# MODULE - IV

## Multiple Choice Type Questions

1. pH control is [WBUT 2010, 2012, 2014]
a) linear b) non-linear c) both (a) and (b) d) none of these

**Answer:** (c)

2. Dynamic response time of control valve is related to [WBUT 2015]
a) integral control action b) derivative control action
c) proportional gain of process d) all of these

**Answer:** (d)

## Short Answer Type Questions

1. Explain 3-element control of a boiler tank. What is swell and shrink? [WBUT 2015]

**Answer:**

**1st Part:**

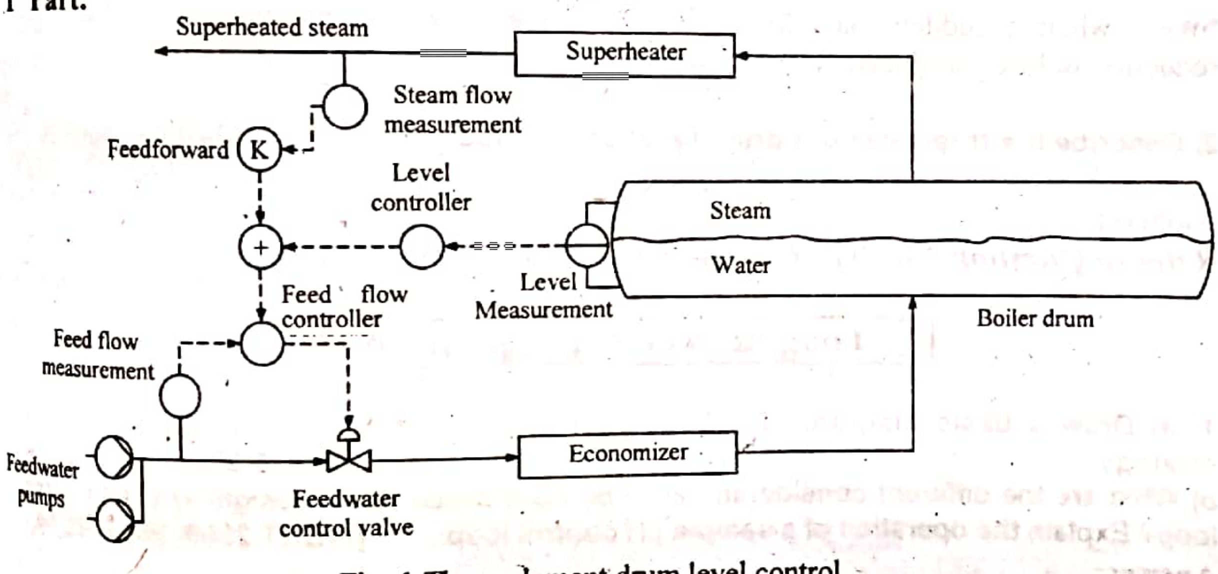



Fig: 1 Three-element drum level control

The three-element drum level control is ideally suited where a boiler plant consists of multiple boilers and multiple feedwater pumps or where the feedwater has variations in pressure or flow.

The three-elements are made up of the following:

**Level Element & Steam Flow Element:** corrects for unmeasured disturbances within the system such as

- Boiler blowdown
- Boiler and superheater tube leaks

**Feedwater Flow Element:** responds rapidly to variations in feedwater demand, either from the

- Steam flow rate feedforward signal
- Feedwater pressure or flow fluctuations

In order to achieve optimum control, both steam and feedwater flow values should be corrected for density.

**2nd Part:**

**Shrink/swell** is a phenomenon that produces variations in the level of the liquid surface in the steam drum whenever **boiler** load (changes in steam demand) occur.

**Shrink:** A sudden steam load increase will naturally produce a drop in the pressure in the steam drum. When the pressure in the drum drops, it has a dramatic effect on the natural convection within the boiler. The drop in pressure causes a small fraction of the saturated water in the boiler to immediately vaporize, producing a large amount of boil-up from most of the tubes in the boiler. The result is that the level in the steam drum above the combustion chamber rises.

**Swell:** when a sudden load decrease occurs due to a sudden decrease in load, the reduction in level produced. This is swelling.

**2. Describe the three element drum level control technique with suitable diagram.** **[WBUT 2017]**

**Answer:**

***Refer to Question No. 1(1st Part) of Short Answer Type Questions.***

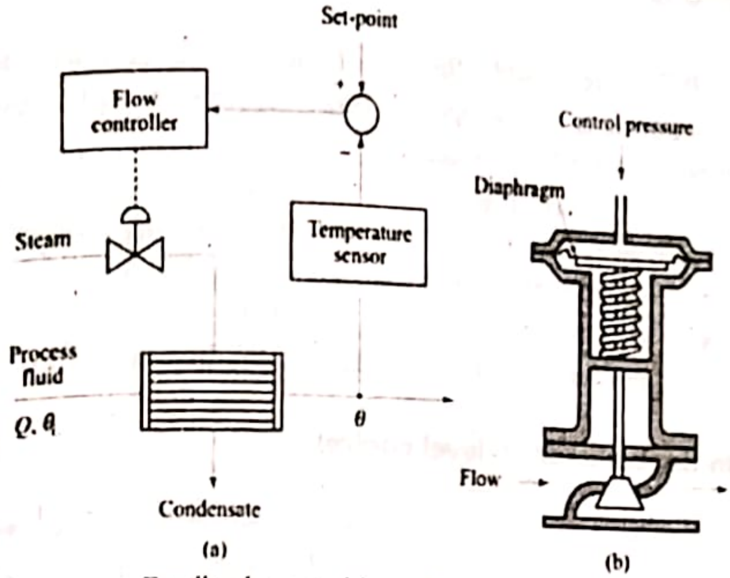
## Long Answer Type Questions

**1. a) Draw a basic diagram of a heat exchanger control and explain its control strategy.** **[WBUT 2009, 2011, 2014]**

**b) What are the different considerations to be considered when designing a pH control loop? Explain the operation of a sample pH control loop.** **[WBUT 2009, 2012, 2014]**

**Answer:**

**a) Heat Exchanger:** The schematic diagram of a heat exchanger is shown in Fig. below In the above arrangement, the process fluid flows inside the tubes of the heat exchanger and is heated by steam condensing on the outside of the tubes. The objective is to control the outlet temperature $\theta$ of the process fluid in the presence of variations in process fluid flow Q and its inlet temperature $\theta_i$. This objective, in the presence of disturbances can be accomplished by setting up a feedback control loop as shown in Fig. The flow controller consists of an electronic amplifier and an electro pneumatic transducer, which converts the voltage corresponding to the error between the controlled temperature and its set-point value to a pneumatic pressure variable (based on proportional control logic).




Feedback control loop for heat exchanger

The error voltage is derived from the output voltage of the temperature sensor (corresponding to the output temperature $\theta$) and the set-point voltage corresponding to the desired temperature. The pneumatic pressure actuates a pneumatic value, whole essential features are shown in Fig. The actuator section of the valve comprises a diaphragm whose position is set by the balance between the force exerted by a spring and the controller output pressure on the diaphragm.

In the control scheme of Fig., the feedback controller, which manipulates the heat input to the heat exchanger, will not act until an error has developed. If the system involves large time lags, it will take some time before any corrective action taken place.

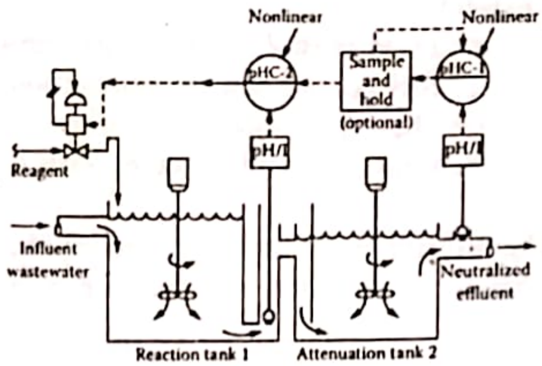
If feed forward control is provided in such a system, then as soon as a change in Q and/or $\theta_i$ occurs, a corrective measure will be taken simultaneously by manipulating the heat input to the heat exchanger. Figure below shows the disturbance-feed forward control scheme.

Feed forward control can minimize the transient error. However, since it is an open-loop control, there are limitations to its functional accuracy. Feed forward control will not cancel the effects of un-measurable disturbances.

**b) pH Control scheme:**

In the above diagram two pH control loops are used in cascade system system. The output of the pHC1 is the set point of the secondary controller pHC2. This type of controllers are particulary useful when lime is used as the reagent.

For the above arrangement, the set point of the pHC2 may have to be lower than the desired pH of the final effluent, because the materials are may be there still reacting with each other after they have left the first tank.




pH control scheme

If the set point of pHC2 is very high, the pH of the final stream will be greater than desired. When flocculation is to be carried out downstream of the pH treatment facility, stable pH values can be extremely important.
A delicate balance must be struck in this type of system with respect to the size of the first vessel. A long residence time in the first tank ensures long contact time between regeants, thereby producing an effluent pH that is close to the desired value, but at the same time it may result sheggish control loop around the vessel. For efficient cascade control, response of the inner loop (control loop around the first tank) must be fast.

**2. Draw and explain the boiler drum level control.** **[WBUT 2014]**

**Answer:**

Here to objective is to keep the liquid level in the drum constant. The two disturbances are the steam flow from the boiler, which is dictated by varying demand elsewhere in the plant and the flow of the feedwater which is also the principal manipulated variable.

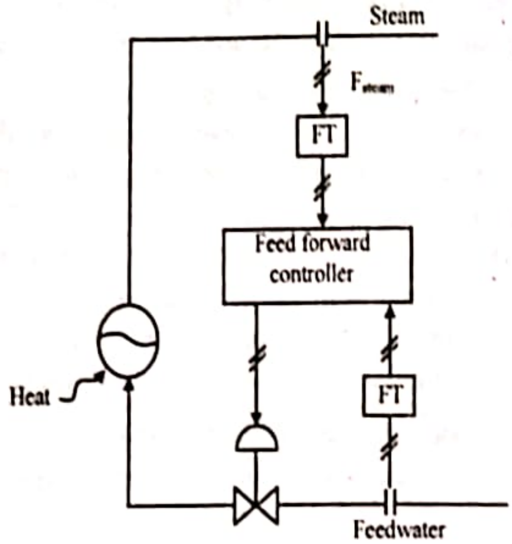


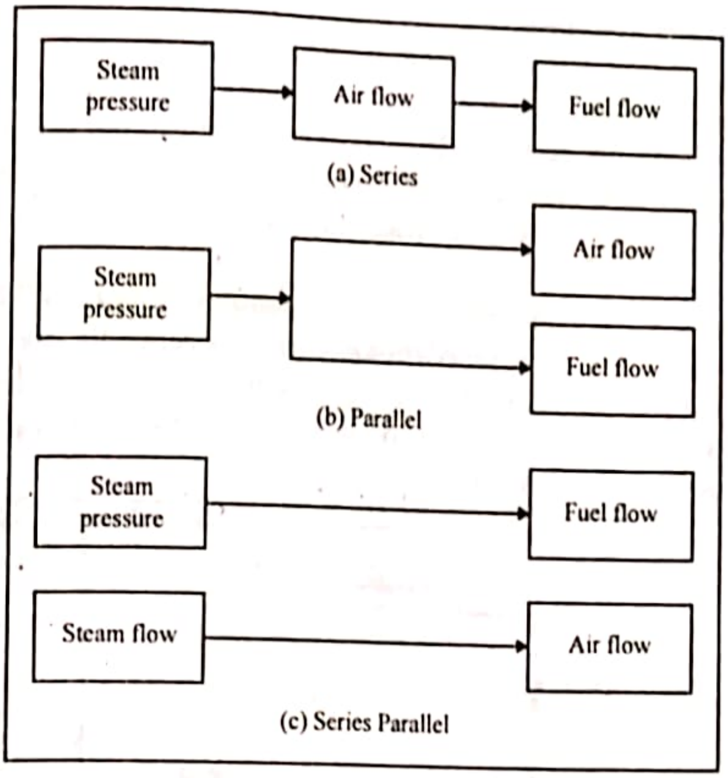

Fig. 1: Drum boiler

**3. Explain combustion control of a process plant with suitable block diagram. What is the function of FD fan & ID fan? What is pulverization?** **[WBUT 2015]**

**Answer:**

A combustion control system is maintenance of fuel air ratio which is of broken down into (a) fuel control and (b) combustion air control subsystems. The interrelationship between these two subsystems necessitates the use of controls. In ratio control, one variable is taken as wild and other needs to be controlled.

The primary boiler fuels are coal, oil and gas. The control of gas and oil fuels requires simplest controls i.e., a control valve in the fuel line. Air flow is taken as the wild variable.
The steam drum pressure is an indication of balance between the inflow and outflow of heat. Therefore, by controlling the steam supply one can establish balance between the demand for steam (process load) and supply of water.




**2nd part:**
I.D. is "Induced Draft" and FD is "Forced Draft." Induced Draft fans are commonly used to draw flue gases from the combustion chamber and through the rest of the system to the stack. They help most to regulate the pressure inside of the boiler system. A forced draft fan will draw in air and force it into the combustion chamber of the boiler, where it mixes with the fuel being supplied. FD fans are typically used to regulate the proper amount of air-to-fuel ratios in an effort to maximize fuel efficiency and to minimize EPA-regulated emissions, such as NOx (Nitrogen Oxides).

**3rd Part**
**Pulvarization is the process of making** powdered coal or coal dust from its solid form for maximum utilization of heat content in it.

**4. Write short notes of the followings:**
**a) pH control of any process plant** **[WBUT 2015]**
**b) Temperature control in a heat exchanger** **[WBUT 2017]**
**c) Combustion control of a furnace** **[WBUT 2017]**
**d) Control of heat exchanger** **[WBUT 2018]**

**Answer:**
**a) pH control of any process plant:**
**Working of pH Control Systems:** A pH control system measures the pH of the solution and controls the addition of a neutralizing agent to maintain the solution at the pH of neutrality, or within certain acceptable limits. It is, in effect, a continuous titration.
These pH control system design depends on factors as flow, acid or base strength or variability of strength, method of adding neutralizing agent, accuracy of control.

**Two-Position (On-Off) Systems:**

The two position or on-off control system is designed so that the element controlling reagent additions is always set in one of two positions, either fully open (on) or fully closed (off), such systems are generally limited to continuous processes where waste flow rate is relatively small and residence (or hold-up) time within the control system is relatively large. Residence time is the average time a unit of volume is "held up" within the reaction vessel.

An on-off system should have a hold-up time of 5 minutes or more. With relatively large flow rates and small hold-up times, proportional control is generally used.

A representative control system is shown in Fig. 1, with the type of control achieved.

If the flow and total acidity or basically of the waste stream can vary by a factor of 10,000, then two reagent pumps will be needed (see Fig. 2).

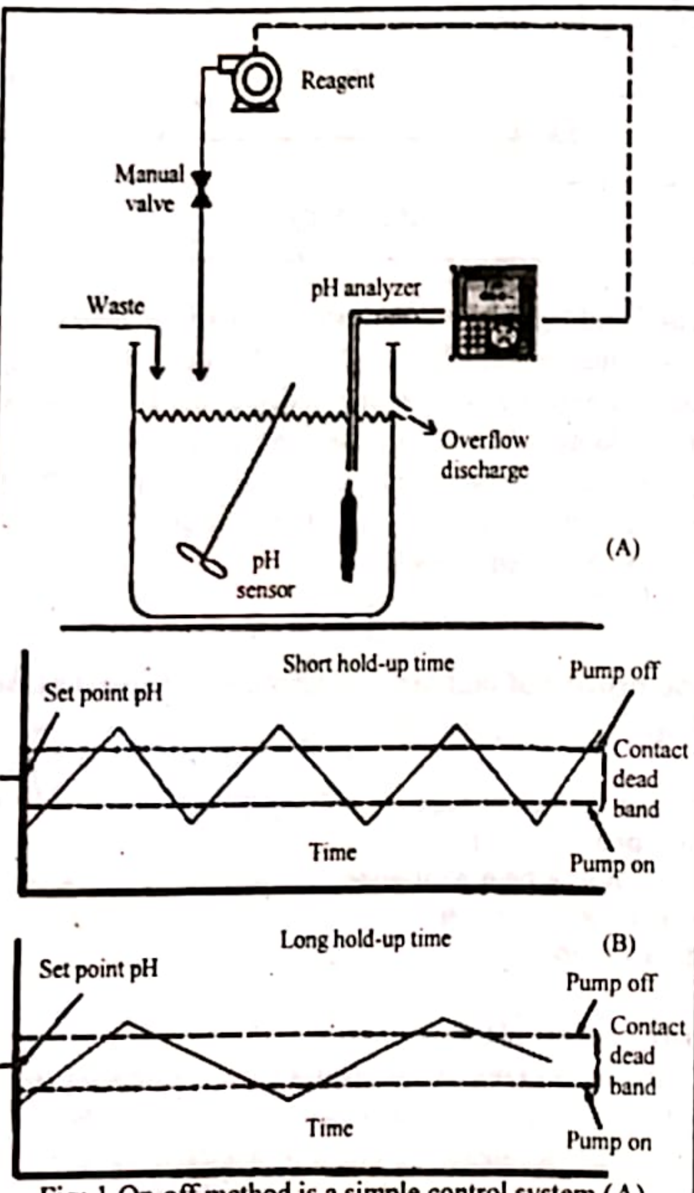



Fig: 1 On-off method is a simple control system (A), with good control characteristics (B) when hold-up time is sufficient

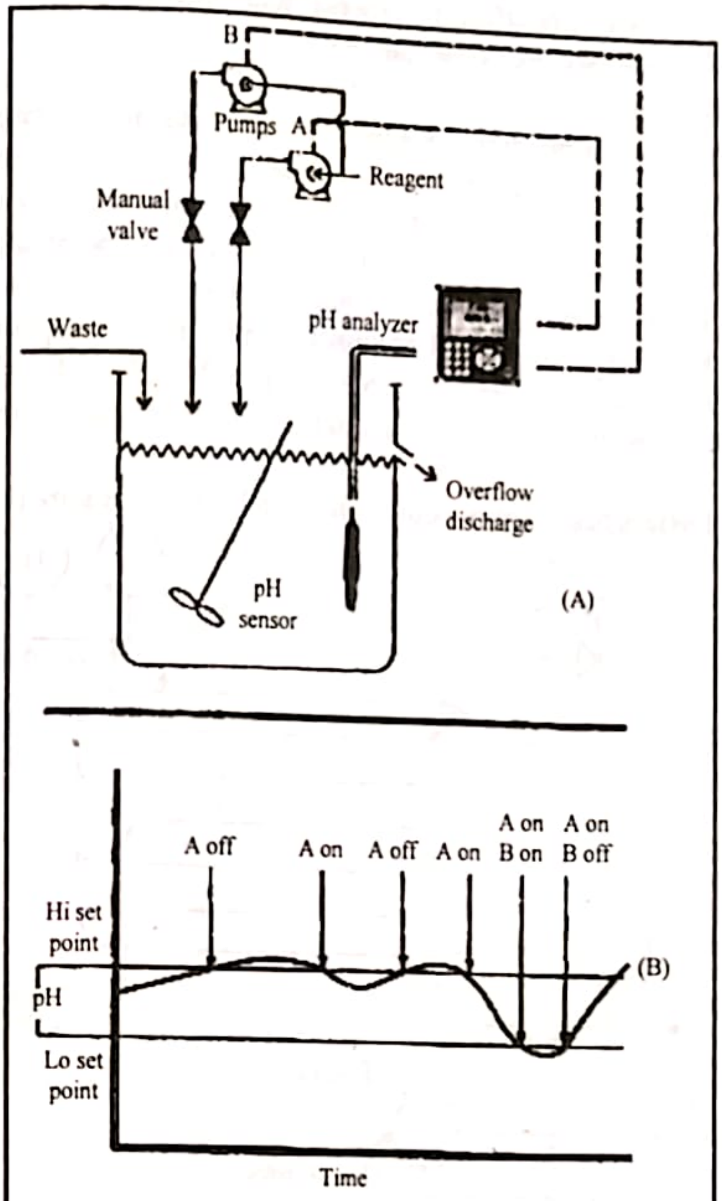



Fig: 2 Dual-flow one-reagent control handles variable-flow situations with two pumps (A and B above)

**b) Temperature control in a heat exchanger**

Heat exchanger transfers thermal energy between fluids. The main purpose of a heat exchanger system is to transfer heat from a hot fluid to a cooler fluid. Consider the heat exchanger shown in the figure (a). The shell side fluid is the process fluid that is required to be heated to a certain temperature set point. The resulting temperature is measured at the outlet of the heat exchanger $T1_{Out}$ (controlled variable). In a simple feedback control strategy, Heating is achieved by passing steam through the tube side. The more steam passing through the tubes, the more heat is transferred to the process fluid, and vice versa. Control of the steam flow F2 (manipulated variable) is achieved by throttling a modulating valve installed on the steam inlet side.

Three major disturbances can affect the process fluid outlet temperature:

- Changes in process fluid flow rate, F1
- Changes in process fluid inlet temperature, $T1_{In}$
- Changes in steam pressure, causing a change in steam flow rate, F2.

In the feedback control scheme, the process variable, $T1_{Out}$, is measured and applied to a proportional-integral-derivative (PID)-based feedback temperature controller (TC), which compares the process variable with the desired temperature setpoint and in turn calculates and generates the control action required to open or close the steam control valve (Fig. b). However, the major disadvantage of feedback control is its incapability to respond to disturbances until the controlled variable is already affected. Also, if too many disturbances occur with significant magnitude, they can create unrecoverable process instability.

Cascade control offers better temperature control in heat exchanging process.

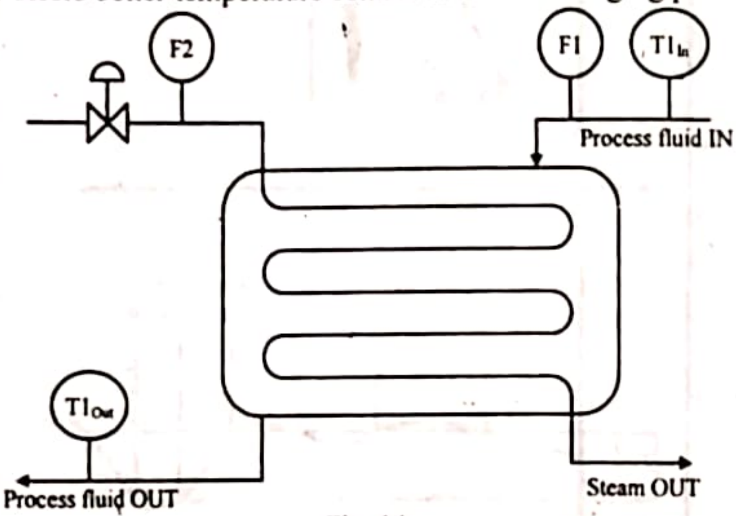



Fig: (a)

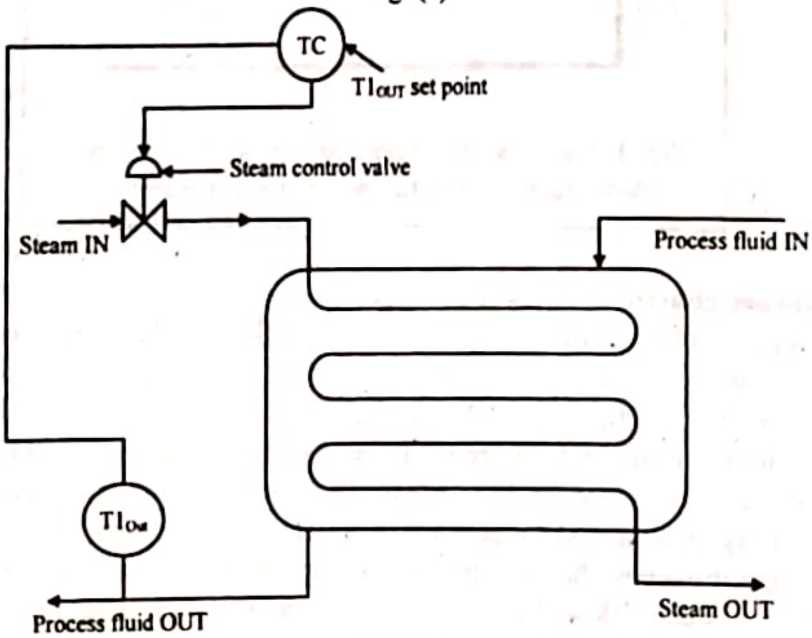



Fig: (b)

In the cascade control scheme, instead of feeding the output of the PID temperature controller directly to the control valve, it is fed as a setpoint to a feedback PID-based, steam-flow controller (fbFC). This second loop is responsible for ensuring the flow rate of the steam doesn't change due to uncontrollable factors, such as steam pressure changes or valve problems. The controller in the second loop (Inner flow loop) takes feedback from the controller of the first loop (Outer temperature loop) (Fig. c)

In the cascade strategy, the flow-control loop FC will adjust the valve position immediately when the steam flow rate has changed. The flow comes back to the value of the previous steady-state condition before it can affect the controlled variable.

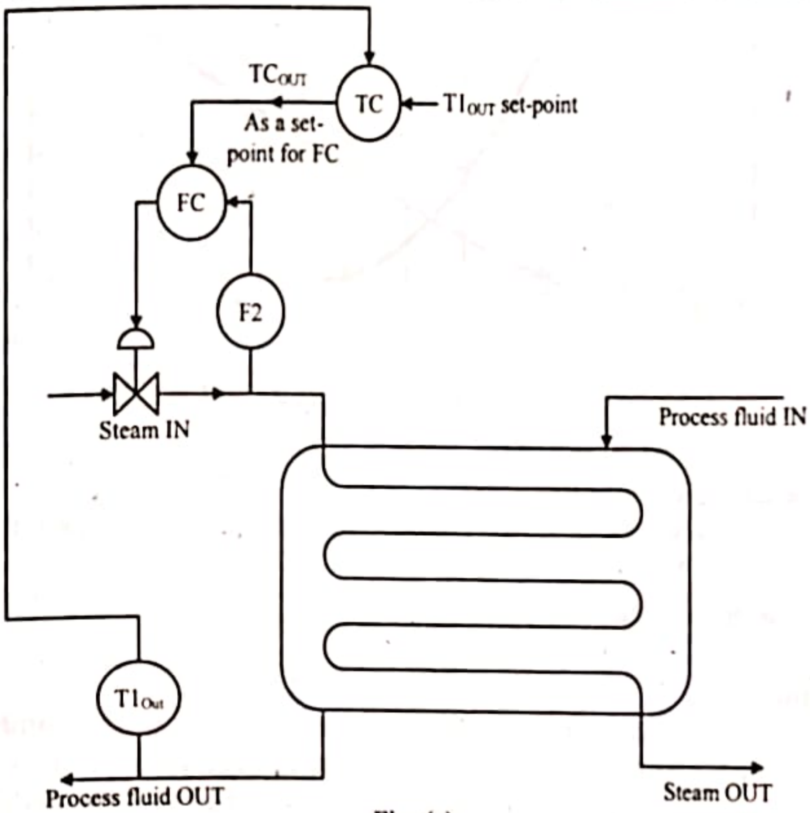



Fig: (c)

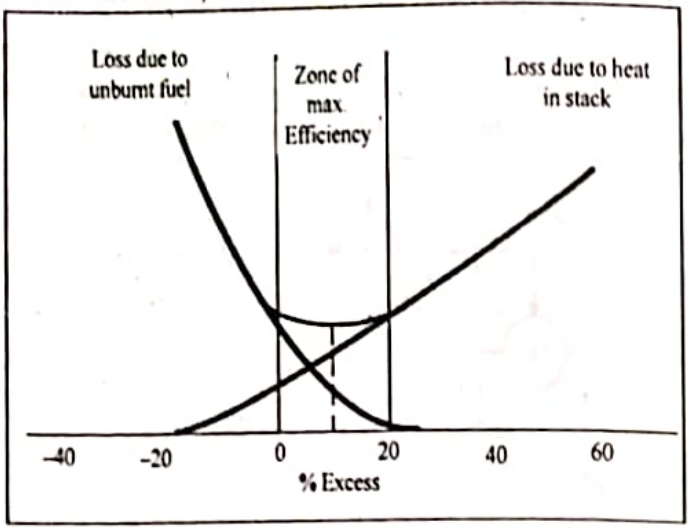
**c) Combustion control of a furnace:**

Furnace is a confined enclosed place where heat is generated using fuel and air. Consequently, they must be designed to operate efficiently and safely whilst responding rapidly to any change in demand. Furnace management systems must be equally adaptive. Burner combustion control generally includes one or combustion of the following methods.

- Regulation of excess air
- Oxygen modulation
- Burner cross – limiting
- Total heat control

**Excess air regulation**

In actual practice, gas, oil, coal burning and other systems do not do a perfect job of mixing the fuel and air even under the best achievable conditions. Additionally, complete mixing may be a lengthy process. Figure shows that in order to ensure complete combustion and reduce heat loss, excess air has to be kept within a suitable.




(1) Boiler efficiency

The regulation of excess air provides

- A better boilers hear transfer rate.
- An advance warming of flue gas problems (excess air coming out of the zone of maximum efficiently)
- Substantial savings on fuel

**Oxygen trim**

When a measurement of oxygen in the flue gas is available, the combustion control Mechanism can be vastly improved (since the percentage of oxygen in flue is closely related to the amount of excess air) by adding an oxygen trim control module, allowing

- Tighter control of excess air to oxygen set point for better efficiency
- faster return to set point following disturbances
- Tighter control over flue emissions
- compliance with emission standards
- Easy incorporation of carbon monoxide or capacity override.

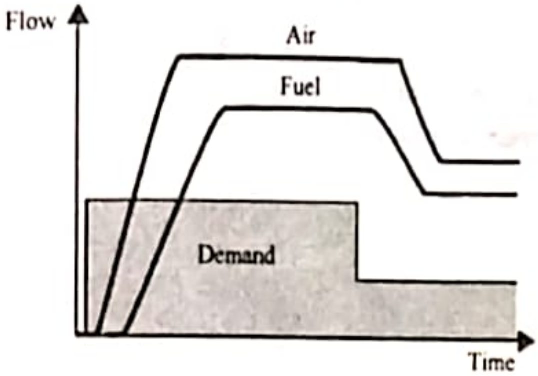
**Burner Modulation**

Modulating control is a basic improvement in controlling combustion. A continuous control signal is generated by a controller monitoring the steam or hot water line. Reductions in steam pressure or hot water temperature lead to an increase in firing rate. The advantages of introducing burner modulation in combustion control include.

- Fuel and air requirements are continuously matched to the combustion demand
- Steam pressure or hot water temperature is maintained within closer tolerances
- Greater boiler efficiency
- Weighted average flue gas temperature is lower

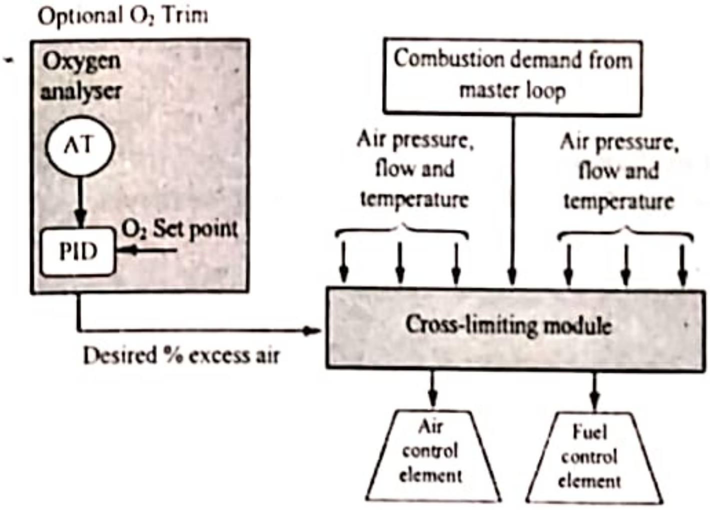
**Air/fuel cross-limiting**

A cross0limiting combustion control strategy ensures that there can never be a dangerous ration of air and fuel within a combustion process. This is implemented by always raising the air flow before allowing the fuel flow to increase as shown in figure, or by lowering the fuel flow before allowing the air flow to drop.




(2) Cross-limiting Combustion Mechanism

Figure below depicts a simplified control block diagram of the cross-limiting combustion circuit. Combination firing of multiple fuels simultaneously can also be easily accommodated within the scheme.




(3) Cross-limiting Combustion Control with 02 Trim

Cross-limiting combustion control is highly effective and can easily provide the following:

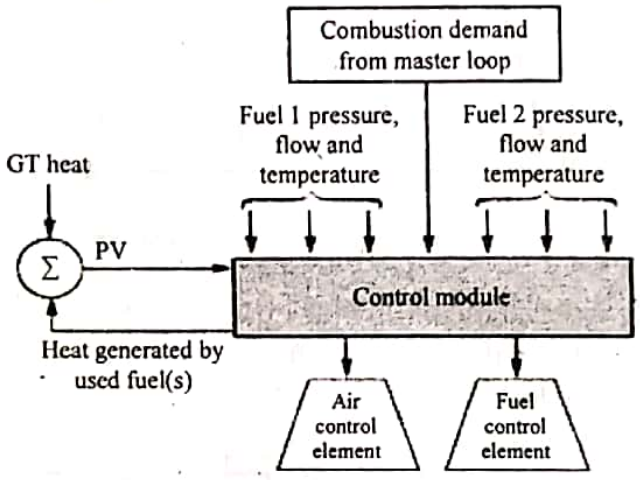
- Optimization of fuel consumption
- safer operating condition by reducing risk of explosion
- Fast adaptation to variation in fuel and air supplies
- Satisfaction of the plant demand fore steam

**Enhanced cross-limiting**

Double cross-limiting combustion control is an enhancement to the above. It is achieved by applying additional dynamic limits the actual air and fuel set points. This translates to having the actual air/fuel ratio maintained within a preset band during and after transition. This method protects against having the demand signal driving the air/fuel ration too lean, therefore reducing heat loss.

**Total heat control**

In situation where combustion is not the principle heat source and when several factors contribute to the total heat to be generated by a boiler, a control loop can be introduced in order to monitor and manage the generated heat. This is particularly true for CIIP plants, where gas turbines and supplementary firing are used. This type of implementation is shown in Figure 4.




(4)

**d) Control of heat exchanger:**

***Refer to Question No. 1(a) of Long Answer Type Questions.***