

# 9

## Combustion

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## 9.1 Basic Definitions

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### 9.1.1 Stoichiometric Air Fuel Ratio

- ▶ Stoichiometric (or chemically correct) mixture of air and fuel is one that contains just sufficient oxygen for complete combustion of the fuel.

### 9.1.2 Enthalpy of Formation ( $\Delta H_f$ )

- ▶ A combustion reaction is a particular kind of chemical reaction in which products are formed from reactants with the release or absorption of energy as heat is transferred to or from the surroundings.
- ▶ In some substances like hydrocarbon fuels which are many in number and complex in structure the *heat of reaction* or *combustion* may be calculated on the basis of known values of the enthalpy of formation,  $\Delta H_f$  of the constituent of the reactants and products at the temperature  $T_0$  (reference temperature).

### 9.1.3 Enthalpy of Reaction

- ▶ The enthalpy of reaction is the difference between the total enthalpy of the products of a reaction and the total enthalpy of the reactants.

### 9.1.4 Adiabatic Flame Temperature

- ▶ In a given combustion process, that takes place adiabatically and with no work or changes in kinetic or potential energy involved, the temperature of the products is referred to as the adiabatic flame temperature.

### 9.1.5 Higher Calorific Value (HCV) or Higher Heating Value (HHV) or Gross Calorific Value

- ▶ When 1 kg of a fuel is burnt, the heat obtained by the complete combustion after the products of the combustion are cooled down to room temperature is called higher calorific value of that fuel.

### 9.1.6 Lower Heating Value (LLV) or Lower Calorific Value (LCV) or Net Calorific Value

- ▶ When 1 kg of a fuel is completely burned and the products of combustion are not cooled down or the heat carried away the products of combustion is not recovered and the steam produced in this process is not condensed then the heat obtained is known as the Lower Calorific Value.

## 9.2 Determination of Calorific or Heating Values

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- ▶ The calorific value of fuels can be determined either from chemical analysis or in the laboratory.

### 1) Laboratory method (Bomb calorimeter)

- ▶ The calorific value of *solid and liquid fuels* is determined in the laboratory by 'Bomb calorimeter'. It is so named because its shape resembles that of a bomb. Fig.9.2 - Junker's gas calorimeter. shows the schematic sketch of a bomb calorimeter.
- ▶ The calorimeter is made of austenitic steel which provides considerable resistance to corrosion and enables it to withstand high pressure.
- ▶ In the calorimeter is a strong cylindrical bomb in which combustion occurs. The bomb has two valves at the top. One supplies oxygen to the bomb and other releases the exhaust gases.
- ▶ A crucible in which a weighted quantity of fuel sample is burnt is arranged between the two electrodes as shown in Fig.9.2 - Junker's gas calorimeter.
- ▶ The calorimeter is fitted with *water jacket* which surrounds the bomb. To reduce the losses due to radiation, calorimeter is further provided with a jacket of water and air .

- ▶ A stirrer for keeping the temperature of water uniform and a thermometer to measure the temperature up to an accuracy of  $0.001^{\circ}\text{C}$  are fitted through the lid of the calorimeter.

### Procedure

- ▶ To start with, about 1 gm of fuel sample is accurately weighed into the crucible and a fuse wire (whose weight is known) is stretched between the electrodes. It should be ensured that wire is in close contact with the fuel.
- ▶ To absorb the combustion products of sulphur and nitrogen 2 ml of water is poured in the bomb. Bomb is then supplied with pure oxygen through the valve to an amount of 25 atmosphere. The bomb is then placed in the weighed quantity of water, in the calorimeter.

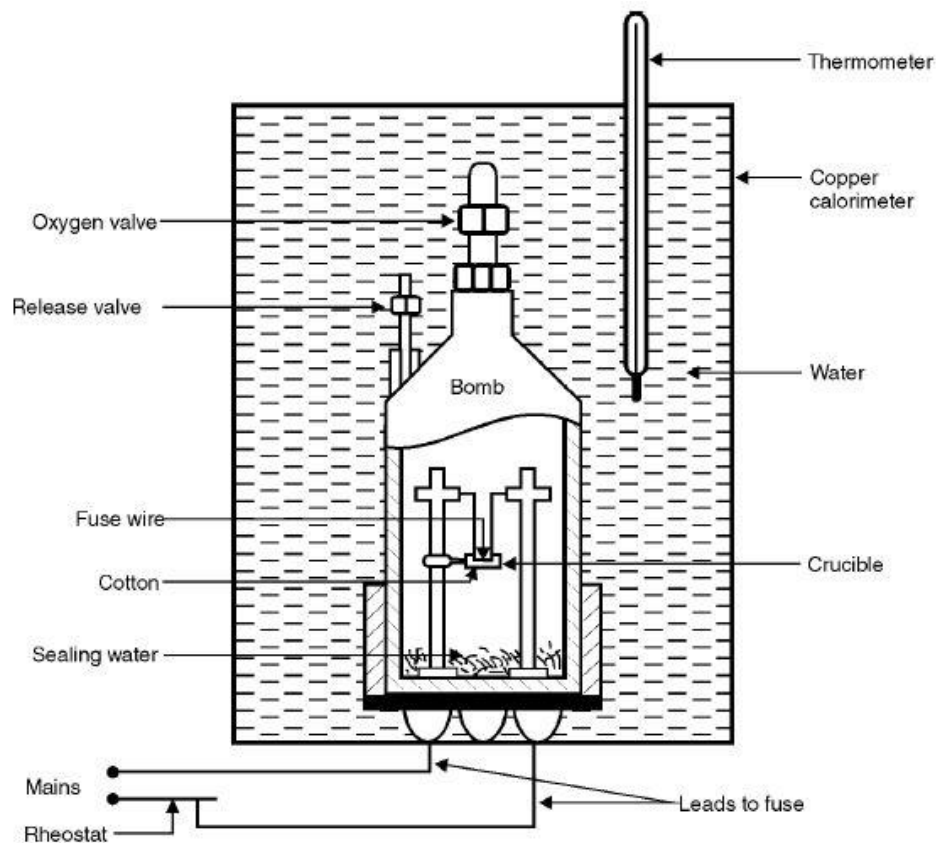


Fig.9.1 - Bomb calorimeter

- ▶ The stirring is started after making necessary electrical connections, and when the thermometer indicates a steady temperature fuel is fired and temperature readings are recorded after 1/2 minute intervals until maximum temperature is attained.
- ▶ The bomb is then removed ; the pressure slowly released through the exhaust valve and the contents of the bomb are carefully weighed for further analysis.
- ▶ From the above data the calorific value of the fuel can be found in the following way :

Let  $w_f$  = Weight of fuel sample (kg),

$w$  = Weight of water (kg),

$C$  = Calorific value (higher) of the fuel (kJ/kg),

$w_e$  = Water equivalent of calorimeter (kg),

$t_1$  = Initial temperature of water and calorimeter,

$t_2$  = Final temperature of water and calorimeter,

$t_c$  = Radiation corrections, and

$c$  = Specific heat of water.

- ▶ Heat released by fuel sample

$$= W_f \times C \quad \text{Eq. (9.1)}$$

- ▶ Heat received by water and calorimeter

$$= (w_w + w_e) \times c \times [(t_2 - t_1) + t_c] \quad \text{Eq. (9.2)}$$

- ▶ Heat loss = Heat gain

$$w_f \times C = (w_w + w_e) \times c \times [(t_2 - t_1) + t_c] \quad \text{Eq. (9.3)}$$

$$C = \frac{(w_w + w_e) \times c \times [(t_2 - t_1) + t_c]}{W_f} \quad \text{Eq. (9.4)}$$

## 2) Gaseous Fuels (Junker's gas calorimeter)

- ▶ The calorific value of gaseous fuels can be determined by Junker's gas calorimeter. Fig. Fig.9.2 - Junker's gas calorimeter. illustrates Junker's gas calorimeter. Its principle is some what similar to Bomb calorimeter in respect that heat evolved by burning the gas is taken away by the water. In its simplest construction it consists of a combustion chamber in which the gas is burnt (in a gas burner). A water jacket through which a set of tubes called flues pass surrounds this chamber. Thermometers are incorporated at different places (as shown in Fig. Fig.9.2 - Junker's gas calorimeter.) to measure the temperatures.

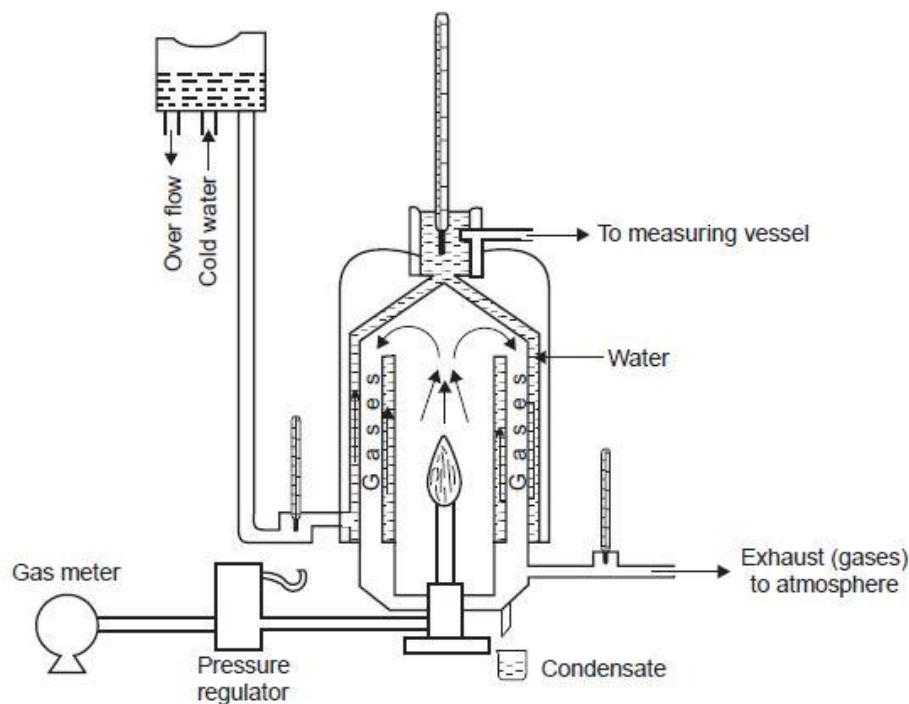


Fig.9.2 - Junker's gas calorimeter.

### Procedure.

- ▶ A metered quantity of gas whose calorific value is to be determined is supplied to the gas burner via a gas meter which records its volume and a gas pressure regulator which measures the pressure of the gas by means of a manometer.
- ▶ When the gas burns the hot products of combustion travel upwards in the chamber and then downwards through the flues and finally escape to the atmosphere through the outlet. The temperature of the escaping

gas is recorded by the thermometer fitted at the exit and this temperature should be as close to room temperature as possible so that entire heat of combustion is absorbed by water.

- ▶ The cold water enters the calorimeter near the bottom and leaves near the top. Water which is formed by condensation of steam is collected in a pot.
- ▶ The quantity of gas used during the experiment is accurately measured by the meter and temperature of ingoing and outgoing water are indicated by the thermometers. From the above data the calorific value of the gas can be calculated.

### 9.3 Reference Book

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- ▶ Engineering Thermodynamics by R. K. Rajput