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DEPARTMENT OF AGRICULTURE ENGINEERING

COURSE CODE & NAME: 16AGT301 & HEAT POWER ENGINEERING

III YEAR / V SEMESTER

UNIT : 1 FUELS AND COMBUSTION
TOPIC 2 : Calorific Value and Analysis of Coal

CALORIFIC VALUE

Calorific value of a fuel is "**the total quantity of heat liberated, when a unit mass (or volume) of the fuel is burnt completely**."

Units of heat :

(1) **'Calorie'** is the amount of heat required to raise the temperature of one gram of water through one degree Centigrade (15-16°C).

(2) "**Kilocalorie**" is equal to 1,000 calories. It may be defined as 'the quantity of heat required to raise the temperature of one kilogram of water through one degree Centigrade. Thus**: 1 kcal = 1,000 cal**

(3) "**British Thermal unit" (B.T.U.)** is defined as "the quantity of heat required to raise the temperature of one pound of water through one degree Fahrenheit (60-61°F). This is the English system unit.

1 B.T.U. = 252 cal = 0.252 kcal   1 kcal = 3.968 B.T.U.

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Higher or gross calorific value (HCV)

- Usually, all fuels contain some hydrogen and when the calorific value of hydrogen-containing fuel is determined experimentally, the hydrogen is converted into steam.
- If the products of combustion are condensed to the room temperature (15°C or 60°F), the latent heat of condensation of steam also gets included in the measured heat, which is then called "higher or gross calorific value".
- So, gross or higher calorific value (HCV) is "the total amount of heat produced, when unit mass/volume of the fuel has been burnt completely and the products of combustion have been cooled to room temperature"(i.e., 15°C or 60°F).

Lower or net calorific value (LCV)

- In actual use of any fuel, the water vapour and moisture, etc., are not condensed and escape as such along-with hot combustion gases. Hence, a lesser amount of heat is available. So, net or lower calorific value (LCV) is "the net heat produced, when unit mass /volume of the fuel is burnt completely and the products are permitted to escape".
- Net calorific value= Gross calorific value - Latent heat of condensation of water vapour produced
- = GCV - Mass of hydrogen per unit weight of the fuel burnt x 9 x Latent heat of condensation of water vapour

So, carbon compounds have been used for many centuries as the source of heat and energy.

- **Dulong's formula** for calorific value from the chemical composition of fuel is :
- HCV = 1/100 [8,080 C + 34,500 (H – O/8)+ 2,240 S] kcal/kg
- where C, H, O, and S are the percentages of carbon, hydrogen, oxygen and sulphur in the fuel respectively. In this formula, oxygen is assumed to be present in combination with hydrogen as water, and
- LCV = [HCV - 9H/100 x 587] kcal/kg = [HCV - 0.09 H x 587] kcal/kg
- This is based on the fact that 1 part of H by mass gives 9 parts of H2O, and latent heat of steam is 587 kcal/kg.

Analysis of Coal

- In order to assess the quality of coal the following two types of analysis are made.

- **1. Proximate Analysis** It includes the determination of moisture, volatile matter, ash and fixed carbon. This gives quick and valuable information regarding commercial classification and determination of suitability for a particular industrial use.

- **2. Ultimate Analysis** It includes the determination of carbon, hydrogen, nitrogen, sulphur and oxygen in coal. Since it is used
- For the determination of elements present in the coal, it is also called elemental analysis. This analysis gives exact results and are useful in calculating the calorific value of coal using Dulong's formula.

Proximate analysis

- (1) **Moisture**: About 1 g of finely powered air-dried coal sample is weighed in a crucible. The crucible is placed inside an electric hot air-oven, maintained at 105° - 110°C. The crucible is allowed to remain in oven for 1 hour and then taken out, cooled in a desiccator and weighed. Loss in weight is reported as moisture (on percentage-basis).

- $$\text{Percentage of moisture} = \frac{\text{Loss in weight}}{\text{Wt. of coal taken}} \times 100$$

- (2) **Volatile matter**: The dried sample of coal left in the crucible in (1) is then covered with a lid and placed in an electric furnace (muffle furnace), maintained at 925°± 20°C. The crucible is taken out of the oven after 7 *minutes* of heating. The crucible is cooled first in air, then inside a desiccator and weighed again. Loss in weight is reported as volatile matter on percentage-basis.

Percentage of volatile matter=

$$\frac{\text{Loss in weight due to removal of volatile matter}}{\text{Wt. of coal sample taken}} \times 100$$

- (3) **Ash:** The residual coal in the crucible in (2) is then heated without lid in a muffle furnace at 700 ± 50° C for 1/2 *hour*. The crucible is then taken out, cooled first in air, then in desiccator and weighed.

- Heating, cooling and weighing is repeated, till a *constant weight* is obtained. The residue is reported as ash on percentage-basis.

$$\text{Percentage of ash} = \frac{\text{Wt. of ash left}}{\text{Wt. of coal taken}} \times 100$$

(4) **Fixed carbon**: Percentage of fixed carbon = 100 - % of (moisture + volatile matter + ash)

- high percentage of rued carbon is desirable.

Importance of proximate analysis

- Proximate analysis provides following valuable informations in assessing the *quality of coal:*

- **(1) Moisture:** Moisture lowers the effective calorific value of coal. Moreover, it quenches the fire in the furnace. Hence, lesser the moisture content, better the quality of coal as a fuel. However, presence of moisture, up to 10%, produces a more uniform fuel-bed and less of "fly-ash".

- **(2) Volatile matter**: A high volatile matter containing coal burns with a long flame, high smoke and has low calorific value. Hence, lesser the volatile matter, better the rank of the coal. Higher volatile content in coal is undesirable.

- A high volatile matter content means that high-proportion of fuel will be distilled and burned as a gas or vapour. The volatile matter present in the coal may be combustible gases (such as methane, hydrogen, carbon monoxide and other hydrocarbons) or non-combustible gases (like CO_2 and N_2). Volatile matter content is of special significance in coal gas manufacture and in carbonization plants, particularly when by-product recovery is the main object. Thus, high-volatile matter containing coals do not cake well; whereas medium-volatile matter content coals are capable of yielding hard and strong coke on carbonization.

- **(3) Ash** is a useless, non-combustible matter, which reduces the calorific value of coal. Moreover, ash causes the hindrance to the flow of air and heat, thereby lowering the temperature. Also, it often causes. trouble during firing by forming clinker), which block the inters paces of the grate. This in-turn causes obstruction to air supply; thereby the burning of coal becomes *irregular*. Hence, lower the ash content, better the quality of coal. The presence of ash also increases transporting, handling and storage costs. The presence of ash also causes early wear of furnace walls, burning of apparatus and *feeding* mechanism.

- **(4) Fixed carbon**: Higher the percentage of fixed carbon, greater is its calorific and better the quality coal. Greater the percentage of fixed carbon, smaller is the percentage of volatile matter. This also represents the quantity of carbon (in coal) that can be burnt by a primary current of air drawn through the hot bed of a fuel.

Ultimate analysis

Carbon and hydrogen: About 1-2 g of accurately weighed coal sample is burnt in a current of oxygen in a combustion apparatus. C and H of the coal are converted into CO_2 and H_2O respectively. The gaseous products of combustion are absorbed respectively in KOH and $CaCl_2$ tubes of known weights. The increase in weights of these are then determined.

- $$\text{Percentage of C} = \frac{\text{Increase in weight of KOH tube} \times 12 \times 100}{\text{Weight of coal sample taken} \times 44}$$

- $$\text{Percentage of H} = \frac{\text{Increase in weight of } CaCl_2 \text{ tube} \times 2 \times 100}{\text{Weight of coal sample taken} \times 18}$$

Significance of ultimate analysis

- **(1) Carbon and hydrogen**: Greater the percentage of carbon and hydrogen better is the coal in quality and calorific value. However, hydrogen is mostly associated with the volatile matter and hence, it affects the use to which the coal is put. Also higher percentage of carbon in coal reduces the size of combustion chamber required. The amount of carbon, the major combustible consti1fent of coal, depends on the type of coal and its percentage increases with rank from lignite to anthracite. Thus, percentage of carbon forms the basis of classification of coal.

- **(2) Nitrogen** has no calorific value and hence, its presence in coal is undesirable; thus, a good quality coal should have very little nitrogen content.

Nitrogen: About 1 g of accurately weighed powdered 'coal is heated with concentrated H2SO4 along-with K2S04(catalyst) in a long-necked flask(called *Kjeldahl's flask).* After the solution becomes clear, it is treated with excess of KOH and the liberated ammonia is distilled over and absorbed in a *known volume of standard acid solution.* The unused acid is then determined by back titration with standard NaOH solution. From the volume of acid used by ammonia liberated, the percentage of N in coal is calculated as follows:

- $$\text{Percentage of N} = \frac{\text{Volume of acid used x Normality x 1.4}}{\text{Weight of coal taken}}$$

Sulphur is determined from the washings obtained from the known mass of coal, used in a bomb calorimeter for determination of a calorific value. During this determination, S is converted into sulphate. The washings are treated with barium chloride solution, when barium sulphate is precipitated. This precipitate is filtered, washed and heated to constant weight.

- $$\text{Percentage of S} = \frac{\text{Weight of BaSO4 obtained x 32 x 100}}{\text{Weight of coal sample taken in bomb x 233}}$$

Ash determination is carried out as in proximate analysis.

Oxygen: It is obtained by difference.

- Percentage of O = 100 - Percentage of (C + H + S + N + ash)

- **(3) Sulphur**, although contributes to the heating value of coal, yet on combustion produces acids (S02 and S03), which have harmful effects of corroding the equipments and also cause atmospheric pollution. Sulphur is, usually, present to the extent of 0.5 to 3.0% and derived from ores like iron pyrites, gypsum, etc., mines along-with the coal.
- Presence of sulphur is highly undesirable in coal to be, used for making coke for iron industry, since it is transferred to the iron metal and badly affects the quality and properties of steel. Moreover, oxides of sulphur (formed as combustion products) pollute the atmosphere and leads to corrosion.

- **(4) Oxygen** content decreases the calorific value of coal. High oxygen-content coals are characterized by high inherent moisture, low calorific value, and low coking power. Moreover, oxygen is in combined form with hydrogen in coal and thus, hydrogen available for combustion is lesser than actual one. An increase in 1% oxygen content decreases the calorific value by about 1. 7% and hence, oxygen is undesirable. Thus, a good quality coal should have low percentage of oxygen

THANK YOU...