UNIT 2 FUELS AND THEIR CHARACTERISTICS

Structure

2.1 INTRODUCTION

When we consider power generation by power plant industry, fuel may be defined as any material that combines chemically with oxygen and releases heat which is used to convert water into steam. Energy store is defined as the fuel. Higher is the concentration of energy store, better is the fuel. A fuel necessarily contains one or several of the combustible elements : carbon, hydrogen, sulphur, etc. When fuel is burnt, it produces heat. Fuel is burnt when it comes in contact with oxygen or air. This is referred to as combustion.

The most important fuels which are generally used are coal, petroleum oil and natural gas. These fuels are known as hydrocarbons and are discussed in this unit.

How can you utilize the chemical energy of a fuel efficiently? It can be done provided you are able to :

- transform the fuel from solid to liquid or gaseous state.
- transform the fuel from liquid to gaseous state.
- transform its chemical energy to some other form of energy.

We are going to discuss the principle of classification of fuels and their characteristics, etc.

Objectives

After studying this unit, you will be able to

- understand different types of fuels,
- understand the characteristics of different fuels, and
- understand the combustion properties of different fuels.

2.2 CLASSIFICATION OF FUELS

There are various ways by which we can classify different fuels. However, two ways which are used widely are given in Table 2.1.

Table 2.1 : Classification of Fuels

Fuel Classification Type	Fuel Type
Physical state of existence	solid, liquid and gaseous fuels
Mode of their procurement	natural and manufactured fuels

Some of the widely available natural fuels and manufactured fuels (solid, liquid and gaseous) are discussed below.

2.3 SOLID FUELS AND THEIR CHARACTERISTICS

Solid fuels are mainly classified into two categories as mentioned below :

(1) Natural fuels, such as wood, coal, etc.

(2) Manufactured fuels, such as charcoal, coke, briquettes, etc.

Solid fuels are easy to transport, convenient to store, low cost of production and have moderate ignition temperature. Solid fuels, however, have high ash content, burn with clinker formation and their cost of handling is relatively high. The combustion process is difficult to be controlled and therefore large proportion of heat is wasted.

SAQ 1

What are the natural fuels?

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SAQ 2

What are the manufactured fuels?

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2.3.1 Characteristics of Wood

Wood is the oldest type of fuel which had been used for centuries. Wood is used largely in rural areas and in small towns for cooking purposes and heating applications. In some parts of the country, wood is also used for industrial applications.

The main constituents of several kinds of wood are given in Table 2.2. The constituents of cellular tissue and lignin of wood are given in Table 2.3. The constituent elements (C, H, N, O, and ash) of different kinds of wood are given in Table 2.4 while the average values of constituents of wood are given in Table 2.5. The calorific values of different kinds of wood are given in Table 2.6.

SAQ 3

What are the merits of solid fuels?

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Table 2.2 : Constituents of Wood (%)

Type of Wood	Water	Sugar	Fat-tar	Cellular Tissue	Lignin
Beech Wood	12.57	2.41	0.41	45.47	39.14
Birch Wood	12.48	2.65	1.14	55.62	28.21
Fir (Boot)	13.87	1.26	0.97	55.99	26.91
Pine wood	12.87	4.05	1.63	53.27	28.18

Table 2.3 : Constituents of Cellular Tissue and Lignin of Wood (%)

Constituents	Cellular Tissue	Lignin
Carbon	44.4	54.58
Hydrogen	6.2	5.8-6.3
Oxygen	49.4	35.39

Table 2.4 : Constituents of different kinds of Wood (%)

Element	Pine Wood	Birch Wood	Oak Wood
Carbon	50.05	48.45	49.8
Hydrogen	6.04	5.95	5.81
Oxygen+Nitrogen	43.21	45.26	44.00
Ash	0.70	0.34	0.4

Table 2.5 : Average Values of Constituents of Wood

Element	%, Composition
C	50.00
H	6.00
O	43.10
N	0.30
Ash	0.60

SAQ 4

What are the demerits of solid fuels?

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Table 2.6 : Calorific Values of Wood

Kinds of Wood	Lowest Calorific Value (Cal/Kg)	Highest Calorific Value (Cal/Kg)
Oak	4729	4750
Birch	4695	4831
Elm	4674	4833
Alder	4745	4839
Pine	4818	5310

SAQ 5

What are the main constituents of wood?

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Ash Content of Wood

The ash consists of mainly potassium carbonate with varying degrees of calcium, magnesium and sodium carbonate, as well as minute quantities of iron oxides, alumina and silica.

Moisture Content of Wood

The moisture content of wood varies from about 40 to 60%. It strongly depends upon the type of the tree as well as the season of the year.

Characteristics of Flame

The nature of the flame depends on the tar content of wood. Wood samples containing more tar burn with a thick and bright flame, while some wood samples burn with a dim, transparent flame. The length of the flame also depends on the tar content.

Combustion Characteristics

You must have observed that lighter wood burns more intensely with a long flame as compared to thick wood. The reason is simple. In case of lighter wood, air penetrates easily throughout the whole piece during combustion. On the contrary, in case of heavy wood, the penetration of air is rather difficult and a concentrated flame results with the development of more heat at the point of burning.

Ignition Temperature

Wood ignites very easily. The average ignition temperature of different kinds of wood is given in Table 2.7.

Table 2.7 : Ignition Temperatures of Wood

Type of Wood	Ignition Temperature (°C)
Pine	295
Oak	287
Larch	290
Fir	292

2.3.2 Characteristics of Coal

Coal is one of the widely used solid fuels in all major industries and power stations. Most of the Indian coal is of low grade variety. The coal consumption by different economic sectors is shown in Figure 2.1.

Coal has three components distributed throughout its mass : (1) coal substance, (2) mineral matter, and (3) moisture. The coal substance consists of many organic compounds of carbon, hydrogen and oxygen derived from the original vegetable matter. The moisture content of coal, often called “mechanical moisture” means water retained by the coal.

The average ash content in Indian coal is as high as 20%. The high ash content of coal reduces thermal efficiency of the boiler as loss of heat through un-burnt carbon, excessive clinker formation and heat in ashes is considerably high. Therefore, use of high ash content coal increases the size of the plant, increases the transportation cost of fuel per unit of heat produced and reduces the thermal efficiency. Besides all these difficulties, it makes the control difficult due to irregular combustion.

Such high ash content fuels can be used more economically in pulverized form. Thermal efficiency is increased to about 90% and controls are simplified by adjusting the position of burners in boiler furnaces. The recent thermal power plants in India are generally designed to use pulverized coal.

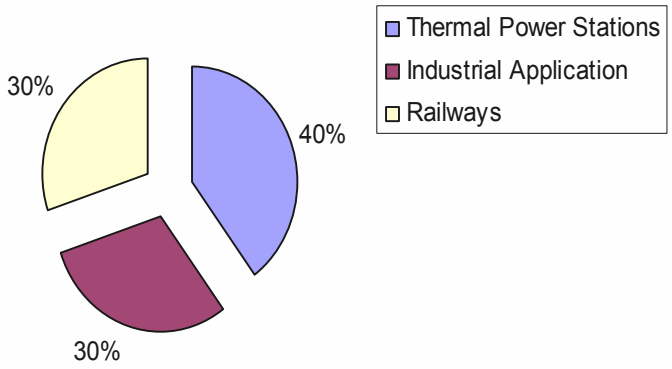

Figure 2.1 : Percentage Use of Coal

Analysis of Coal

Coal properties are determined by following two processes :

- Proximate Analysis for determining heating value of coal
- Ultimate Analysis for determining chemical composition of coal

Proximate Analysis of Coal

The proximate analysis of coal is carried out to determine heating and burning properties of coal. The proximate analysis determines the percentage by weight of

- moisture
- volatile matter
- ash
- fixed carbon

Moisture : All varieties of coal contain some moisture.

Volatile matter : Volatile matter is that part which is driven off as a gas when the coal is heated such as that discharged from a beehive type coke oven.

Fixed Carbon and Ash : In above process, coke is left and is composed of fixed carbon and ash. The sum of the carbon in the volatile matter and the fixed carbon gives the total carbon. This total carbon, together with the percentages, by weight, of hydrogen, oxygen, nitrogen, sulphur, and ash, gives the ultimate analysis.

The variation of moisture, volatile matter, ash and fixed carbon by weight of most coals is given in Table 2.8.

Table 2.8 : Variation of Moisture, Volatile Matter, Ash and Fixed Carbon in Coal

Moisture	3-30%
Volatile matter	3-50%
Ash	2-30%
Fixed carbon	16-92 %

Point to Remember :

Volatile matter in coal largely governs the combustion which in turn governs the design of grate and combustions space used.

Ultimate Analysis of Coal

The ultimate analysis of coal is used to find more precisely the chemical composition of coal like carbon, hydrogen, oxygen, nitrogen, sulphur and ash. The variation of carbon, hydrogen, oxygen, nitrogen, sulphur and ash by weight for most of the coals is given in Table 2.9.

Table 2.9 : Variation of carbon, hydrogen, oxygen, nitrogen, sulphur and ash in coal

Carbon	50-95%
Hydrogen	2.5-5 %
Oxygen	2-4%
Sulphur	0.5-7 %
Nitrogen	0.5-3%
Ash	2-30 %

SAQ 6

What is the difference between proximate analysis and ultimate analysis of coal?

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2.3.3 Classification of Coal

There exists a number of methods for classifying coal and are based on (1) rank, (2) grade and size and (3) source. The coal is also classified based on the various products of metamorphosis of the original vegetable matter of which the coal is the final product. The coal is thus named as peat, lignite, bituminous, semi-bituminous, semi-anthracite and anthracite.

Anthracite coal ⟶ fully transformed coal

Peat ⟶ first stage of this transformation

Other varieties ⟶ intermediate stages of transformation

Some characteristics of peat are as follows :

- fibrous decaying material
- brown in colour
- highly moist
- burn freely

Typical proximate and ultimate analysis of peat is given in Table 2.10.

Table 2.10 : The Ultimate and Proximate Analysis of Peat

Ultimate Analysis		Proximate Analysis	
Content	**% Composition**	**Content**	**% Composition**
Moisture	90.3	Carbon	58
Fixed Carbon	3	Oxygen	35
Volatile Matter	5	Hydrogen	6
Ash	1.6	Nitrogen	1

2.3.4 Characteristics of Lignite

- intermediate stage between peat and bituminous coal.
- brown or black in colour.
- exhibits distinctly woody structure.
- when mined, moisture content varies from about 30 to 40%.
- when air dried, moisture content varies from about 15 to 20%.
- ash content is about 4 to 6%.
- ash free lignite has 60 to 75% of carbon and 20 to 35% of oxygen.
- average density varies from 641 Kg/m^3 to 1282 Kg/m^3.
- volatile matter is about 50%, and sometime in equal ratio with carbon.
- calorific value on a dry, oxygen-free basis varies from 5000 to 6112 KCal/Kg.
- well dried lignite can be used as pulverized fuel.
- raw lignite after being dried to moisture content of about 15%, may be briquetted for industrial and household use.

2.3.5 Characteristics of Sub-bituminous Coal

- similar to lignite except in terms of moisture content.
- moisture content is about half of that of the lignite.
- low ash content as compared to lignite.
- useful in the form of briquettes or pulverized state.

2.3.6 Characteristics of Bituminous Coal

- popular, all purpose fuel.
- mostly used for steam generation.
- distinguished from the lower grade coal in its ability to resist slacking.
- ratio of volatile matter to fixed carbon is about the same as in sub-bituminous or lignite.
- ash content varies from 6 to 12%.

2.3.7 Characteristics of Semi-Bituminous Coal

- intermediate between anthracite and bituminous coal in properties.
- used for steam raising : on grate or in pulverized form.
- low percentage of moisture, ash and sulphur.
- carbon content ranges between 90 to 93%.
- volatile matter between 10 to 20%.
- oxygen between 2 to 4%.

2.3.8 Characteristics of Anthracite

- end product of the metamorphosis of original vegetable material.
- ranked highest among coals with high commercial value.
- has over 92% carbon.
- volatile matter is below 8%.
- ash is lower than that of bituminous coal.
- hard and lustrous, and has high density.
- burns only at a high temperature with little or no flame and does not fuse or soften.
- pulverization is difficult and expensive.
- best used on grate with forced draft for production of steam.

SAQ 7

What are the uses of different types of coal?

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2.3.9 Characteristics of Manufactured Solid Fuels

The charcoal, coke, briquettes, etc. are the manufactured solid fuels and are obtained from the natural fuels, like wood, coal, etc.

Charcoal and its Characteristics

What is charcoal?

Charcoal is a product derived from destructive distillation of wood, being left in the shape of solid residue. The charcoal is widely preferred fuel in our country. It is used not only for industrial applications but also for cooking purposes. Charcoal burns rapidly with a clear flame, producing no smoke and developing heat of about 6050 Cal/Kg.

Coke and its Characteristics

It is also obtained from destructive distillation of coal, being left in the shape of solid residue. There are two categories of coal : Soft coke and Hard Coke.

Soft Coke : Soft coke is obtained as the solid residue from the destructive distillation of coal in the temperature range of 600-650°C. It contains 5 to 10% volatile matter. It burns without smoke. It is extensively used as a domestic fuel.

Hard Coke : Hard coke is obtained as solid residue from the destructive distillation of coal in the temperature range of 1200-1400°C. It burns with smoke and is a useful fuel for metallurgical processes.

Briquettes and their Characteristics

What is Briquettes?

The briquettes is usually defined as the dust, culm, slack and other small size waste remains of lignite, peat, coke, etc. compressed into different shapes of regular form, with or without binder. Good quality briquettes should be quite hard and as little friable as possible. They must withstand the hazards of weather, and must be suitable for storing and handling.

SAQ 8

What are the characteristics of coke and briquette fuels

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2.3.10 Bagasse and its Characteristics

Bagasse is referred to as the residue of sugarcane, which is left as waste in the sugar mill after extraction of sugar juice. It is a fibrous fuel which can be compared to wood. It contains 35-45% fibre, 7-10% sucrose and other combustible constituents, 45-55% moisture, and possesses an average calorific value of 2200 Cal/Kg.

The average composition of bagasse is :

$$C = 45\%, H_2 = 6\%, O_2 = 46\% \text{ and Ash} = 3\%$$

If dried properly, it is a quick burning fuel with good efficiency. Usually bagasse is dried in open sun after spreading it in the open field. Now with the energy conservation culture getting momentum, waste flue gases are being used in dryers to reduce the moisture of bagasse.

2.4 LIQUID FUELS AND THEIR CHARACTERISTICS

Liquid fuels are hydrocarbons and they are classified as light oils, and heavy oils, depending on the number of carbon atoms. Some of commonly used liquid fuels for power engineering are the following :

(1) Gasoline or petrol

(2) Paraffins

(3) Diesel oil

(4) Heavy fuel oil or crude oil

The liquid fuels are also classified as

(i) Natural or crude oil and

(ii) Artificial or manufactured oils.

2.4.1 Advantages and Disadvantages of Liquid Fuels

The advantages and disadvantages of liquid fuels are the following :

Advantages of Liquid Fuels

- higher calorific value per unit mass than solid fuels.
- burn without dust, ash, clinkers, etc.
- easy to transport through pipes.
- can be stored indefinitely without any loss.
- clean in use and economic to handle.
- requires less excess air for complete combustion.
- requires less furnace space for combustion.

Disadvantages of Liquid Fuels

- cost of liquid fuel is relatively much higher as compared to solid fuels.
- special and costly storage tanks are required for storing.
- greater risk of fire hazard, particularly, in case of highly inflammable and volatile liquid fuels.
- give bad odour.
- specially constructed burners and spraying apparatus are required for burning.

2.4.2 Petroleum and its Characteristics

Petroleum is a basic natural fuel and are graded according to specific gravity, calorific value, flash point or ignition point, viscosity, sulphur contents, moisture and sediment content, specific heat and coefficient of expansion.

The average composition of crude petroleum is :

Carbon	= 79.5 to 87.1%
Hydrogen	= 11.5 to 14.8%
Sulphur	= 0.1 to 3.5%
Nitrogen	= 0.1 to 0.5%.
Oxygen	= 0.1 to 0.5%.

2.4.3 Characteristics of Manufactured Liquid Fuels

Manufactured liquid fuels include Gasoline, Diesel oil, Kerosene, Heavy oil, Naptha, Lubricating oils, etc. These are obtained mostly by fractional distillation of crude petroleum or liquifaction of coal.

Gasoline or Petrol and its Characteristics

Some of the characteristics of an ideal gasoline are the following :

- must be cheap and readily available.
- must burn clean and produce no corrosion, on combustion.
- should mix readily with air and also should easily vaporize.
- should not pre-ignite easily.
- must have a high calorific value.

Diesel and its Characteristics

- diesel or gas oil is obtained between 250-320°C during the fractional distillation of crude petroleum. It is used in diesel engines as heating oil and for cracking to get gasoline.
- contains 85% C, 12% H.
- calorific value is about 11,000 KCal/Kg.

Kerosene Oil and its Characteristics

- kerosene oil is obtained between 180-250°C during fractional distillation of crude petroleum.
- it is used as an illuminant, jet engine fuel, tractor fuel, and for preparing laboratory gas.
- kerosene when used in domestic appliances, gets vaporised before combustion.
- by using a fair excess of air it burns with a smokeless blue flame.

Heavy Oil and its Characteristics

Heavy oil is obtained between 320-400°C during fractional distillation of crude petroleum. This oil on refractionation gives :

- Lubricating oils which are used as lubricants.
- Petroleum-jelly (vaseline) which is used as lubricants in medicines and in cosmetics.
- Greases which are used as lubricants.
- Paraffin wax which is used in candles, boot polishes, wax paper, tarpolin cloth and for electrical insulation purposes.

Some important properties and brief information about liquid fuels are given in Table 2.11.

Table 2.11 : Characteristics of Liquid Fuels

Fuel	Specific Gravity	Percentage Composition by Weight			Higher Calorific Value KCal/Kg
		C	H_2	S	
Gasoline	7.74	85.4	14.6	-	11200
Paraffins	0.79	86.3	13.6	0.1	11100
Diesel Oil	0.87	86.3	12.8	0.9	11000
Heavy Fuel oil	0.95	86.1	11.8	2.1	10500

SAQ 9

What is the average composition of crude petroleum?

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SAQ 10

What are the uses of different types of manufactured liquid fuels?

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2.5 GASEOUS FUELS AND THEIR CHARACTERISTICS

Gaseous fuels occur in nature and are manufactured from solid and liquid fuels. The gaseous fuels need very large storage tanks and are highly inflammable, so chances of fire hazards in their use is high. Even then there are several advantages of these fuels when compared with solid and gaseous fuels.

2.5.1 Advantages of Gaseous Fuels

Some of the well known advantages of gaseous fuels are :

- easy to transport through pipelines to the place of use.
- can be lighted at ease, are clean in use, do not require any special burner.
- high heat contents.
- can be pre-heated by the heat of hot waste gases.
- combustion can readily be controlled.
- burn without any shoot, or smoke, and ashes.

2.5.2 Natural Gas and its Characteristics

Natural gas is obtained from wells dug in the oil-bearing regions. The approximate composition of natural gas is :

CH_4 = 70.9%

C_2H_6 = 5.10%

H_2 = 3%

$CO + CO_2$ = 22%

The calorific value varies from 12,000 to 14,000 KCal/m^3. It is a colourless gas and is non-poisonous. Its specific gravity is usually between 0.57 to 0.7.

SAQ 11

Discuss the origin and composition of natural gas.

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2.5.3 Characteristics of Manufactured Gases Fuels

Manufactured gases are coal gas, blast furnace gas, water gas, producer gas and oil gas. Their characteristics are discussed below :

Coal Gas and its Characteristics

Coal gas is obtained when coal is carbonized or heated in absence of air at about 1300°C in either coke ovens or gas-making retorts.

$$Coal \xrightarrow[(in\ absence\ of\ air)]{1300^0 C} Coke + Coal\ Gas\ (Residue)$$

Coal gas is a colourless gas having a characteristic odour. It is lighter than air and burns with a long smoky flame. It is used for illumination purposes as well as a fuel.

Its average composition is as follows :

H_2 = 47%

CH_4 = 32%

CO = 7%

C_2H_2 = 2%

C_2H_4 = 3%

N = 4%

CO_2 = 1%

Its calorific value is about 4900 KCal/m^3.

Blast Furnace Gas and its Characteristics

- Blast furnace gas has calorific value of about 1,000 KCal/m^3.
- It contains about 20-25 % carbon monoxide along with CO_2, N_2, etc.
- used for preheating air used in blast furnace, in boilers or after cleaning in gas engines.

Water Gas and its Characteristics

Water gas is essentially a mixture of combustible gases CO and H_2 with a little fraction of non-combustible gases.

The average composition of water gas is :

H_2 = 51%;

CO = 41%

N_2 = 4%

CO_2 = 4%.

Its calorific value is about 2,800 KCal/m^3. Water gas is used for illumination purposes, as a fuel gas and as a source of hydrogen gas.

Producer Gas and its Characteristics

Producer gas is essentially a mixture of combustible gases carbon monoxide and hydrogen associated with non-combustible gases N_2, CO_2 etc. The average composition of producer gas is :

CO = 22.3%

H_2 = 8.12%

N_2 = 52.55%

CO_2 = 3%.

Its calorific value is about 1300 KCal/m^3.

It is used for heating open-hearth furnaces, muffle furnaces and as a reducing agent in metallurgical operations.

Oil Gas and its Characteristics

Oil gas is obtained by cracking Kerosene oil. The average composition of oil gas is :

CH_4 = 25.30%

H_2 = 50-55%

CO = 10.12%

CO_2 = 3%.

Its calorific value is about 6600 KCal/m^3.

The calorific values of gaseous fuels are summarized in Table 2.12.

Table 2.12 : Calorific Values of Gaseous Fuels

Gaseous Fuel	Calorific value in KCal/m^3 at STP	
	HCV	LCV
Coal gas	7630	6920
Producer gas	1200	1150
Coke oven gas	5100	4600
Blast furnace gas	970	900
Town gas	4670	4170

SAQ 12

What are the characteristics of the following gaseous fuels.

a. Coal gas

b. Water gas,

c. Producer gas,

d. Blast furnace gas.

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2.6 LET US SUM UP

Fuels are classified either as natural fuels or as manufactured fuels on the basis of procurement. Fuels are also classified according to the physical state in which they exist such as solid, liquid and gaseous fuels.

The natural liquid fuels are petroleum and manufactured liquid fuels such as gasoline, or petrol, diesel oil, heavy oil, kerosene oil, coal tar, etc. The manufactured liquid fuels can be obtained by fractional distillation of natural petroleum or destructive distillation of solid fuels.

The natural gaseous fuels are natural gas and artificial gaseous fuels are as coal gas, water gas, producer gas, blast furnace gas, oil gas, etc.

2.7 KEY WORDS

Chemical Energy

The energy released when a fossil fuel (coal, oil and gas) are put to combustion

Biogas

A combustible gas derived from decomposing biological waste; normally consists of 50 to 60 percent methane.

Conversion Efficiency

A comparison of the useful energy output to the potential energy contained in the fuel.

Natural Gas

Hydrocarbon gas found in the earth, composed of methane, ethane, butane, propane and other gases.

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.

2.8 ANSWERS TO SAQs

SAQ 1

The fuels which occur in nature are called natural fuels.

SAQ 2

The manufactured fuels are obtained by using some artificial methods.

SAQ 3

Merits of solid fuels are :

- convenient to store
- low cost of production
- easy to transport
- have moderate ignition temperature

SAQ 4

The demerits of solid fuels are :

- ash content is high
- large proportion of heat is wasted
- burn with clinker formation.
- high cost of handling

SAQ 5

The main constituents of wood are :

- cellular tissue
- lignin
- tar
- sugar

SAQ 6

Proximate Analysis of Coal

The proximate analysis of coal gives the composition in respect of moisture, volatile matter, ash and fixed carbon.

Ultimate Analysis of Coal

The ultimate analysis of coal gives chemical composition for carbon, hydrogen, nitrogen, sulphur and ash.

SAQ 7

The uses of different types of coal are :

Peat : Manufacture of paper stock and alcohols.

Lignite : Used as pulverized fuel for locomotive and production of town gas.

Bituminous : Domestic and industrial.

Anthracite : Production of steam.

SAQ 8

The characteristics of Coke are :

Soft coke : Contains 5 to 10% volatile matter, burns without smoke.

Hard coke : Contains less moisture than soft coke, burns with smoke.

The characteristics of briquette are :

- hard and little friable.
- can withstand weather hazards.
- are suitable for storing and general handling.

SAQ 9

The composition of crude petroleum is :

C = 79.5 to 87.1%, H = 11.5 to 14.8%, S = 0.1 to 3.5%, N and O = 0.1 to 0.5%

SAQ 10

The uses of manufactured liquid fuels :

Gasoline or Petrol : It is used in aircrafts, automobiles, as a solvent.

Diesel Fuel : It is used in automobiles, as heating oil and for cracking to get gasoline.

Kerosene Oil : It is used as illuminant, in jet engine, tractor and preparing laboratory gas and for cooking.

Heavy Oil : It is used to obtain lubricating oils, petroleum-jelly, greases, etc. by fractional distillation.

SAQ 11

The origin of natural gas is wells dug in oil bearing regions.

The approximate composition of natural gas is

CH_4 = 70.9%

C_2H_6 = 5.10%

H_2 = 3%

$CO + CO_2$ = 22%.

SAQ 12

The characteristics of these gaseous fuels are summarized in the following Table :

Gaseous Fuel	Characteristics
Coal gas	• colourless gas having characteristic odour • lighter than air • burns with a long smoky flame
Water gas	• mixture of combustible gases CO, and H_2 with a little non-combustible gases • burns with blue flame
Producer gas	• cheap, clean and easily preparable gas • burns with blue flame
Blast Furnace gas	• by product of flue gas obtained during the reduction of iron ore by coke in blast furnace • contains dust • needs to be cleaned before use

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M.P. Murgai and Ram Chandra, Progress in Energy Auditing and Conservation, Boiler Operations, Wiley Eastern Ltd, New Delhi, 1990.

Lexical Units: constituent units of lexicon (morphemes, words, phraseological units and variable word-groups). Features of Lexical Units: Ã˜two-facet (having meaning and form); Ã˜ready-made (registered in a dictionary and reproducible in speech). The Morpheme: the smallest meaningful indivisible two-facet language unit. - flower-pot: morphemes flower -, -pot; - teacher: teach-, -er.Â Characteristics of Words: 1. distinguishing between the internal and the external structures of the word; 2. unity of the word (formal and semantic); 3. susceptibility to grammatical employment (in speech words can be used in different grammatical forms in which their interrelations are realized). In this way, the energy of fuels can be utilized more effectively and efficiently for various purposes. Objectives After studying this unit, you should be able to describe the classification of fuels, explain the various types of fuels and their characteristics, and know their applications in various fields. 3.2 PRINCIPLES OF CLASSIFICATION OF FUELS Fuels may broadly be classified in two ways, i.e. according to the physical state in which they exist in nature solid, liquid and gaseous, and according to the mode of their procurement natural and manufactured. 37.