MODULE – IV

FUELS AND COMBUSTION

4.5 Combustion

Combustion is an exothermic oxidation reaction in which a fuel burns in the presence of oxygen with the evolution of heat and light.

Calorific value

The total quantity of heat of liberated when unit mass of fuel is burnt completely.

Units for calorific value

i. Calorie / gram

ii. Kilocalorie / kg

iii. iii)British thermal unit (for solid or liquid fuels)

1. **Higher calorific value (HCV) or Gross calorific value (GCV)**

   The total amount of heat produced when unit mass of the fuel is burnt completely and the products of combustion are cooled to room temperature.

2. **Lower calorific value (LCV) or Net calorific value (NCV)**

   The net heat produced when unit mass of the fuel is burnt completely and the products of combustion are allowed to escape.

Dulong's formula for GCV is,

GCV or HCV = [8080 C + 34500 (H -) + 2240 S] kcal / kg

where C, H, O & S represents the % of the corresponding elements.

Dulong's formula for NCV is,

NCV = GCV – 0.09H x 587 kcal / kg. (H = % of H2 in the fuel) Problems based on calorific value

1. Calculate the gross and net calorific values of coal having the following compositions, carbon = 85%, hydrogen = 8%, sulphur = 1%, nitrogen =2%, ash = 4%, latent heat of steam = 587 cal/g.

i) Gross calorific value

GCV or HCV = [8080 C + 34500 (H -) + 2240 S] kcal /kg

= [8080 x 85 + 34500 (8 -) + 2240 x 1] kcal /kg

= [686800 + 276000 + 2240] kcal /kg

GCV or HCV= 9650.4 kcal / kg.

ii) Net calorific value

= 9650.4 - 8 x 587

= 9650.4 – 422.64

NCV = 9227.76 kcal / kg

4.5.1 Ignition Temperature

- The minimum temperature at which a fuel starts to burn is called its **ignitiontemperature**. It is otherwisecalled autogenous ignition temperature.
- Some fuels have low ignition temperature and some have high ignition temperature.
- The fuels that have low ignition temperature are highly inflammable and burn quickly at the spark of fire.
- While some fuels that have high ignition temperature do not burn quickly. They require heating to burn.
- For example kerosene oil does not burn unless it is heated up to its ignition temperature.
- For liquid fuels it is called as Flash point that ranges from 200 – 450^{0}C.
- Ignition temperature for coal is 300^{0}C.
- Ignition temperature for gaseous fuels is 400^{0}C - 600^{0}C.

4.5.2 Spontaneous Ignition Temperature (SIT)

- It is defined as, "the minimum temperature at which the fuel catches fire spontaneously without external heating".
- It is otherwise known as **Self Ignition Temperature.**
- When the system reaches Spontaneous Ignition Temperature, the system burns on its own.
- The **self ignition temperature** of **diesel** is 210°C and that of **petrol** varies from 247°C to 280°C.

4.5.3 Explosive Range

- Before a fire or explosion can occur, three conditions must be met simultaneously. A fuel and oxygen must exist in certain proportions, along with an ignition source. The ratio of fuel and oxygen that is required varies with each combustible gas or vapor.
- The minimum concentration of a particular combustible gas or vapor necessary to support its combustion in air is defined as the Lower Explosive Limit (LEL) for that gas. Below this level, the mixture is too "lean" to burn.
- The maximum concentration of a gas or vapor that will burn in air is defined as the Upper Explosive Limit (UEL). Above this level, the mixture is too "rich" to burn.

- The range between the LEL and UEL is known as the flammable range for that gas or vapor.

4.5.4 Flue gas analysis by Orsat method

- Flue gas is the **the mixture of gases (like CO2, O2& CO) coming out fromthe combustion chamber.**
- The analysis of a flue gas would give an idea about **the complete orincomplete combustion process**.
- The analysis of flue gas is carried out by using **Orsat's apparatus.**

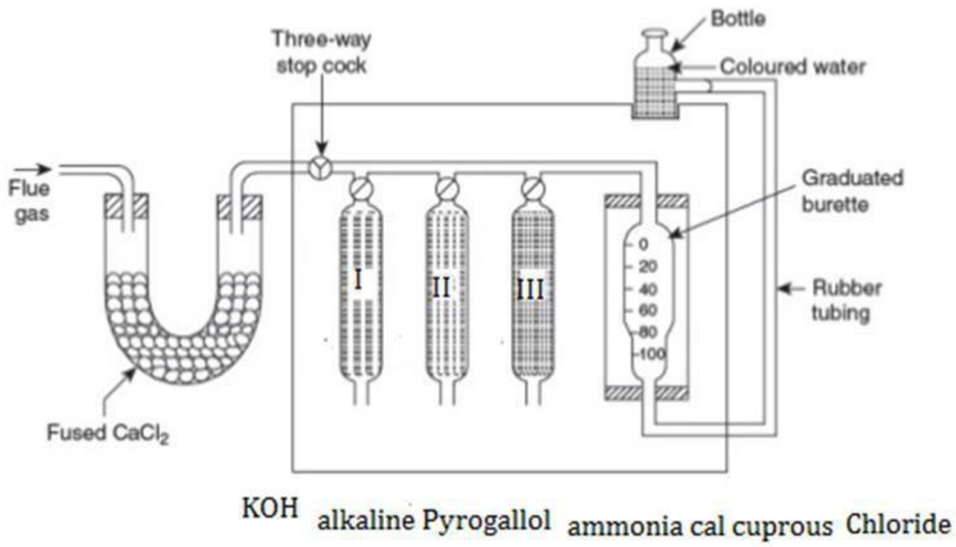
Description of Orsat's apparatus

- It consists of a horizontal tube.
- At one end of this tube, „U" tube containing fused CaCl2 is connected through 3 – way stop cock.
- The other end of the tube is connected with a graduated burette.
- The burette is surrounded by a water jacket (keeps the temperature of the gas constant).
- The lower end of the burette is connected to a water reservoir by means of a rubber tube.
- The level of water in the burette can be raised or lowered by raising or lowering the reservoir.
- The horizontal tube is connected with three different absorption bulbs 1, 2 and 3 for absorbing CO2, O2 and CO.

Bulb -1 contains **KOH** and it absorbs **CO2** only.

Bulb - 2 contains **alkaline pyrogallol** and it absorbs CO2and O2.

Bulb - 3 contains **ammoniacal cuprous chloride** and it absorbs **CO2, O2 and CO.**



Working

- The three way stop cock is opened to the atmosphere and the burette is completely filled with water and air is sent out.

- The burette is filled with flue gas to 100cc by raising or lowering the reservoir. Now the 3- way stop cock is closed.

1. Absorption of CO_2

- The Bulb-1 is filled with the flue gas is by raising the level of water in the burette.
- Here CO_2 is absorbed by KOH. The gas is again sent to the burette.
- The process is repeated several times to ensure complete absorption of CO_2.
- **The decrease in volume of the flue gas = the volume of CO_2 in 100cc of the flue gas.**

2. Absorption of O_2

- Bulb-1 is closed and Bulb-2 is opened.
- The gas enters into Bulb-2 where O_2 is absorbed by alkaline pyrogallol.
- **The decrease in volume of the flue gas = the volume of O_2.**

3. Absorption of CO

- Bulb 2 is closed and Bulb-3 is opened.
- The remaining gas is sent into Bulb-3, where CO is absorbed by ammoniacal cuprous chloride.
- **The decrease in volume of flue gas = the volume of CO.**
- The remaining gas in the burette is taken as nitrogen.

Significance

i) It gives an idea about the complete or incomplete combustion.

ii) If the flue gas contains high amount of CO, it shows incomplete combustion and short supply of O_2.

iii) If the flue gas contain high amount of O_2, it indicates complete combustion and excess supply of O_2.