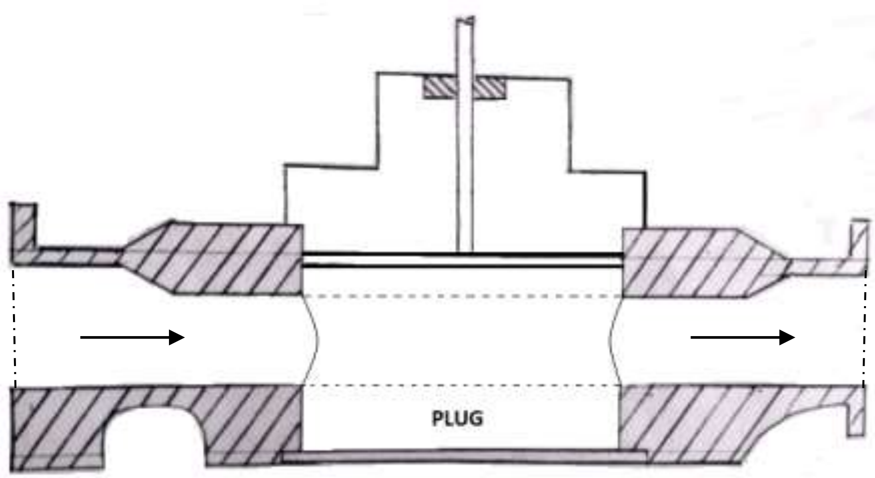


Fig: Rotating Plug Valve

CHAPTER - 5

Application Of Control Engineering

(a) Liquid level control/flow control.

Let us consider a vessel which is being continuously filled with water. A level of (x ft) is to be maintained in this vessel and if it goes beyond we have a manual control valve to drain out the water. It is okay if the control is to be operated once, twice or little more. But if it is continuous/very often we need the help of automatic process control.

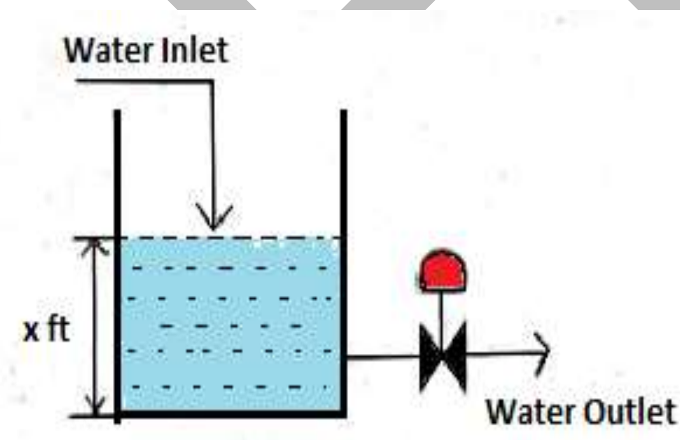


Fig: Manual Control Valve

In this case a level transmitter (which is an electronic item) is mounted on the vessel. This transmitter gives signal to the controller (electronic item) which has the set point i.e. x ft. Finally the control valve or a pump (both considered as a final control element) opens and drains the water. It goes beyond x feet the level transmitter signals the control valve to close accordingly.

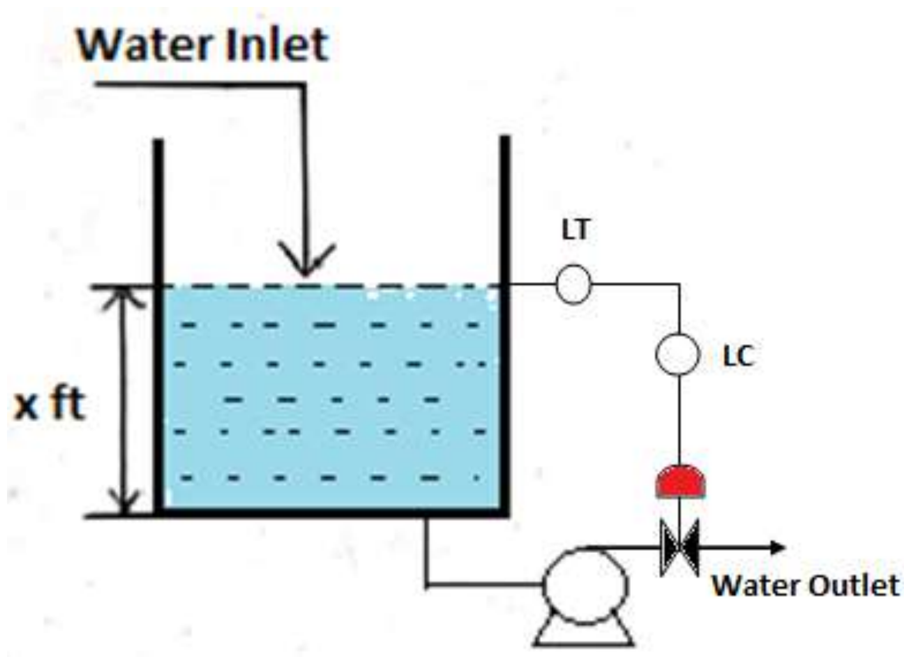


Fig: Maintaining Tank Level with Automatic Controller

Similarly flow may also be controlled as level and flow speed is interrelated. We cannot control flow without changing level or vice versa. They are necessary in feed, tanks, reactors, distillation columns, reflux drums, reboiler and so on. Without flow measurement and control plans, material balancing, quality control and even the operation of any continuous process would be almost impossible. When we say flow control we mean control of steam, water, process liquids and gases. Again levels of liquid may affect both the pressure and as mentioned on the flow-rate.

(b) Control of furnace temperature:

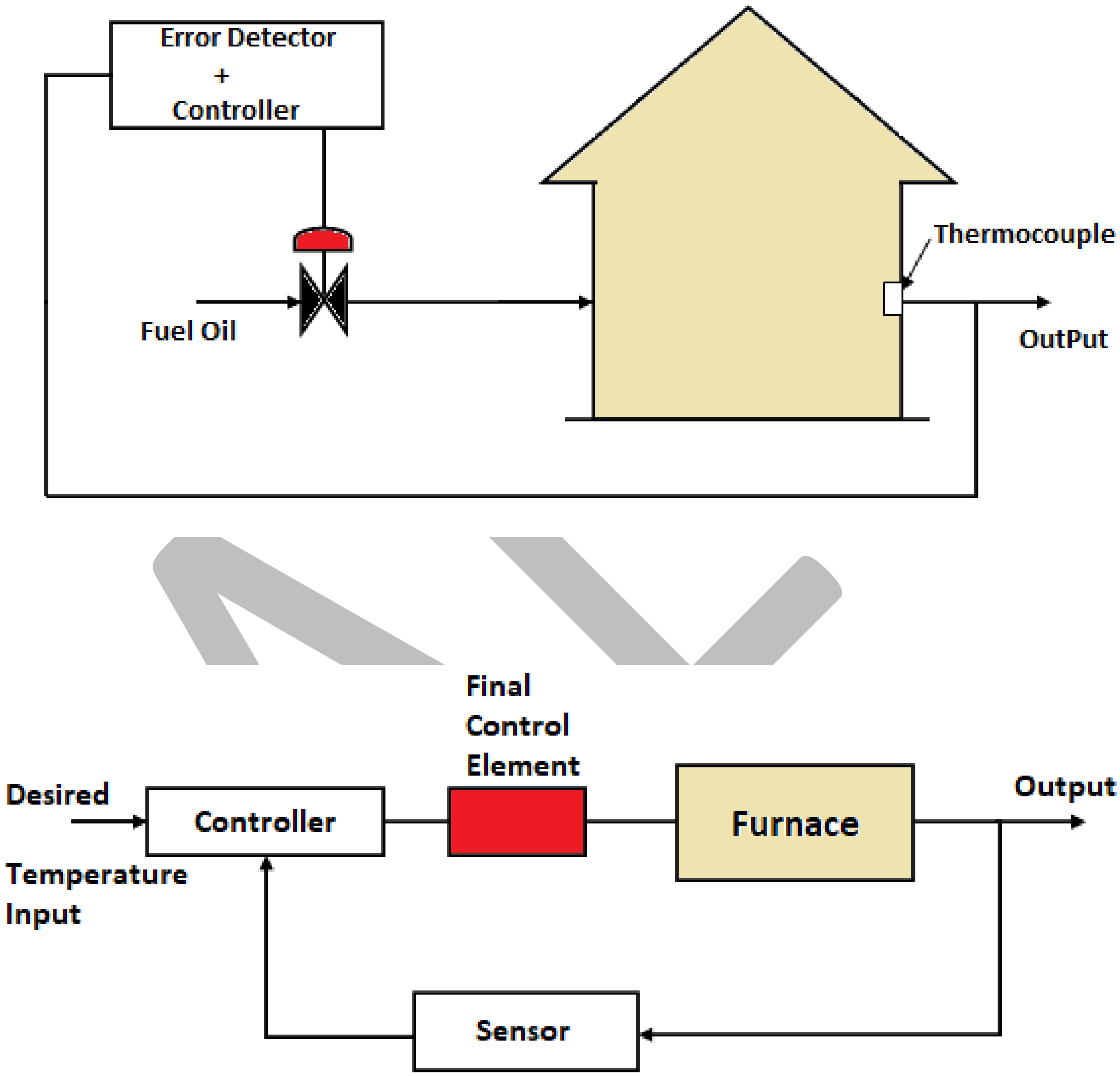


Fig : Graphical representation Of Temperature Control of a Furnace.

Temperature is probably the most fundamental parameter and is widely measured and controlled industrial variable. It is required in the routine control of an industrial plant. The conditions under which temperature has to be measured and controlled differ so widely that no fixed rule can be followed. All that is essential is that we have to select the most appropriate method of temperature measurement for a particular use, considering the points as sources of error and limitations, precautions to be observed, the exact location of the sensing probe, etc. Safety is also a prime concern in the case of temperature measurement and control.

Distributed Digital Control System :

A distributed control system (DCS) refer to a control system usually of a manufacturing system ,process or any kind of dynamic system in which the controller elements are not Central in location (like the brain) but are distributed throughout the system with each component sub-system controlled by one or more controllers. The entire systems of controllers are connected by networks for communication and monitoring.

DCS is a very broad term used in a variety of industries to monitor and control distributed equipments. Such industries and systems are:-

- Electrical power grids and electrical generation plants
- Environmental control systems
- Traffic signals
- Water management systems
- Oil refining plants
- Chemical plants
- Pharmaceutical manufacturing, etc

A DCS typically uses custom designed processors as controllers and uses both interconnections and protocols for communication input and output modules form component parts of the DCS the processor receives information from input models and send information to output models. The input module receives information from input instruments in the process and transmits instructions to the output instruments in the field. Computer lens or electrical lenses connect the processor and module through multiplexer and demultiplexers. Buses also connect the DCS with the central controller and finally to the human machine interface for control consoles

Elements of DCS main directly connect to physical equipment such as switches, pumps and valve or may work through an intermediate system such as a SCADA system.