- Oxygen present in coal lowers the calorific value as it is usually associated with moisture thereby decreasing available hydrogen for combustion process. An increase in oxygen content by 1% decreases the calorific value by about 1.7%.

2.3 CALORIFIC VALUE OF A FUEL

An important parameter of fuels is calorific value. It gives useful information about its heating efficiency. The performance of a fuel is expressed in terms of its calorific value.

Calorific value is defined as the amount of heat energy released by the complete combustion of unit quantity (mass or volume) of the fuel.

Calorific value is normally expressed in calories per gram (cal/g) in cgs units. It is also expressed in joules per kg (J/Kg) for solid fuels, and joules per cubic meter (J/m^3) for gaseous fuels in SI units.

Types of Calorific value

2.3.1 GROSS OR HIGHER CALORIFIC VALUE (HCV)

Gross calorific value is the amount of heat energy released when a unit mass of fuel is burnt completely in air and the products of combustion are cooled down to room temperature (15°C or 60°F).

All fuels invariably contain carbon and hydrogen. On combustion, carbon and hydrogen present in the fuel are converted to CO_2 and steam respectively. On cooling the combustion products, steam gets condensed to water and liberates its latent heat. The measured gross calorific value includes the heat of combustion of the fuel and latent heat of steam.

Theoretical higher calorific value of a fuel can be calculated by knowing the percentage of constituents of the fuel. Calorific value can be calculated using **Dulong's formula**.

$$HCV = \frac{1}{100}\left[8080\,C + 34500\left(H - \frac{O}{8}\right) + 2240 \times S\right] \text{kcal/kg or cal/g}$$

Where, C, H, O and S = percentages of carbon, hydrogen, oxygen and sulphur in the fuel sample

8080 = Calorific value of carbon

Heat liberated by the fuel = Heat absorbed by water and calorimeter

$$mL = (W+w) \times (t_2-t_1)$$

$$\text{HCV of the fuel} = \frac{(W+w) \times (t_2-t_1)}{m} \text{ cal/g}$$

If H is the percentage of Hydrogen in fuel, then lower (net) calorific value (LCV) can be calculated as

$$LCV = (HCV - 0.09\ H \times 587) \text{ cal/g}$$

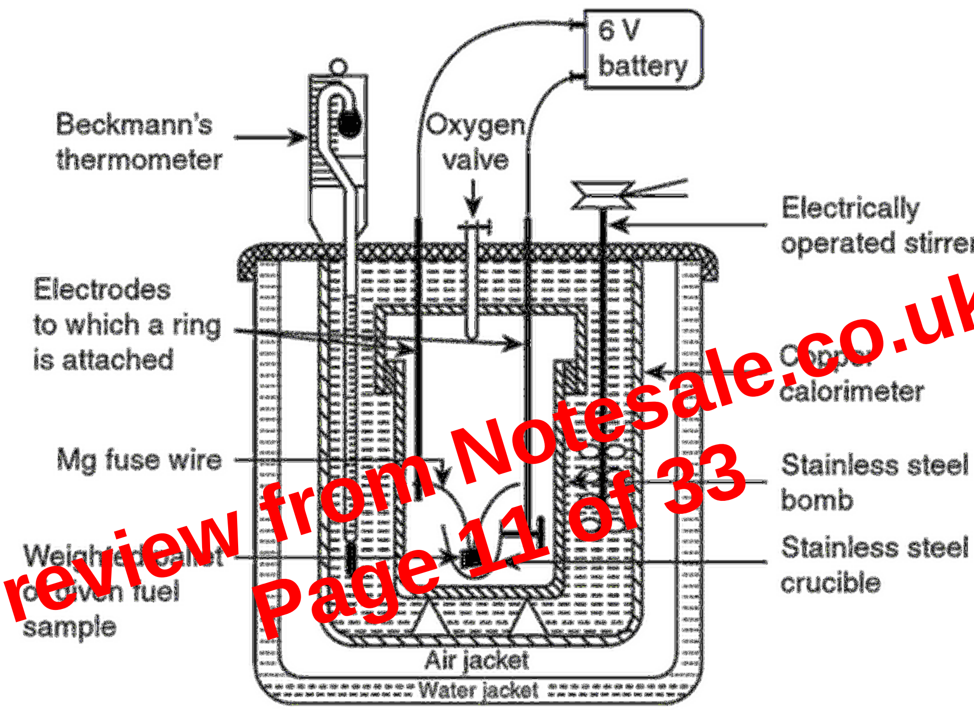

Figure 2.3: Bomb calorimeter

Corrections

(i) Fuse wire correction: The heat liberated includes the heat given out by ignition of the fuse wire used.

(ii) Acid correction: Fuels containing sulphur and nitrogen are oxidized under high pressure and temperature of ignition to sulphuric acid and nitric acid.

$$S + 2O_2 + H_2 \rightarrow H_2SO_4 \quad \Delta H = -72000 \text{ cal}$$

$$2N + H_2 + 3O_2 \rightarrow 2HNO_3 \quad \Delta H = -28600 \text{ cal}$$

Formation of these acids is an exothermic reaction, thus the measured heat also includes the heat given out during acid formation so it has to substracted.

$$\text{HCV} = \frac{(1500+470) \times 4.187 \times (27.3-25.0)}{0.73 \times 10^{-3}}$$

$$= 2.599 \times 10^{7}\ \text{Jkg}^{-1}$$

Net Calorific value = HCV- (0.09H x 587)

$= 2.599 \times 10^{7} - (0.09 \times 2.5 \times 587 \times 4.187 \times 10^{3})$

$= = 2.544 \times 10^{7}\ \text{Jkg}^{-1}$

Example 3: Calculate the gross and net calorific value of a coal sample from the following data obtained from bomb calorimeter experiment.

Mass of coal (m) = 0.92 g

Weight of water taken in the calorimeter (W)= 550 g

Water equivalent of calorimeter (w) = 2200 g

Initial temperature = 25.0°C

Final temperature= 27.42°C

Percentage of carbon and hydrogen in coal sample = 93% and 6 %

Latent heat of steam = 580 cal g^{-1}

Fused wire correction =10.0 cal

Acid correction = 50.0 cal

Solution:

$$\text{HCV} = \frac{(W+w) \times (t_2 - t_1 + \text{cooling correction}) - [(\text{Acid+fuse wire correction})]}{m}$$

$$= \frac{[(550+2200)(2.42)-[50+10]}{0.92}$$

= 7168.48 cal/g

LCV = [GCV- 0.09H x latent heat of steam]

= [7168.48 – 0.09 x 6 x 580]

= 6855.28 cal/g

per unit time. Pressure governor is used to regulate the supply of gas at constant pressure. Gas calorimeter includes a vertical cylinder in which the fuel is burnt. It is surrounded by water jacket. Three thermometers are used, two of them are used to measure the temperature of inlet water and outlet water. Third one is used to measure the temperature of outgoing gases.

Working:

A known volume of gas is burnt in excess of air at a constant rate in combustion chamber. The heat liberated increases the temperature of the water jacket. Circulation of water and the burning of gases are performed continuously about 15 minutes at uniform rates. The total amount of water circulated is a measured and the final rise in temperature is noted. Water formed by the condensation of steam is also collected in a graduated cylinder through a small outlet at the bottom.

Calculations:

Let the volume of gas burnt at STP in certain time t = V

Weight of water circulated through the calorimeter = W

Temperature of incoming water = t_1

Temperature of outgoing water = t_2

Then, HCV of the gaseous fuel

can be calculated by the equation, HCV $= \frac{W(t_2 - t_1)}{V}$ Kcal/m^3

Mass of the steam in time 't' collected in

Graduated cylinder from 'V' m^3 of gas = m

Amount of water condensed from the steam

Produced by burning 1m^3 of gas $= \frac{m}{V}$

Latent heat of steam is 587 Kcal/g

Lower calorific value (LCV) = HCV- $\frac{m}{V}$ x 587 Kcal/m^3

Example 1: A gaseous fuel was burnt in Junker's calorimeter to find out high and low calorific value, the following data were obtained:

Volume of gaseous fuel burnt in certain time = 0.1 m^3

Volume of water collected in certain time = 20 kg

Solution

$$\begin{array}{ccccc} C & + & O_2 & \longrightarrow & CO_2 \\ 12 & & 32 & & 44 \end{array}$$

12 kg of C requires 32 kg of O_2

$$1 \text{ kg of coke requires } = \frac{32}{12} \times 1 = 2.67 \text{ kg of } O_2.$$

23 kg of O_2 is supplied by 100 kg of air

$$2.67 \text{ kg of } O_2 \text{ is supplied by} = \frac{100}{23} \times 2.67 = 11.6 \text{ kg}.$$

32 kg of O_2 occupies 22.4 m^3 at NTP

$$2.67 \text{ kg of } O_2 \text{ occupies } = \frac{100}{32} \times 2.67 = 1.87 \text{ m}^3 \text{ at NTP}.$$

21 m^3 of O_2 is supplied by 100 m^3 of air

$$1.87 \text{ m}^3 \text{ of } O_2 \text{ is supplied by} = \frac{100}{21} \times 1.87 = 8.9 \text{ m}^3.$$

Weight of air required for the combustion of 1 kg of coke = 11.6 kg.
Volume of air required for the combustion of 1 kg of coke = 8.9 m^3.

6. A fuel contains C= 75%; H= 4%; O= 5%; S= 7% remaining ash. Calculate the minimum quantity of air required for the complete combustion of fuel.

Solution. 1 kg of the fuel contains 0.75 kg of carbon ; 0.04 kg of Hydrogen
0.05 kg of Oxygen ; 0.07 kg of Sulphur

The combustion equations of the various elements present in the fuel are as follows:

(*a*) $C + O_2 \longrightarrow CO_2$
12 kg 32 kg

(*b*) $H_2 + 1/2\ O_2 \longrightarrow H_2O$
2 kg 16 kg

(*c*) $S + O_2 \longrightarrow SO_2$
32 kg 32 kg

(*a*) 12 kgs carbon requires 32 kgs of Oxygen

$$\therefore \quad 0.75 \text{ kg of carbon requires } = \frac{32 \times 75}{12} = 2 \text{ kg of Oxygen}$$

(*b*) 2 kgs of hydrogen requires = 16 kgs of Oxygen

$$\therefore \quad 0.04 \text{ kg of hydrogen requires } = \frac{16 \times 0.04}{2} = 0.32 \text{ kg of Oxygen}$$