1. BOMB CALORIMETER EXERCISE

EXERCISE OBJECTIVES:

1. To apply fundamentals of heating water in an adiabatic bomb calorimeter
2. To determine the energy content of a combustible material.
3. To compare measured values of materials to published values of the material.
4. To understand transformations of chemical energy to heat energy.

BACKGROUND INFORMATION:

The Heat of Combustion and its Determination

Fuels are those substances predominantly containing carbon, or carbon and hydrogen, or carbon, hydrogen and oxygen, which are utilized for the energy they produce upon union with oxygen. The products of combustion are carbon dioxide, water and other oxides.

The amount of heat given out in a chemical reaction depends on the conditions under which the reaction is carried out. The standard heat of reaction is the heat released when the reaction is carried out under standard conditions: pure components, pressure (1 ATM.), temperature, usually but not necessarily, at 25°C.

The Heat of Combustion (Calorific Value or Heat Value) of a compound is the standard heat of reaction for complete combustion of the compound with oxygen. The terms higher calorific value (HCV) and lower calorific value (LCV), are used, respectively, to distinguish the cases in which any water formed is in the liquid or gaseous phase. The two calorific values are related as follows:

$$HCV = LCV + M_m * H_e$$

Where

M_m : mass of water produced per unit mass of fuel

H_e : latent heat of evaporation of water.

The heat of combustion is a required value in the design of any type of combustion system. There are two methods for its determination - one by calculation based on the chemical composition and the other by actual combustion in a bomb calorimeter. For fuels with complex chemical formulae, it is more reliable and simpler to evaluate the heat of combustion by doing a bomb calorimeter test. Further, if there is any doubt in the composition and structure of a fuel or the formula for calculating the heat of combustion, it may prove more reliable to do a bomb calorimeter test, as it is a direct measure of the heat of combustion.

Bomb calorimeters for rapid combustion are composed of a combustion chamber (bomb) and a calorimetric bath, usually a cylinder surrounding the bomb and containing a known quantity of water, the elevation in temperature of which is measured. The combustion is made in oxygen, pure or diluted. Combustion chambers are either under a constant pressure or with a constant volume. The results obtained with a calorimeter of constant volume are not exactly the same as those obtained with constant pressure, but for solid or liquid substances the difference is too small to consider.

THE ADIABATIC BOMB CALORIMETER

This instrument (Figure 1a) consists of (1) **the bomb**; (2) the **container of water** in which the bomb is placed and (3) a **surrounding compartment** of temperature controlled water. The bomb is a small cylindrical pressure vessel with a tight fitting head clamped on the external face of the bomb by a screw cap, a port for a pressure relief valve and two ports for the two electrodes. The material to be combusted is put in a metal cup that is suspended in the bomb by two supports that also are part of the electrical circuit containing the fuse wire. The fuse wire spans across the top of the metal cup and when current is passed through the fuse wire it heats up rapidly and ignites the fuel.

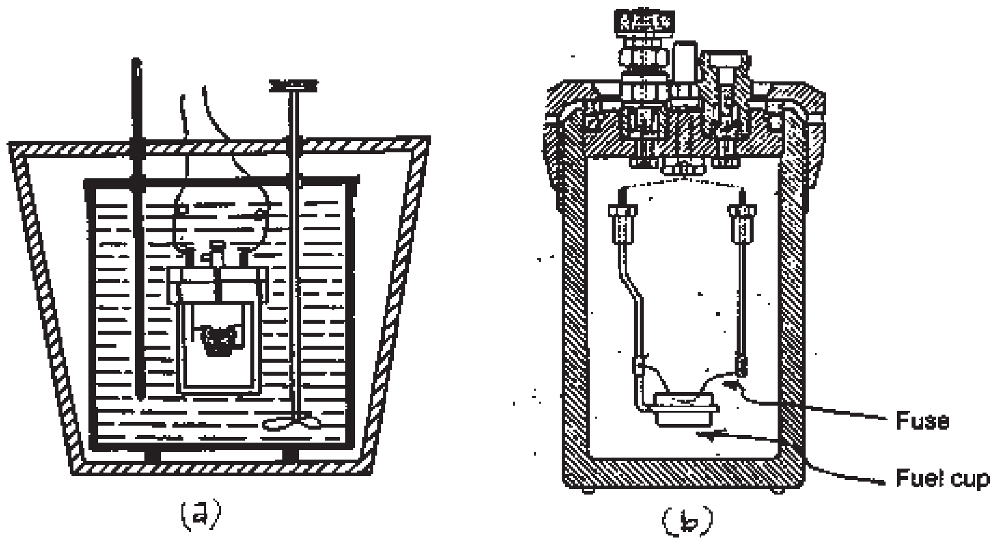


Figure1. (a) Calorimeter (b) The fuel bomb to be used for energy content measurement

The bomb is placed in a container with a known amount of water, together with an agitator and thermometer. The agitator is used to maintain a uniform temperature in the water and aid heat transfer from the bomb. The thermometer measures the water temperature (its range is 24 to 30°C with 0.01°C precision). Between the container of water and the surrounding compartment of water is an air gap, which is an excellent heat insulator. When the calorimeter is running, the temperature of the calorimeter body is automatically maintained at the same temperature as that in the container of water holding the bomb. This provides an adiabatic condition and thus, no heat transfers to or from the container of water, except from the heat released in the bomb.

OPERATING PROCEDURE (BOMBING)

1. Dismantle the calorimeter, clean and dry the crucible.
2. Weigh crucible empty and then weigh it with approximately 1 gm. of pulverized coal and bagasse respectively.
3. Install fuse wire in the form of a coil and attach a piece of fine cotton wool to assist ignition. The fuse wire should touch the coal, but not the crucible.
4. Add about 10 cc of water in the bomb to saturate the space inside the bomb. This will cause complete condensation of water vapour of combustion.
5. Reassemble the bomb and be careful not to spill the fuel.
6. Charge the bomb with oxygen to about 25 atmospheres. Do not charge much more than that, otherwise some of the fuel may be blown off.
7. Check leaks by immersing the bomb in water and then dry it and place it in the bomb jacket.
8. Put 1750 cc of water in the calorimeter.
9. Install the stirrer and the thermometer. The thermometer (Beckman) should be immersed at least 3″ in water and nor nearer than ½″ from the bomb.
10. Start the stirrer and allow 3 minutes for the temperature equalization of water in bucket. Take the temperature readings for intervals of 1 minute for 5 minutes. The readings are required for determining heat exchange with the jacket.
11. Close firing switch for an instant and then release it as soon as the indicator of the ammeter goes back. Record temperatures every 30 seconds till maximum temperature is reached. Be alert because temperature rise is very rapid.

12. Read falling temperatures every minute for 3 minutes. These readings are required in accounting for heat exchange in jacket.

CALCULATION OF THE HEAT OF COMBUSTION

The following data should be available at the completion of a test in an adiabatic calorimeter.

1.	T_o : temperature at firing.	
2.	c_3 : centimeters of fuse consumed in firing.	
3.	**W: = 2402 cal per °C**. Energy equivalent of calorimeter in calories per °C temperature rise.	
4.	M_s : mass of sample in grams.	
5.	Temperature Rise. Compute the net temperature rise, T, by substituting in the following equation: $T = T_f - T_o$	

Thermochemical Corrections.

e_3: correction in calories for heat of combustion of fuse wire.

= (2.3)(c_3) when using Parr 45C10 nickel-chromium fuse wire, or

= (2.7) (c_3) when using 34 B. & S. gauge iron fuse wire.

Compute the heat of combustion, H_c, in calories per gram by substituting in the following equation:

$$\mathbf{H_c = [(T*W) - e_3]/M_s}$$

INSTRUCTIONS AND DATA SHEET

NOTES: After completing the calorimeter tests.

- Enter your data **IN TABULAR FORMAT and ANALYSE THEM USING the computer.**

1. **LABORATORY REPORT: As per instructions on lab reports**
2. **LITERATURE REVIEW: Review types of calorimeters and standard methods of energy determination in biomass**

DATA ACQUISITION:

Fuel Types ____________________ ____________________

<u>**Observations**</u>	Weight of empty crucible	x gm.
	Weight of crucible + coal	y gm.
	Weight of coal	(y-x) gm.
	Volume of water in calorimeter	1750 gm.
	Water equivalent of bomb	520
	Total equivalent of water	**2270 gm.**

IGNITION WIRE (*Use scale and read calories (e_3 correction value) directly.)*

Beginning ____________________ ____________________

End ____________________ ____________________

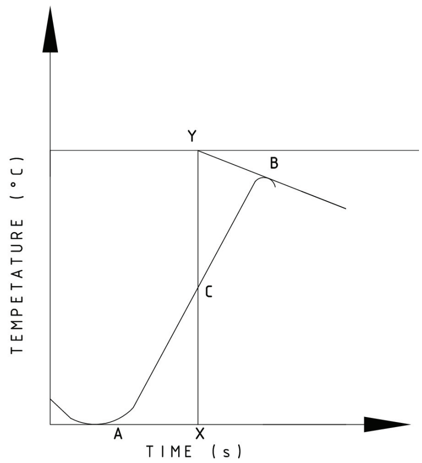
Net length ____________________ ____________________

CALCULATIONS: Draw the graph of temperature against time as follows:

Draw two lines tangent to the curve as shown.

Draw line XY such that area ACY = area XCB.

Then t is the corrected temperature rise.



Then HCV =

$$\frac{\text{Corrected temp. Rise x total water equivalent}}{\text{Weight of fuel}} \times \text{ the Specific heat capacity of water}$$

Time (min)	Temperature °C	Time (min)	Temperature °C	Time (min)	Temperature °C
0		15.5		28.5	
1		16		29	
2		16.5		29.5	
3		17		30	
4		17.5		30.5	
5		18		31	
5.5		18.5		31.5	
6		19		32	
6.5		19.5		32.5	
7		20		33	
7.5		20.5		33.5	
8		21		34	
8.5		21.5		34.5	
9		22		35	
9.5		22.5		35.5	
10		23		36	
10.5		23.5		36.5	
11		24		37	
11.5		24.5		37.5	
12		25		38	
12.5		25.5		38.5	
13		26		39	
13.5		26.5		39.5	
14		27		40	
14.5		27.5		40.5	
15		28		41	