**Objective:**

In this experiment we will use a bomb calorimeter to calculate the heating value from the weight of the fuel used and the change in the temperature of the water. The heating value (HV) of a specific type of fuel helps us measure and describe the energy that is produced by a given type of fuel. The bomb calorimeter is a device that burns a fuel sample and transfers the heat into a known mass of water. The objective of this lab is to determine the HV of not only a solid fuel, but a liquid fuel as well. From this experiment we will also be reiterating the first law of Thermodynamics for a controlled mass.

**Apparatus:**

Figure 1 and 2 show the bomb calorimeter in detail. It consists of a precision scale for weighing fuse and fuel samples, the oxygen bottle with suitable valves, and the bomb calorimeter. Inside the calorimeter is the fuel cup containing the fuel and the cup is held in a wire cradle that hangs from top of the cradle. A fuse wire is attached between the two arms of the cradle and it dips into the fuel but does not hit the sides of the fuel cup. The bomb itself it s rigid constant volume steel vessel and the assembly described earlier is places inside of it. Also inside the bomb, there will be 2000 grams of water and ignition leads are attached to the bomb. Once everything is placed and the cover is closed, the cover has a hole that allows a thermometer to be lowered into the water to measure the temperature. Also, an electrically driven paddle wheel can be used to stir the water and make the temperature of the water constant throughout the bucket.



**Figure 1:** Schematic of the Complete Bomb Calorimeter.



**Figure 2:** Schematic of the Bomb Vessel.

Theory:

The best way to find the fuels heating value (HV) is in terms of the energy it will produce per unit mass of the fuel. For the most part, when a weighed liquid or solid fuel sample is in a calorimeter, it would be completely burned. Then, all of the heat released would be conducted into a known mass of water. Once the temperature of the water rises, you can calculate the amount of energy released.

The following derivation is from the document “Bomb Calorimeter-LAB 2” written by Dr. Kassegne for the ME495 Laboratory.

The heating value can be determined by using the equation:

 Equation 1

In practice, however, there are complications, which are handled as described below. These complications are accounted for in the equation:

 Equation 2

|  |  |
| --- | --- |
| **Term** | **Value** |
| HV | Heating Value |
|  | Change in internal energy [] |
|  | Mass of fuel [g] |
|  | Mass [g] |
|  | Pressure [unitless] |
|  | Change in Temperature [K] |

Complication

The combustion must be contained in a rigid steel vessel or bomb and the water must be held in a bucket. The heat from combustion gets channeled into the bomb, the bucket, the known mass of water and some other miscellaneous parts. Instead of Uwater, one should use a summation of every U for all of the parts that absorb heat. This would be awkward and accuracy would be difficult. The expressed purpose of equation 1 is to calculate HV when everything on the right hand side is known or measured in the test. Suppose we knew HV for a special fuel sample, and assume that all of the heat released was channeled into an unknown theoretical mass of water. This is the actual procedure used. In the first part of the experiment we will burn a benzoic acid sample for which the heating value is reliably known. During this burn the bucket will actually contain 2000g of water. We then solve equation 2 for the theoretical water mass (m\*), which is necessarily greater than 2000g. This theoretical mass is the mass of water that would be required to absorb all of the heat that, in reality, was absorbed by the bucket, the steel bomb, the actual 2000g of water and all of the minor parts that get heated. In the second part of the experiment we actually burn the diesel fuel sample of interest. During this burn we again use an actual 2000g of water, but me use the theoretical mass of water (m\*) that was calculated from the first burn.

Complication

The fuel is not the only thing that burns in the bomb calorimeter. Most of the fuse material also burns. Therefore, the fuse wire must be weighed prior to the burn and any remaining fuse material must be weighed after the burn. The amount of heat released from the combustion of the fuse wire must be deducted from the Uwater in equation 2. HVwire is given on the fuse wire package.

Complication

There are heat losses from the calorimeter during the experiment because of its elevated temperature. These losses are small because the calorimeter box is well insulated. We have a semi-empirical way to correct for the heat losses. This is described in the data reduction section. We use a relatively large mass of water so that its temperature rise is small. This minimizes heat losses while preserving accuracy since precision thermometers are used. In very accurate bomb calorimeter work, heat losses from the calorimeter can be almost eliminated by creating an adiabatic situation. The calorimeter is surrounded by water flowing through a jacket. During a test, warmer water is added to this jacket at such a rate that the temperature in the jacket closely follows the rise in the experiment’s 2000 g of water. The warmer water in the jacket loses heat to the surrounding room. There can be little heat loss from the test water jacket water since there is no driving temperature difference.

Complication

Burning hydrocarbon fuel produces water vapor. The heating value determined would depend on whether or not this water vapor is condensed. We must distinguish between the higher and lower heating value. The lower value (LHV) assumes that the water vapor is not condensed. This heating value is lower due to enthalpy of vaporization equal to the amount of steam produced. The higher heating value (HHV) assumes that the entire vapor produced condenses. Ironically, fuel is normally sold based on its HHV, even though in most uses of fuel the LHV gives a more realistic value of what can be expected i.e., the steam in a car or furnace exhaust does not get condensed. With the drive for improved energy efficiency that began with the oil shock of 1973, some modern furnace designs actually do condense the water vapor and usefully extract this energy. In this experiment we will calculate the HHV. Consequently, we must condense all of the steam that is produced by combustion. This condensation is forced by saturating the bomb’s oxygen supply with water prior to combustion. Adding exactly 2 ml of water to the bomb before sealing it does this. If the oxygen is already saturated then any water produced by combustion must condense if the temperature is to remain relatively constant.

Complication

Equation 1 assumes that the measured temperature rise is uniform within the system boundary. A small paddle wheel driven by a drive belt gently stirs the water during the test. This promotes temperature uniformity in the water. The amount of work added by the paddle wheel is negligible. Most of the other parts that get heated are made of steel and are, therefore, good conductors. They should stay at a temperature close to that of the water.

Heating values vary according to ambient temperature and pressure conditions. For accuracy, heating values should be corrected to standard temperature and pressure conditions before comparisons are made.

**WARNING**

1. Do not add oxygen to the bomb without the close supervision of the instructor.
2. Ensure that there are no sources of open flame in the area. Oxygen bottles contain very high pressure and are very dangerous.
3. The ignition unit should not be plugged in before you are ready for ignition. Accidental pre-ignition would require you to disassemble and restart the whole experiment.