UNIT 4 CALORIFIC VALUES OF FUELS

Structure

4.1 INTRODUCTION

You are now familiar with various types of energy sources i.e. fuels. Each fuel is characterized by the heating values contained in it. In this unit, we will discuss the heating values of various fuels (solid, liquid and gaseous).

Objectives

After studying this unit, you will be able to understand

- calorific values of solid fuels,
- calorific values of liquid fuels, and
- calorific values of gaseous fuels.

4.2 CALORIFIC VALUE DEFINED

The calorific value or heating value of a fuel is defined as the quantity of heat released during combustion of a specified amount of it. The calorific value is a characteristic for each substance.

4.2.1 Units of Calorific Values

The units of calorific value are energy per unit of the substance, such as: kcal/kg, kJ/kg.

4.2.2 The Higher Calorific Value or Higher Heating Value (HHV) or Gross Calorific Value (GCV)

In the Higher Calorific Value or Higher Heating Value (HHV) or Gross Calorific Value (GCV), it is assumed that the water of combustion is entirely condensed and that the heat contained in the water vapor is recovered.

It is defined as the heat released when unit mass of fuel is burned completely at constant volume under pressure 25-30 bars in saturated oxygen.

4.2.3 The Lower Calorific Value or Lower Heating Value (LHV) or Net Calorific Value (NCV)

In the Lower Calorific Value or Lower Heating Value (LHV) or Net Calorific Value (NCV), it is assumed that the products of combustion contained the water vapor and that the heat in the water vapor is not recovered. In other words, the NCV is derived from the GCV by deducting the latent heat of vaporization of water present and formed.

Thus, NCV (MJ/kg.) = GCV (MJ/kg.) − 0.222 (% H) . . . (4.1)

It can also be calculated by proximate /ultimate analysis and is given by

$$NCV = GCV - [2.45(9M_H + M_{mw}) + H_w] \quad \ldots (4.2)$$

where M_H = percentage of hydrogen,

M_{mw} = percentage of external moisture, and

H_w = sensible heat of water between 25-100 ºC in MJ.

SAQ 1

(1) Higher calorific value (HCV) is the heating value of the fuel……

a) With water vapour which are formed by combustion

b) Without water vapour which are formed by combustion

c) none of the above

(2) What is the difference between GCV and NCV?

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Example 4.1

A coal has gross calorific value as 30 MJ/kg. It has 5% hydrogen and 15% moisture. If the sensible heat of water is 2.45 MJ/kg, determine the net calorific value.

Answer

We have given the following data:

GCV = 30 MJ/Kg.

M_H = 5% = 0.05

M_{mw} = 15% = 0.15

H_w = 2.45 MJ/Kg.

Using Eq. (4.2), we obtain

$$NCV = 30 - [2.45 \times (9 \times 0.05 + 0.15) + 2.45]$$
$$= 30 - 3.92 = 26.08 \text{ MJ/Kg.}$$

In many applications burning fuels produce water vapor which is not used. This means that heat contents of this water vapor are wasted. In such applications, the lower heating value is used. For example, in case of natural gas, much water is produced because of high hydrogen content in the natural gas. The gross calorific value is useful for gas burnt in condensing boilers and power plants with flue gas condensation which condense the water vapor produced by combustion, recovering heat which would otherwise be wasted.

4.3 CALORIFIC VALUES OF COAL

The calorific values of coal are better expressed in terms of the following parameters :

AR (As Received basis) : This indicates that the fuel heating value has been measured with all moisture and ash forming minerals present.

MF (Moisture Free) or Dry : This indicates that the fuel heating value has been measured after the fuel has been dried of all inherent moisture but still retaining its ash forming minerals.

MAF (Moisture and Ash Free) or DAF (Dry and Ash Free) : This indicates that the fuel heating value has been measured in the absence of inherent moisture and ash forming minerals.

The calorific value of a coal depends upon its grade and its chemical composition. The chemical composition of the coal is usually defined in terms of proximate analysis and ultimate analysis.

Proximate Analysis

The variables of proximate analysis are fixed carbon, moisture, ash and volatile matter. The Gross Calorific Value (KJ/Kg.) may be estimated from the proximate analysis of coal and is given by the following relation:

$$GCV = 4.19(82\ FC + a\ VM) \quad \text{kJ/kg.} \qquad \ldots (4.3)$$

where FC = fixed carbon,

a = empirical constant, and

VM = volatile matter.

Ultimate Analysis

The ultimate analysis aims at determination of carbon, hydrogen, nitrogen, sulphur and oxygen within the coal.

If we know mass percentages of C, H, O and S, then the carorific value of the coal, GCV (KJ/Kg), can be determined by the folowing expression if oxygen content is less than 10%.

$$GCV = 33.7\ C + 1442\ (H - O/8) + 93\ S \qquad \ldots (4.4)$$

where C, H, O and S are the mass percentages of carbon, hydrogen, oxygen and sulphur.

Example 4.2

The ultimate analysis of coal gives the following :

Mass percentage of C = 65.7

Mass percentage of H = 4

Mass percentage of O = 6.2

Mass percentage of S = 1.7

Calculate the calorific value of coal.

Solution

We can use Eq.(4.4) and calculate calorific value of coal as follows :

$$GCV = 33.7 \times 65.7 + 1442 \times (4 - 6.2/8) + 93 \times 1.7$$

$$= (22.14 + 4.65 + 0.15) \times 10^3 \text{ KJ/Kg.}$$

$$= 26.94 \text{ MJ/Kg.}$$

The calorific values of some of the widely used solid fuels are given in the Table 4.1. It is seen that anthracite has the highest calorific value amongst the fuels given in the table.

Table 4.1 : Calorific Values of Solid Fuels

Fuel	Higher Calorific Value (Gross Calorific Value-GCV), kJ/kg
Anthracite	32,500-34,000
Bituminous coal	17,000-23,250
Butane	49,510
Charcoal	29,600
Coal	15,000-27,000
Coke	28,000-31,000
Wood (dry)	14,400-17,400

4.4 CALORIFIC VALUES OF PETROLEUM PRODUCTS

The carorific values of petroleum products are given in the Table 4.2. It may be seen that petrol has the highest-calorific value of all the petroleum products.

Table 4.2 : Calorific Values of Petroleum Products

Fuel	Higher Calorific Value (Gross Calorific Value-GCV), KJ/l
Gas oil	38,000
Heavy fuel oil	41,200
Diesel	44,800
Ethanol	29,700
Gasoline	47,300
Petrol	48,000

4.5 CALORIFIC VALUES OF GASEOUS FUELS

The calorific values of gaseous fuels are given in the Table 4.3. It may be seen that hydrogen has the highest-calorific value of all the gaseous fuels given in the table.

Table 4.3 : Calorific Values of Gaseous Fuels

Fuel	Higher Calorific Value (Gross Calorific Value-GCV), kJ/m^3
Acetylene	56,000
Butane C_4H_{10}	133,000
Hydrogen	13,000
Natural gas	43,000
Methane CH_4	39,820
Propane C_3H_8	101,000
Town gas	18,000
Hydrogen	141,790

You can estimate the amount of different fuels for doing a specific work by using above mentioned calorific values.

SAQ 2

Heating value of diesel oil is about

a) 6000 kCal/kg
b) 8000 kcl/kg
c) 10000 kcal/kg
d) 10662 kcal/kg

……

……

SAQ 3

Heating value of the natural gas is

a) 5900 kal/m^3
b) 8850 kcal/m^3
c) 10234 kcal/m^3

……

……

SAQ 4

Which of the following coals has the highest calorific value?

a) anthracite coal

b) lignite

c) bituminous

d) peat

……

……

Example 4.3

Determine the energy needed from different fuels (electricity, coal, natural gas and wood) to run a 100 W lightbulb for a year.

Solution

Electricity

Electricity needed = 365 days/year x 24 hrs/day x 100 W/1000

= 876 kWh = 3153.6 MJ

Wood : Calorific value of wood (14400 – 17400 kJ/kg)

$$\text{Wood required} = \frac{3153.6\,\text{kJ/kg} \times 1000}{14400\,\text{kJ/kg}} = 219\,\text{kg}$$

$$\text{Wood required} = \frac{3153.6\,\text{kJ/kg} \times 1000}{17400\,\text{kJ/kg}} = 181\,\text{kg}$$

So wood required will be 181 to 219 kg corresponding the calorific values under consideration.

Coal : Calorific values of coal (15000 – 27000 KJ/Kg)

So coal required will be 117 to 210 Kg.

Kerosene = 73.34 Kg

Natural Gas : Calorific value of natural gas (43000 KJ/m^3)

Natural gas required = 73.4 m^3

Remember, we have not taken into consideration various conversion efficiencies.

4.6 LET US SUM UP

The calorific value of a fuel is defined as the quantity of heat released during combustion of a specified amount of it. The calorific value is a characteristic for each substance. The unit of calorific value is energy per unit of the substance, such as : KCal/Kg, KJ/Kg.

The Higher Calorific Value or Higher Heating Value (HHV) or Gross Calorific Value (GCV), is defined as the heat released when unit mass of fuel is burned completely at constant volume under pressure 25-30 bars in saturated oxygen.

The Lower Calorific Value or Lower Heating Value (LHV) or Net Calorific Value (NCV), is derived from the GCV by deducting the latent heat of vaporization of water present and formed.

The calorific value of a coal depends upon its grade and its chemical composition. The chemical composition of the coal is usually defined in terms of proximate analysis and Ultimate analysis. The variables of proximate analysis are fixed carbon, moisture, ash and volatile matter. The ultimate analysis aims at determination of carbon, hydrogen, nitrogen, sulphur and oxygen within the coal.

4.7 KEY WORDS

Calorific Value of a Fuel : The quantity of heat released during combustion of a specified amount of it. The units of calorific value are energy per unit of the substance, such as: KCal/Kg, KJ/Kg.

Higher Calorific Value or Higher Heating Value (HHV) or Gross Calorific Value (GCV) : The heat released when unit mass of fuel is burned completely at constant volume under pressure 25-30 bars in saturated oxygen. It is the maximum potential energy in dry fuel.

Lower Calorific Value or Lower Heating Value (LHV) or Net Calorific Value (NCV) or Net Heating Value (NHV) : The potential energy available in the fuel as received, taking into account the energy loss in evaporating and superheating the water in the sample. It is derived from the GCV by deducting the latent heat of vaporization of water present and formed.

Proximate Analysis : Refers to determination of fixed carbon, moisture, ash and volatile matter.

Ultimate Analysis : Refers to determination of carbon, hydrogen, nitrogen, sulphure and oxygen within the coal.

4.8 ANSWERS TO SAQs

SAQ 1

(1) (b)

(2) The difference between GCV and NCV is the latent heat of condensation of the water vapours produced during the combustion process.

SAQ 2

(d)

SAQ 3

(b)

SAQ 4

(a)

REFERENCES

Bartok, William; Sarofim, Adel F. Fossil Fuel Combustion: A Source Book. New York: John Wiley and Sons, Inc., 1991.

Seidel, Stephen. Can We Delay a Greenhouse Warming? Washington, D.C.: Strategic Studies Staff, Office of Policy Analysis, 1983

- http://www.hubbertpeak.com/campbell/index.html
- http://zebu.uoregon.edu/1997/ph161/|10.html
- http://library.advanced.org/10867/gathered/effected_resources.shtml
- http://www.infowest.com/Utah/dinosaurland/map2.gif
- http://www.wri.org/wri/heath/ghg-note.html
- http://www.wri.org/press/lancetnr.html#summary
- http://www.ucsa.org/energy/renew.today.html
- http://www.shell.com/
- http://www.allison.com/school/jet/home.html
- http://www.mne.ksu.edu
- http://troyadii.fi-p.unam.mx/www2/gen97/sgmc97/www/html/mexico/spark.html