FUELS

A fuel is defined as combustible material which on combustion in air gives large amount of heat that can be used economically for both domestic and industrial purposes. The important commonly used fuels are: wood, coal, petrol diesel etc.

Classification of fuels: Fuels are classified into two types.

According to source

Natural (Primary) — (on the basis of Physical State): Solid, Liquid, Gas

Artificial (Synthetic) Secondary — (on the basis of Physical State): Solid, Liquid, Gas

1) Based on their origin they are classified into

a) Primary fuels b) Secondary fuels.

a) Primary Fuels: There are naturally occurring fuels which serves as source of energy without any chemical processing.

Ex: Wood, Coal, Crude oil, Natural gas, Peat, Lignite, Anthracite.

b) Secondary Fuels: - They are derived from primary fuels & serves as source of energy only after subjecting to chemical processing.

Ex: Charcoal, Coke, producer gas, Petrol, Diesel etc.,

2) Bases on their physical state fuel are classified into

a) Solid b) Liquid c) Gaseous fuels.

	SOLID	LIQUID	GASEOUS
Primary Fuels	Wood, Coal, Peat, Anthracite	Crude oil	Natural gas.
Secondary Fuels	Coke, Charcoal	Petrol, Gasoline,	LPG, Produser gas, Coal gas.

Calorific Value: Calorific value is defined as the amount of heat liberated when a unit mass of fuel is burnt completely in presence of air or oxygen.

Calorific value is of two types as follows:-
1) Higher calorific value. (HCV) or Gross calorific value. (GCV)
2) Lower calorific value. (LCV) or Net calorific value. (NCV)

1) HCV: - It is the amount of heat liberated when a unit mass of fuels burnt completely in the presence of air or oxygen and the products of combustion are cooled to room temperature. Here it includes the heat liberated during combustion and the latent heat of steam. Hence its value is always higher than lower calorific value.

2) LCV: It is amount of heat liberated when a unit mass of fuel is burnt completely in the presence of air or oxygen and the product of combustion are let off completely into air. It does not include the latent heat of steam. Therefore it is always lesser than HCV.

$$\mathbf{NCV = HCV - 0.09 \times \%\, H_2 \times 587\ cal/g}$$

SI units of calorific value.

In SI system the units of calorific values for solid fuels are expressed in J/Kg and for gaseous and liquid are expressed in J/m^3.

UNITS OF HEAT: The most common units for heat are

- *Calorie*
- *Kilo Calories*
- *BTU (Btu) - British Thermal Unit - also known as a "heat unit" in United States*
- CHU (Centigrade heat unit)

Calorie: Calorie is defined as the amount of heat required to raise the temperature of one gram of water *1°C* . 1 Calorie = 4.185 Joule

Kilogram Calories: is the amount of energy required to raise the temperature of one kilogram water by one degree Celsius.

1 Kcal = 1000 Cal.

SNo	UNIT	Weight of water	Rise in temp.
1.	Calorie	1 gm	1°C
2.	K. Calorie	1 Kg	1°C
3.	BTU	1 Pound	1°F
4.	CHU	1 Pound	1°C

same temp.

weight same

$1 kcal = 4186.8\ J = 426.9\ kp\ m = 1.163\ 10^{-3}\ kWh = 3.088\ ft\ lb_f = 3.9683$
$Btu = 1000\ cal$

BTU - British Thermal Unit: the amount of heat required to raise the temperature of one pound of water through $1°F$).

$1\ Btu$ *(British thermal unit)* $= 1055.06\ J = 0.252\ kcal = 252\ cal$

Centigrade Heat Unit: The amount of heat necessary to raise the temp. of one pound weight of water through 1° C.

1 K.Cal = 3.968 BTU
= 2.2 CHU

Characteristics of a good fuel:

1. **Calorific value:** Calorific value is defined as the amount of heat liberated when a unit mass of fuel is burnt completely in presence of air/ oxygen. A good fuel should possess high calorific value.
2. **Ignition temperature:** It is the minimum temperature of which a fuel catches fire. A good fuel should have moderate ignition temperature.
3. Low moisture content: A good fuel should have low moisture content, because moisture decreases its calorific value.
4. Low cost: A good fuel should be readily available in bulk at a low cost.
5. Harmless combustion products: Fuels on combustion should not produce any harmful products which may be toxic for nearby population.
6. Low non combustible matter: A good fuel should have low non-combustible matter.
7. Easy to transport: A good fuel is that, which can be easy to handle, store, and transport at a low cost.

Determination of calorific value of solid fuel using Bomb calorimetric method:

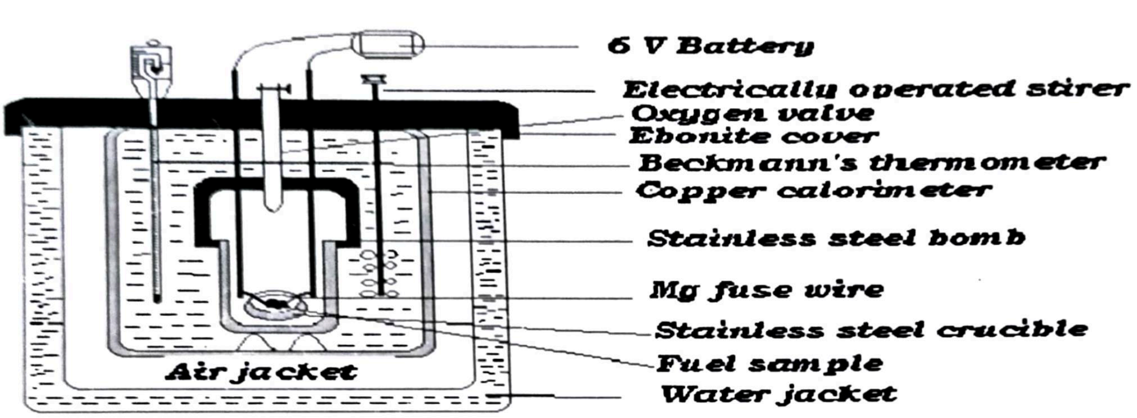
The calorific value of solids and non –volatile liquid fuels is determined by bomb calorimeter.

Principle: A know amount of the fuel is burnt in excess of oxygen and the heat liberated is transferred to known amount of water. The calorific value is then determined by applying the principle of calorimaterty i.e.

Heat gain = Heat loss

Construction: It consists of a cylindrical stainless steel bomb which is capable of withstanding pressure of atleast 50 atp. The bomb is generally provided with a gas tight screw cap or lid. This lid is provided with three holes, two for stainless steel electrodes and third as oxygen inlet valve. To one of the electrodes, a small ring is attached. In this ring a silica or stainless steel crucible can be supported.

The bomb is placed in a copper calorimeter, which is surrounded by air jacket to prevent loss of heat due to radiation.The calorimeter is provided with an electrically operated stirrer and Beckmann's thermometer, which can accurately read temperature difference upon 1/100th of a degree centigrade.



Bomb Calorimeter

Working: A small quantity of a fuel is weighed accurately (M Kg) and is placed in the Bomb. The bomb is placed in known amount water taken in a copper calorimeter. The initial temp of water is noted as a t_1^0C with the help of thermometer. Oxygen gas is pumped under pressure 20 to 25 atm through the O_2 valve provided. The fuel is ignited by passing electric current through the wires provided. As the fuel undergoes combustion and liberates heat, which is absorbed by surrounding water. The water is stirred continuously to distribute the heat uniformly and the final temp attained by water is noted t_2^0C. & gross calorific value of the fuel is calculated as follows:-

Calculation:

Mass of the fuel = x Kg g, Weight of water in the Calorimeter = W g
Initial temp of the water = t_1^0C Water equivalent of Calorimeter = w g
Final temp of the water = t_2^0C
Change in temp = t = $(t_2 - t_1)^0$ C GCV = C cal/g

Heat gained by water = W × Δt × sp. heat of water
$W[t_2 - t_1] \times 1$ Cal.

Heat gained by Calorimeter = $w(t_2 - t_1)$ Cal.

Heat liberated by the fuel = x C cal

Heat lost = Heat gai...

Observations :-

Weight of the fuel taken in crucible = x g

Weight of water taken in the calorimeter = W gm

Water equivalent of the calorimeter, stirrer, thermometer & bomb = w gm

Initial temp. of water in the calorimeter = t_1°C

Final temp. of water in the calorimeter = t_2°C

Temp. rise = $(t_2 - t_1)$°C

Gross Calorific value of fuel = C cal / gm.

Calculations :

Heat loss = Heat gain

Heat loss = $\underline{x \times C}$ cal / gm.

Heat gain = (Heat gain by water) + (Heat gain by Cu Calorimeter)

Heat gain by water ( ) = $W(t_2 - t_1)$ cal.

Heat gain by Cu Calorimeter = $w(t_2 - t_1)$ cal.

Total heat absorbed = $W(t_2 - t_1) + w(t_2 - t_1)$ cal

$= (W + w)(t_2 - t_1)$ cal.

Heat liberated by fuel = Heat gained by water & Calorimeter

$$xC = (W+w)(t_2 - t_1) \text{ Cal.}$$

$$\boxed{C = \frac{(W+w)(t_2 - t_1)}{x} \text{ Cal/gm.}}$$

(b) Determination of NCV (LCV) :-

Let the percentage of hydrogen in fuel be H.

∴ ~~Weight of water produced~~

∴ weight of water produced from 1 gm. of fuel =

$$\frac{9H}{100} \text{ gm.}$$

$$= 0.09 \times H \text{ g.}$$

∴ Heat taken by water in forming ~~it~~

$$0.09H \times 587 \text{ Cal.}$$

(∵ Latent heat of Condensation of steam = 587 Cal/g)

∴ NCV = GCV − Latent heat of Condensation of steam

$$\text{NCV} = \text{GCV} - 0.09H \times 587 \text{ Cal/g}$$

Note:- When H content is nil in fuel then GCV = NCV.

CORRECTIONS :-

Acid Correction: During combustion of fuel Sulphur & nitrogen (if present) are oxidised to H_2SO_4 & HNO_3 respectively with the evolution of heat.

$$S + 2H + 2O_2 \rightarrow H_2SO_4 + Heat$$

$$2N + 2H + 3O_2 \rightarrow 2HNO_3 + Heat$$

This heat liberated in above exothermic reactions is also included in the measured heat & hence it must be subtracted as this is not the part of Calorific value.

(b) **Fuse wire correction:-** The measured C.V also includes the heat given by burning of fuse wire, but it is not the heat of fuel. So it must be subtracted from the total value.

(c) **Cotton thread Correction:** The heat liberated by burning of cotton thread is to be subtracted from total value as it is not the heat produced by burning of fuel.

(d.) Cooling correction (t_c) :- Rate & time taken for cooling the water in calorimeter from maximum temperature to room temperature must be considered. Cooling correction are calculated from rate of cooling (dt°/minute) and the actual time (x minutes) required from cooling. Thus, cooling correction $t_c = dt^\circ \times x$ must be added to the temperature rise $(t_2 - t_1)$

Thus, $GCV = \dfrac{(W+w)\left[(t_2-t_1) + \text{Cooling Correction}\right] - \left[\text{Acid Correction} + \text{Fuse wire} + \text{Cotton thread Corr}\right]}{\text{Weight of fuel taken}}$

$$\boxed{GCV = \dfrac{(W+w)\left[(t_2-t_1) + \text{Cooling Correction}\right] - \left[\text{Acid Correction} + \text{Fuse wire} + \text{Cotton thread Correction}\right]}{\text{Weight of fuel taken}}}$$