

1. FUELS AND COMBUSTION

Introduction to Fuels, Properties of Liquid Fuels, Coal, Gas and Agro Residues, Storage, Handling and Preparation of fuels, Principle of Combustion, Combustion of Oil, Coal, Gas and Biomass, Draft System, Combustion Controls.

1.1 Introduction to Fuels

The various types of fuels like liquid, solid and gaseous fuels are available for firing in boilers, furnaces and other combustion equipments. The selection of right type of fuel depends on various factors such as availability, storage, handling, pollution and landed cost of fuel.

The knowledge of the fuel properties helps in selecting the right fuel for the right purpose and efficient use of the fuel. The following characteristics, determined by laboratory tests, are generally used for assessing the nature and quality of fuels.

1.2 Properties of Liquid Fuels

Liquid fuels like furnace oil and LSHS are predominantly used in industrial application. The various properties of liquid fuels are given below.

Density

This is defined as the ratio of the mass of the fuel to the volume of the fuel at a reference temperature of 15°C. Density is measured by an instrument called hydrometer. The knowledge of density is useful for quantity calculations and assessing ignition quality. The unit of density is kg/m^3 .

Specific gravity

This is defined as the ratio of the weight of a given volume of oil to the weight of the same volume of water at a given temperature. The density of fuel, relative to water, is called specific gravity. The specific gravity of water is defined as 1. Since specific gravity is a ratio, it has no units. The measurement of specific gravity is generally made by a hydrometer.

Specific gravity is used in calculations involving weights and volumes. The specific gravity of various fuel oils are given in Table 1.1

Table 1.1 Specific Gravity of Various Fuel Oils			
Fuel Oil	L.D.O Light Diesel Oil	Furnace oil	L.S.H.S Low Sulphur Heavy Stock
Specific Gravity	0.85-0.87	0.89-0.95	0.88-0.98

Viscosity

The viscosity of a fluid is a measure of its internal resistance to flow. Viscosity depends on temperature and decreases as the temperature increases. Any numerical value for viscosity has no meaning unless the temperature is also specified. Viscosity is measured in Stokes / centiStokes. Sometimes viscosity is also quoted in Engler, Saybolt or Redwood. Each type of oil has its own temperature - viscosity relationship. The measurement of viscosity is made with an instrument called Viscometer.

Viscosity is the most important characteristic in the storage and use of fuel oil. It influences the degree of pre-heat required for handling, storage and satisfactory atomization. If the oil is too viscous, it may become difficult to pump, hard to light the burner, and tough to operate. Poor atomization may result in the formation of carbon deposits on the burner tips or on the walls. Therefore pre-heating is necessary for proper atomization.

Flash Point

The flash point of a fuel is the lowest temperature at which the fuel can be heated so that the vapour gives off flashes momentarily when an open flame is passed over it. Flash point for furnace oil is 66^oC.

Pour Point

The pour point of a fuel is the lowest temperature at which it will pour or flow when cooled under prescribed conditions. It is a very rough indication of the lowest temperature at which fuel oil is readily pumpable

Specific Heat

Specific heat is the amount of kCal needed to raise the temperature of 1 kg of oil by 1^oC. The unit of specific heat is kcal/kg^oC. It varies from 0.22 to 0.28 depending on the oil specific gravity. The specific heat determines how much steam or electrical energy it takes to heat oil to a desired temperature. Light oils have a low specific heat, whereas heavier oils have a higher specific heat.

Calorific Value

The calorific value is the measurement of heat or energy produced, and is measured either as gross calorific value or net calorific value. The difference being the latent heat of condensation of the water vapour produced during the combustion process. Gross calorific value (GCV) assumes all vapour produced during the combustion process is fully condensed. Net calorific value (NCV) assumes the water leaves with the combustion products without fully being condensed. Fuels should be compared based on the net calorific value.

The calorific value of coal varies considerably depending on the ash, moisture content and the

type of coal while calorific value of fuel oil is much more consistent. The typical Gross Calorific Values of some of the commonly used liquid fuels are given below:

<u>Fuel Oil</u>	<u>Gross Calorific Value (kCal/kg)</u>
Kerosene	- 11,100
Diesel Oil	- 10,800
L.D.O	- 10,700
Furnace Oil	- 10,500
LSHS	- 10,600

Sulphur

The amount of sulphur in the fuel oil depends mainly on the source of the crude oil and to a lesser extent on the refining process. The normal sulfur content for the residual fuel oil (furnace oil) is in the order of 2-4 %.

Typical figures are:

<u>Fuel oil</u>	<u>Percentage of Sulphur</u>
Kerosene	0.05—0.2
Diesel Oil	0.05 – 0.25
L.D.O	0.5 – 1.8
Furnace Oil	2.0 – 4.0
LSHS	< 0.5

The main disadvantage of sulphur is the risk of corrosion by sulphuric acid formed during and after combustion, and condensing in cool parts of the chimney or stack, air pre heater and economiser.

Ash Content

The ash value is related to the inorganic material in the fuel oil. The ash levels of distillate fuels are negligible. Residual fuels have more of the ash-forming constituents. These salts may be compounds of sodium, vanadium, calcium, magnesium, silicon, iron, aluminum, nickel, etc.

Typically, the ash value is in the range 0.03-0.07 %. Excessive ash in liquid fuels can cause fouling deposits in the combustion equipment. Ash has erosive effect on the burner tips, causes damage to the refractories at high temperatures and gives rise to high temperature corrosion and fouling of equipments.

Carbon Residue

Carbon residue indicates the tendency of oil to deposit a carbonaceous solid residue on a hot surface, such as a burner or injection nozzle, when its vaporisable constituents evaporate. Residual oil contains carbon residue ranging from 1 percent or more.

Water Content

Water content of furnace oil when supplied is normally very low as the product at refinery site is handled hot and maximum limit of 1% is specified in the standard.

Water may be present in free or emulsified form and can cause damage to the inside furnace surfaces during combustion especially if it contains dissolved salts. It can also cause spluttering of the flame at the burner tip, possibly extinguishing the flame and reducing the flame temperature or lengthening the flame.

Typical specification of fuel oil is summarised in the Table 1.2.

Table 1.2 Typical Specification of Fuel Oils			
Properties	Fuel Oils		
	Furnace Oil	LS.H.S.	L.D.O.
Density (Approx. g/cc at 15 ^o C)	0.89-0.95	0.88-0.98	0.85-0.87
Flash Point (° C)	66	93	66
Pour Point (° C)	20	72	18
G.C.V. (Kcal/kg)	10,500	10,600	10,700
Sediment, % Wt. Max.	0.25	0.25	0.1
Sulphur Total, % Wt. Max.	Up to 4.0	Up to 0.5	Up to 1.8
Water Content, % Vol. Max.	1.0	1.0	0.25
Ash % Wt. Max.	0.1	0.1	0.02

Storage of Fuel oil

It can be potentially hazardous to store furnace oil in barrels. A better practice is to store it in cylindrical tanks, either above or below the ground. Furnace oil, that is delivered, may contain dust, water and other contaminants.

The sizing of storage tank facility is very important. A recommended storage estimate is to provide for at least 10 days of normal consumption. Industrial heating fuel storage tanks are generally vertical mild steel tanks mounted above ground. It is prudent for safety and environmental reasons to build bund walls around tanks to contain accidental spillages.

As a certain amount of settlement of solids and sludge will occur in tanks over time, cleaning should be carried out at regular intervals-annually for heavy fuels and every two years for light fuels. A little care should be taken when oil is decanted from the tanker to storage tank. All leaks from joints, flanges and pipelines must be attended at the earliest. Fuel oil should be free from possible contaminants such as dirt, sludge and water before it is fed to the combustion system.

LOSS OF EVEN ONE DROP OF OIL EVERY SECOND CAN COST YOU OVER 4000 LITRES A YEAR

Removal of Contaminants

Furnace oil arrives at the factory site either in tank lorries by road or by rail. Oil is then decanted into the main storage tank. To prevent contaminants such as rags, cotton waste, loose nuts or bolts or screws entering the system and damaging the pump, coarse strainer of 10 mesh size (not more than 3 holes per linear inch) is positioned on the entry pipe to the storage tanks.

Progressively finer strainers should be provided at various points in the oil supply system to filter away finer contaminants such as external dust and dirt, sludge or free carbon. It is advisable to provide these filters in duplicate to enable one filter to be cleaned while oil supply is maintained through the other. The Figure 1.1 gives an illustration of the duplex system of arrangement of strainers.

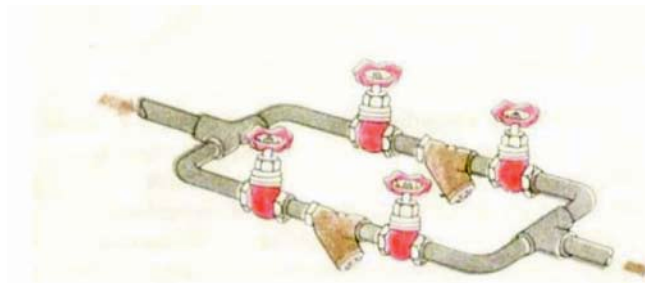


Figure 1.1 Duplex Arrangement of Strainers in a Pipeline

The Table 1.3 gives sizing of strainers at various locations.

Table 1.3 Sizing of Strainers		
Location	Strainer Sizes	
	Mesh	Holes/Linear inch
Between rail/tank lorry decanting point and main storage tank	10	3
Between service tank and pre-heater	40	6
Between pre-heater and burner	100	10

Pumping

Heavy fuel oils are best pumped using positive displacement pumps, as they are able to get fuel moving when it is cold. A circulation gear pump running on LDO should give between 7000-10000 hours of service. Diaphragm pumps have a shorter service life, but are easier and less expensive to repair. A centrifugal pump is not recommended, because as the oil viscosity increases, the efficiency of the pump drops sharply and the horsepower required increases. Light fuels are best pumped with centrifugal or turbine pumps. When higher pressures are required, piston or diaphragm pumps should be used.

Fuel Storage and Pumping Temperature

The viscosity of furnace oil and LSHS increases with decrease in temperature, which makes it difficult to pump the oil. At low ambient temperatures (below 25 °C), furnace oil is not easily pump able. To circumvent this, preheating of oil is accomplished in two ways: a) the entire tank may be preheated. In this form of bulk heating, steam coils are placed at the bottom of the tank, which is fully insulated; b) the oil can be heated as it flows out with an outflow heater. To reduce steam requirements, it is advisable to insulate tanks where bulk heating is used.

Bulk heating may be necessary if flow rates are high enough to make outflow heaters of adequate capacity impractical, or when a fuel such as Low Sulphur Heavy Stock (LSHS) is used. In the case of outflow heating, only the oil, which leaves the tank, is heated to the pumping temperature. The outflow heater is essentially a heat exchanger with steam or electricity as the heating medium.

Temperature Control

Thermostatic temperature control of the oil is necessary to prevent overheating, especially when oil flow is reduced or stopped. This is particularly important for electric heaters, since oil may get carbonized when there is no flow and the heater is on. Thermostats should be provided at a region where the oil flows freely into the suction pipe. The temperature at which oil can readily be pumped depends on the grade of oil being handled. Oil should never be stored at a temperature above that necessary for pumping as this leads to higher energy consumption.

1.3 Properties of Coal

Coal Classification

Coal is classified into three major types namely anthracite, bituminous, and lignite. However there is no clear demarcation between them and coal is also further classified as semi- anthracite, semi-bituminous, and sub-bituminous. Anthracite is the oldest coal from geological perspective. It is a hard coal composed mainly of carbon with little volatile content and practically no moisture. Lignite is the youngest coal from geological perspective. It is a soft coal composed mainly of volatile matter and moisture content with low fixed carbon. Fixed carbon refers to carbon in its free state, not combined with other elements. Volatile matter refers to those combustible constituents of coal that vaporize when coal is heated.

The common coals used in Indian industry are bituminous and sub-bituminous coal. The gradation of Indian coal based on its calorific value is as follows:

Grade	Calorific Value Range (in kCal/kg)
A	Exceeding 6200
B	5600 – 6200
C	4940 – 5600
D	4200 – 4940
E	3360 – 4200
F	2400 – 3360
G	1300 – 2400

Normally D, E and F coal grades are available to Indian Industry.

The chemical composition of coal has a strong influence on its combustibility. The properties of coal are broadly classified as

1. Physical properties
2. Chemical properties

Physical Properties

Heating Value

The heating value of coal varies from coal field to coal field. The typical GCVs for various coals are given in the Table 1.4.

Table 1.4 GCV for Various Coals				
Parameter	Lignite (Dry Basis)	Indian Coal	Indonesian Coal	South African Coal
GCV (kcal/kg)	4,500*	4,000	5,500	6,000

*GCV of lignite on ‘*as received basis*’ is 2500 –3000

Analysis of Coal

There are two methods: ultimate analysis and proximate analysis. The ultimate analysis determines all coal component elements, solid or gaseous and the proximate analysis determines only the fixed carbon, volatile matter, moisture and ash percentages. The ultimate analysis is determined in a properly equipped laboratory by a skilled chemist, while proximate analysis can be determined with a simple apparatus. It may be noted that proximate has no connection with the word “approximate”.

Measurement of Moisture

Determination of moisture is carried out by placing a sample of powdered raw coal of size 200-micron size in an uncovered crucible and it is placed in the oven kept at 108 ± 2 °C along with the lid. Then the sample is cooled to room temperature and weighed again. The loss in weight represents moisture.

Measurement of Volatile Matter

Fresh sample of crushed coal is weighed, placed in a covered crucible, and heated in a furnace at 900 ± 15 °C. For the methodologies including that for carbon and ash, refer to IS 1350 part I:1984, part III, IV. The sample is cooled and weighed. Loss of weight represents moisture and volatile matter. The remainder is coke (fixed carbon and ash).

Measurement of Carbon and Ash

The cover from the crucible used in the last test is removed and the crucible is heated over the Bunsen burner until all the carbon is burned. The residue is weighed, which is the incombustible ash. The difference in weight from the previous weighing is the fixed carbon. In actual practice, Fixed Carbon or FC derived by subtracting from 100 the value of moisture, volatile matter and ash.

Proximate Analysis

Proximate analysis indicates the percentage by weight of the Fixed Carbon, Volatiles, Ash, and Moisture Content in coal. The amounts of fixed carbon and volatile combustible matter directly contribute to the heating value of coal. Fixed carbon acts as a main heat generator during burning. High volatile matter content indicates easy ignition of fuel. The ash content is important in the design of the furnace grate, combustion volume, pollution control equipment and ash handling systems of a furnace. A typical proximate analysis of various coal is given in the Table 1.5.

Parameter	Indian Coal	Indonesian Coal	South African Coal
Moisture	5.98	9.43	8.5
Ash	38.63	13.99	17
Volatile matter	20.70	29.79	23.28
Fixed Carbon	34.69	46.79	51.22

Significance of Various Parameters in Proximate Analysis

a) Fixed carbon:

Fixed carbon is the solid fuel left in the furnace after volatile matter is distilled off. It consists mostly of carbon but also contains some hydrogen, oxygen, sulphur and nitrogen not driven off with the gases. Fixed carbon gives a rough estimate of heating value of coal

b) Volatile Matter:

Volatile matters are the methane, hydrocarbons, hydrogen and carbon monoxide, and incombustible gases like carbon dioxide and nitrogen found in coal. Thus the volatile matter is an index of the gaseous fuels present. Typical range of volatile matter is 20 to 35%.

Volatile Matter

- Proportionately increases flame length, and helps in easier ignition of coal.
- Sets minimum limit on the furnace height and volume.
- Influences secondary air requirement and distribution aspects.
- Influences secondary oil support

c) Ash Content:

Ash is an impurity that will not burn. Typical range is 5 to 40%

Ash

- Reduces handling and burning capacity.
- Increases handling costs.
- Affects combustion efficiency and boiler efficiency
- Causes clinkering and slagging.

d) Moisture Content:

Moisture in coal must be transported, handled and stored. Since it replaces combustible matter, it decreases the heat content per kg of coal. Typical range is 0.5 to 10%

Moisture

- Increases heat loss, due to evaporation and superheating of vapour
- Helps, to a limit, in binding fines.
- Aids radiation heat transfer.

e) Sulphur Content:

Typical range is 0.5 to 0.8% normally.

Sulphur

- Affects clinkering and slagging tendencies
- Corrodes chimney and other equipment such as air heaters and economisers
- Limits exit flue gas temperature.

Chemical Properties

Ultimate Analysis

The ultimate analysis indicates the various elemental chemical constituents such as Carbon, Hydrogen, Oxygen, Sulphur, etc. It is useful in determining the quantity of air required for combustion and the volume and composition of the combustion gases. This information is required for the calculation of flame temperature and the flue duct design etc. Typical ultimate analyses of various coals are given in the Table 1.6.

Table 1.6 Typical Ultimate Analyses of Coals		
Parameter	Indian Coal, %	Indonesian Coal, %
Moisture	5.98	9.43
Mineral Matter (1.1 x Ash)	38.63	13.99
Carbon	41.11	58.96
Hydrogen	2.76	4.16
Nitrogen	1.22	1.02
Sulphur	0.41	0.56
Oxygen	9.89	11.88

Table 1.7 Relationship Between Ultimate Analysis and Proximate Analysis			
	%C	=	$0.97C + 0.7(VM - 0.1A) - M(0.6 - 0.01M)$
	%H	=	$0.036C + 0.086(VM - 0.1xA) - 0.0035M^2(1 - 0.02M)$
	%N ₂	=	$2.10 - 0.020 VM$
Where			
	C	=	% of fixed carbon
	A	=	% of ash
	VM	=	% of volatile matter
	M	=	% of moisture

Note: The above equation is valid for coal containing greater than 15% moisture content.

Storage, Handling and Preparation of Coal

Uncertainty in the availability and transportation of fuel necessitates storage and subsequent handling. Stocking of coal has its own disadvantages like build-up of inventory, space constraints, deterioration in quality and potential fire hazards. Other minor losses associated with the storage of coal include oxidation, wind and carpet loss. A 1% oxidation of coal has the same effect as 1% ash in coal, wind losses may account for nearly 0.5 – 1.0% of the total loss.

The main goal of good coal storage is to minimise carpet loss and the loss due to spontaneous combustion. Formation of a soft carpet, comprising of coal dust and soil causes carpet loss. On the other hand, gradual temperature builds up in a coal heap, on account of oxidation may lead to spontaneous combustion of coal in storage.

The measures that would help in reducing the carpet losses are as follows:

1. Preparing a hard ground for coal to be stacked upon.
2. Preparing standard storage bays out of concrete and brick

In process industry, modes of coal handling range from manual to conveyor systems. It would be advisable to minimise the handling of coal so that further generation of fines and segregation effects are reduced.

Preparation of Coal

Preparation of coal prior to feeding into the boiler is an important step for achieving good combustion. Large and irregular lumps of coal may cause the following problems:

1. Poor combustion conditions and inadequate furnace temperature.
2. Higher excess air resulting in higher stack loss.
3. Increase of unburnts in the ash.
4. Low thermal efficiency.

(a) Sizing of Coal

Proper coal sizing is one of the key measures to ensure efficient combustion. Proper coal sizing, with specific relevance to the type of firing system, helps towards even burning, reduced ash losses and better combustion efficiency.

Coal is reduced in size by crushing and pulverizing. Pre-crushed coal can be economical for smaller units, especially those which are stoker fired. In a coal handling system, crushing is limited to a top size of 6 or 4mm. The devices most commonly used for crushing are the rotary breaker, the roll crusher and the hammer mill.

It is necessary to screen the coal before crushing, so that only oversized coal is fed to the crusher. This helps to reduce power consumption in the crusher. Recommended practices in coal crushing are:

1. Incorporation of a screen to separate fines and small particles to avoid extra fine generation in crushing.
2. Incorporation of a magnetic separator to separate iron pieces in coal, which may damage the crusher.

The Table 1.8 gives the proper size of coal for various types of firing systems

S. No.	Types of Firing System	Size (in mm)
1	Hand Firing (a) Natural draft (b) Forced draft	25-75 25-40
2	Stoker Firing (a) Chain grate i) Natural draft ii) Forced draft (b) Spreader Stoker	25-40 15-25 15-25
3	Pulverized Fuel Fired	75% below 75 micron*
4	Fluidized bed boiler	< 10 mm

*1 Micron = 1/1000 mm

(b) Conditioning of Coal

The fines in coal present problems in combustion on account of segregation effects. Segregation of fines from larger coal pieces can be reduced to a great extent by conditioning coal with water. Water helps fine particles to stick to the bigger lumps due to surface tension of the moisture, thus stopping fines from falling through grate bars or being carried away by the furnace draft. While tempering the coal, care should be taken to ensure that moisture addition is uniform and preferably done in a moving or falling stream of coal.

If the percentage of fines in the coal is very high, wetting of coal can decrease the percentage of unburnt carbon and the excess air level required to be supplied for combustion. Table 1.9 shows the extent of wetting, depending on the percentage of fines in coal.

Fines (%)	Surface Moisture (%)
10 - 15	4 - 5
15 - 20	5 - 6
20 - 25	6 - 7
25 - 30	7 - 8

(c) Blending of Coal

In case of coal lots having excessive fines, it is advisable to blend the predominantly lumped coal with lots containing excessive fines. Coal blending may thus help to limit the extent of fines in coal being fired to not more than 25%. Blending of different qualities of coal may also help to supply a uniform coal feed to the boiler.

The proximate and ultimate analysis of various coal is given in Table 1.10 and 1.11.

	Lignite	Bituminous Coal (Sample I)	Bituminous Coal (Sample II)	Indonesian Coal
Moisture (%)	50	5.98	4.39	9.43
Ash (%)	10.41*	38.65	47.86	13.99
Volatile matter (%)	47.76*	20.70	17.97	29.79
Fixed carbon (%)	41.83*	34.69	29.78	46.79

*Dry Basis

	Bituminous Coal (Sample I)	Bituminous Coal (Sample II)	Indonesian Coal
Moisture (%)	5.98	4.39	9.43
Mineral matter (%)	38.63	47.86	13.99
Carbon (%)	42.11	36.22	58.96
Hydrogen (%)	2.76	2.64	4.16
Nitrogen (%)	1.22	1.09	1.02
Sulphur (%)	0.41	0.55	0.56
Oxygen (%)	9.89	7.25	11.88
GCV (kCal/kg)	4000	3500	5500

1.4 Properties of Gaseous Fuels

Gaseous fuels in common use are liquefied petroleum gases (LPG), Natural gas, producer gas, blast furnace gas, coke oven gas etc. The calorific value of gaseous fuel is expressed in kilo Calories per normal cubic meter (kCal/Nm³) i.e. at normal temperature (20 °C) and pressure (760 mm Hg)

Calorific Value

Since most gas combustion appliances cannot utilize the heat content of the water vapour, gross calorific value is of little interest. Fuel should be compared based on the net calorific value. This is especially true for natural gas, since increased hydrogen content results in high water formation during combustion.

Typical physical and chemical properties of various gaseous fuels are given in Table 1.12.

Fuel Gas	Relative Density	Higher Heating Value, kCal/Nm³	Air/Fuel ratio, m³ of air to m³ of Fuel	Flame Temp., °C	Flame Speed, m/s
Natural Gas	0.6	9350	10	1954	0.290
Propane	1.52	22200	25	1967	0.460
Butane	1.96	28500	32	1973	0.870

LPG

LPG is a predominant mixture of propane and Butane with a small percentage of unsaturates (Propylene and Butylene) and some lighter C_2 as well as heavier C_5 fractions. Included in the LPG range are propane (C_3H_8), Propylene (C_3H_6), normal and iso-butane (C_4H_{10}) and Butylene (C_4H_8).

LPG may be defined as those hydrocarbons, which are gaseous at normal atmospheric pressure, but may be condensed to the liquid state at normal temperature, by the application of moderate pressures. Although they are normally used as gases, they are stored and transported as liquids under pressure for convenience and ease of handling. Liquid LPG evaporates to produce about 250 times volume of gas.

LPG vapour is denser than air: butane is about twice as heavy as air and propane about one and half times as heavy as air. Consequently, the vapour may flow along the ground and into drains sinking to the lowest level of the surroundings and be ignited at a considerable distance from the source of leakage. In still air vapour will disperse slowly. Escape of even small quantities of the liquefied gas can give rise to large volumes of vapour / air mixture and thus cause considerable hazard. To aid in the detection of atmospheric leaks, all LPG's are required to be odorized. There should be adequate ground level ventilation where LPG is stored. For this very reason LPG cylinders should not be stored in cellars or basements, which have no ventilation at ground level.

Natural Gas

Methane is the main constituent of Natural gas and accounting for about 95% of the total volume. Other components are: Ethane, Propane, Butane, Pentane, Nitrogen, Carbon Dioxide, and traces of other gases. Very small amounts of sulphur compounds are also present. Since methane is the largest component of natural gas, generally properties of methane are used when comparing the properties of natural gas to other fuels.

Natural gas is a high calorific value fuel requiring no storage facilities. It mixes with air readily and does not produce smoke or soot. It has no sulphur content. It is lighter than air and disperses into air easily in case of leak. A typical comparison of carbon contents in oil, coal and gas is given in the Table 1.13.

Table 1.13 Comparison of Chemical Composition of Various Fuels			
	Fuel Oil	Coal	Natural Gas
Carbon	84	41.11	74
Hydrogen	12	2.76	25
Sulphur	3	0.41	-
Oxygen	1	9.89	Trace
Nitrogen	Trace	1.22	0.75
Ash	Trace	38.63	-
Water	Trace	5.98	-

1.5 Properties of Agro Residues

The use of locally available agro residues is on the rise. This includes rice husk, coconut shells, groundnut shells, Coffee husk, Wheat stalk etc. The properties of a few of them are given in the Tables 1.14 and 1.15.

	Deoiled Bran	Paddy Husk	Saw Dust	Coconut Shell
Moisture	7.11	10.79	37.98	13.95
Ash	18.46	16.73	1.63	3.52
Volatile Matter	59.81	56.46	81.22	61.91
Fixed Carbon	14.62	16.02	17.15	20.62

	Deoiled Bran	Paddy Husk	Saw Dust	Coconut Shell
Moisture	7.11	10.79	37.98	13.95
Mineral Matter	19.77	16.73	1.63	3.52
Carbon	36.59	33.95	48.55	44.95
Hydrogen	4.15	5.01	6.99	4.99
Nitrogen	0.82	0.91	0.80	0.56
Sulphur	0.54	0.09	0.10	0.08
Oxygen	31.02	32.52	41.93	31.94
GCV (kCal/kg)	3151	3568	4801	4565

Biomass Storage, Handling and Preparation

Biomass fuels have low bulk density which results in higher transportation cost. The transportation cost constitutes a significant portion of the landed cost of biomass. The low bulk density also requires vast area for storage. A common concern in biomass systems is the difficulty to ensure availability of any particular type of biomass throughout the entire year. A variety of types of biomass necessitate different types of collection and handling equipment. Most of the common biomass fuels, such as Woody biomass, Juliflora, Palm bunches, Jute Sticks, Cotton Stalks, De-oiled bran, Coir pith etc., require special types of handling machines, which add up to additional capital investment.

1.6 Combustion

Principle of Combustion

Combustion refers to the rapid oxidation of fuel accompanied by the production of heat, or heat and light. Complete combustion of a fuel is possible only in the presence of an adequate supply of oxygen.