UNIT 1

- **Introduction to Process Control**

PROCESS :

- *A process denotes an operation or series of operations on fluid or solid materials during which the materials are placed in a more useful state.*
- *The objective of a process is to convert certain raw materials (input feedstock) into desired products (output) using available sources of energy in the most economical way.*
- *A unit process may involve either a change of chemical state or a change in physical state. Many external and internal conditions affect the performance of a process. These conditions may be expressed in terms of process variables such as temperature, pressure, flow, liquid level, dimension, weight, volume etc.*
- *A process must satisfy several requirements imposed by its designers and the general technical, economic and social conditions in the presence of ever-changing external influences (disturbances). The requirements include safety of men and machine, environmental regulations, production specifications, operational constraints and economics.*

- ***CONTROL :***
- *The term control means methods to force parameters in the environment to have specific values. This can be as simple as making the temperature in a room stay at 25°C or as complex as manufacturing an integrated circuit or guiding a spacecraft to Jupiter. In general, all of the elements necessary to accomplish the control objective are described by the term control system.*
- *The basic strategy by which a control system operates is quite logical and natural. In fact, the same strategy is employed in living organisms to maintain temperature, fluid flow rate, and a host of other biological functions. This is natural process control.*
- *The technology of artificial control was first developed with a human as an integral part of the control action. When it is learnt how to use machines, electronics, and computers to replace the human function, the term 'automatic control' came into use*

PROCESS CONTROL :

- *The process may be controlled by measuring a variable representing the desired state of the product and automatically adjusting one of the other variables of the process. In process control, the basic objective is to regulate the value of some quantity. To regulate means to maintain that quantity at some desired value (reference value or set point) regardless of external influences.*

- *During the first industrial revolution the work done by human muscles was gradually replaced by the power of machines. Process control opened the door to the second industrial revolution, where the routine functions of the human mind and the need for the continuous presence of human observers were also taken care of by machines.*
- *In true sense process control had made optimization, and thereby, the beginning of the third industrial revolution possible. Here the traditional goal of maximizing the quantity production is gradually replaced by the goal of maximizing the quality and durability of the produced goods, while minimizing the consumption of energy and raw materials and maximizing recycling and reuse. Optimized process control is the moto.*

- **Types of control**
- **Sequence Control**
- **Regulatory Control**
- **Automatic control**

- **Sequence Control**

A predetermined set of control actions need to take place so :

operation A — operation B — operation C

Each operation is controlled and when complete the next is started up. For example consider an automatic washing machine –

1. open hot and cold water valves — mix until correct temperature and water volume is reached.

2. switch off valves and start motor.

3. after certain time stop motor and pump out water.

4. enter new water for rinse and start motor.

5. stop motor and pump out water — spin dry.

each part of the process would be controlled depending upon the type of wash to be carried out, i.e. various water temperatures for different materials. Another application would be a steel rolling mill where a predetermined rolling sequence is used from a given ingot size and type.

- **Regulatory Control**

process parameters are maintained at a desired level (within specified limits or error) for a specified time. This involves taking a measurement of the output of the process feeding this back so it can effect the process and change the output. This is called 'feedback. Consider:

- *The set point' is the required value of the output parameter, e.g. a temperature. This is compared with the output and the difference (the error) is fed into some control system that will effect the process in such a way to reduce this error to zero, e.g. switch on a heater to raise the temperature.*
- *For example consider a simple on-off control system (thermostat) for a boiler temperature control. The operator sets the 'set point .*

- **AUTOMATIC PROCESS CONTROL**

Automatic control is the maintenance of a desired value of a quantity or condition by measuring the existing value, comparing it to the desired value, and employing the difference to initiate action for reducing this difference. Thus automatic control requires a closed loop of action and reaction operating without human aid.

- **Variables of Automatic Process Control**

(a)*Set point variable :*

It is the one that is set by the operator, master controller or computer as a desired value for a 'controlled variable' . It is also called sometimes as 'reference value'.

(b) Controlled variable :

It is the one that must be maintained precisely at the set point. Typically, the variable chosen to represent the state of the system is termed the ‘controlled variable’. Examples of controlled variables are temperature, pressure, flow rate, level, vaccum pressure, concentration, density etc.

(*c) Manipulated variable :*

It is the one that can be changed in order to maintain the controlled variable at the set point value. In other words, the variable chosen to control the system's state is termed the ‘manipulated variable’. It is also called sometimes as ‘controlling variable’. Examples of manipulated variables are coolant flow, fuel flow, feed water flow etc.

(*d) Load variables :*

Are those variables that cause disturbances in the process. They are also called as load disturbances. The load variable may change either continuously or sporadically with some function of time. Sometimes it is fixed and not a function of time. Examples are feed rate, feed composition, steam header pressure, coolant temperature etc.

The load variables are uncontrolled independent variables, which, when they change, will upset the control system, and their effects can only be corrected in a 'feedback' manner. This means that a change in load variables is not responded until they have upset the controlled variable.

- **Dynamics of the process**

This is a very complex subject but this part of the text will cover the most basic considerations.

The term 'time constant', which deals with the definition of the time taken for actuator movement, has already been outlined in Tutorial 5.1; but to reiterate, it is the time taken for a control system to reach approximately two-thirds of its total movement as a result of a given step change in temperature, or other variable.

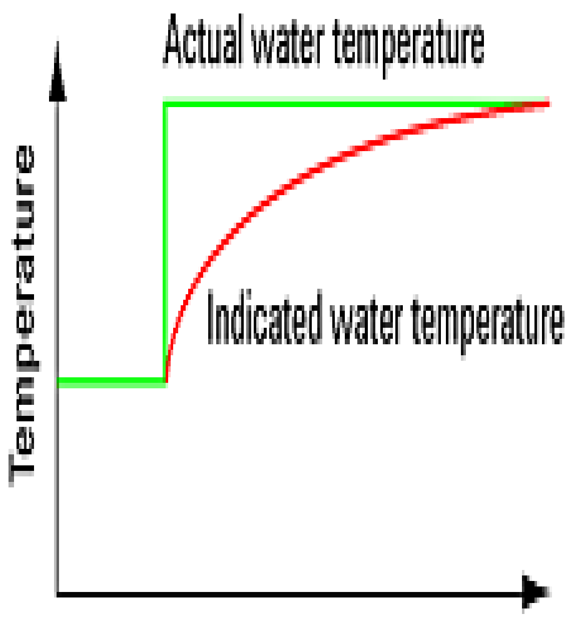


Fig. Step change 5°C

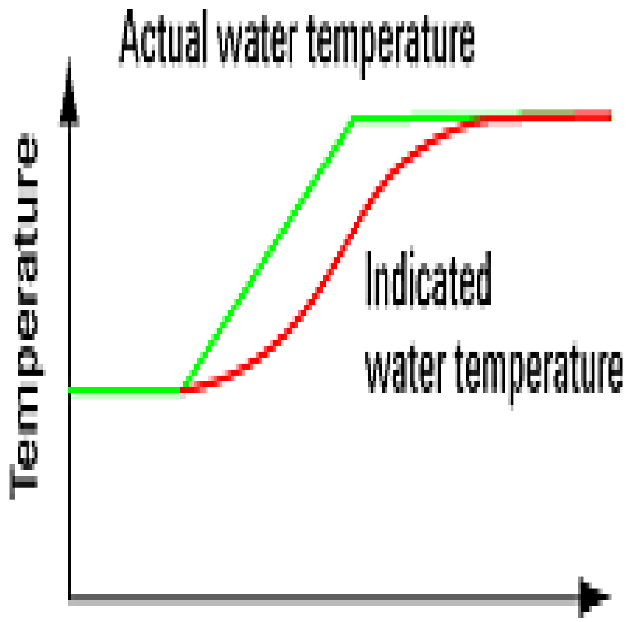


Fig. Ramp change 5°C

Other parts of the control system will have similar time based responses - the controller and its components and the sensor itself. All instruments have a time lag between the input to the instrument and its subsequent output. Even the transmission system will have a time lag - not a problem with electric/electronic systems but a factor that may need to be taken into account with pneumatic transmission systems.

Figures show some typical response lags for a thermocouple that has been installed into a pocket for sensing water temperature.

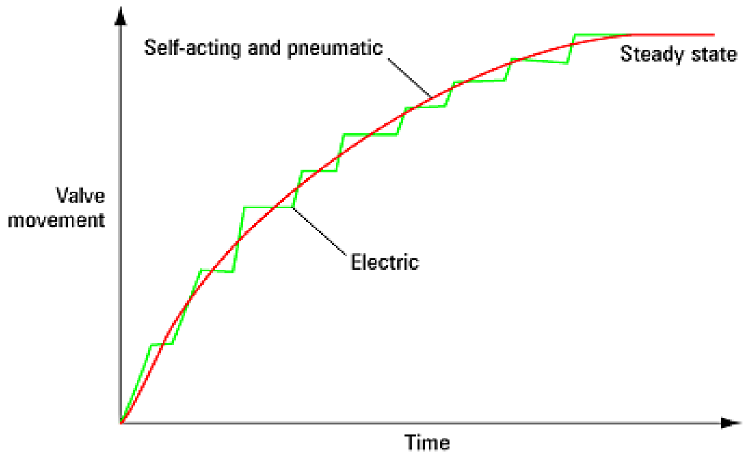


Fig. Comparison of response by different actuators

- **Control Actions**

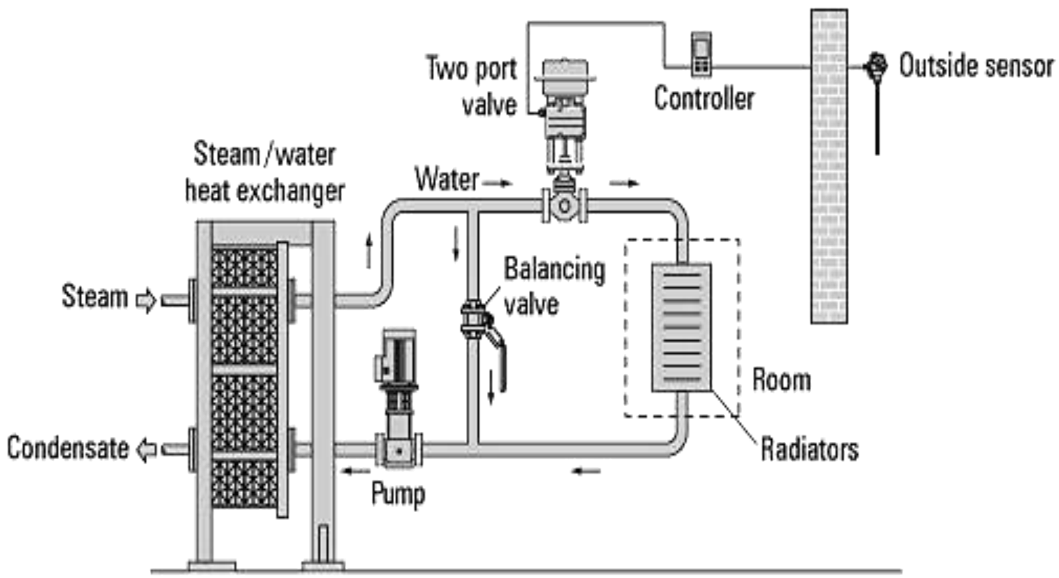
There are four types of control action :

- **on-off or two-position control .**
- **proportional control .**
- **integral control .**
- **derivative control .**

- Control loops

❑ **An open loop control system:**

Open loop control simply means there is no direct feedback from the controlled condition; in other words, no information is sent back from the process or system under control to advise the controller that corrective action is required. The heating system shown in Figure *demonstrates this by using a sensor outside of the room being heated. The system shown in Figure is not an example of a practical heating control system; it is simply being used to depict the principle of open loop control.*



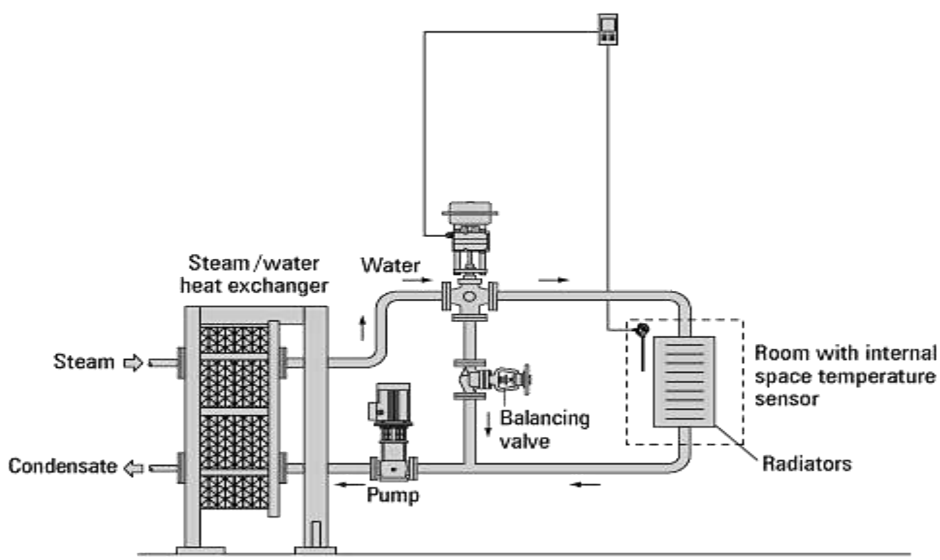
Open loop control system

The system consists of a proportional controller with an outside sensor sensing ambient air temperature. The controller might be set with a fairly large proportional band, such that at an ambient temperature of -1°C the valve is full open, and at an ambient of 19°C the valve is fully closed. As the ambient temperature will have an effect on the heat loss from the building, it is hoped that the room temperature will be controlled.

However, there is no feedback regarding the room temperature and heating due to other factors. In mild weather, although the flow of water is being controlled, other factors, such as high solar gain, might *cause the room to overheat. In other words, open control tends only to provide a coarse control of the application.*

- **Closed loop control**

Quite simply, a closed loop control requires feedback; information sent back direct from the process or system. Using the simple heating system shown in Figure the addition of an internal space temperature sensor will detect the room temperature and provide closed loop control with respect to the room.
In Figure the valve and actuator are controlled via a space temperature sensor in the room, providing feedback from the actual room temperature.



Closed loop control system with sensor for internal space temperature

❑ *Single loop control*

This is the simplest control loop involving just one controlled variable, for instance, temperature. To explain this, a steam-to-water heat exchanger is considered as shown in Figure. The only one variable controlled in Figure is the temperature of the water leaving the heat exchanger. This is achieved by controlling the 2-port steam valve supplying steam to the heat exchanger. The primary sensor may be a thermocouple or PT100 platinum resistance thermometer sensing the water temperature.

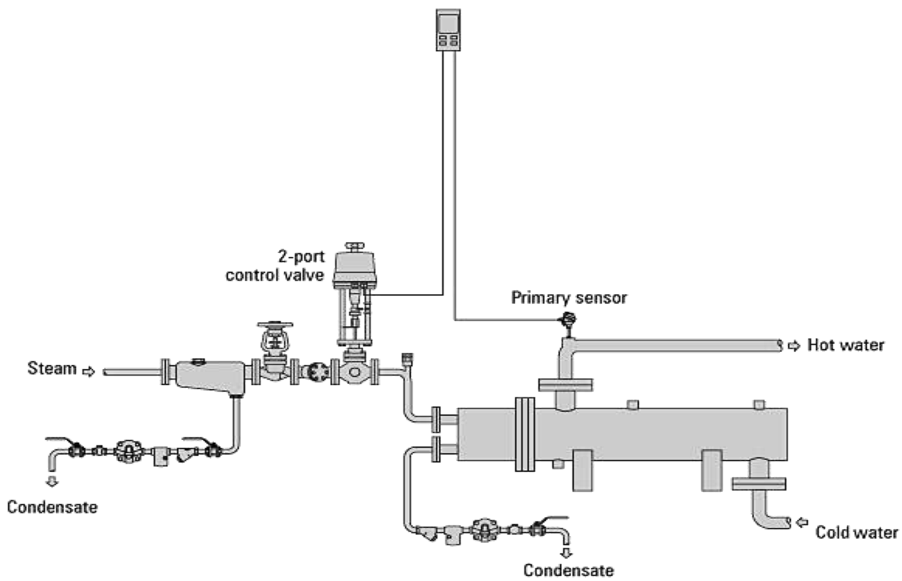


FIG - Single loop control on a heating calorifier

- ***The controller compares the signal from the sensor to the set point on the controller. If there is a difference, the controller sends a signal to the actuator of the valve, which in turn moves the valve to a new position. The controller may also include an output indicator, which shows the percentage of valve opening.***

Single control loops provide the vast majority of control for heating systems and industrial processes.
Other terms used for single control loops include:

- ***Set value control.***
- ***Single closed loop control.***
- ***Feedback control.***

- ***Multi-loop control***

The following example considers an application for a slow moving timber-based product, which must be controlled to a specific humidity level. In Figure the single humidity sensor at the end of the conveyor controls the amount of heat added by the furnace. But if the water spray rate changes due, for instance, to fluctuations in the water supply pressure, it may take perhaps 10 minutes before the product reaches the far end of the conveyor and the humidity sensor reacts. This will cause variations in product quality.

To improve the control, a second humidity sensor on another control loop can be installed immediately after the water spray, as shown in Figure This humidity sensor provides a remote set point input to the controller which is used to offset the local set point. The local set point is set at the required humidity after the furnace. This, in a simple form, illustrates multi-loop control.

This humidity control system consists of two control loops:

- ***Loop 1 controls the addition of water.***
- ***Loop 2 controls the removal of water.***

Within this process, factors will influence both loops. Some factors such as water pressure will affect both loops. Loop 1 will try to correct for this, but any resulting error will have an impact on Loop 2.

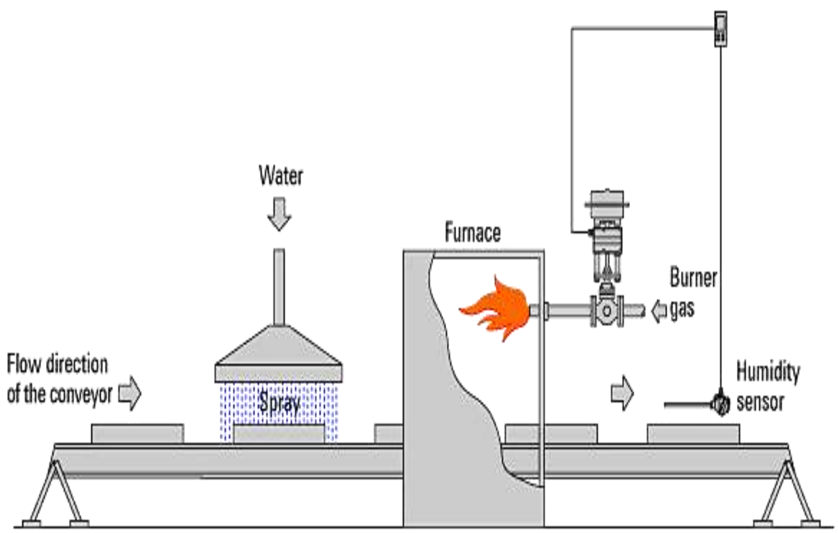
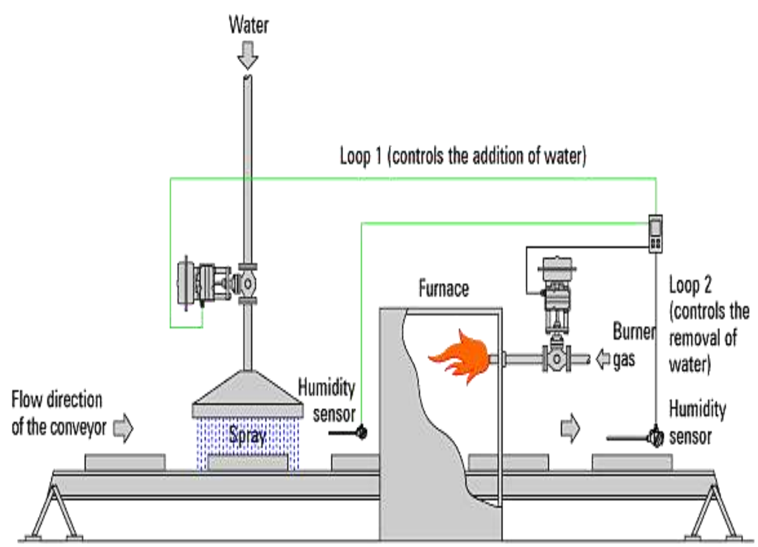


FIG - Single humidity sensor



Dual humidity sensors

❑ *Cascade control*

Where two independent variables need to be controlled with one valve, a cascade control system may be used.
Figure shows a steam jacketed vessel full of liquid product. The essential aspects of the process are quite rigorous:

- ***The product in the vessel must be heated to a certain temperature.***
- ***The steam must not exceed a certain temperature or the product may be spoiled.***
- ***The product temperature must not increase faster than a certain rate or the product may be spoiled.***
- ***If a normal, single loop control was used with the sensor in the liquid, at the start of the process the sensor would detect a low temperature, and the controller would signal the valve to move to the fully open position. This would result in a problem caused by an excessive steam temperature in the jacket.***
- ***The solution is to use a cascade control using two controllers and two sensors:***
- ***A slave controller (Controller 2) and sensor monitoring the steam temperature in the jacket, and outputting a signal to the control valve.***

- ***A master controller (Controller 1) and sensor monitoring the product temperature with the controller output directed to the slave controller.***
- ***The output signal from the master controller is used to vary the set point in the slave controller, ensuring that the steam temperature is not exceeded.***

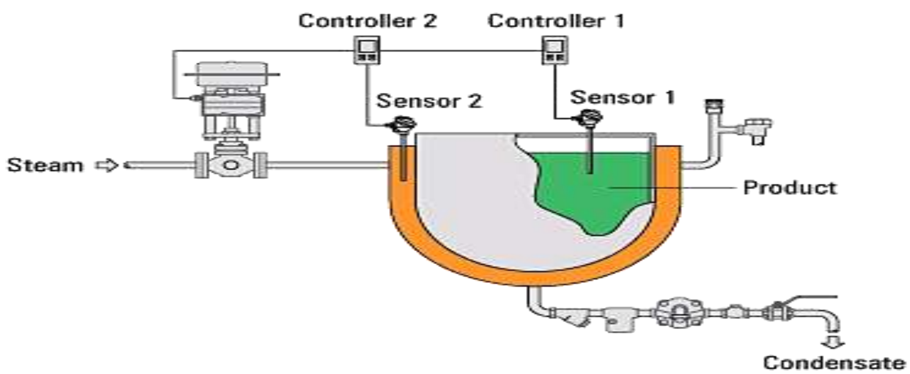


fIg. Jacketed vessel