Water Equivalent Determination of a Known Calorific Value Using Oxygen Bomb Calorimeter

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Abstract- Calorific value is the most important characteristics of fuel. 2g of kerosene and diesel respectively was weighed into the crucible and a firing wire of 10cm length (of about 0.1mm diameter nickel chrome wire) is stretched between the electrodes. It was ensured that the wire is in close contact with the kerosene, while the bomb head was set. Care must be taken not to disturb the sample when moving the bomb head from the support stand to the bomb cylinder. To absorb the combustion products of sulphur and nitrogen, 10 ml of water was poured into the bomb. The bomb was connected to the oxygen cylinder via the oxygen valve and the thin bore tube. Oxygen is admitted into the bomb and the pressure is adjusted to about 25 to 30 atmospheres. The bomb is then placed in a 3000g quantity of distilled water in the inner barrel of the calorimeter. Necessary electrical connections were made. The water in the calorimeter is constantly stirred and temperatures noted. The graph of temperature against time was plotted for kerosene and diesel. The known calorific values were used to determine the water equivalent of the calorimeter which gives 321.234g and 221.321g for kerosene and diesel respectively.

Index Terms: Calorimeter, Diesel, Fuse wire, Kerosene and Water equivalent.

INTRODUCTION

The term fuel is applied to a combustible substance which on burning in air gives large amount of heat that can be used economically for domestic and industrial purposes. The value of fuel depends upon the quality and intensity of the heat obtained per unit of fuel. The important common fuels are diesel oil, kerosene oil, petrol, wood, coal, coal gas, oil gas, etc.

Calorific value is the most important characteristic of the fuel. It may be defined as the total quantity of the heat liberated by the complete combustion of a unit mass of the fuel in air or oxygen. On the basis of physical state; fuel may be solid, liquid and gaseous. All these types of fuel are further divided into primary and secondary fuels.

In reaction the quantity of heat that raises the temperature of some substance by some amount, the same quantity of heat can simultaneously raise the temperature of a certain mass of water, this process is termed as water equivalent.

The Oxygen bomb calorimeter is a classical device used to determine the heating value of solids and liquid fuels sample at a constant volume. The calorific values obtained in the calorimeter test represent the gross heat of combustion per unit mass of fuel sample. This is the heat produced when the sample burns, plus the heat given up when the newly formed water vapour condenses and cool to the temperature of the bomb. Determining calorific values is proudly important; fuels which is one of the biggest commodity in the world; and their price depends primarily on their heating/calorific value. The experiment also demonstrates the first law of thermodynamics for a control of mass.

Kerosene also called paraffin is an oil distillate commonly used as a fuel or solvent. It is a thin clear liquid consisting of a mixture of hydrocarbons that boil between 302°Fand 572°F($150℃$ *and* $275℃$). Kerosene can be extracted from coal, oil shale and wood, it is primarily derived from refined petroleum. Kerosene is pale yellow or colorless and has a pleasant characteristic odor. The chemical composition depends on its source but it usually consists of about 10 different carbons per molecule. Kerosene is less volatile than gasoline. Its flash point is 38^0C or higher.

Diesel fuel is a mixture of hydrocarbons obtained by distillation of crude oil between $200℃(392°F)$ *and* $350℃(662°F)$ *at* atmospheric pressure resulting in a mixture of carbon chains that typically contains between 8 and 21 carbon atoms per molecule. The important properties which are used to characterize diesel fuel include cetane number, density, viscosity; fuel volatility etc. diesel fuel varies from flash point between 52 *and* $96℃$ (126 *and* $205°F$).

Classification of fuels.

On the basis of physical state; fuel may be solid, liquid and gaseous. All these types of fuel are further divided into; primary (natural) secondary (artificial) fuels.

Type of fuel	Natural or Primary	Artificial or secondary
solid	Wood, peat, lignite, bituminous and	Charcoal, charred peat, coke and

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	anthracite coal	petroleum coke
Liquid	Crude petroleum	Various fractions of petroleum; viz: kerosene oil, diesel oil, fuel oil etc.
Gaseous	Natural gas	LPG, coal gas, oil gas, water gas etc

Characteristics of good fuels

Caloric value – A good fuel must have a high calorific value, since the amount of heat obtained from a definite weight of the substance depends upon the factor

Moderate velocity of combustion – the highest temperature achieved by combustion of a fuel depends on the calorific value and the velocity of combustion. For continuous supply of heat fuel must burn with a moderate velocity.

Proper ignition point: - A good fuel must have a moderate ignition point since low ignition temperature of fuels is mostly accompanied by fire hazards, while high ignition point makes the fuel safe for transportation and storage but not favorable for starting a fire.

Low content of non-combustible material: - A good fuel must have a low content of non-combustible material as the non-combustible matter is left in the form of ash which will naturally decrease the calorific value of the fuels. Moreover disposal of ash is itself a big problem and it increases the cost of production.

Combustion is of different types namely:

Rapid combustion: - This is a process in which a substance burns rapidly and produces heat and flame, e.g.Combustion of natural gas.

Spontaneous Combustion: - when a substance suddenly starts burning into a flame; without the supply of external cause. Such as heating e.g.Phosphorus and Sulphur starts burning instantaneously at room temperature etc.

Explosion: - When combustion is accompanied by sudden production of heat, sound and large amount of gas, it is called explosion.

EXPERIMENTAL PROCEDURES

Bomb calorimeter is normally used for determining the higher calorific value of solids and liquid fuels. The combustion of the fuels takes place at constant volume in a totally enclosed vessel. To start with; 2g of kerosene was weighed into the crucible and a firing wire of 10cm length (of about 0.1mm diameter nickel chrome wire) is stretched between the electrodes. It was ensured that the wire is in close contact with the kerosene, while the bomb head was set. Care must be taken not to disturb the sample when moving the bomb head from the support stand to the bomb cylinder. To absorb the combustion products of Sulphur and nitrogen, 10 ml of water was poured into the bomb. The bomb was connected to the oxygen cylinder via the oxygen valve and the thin bore tube. Oxygen is admitted into the bomb and the pressure is adjusted to about 25 to 30 atmospheres. The bomb is then placed in a 3000g quantity of distilled water in the inner barrel of the calorimeter. Necessary electrical connections were made. The water in the calorimeter is constantly stirred and temperatures noted. When the temperature has become steady, the electrical circuit is closed. The fuse wire ignites the fuels in the presence of oxygen. The temperature of the water rises.

However, temperatures were first noted 15 seconds after firing till the maximum temperatures is reached. Afterwards, the temperature readings were taken half a minute for about 10 minutes or till the drop of temperature for about 3-5 minutes successive readings is uniform.

The same procedure was used for diesel fuels.

Experimental Results and Calculations:

For kerosene:

Mass of wire $(x_w)_{=}$ $0.011g$

$$volumeofwaterinthecalorimeter = 10cm^3$$

W = $volumeofdistilledwaterinthecalorimeter = 3000g$

$$C_K = calorificvalueincaloriesofkeroseneburnt = 46200\ KJ/Kg$$

$$C_1 = calorificvalueofthewireburntincalories, = 6700KJ/Kg$$

$$w = waterequivalentofthecalorimeter, bomb.$$

$$x = quantityoffuelburnt = 2g$$

$$\theta_1 = steadytemperaturebeforecombustion = 26.667°C$$

$$\theta_2 = maximumtemperatureaftercombustion = 33.187°C$$

$$thereforeobservedriseintemperature$$

$$\theta_m = \theta_2 - \theta_1 = 6.520°C$$

$$t = timeelapsedformaximumtemperaturetobereac = 6\ s$$

$$C_p, specificheatofwater = 4.1868\mathrm{KJ}/kg°k$$

$$Trueriseintemperature = \theta_m + \frac{r}{2}t$$

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$$Truetemperaturerise = 6.5266°C$$

$$cooliingrate(r) = \frac{33.187 - 33.176}{19 - 14} = 0.0022°C perMin$$

$$Heatlibratedandfirewire = Heatabsorbedbycalorimeter$$

$$C_K.x + C_1 x_w = (W + w)\left(\theta_m + \frac{r}{2}t\right) \times C_p \quad (1)$$

$$solution$$

$$(46200 \times 2) + (0.011 \times 6700) = 4.1868(3000 + w)6.5266$$

$$w = 384.165g$$

Water equivalent of the calorimeter using combustion fuels (kerosene) gives 384.165g.

For diesel fuels:

$$x = quantityoffuelburnt = 2g$$

$$C_d = calorificvalueincaloriesofdieselburnt = 44800\text{KJ}/Kg$$

$$Coolingrate = \frac{33.305 - 33.287}{19 - 14} = 0.0036°C/min$$

$$steadytemperaturebeforecombustion\theta_1 = 26.665°C$$

$$steadytemperaturecombustion\theta_2 = 33.305°C$$

$$observedriseintemperature, \quad \theta_m = (\theta_2 - \theta_1) = 6.64°C$$

$$trueriseintemperature = 6.649°C$$

$$Heatliberatedbydieselfuelandfusewire = Heatabsorbedbycalorimeter.$$

$$C_d.x + C_1 x_w = (W + w)\left(\theta_m + \frac{r}{2}t\right) \times C_P(2)$$

$$(44800 \times 2) + (0.011 \times 6700) = 4.1868(3000 + w)6.649$$

$$w = 221.27g$$

Water equivalent of the calorimeter using combustion fuels (diesel) gives 221.27g.

RESULTS

Kerosene combustion process in the oxygen bomb calorimeter and that of diesel fuel are shown below for various time and their respective temperature. The asterisks values are very important on the basis that, time at 15 minutes was taking into consideration for the plot on the temperature-time curve as shown in the figures below.

Table 1

Temperature- Time Combustion of Bomb Calorimeter of Kerosene Fuel

Min.	Sec.	Temperature ^{0}C	Min.	Sec.	Temperature ^{O}C
0	0	26.667 *	9	15	31.582*
2	0	26.667	9	30	31.777
3	0	26.667*	9	45	31.902
4	0	26.667*	10	0	32.398
Ignition			10	15	32.411*
5	0	26.667	10	30	33.153
5	15	27.069*	10	45	33.169
5	30	27.182	11	0	33.180
5	45	27.593	11	15	33.187*
6	0	28.124	11	30	33.187
6	15	28.347*	11	45	33.187
6	30	28.422	12	0	33.187
6	45	28.611	12	15	33.187*
7	0	28.821	12	30	33.187
7	15	29.074*	12	45	33.187
7	30	29.622	13	0	33.187*
7	45	29.934	14	0	33.187*
8	0	30.276	15	0	33.184*
8	15	30.277*	16	0	33.183*
8	30	30.323	17	0	33.181*
8	45	30.400	18	0	33.179*
9	0	30.427	19	0	33.176*

Table 2

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Temperature- Time Combustion of Bomb Calorimeter of Diesel Fuel

Min.	Sec.	Temperature ^0C	Min.	Sec.	Temperature ^OC
0	0	26.665*	9	15	32.263*
2	0	26.665*	9	30	32.290
3	0	26.665*	9	45	32.299
4	0	26.665*	10	0	33.302
Ignition			10	15	33.305*
5	0	26.665	10	30	33.305
5	15	26.774*	10	45	33.305
5	30	26.825	11	0	33.305
5	45	27.900	11	15	33.305*
6	0	27.091	11	30	33.305
6	15	28.122*	11	45	33.305
6	30	28.337	12	0	33.305
6	45	29.559	12	15	33.305*
7	0	29.832	12	30	33.305
7	15	29.933*	12	45	33.305
7	30	30.104	13	0	33.305*
7	45	30.443	14	0	33.305*
8	0	30.723	15	0	33.302*
8	15	30.811*	16	0	33.299*
8	30	30.948	17	0	33.297*
8	45	31.239	18	0	33.290*
9	0	31.248	19	0	33.287*

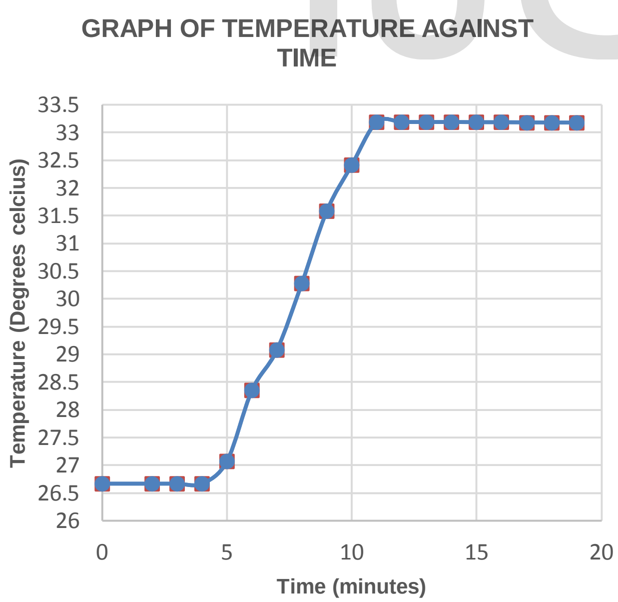

Fig 1: Typical Temperature- Time Curve of Bomb Calorimeter of Kerosene Fuel

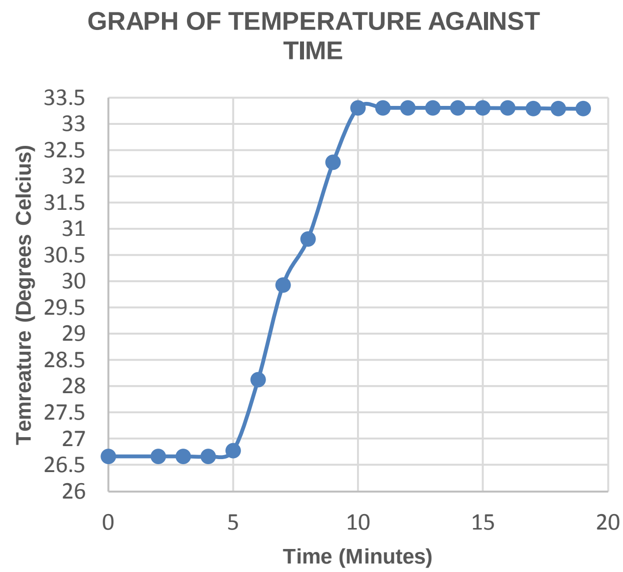

Fig 2: Typical Temperature - Time Curve of a Bomb Calorimeter

CONCLUSION

It is important that the temperature rise be rationally determined. Also it should be noted that bomb calorimeter measures the higher or gross calorific value because; the fuel sample is burnt at a constant volume in the bomb. The graph shows that the temperature recorded both in kerosene and diesel oils are constant before the ignition. Actually there should be a gradual temperature rise, because energy is being impacted to water by stirring it. However, the last portion of both graphs slops downwards appreciably, indicating poor insulation of the calorimeter. In a perfectly insulated calorimeter, cooling correction will be zero. The result shows that water equivalent of kerosene (384.165g) is higher than that of diesel fuels (221g) as a result of their calorific values.

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