FUELS AND COMBUSTION

Fuel

A Fuel is a combustible substance, containing carbon as the main constituent, which on burning gives large amount of heat. During the process of combustion of a fuel, the atoms of carbon, hydrogen, etc. Combine with oxygen with simultaneous liberation of heal.

$C+O_2 \rightarrow CO_2 + 94$ kcals

$2H_2 + O_2 \rightarrow 2H_2O+68.5$ k cals

The main source of fuel is coal and crude petroleum oil. These are stored fuels available in earth's crust and are generally called fossil fuels, because they were formed from fossilised remains of plants and animals.

Classification of fuels:

1. Primary fuels - occur in nature such as coal, petroleum & natural gas.
2. Secondary fuels - derived from primary fuels, such as gasoline, coal gas

Primary & Secondary fuels are further classified

i) Solid fuels - Wood, coal

ii) Liquid fuels - Petroleum oil

iii) Gaseous fuels - Natural gas

Solid Fuels:

1. Easily available
2. Cheap
3. Handling & Transportation are easy
4. Can be stored conveniently without any risk
5. Have a moderate ignition temperature

6. Form large amount of ash during burning, so disposal is a big problem.
7. Large space is required for storage.
8. Combustion is a slow process & cannot be easily controlled.

Liquid Fuel:

1. Have higher calorific value than solid fuels.
2: Occupy less storage space than solid fuels.
3. Combustion is uniform & easily controllable.
4. Do not yield any ash after burning.
5. More costly than solid fuels.
6. Give unpleasant odour during incomplete combustion. ,
7. Special type of burners are required for effective combustion.

Gaseous fuels:

1. Gaseous fuels have high calorific value than solid fuels.
2. During burning they do not produce any ash or smoke.
3. Compared lo solid & liquid fuels, they have high thermal efficiency.
4. Con be easily transported through the pipes.
5. Are highly inflammable & hence the chances for fire hazards are nigh
6. Since gases occupy a large volume, they require large storage tanks.

Requirements of a Good fuel:

1. Should be cheap and readily available.
2. Should be safe & economical.
3. Should not undergo spontaneous combustion.

4. Should have higher calorific value.
5. Should have moderate ignition temperature.
6. Combustion should be easily controllale.
7. Should have low mositure content, because the moisture content reduces the calorific value.
8. Products of combustion should not be harmful.
9. Should have low non-combustible matter or ash content.

SOLID FUELS:

Coal:

• Primary solid fuel.

• Formed as a result of alteration of vegetable matter under some favourbale conditions.

• The process of conversion (or) alteration of vegetable matter to anthracite is called coalification or metamorphism of coal.

Classification of coal:

Classified on the basis of its rank.

Types:

1. Wood
2. Peat
3. Lignite

4 Bituminous coal

5. Anthracite

• Peat is the first stage in the process of coalification of wood.

• Calorific value is about 5450 Kcal/kg.

• Lignite (or) brown coal is the intermediate stage in the process of coalification.

• It bums with a long smoky flame due to the presence of high volatile content.
• Calorific value is about 6500-7100 kcal 1 kg.

Bituminous coal:

• Classified on the basis of its carbon content into three types.

Property	Sub-bitumino	Bituminous	Semi-bitumin
1. Moisture and volatile contents	High	Low	Very low
2. Carbon content	75 - 83%	78-90%	90-95%
3. Calorific value	7000 kcal/kg	8000-8500 kcal/kg.	8500-8600 kcal/kg

- Anthracite is the last stage in the coalification of wood.
- Volatile, moisture and ash contents are very low.
- Calorific value is about 8650 kcal/kg

Average composition from wood to Anthracite:

Fuel	C%	H %	0%	Calorific value kcal/kg
Wood	50	7	43	4000-

				4500
Peat	57	6	35	4125-5400
Lignite	67	5	26	6500-7100
Sub-bituminous coal	77	5	16	7000-7500
Bituminous coal	83	5	10	8000-8500
Semi-bituminous coal	90	4.5	4	8350-8500
Anthracite	93	3	3	8650-8700

Analysis of coal:

Proximate analysis:

1. Moisture content:

   % of mositure in coal

$$= \frac{\text{Loss in weight of the coal}}{\text{Weight of air dried coal}} \times 100$$

2. Volatile matter:

% of volatile matter in coal

$$= \frac{\text{Loss in weight of the coal}}{\text{Weight of air dried coal}} \times 100$$

3. Ash content:

% of ash content in coal

$$= \frac{\text{Weight of ash formed}}{\text{Weight of dried coal}} \times 100$$

4. Fixed carbon:

% of fixed carbon in coal

= 100-% of (moisture content + volatile maltee+ash content)

Ultimate analysis:

a) % of carbon in coal

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

b) % of hydrogen

$$= \frac{\text{Increase in weight of } CaCl_2 \text{ tube}}{\text{Weight of coal sample taken}} \times \frac{2}{8} \times 100$$

c) % of N_2 in coal

$$= \frac{1.4 \times \text{Volume of acid consumed} \times \text{Normality}}{\text{Weight of coal sample}}$$

d) % of sulphur in coal

$$= \frac{32 \times \text{Weight of } BaSO_4 \text{ obtained}}{233 \times \text{Weight of coal sample}} \times 100$$

e) Ash - Proximate analysis.

f) % of oxygen in coal

= 100-% of (C+ H + N + S + Ash)

Significance of ultimate analysis:

a) Carbon & hydrogen:

- Higher the % of carbon and hydrogen, better is the quality of coal and higher is its calorific value.
- Higher % of carbon in coal reduces the size of combustion chamber required.

b) Nitrogen:

i) Nitrogen does not have any calorific value, and its presence in coal is undesirable, if Good quality coal should have very little nitrogen content.

C. Sulphur:

Though sulphur increases the calortic value, its presence in coal is undesirable because.

i) the combustion products of sulphur, i.e. SO_2 & SO_3 are harmful & have commotion effects on equipments.

ii) The coal containing sulphur is not suitable for the preparation of metallurgical coke as it affects the properties of the metal.

d) Oxygen:

i) Lower the % of oxygen higher is its calorific value.

ii) As the oxygen content increases its moisture holding capacity and the calorific value of the fuel is reduced.

Carbonisation:

When coal is heated strongly in the absence of air (called destructive distillation) it is converted into lustrous, dense, porous and coherent mass known as coke. This process of converting coal into coke is known as carbonisation.

Caking coals & Coking coals:

- When cools are heated strongly, the mass becomes soft, plastic and fuses to give a coherent mass. Such type of coals are called caking coals.
- But if the mass so produced is hard, porous and strong then the coals are called coking cools.
- All coking coals are caking coals but all caking coats are not coking coals.

Types of carbonisation:

1. Low temperature carbonisation
LTC (500 - 700°C)
2. High temperature carbonisation
HTC (900-1200°C)

Metallurgical coke:

When bituminous coal is heated strongly in the absence or air, the volatile matter escapes out and the mass becomes hard, strong, porous and coherent which is called metallurgical coke.

Characteristics of good metallurgical coke:

1. Purity-high
2. Porosity-high
3. Strength – high
4. Calorific value – high
5. Combustibility – easy
6. Reactivity – low
7. Cost – cheap

Manufacture of Metallurgical coke:

Two type of ovens used for the manufacture of metallurgical coke.
i) Beehive oven
ii) Otto-Hoffman's by product oven

Disadvantages of Beehive oven process:

- Process is time consuming and low yielding.
- Since all volatile matter present in the coal is allowed to escape into atmosphere as waste, we cannot recover any by-products.

Otto-Hoffman's by product oven:

It is needed to
1. Increase the thermal η of the carbonisation process &
2. Recover all valuable by-products like coal gas ammonia, benzol oil, etc

LIQUID FUELS:

Petroleum:

Petroleum is naturally occurring liquid fuel. It is a dark brown or black coloured viscous oil found deep in earth's crust. The oil is usually floating over a brine solution and above the oil natural gas is present. Crude oil is a mixture of paraffinic, olefin and aromatic hydrocarbons with small amounts of organic compounds like N, O and S.

Average composition of crude oil:
C = 80 - 87%
H = 11-15%
S = 0.1 - 3.5%
N + O = 0.1 - 05%

Classification of Petroleum:

1. Paraffinic - base type crude oil
2 Napthenic or Asphaltic Base type crude oil.
3. Mixed base type crude oil

Refining of Petroleum or Crude oil:

Process of removing impurities and separating the crude oil into various fractions having different boiling points is called refining of petroleum. It involves the following steps:

1. Separation of water - Cottrell's process
2. Removal of harmful sulphur compounds
3. Fractional distillation

Fractions of petroleum:

1. Petrol or Gasoline (C_5 - C_9)

C = 84% : H = 15% ; N + S + O = 1%

Cal. value = 11.250 kcal/kg.

- Used in 1C engines as a full & as a solvent in dry cleaning.

2. Naphtha (C_9-C_{10}):

- It is a colourless, light fraction obtained between 120-180°C during fractional distillation of petroleum. It is a mixture of hydrocarbons such as nonane and decane.
- Naphtha is also called as white spirit, which is generally used in dry cleaning and as thinner for varnish, floor and furniture polishes etc.

3. Kerosene (C_{10}-C_{16}):

- Mixture of hydrocarbons such as decane to hexadecane
- Approximate composition:

C = 84% ; H = 16% : S > 0.1%

Calorific value = 11.100 kcal / kg.

- Mainly used as a domestic fuel in stoves and lamps.
- Also used as jet engine fuel and for making oil gas.

4. Diesel (C_{15} – C_{18}):

- High boiling fraction obtained between 250-320°C during fractional distillation of petroleum.
- Mixture of hydrocarbons such as C_{15} H_{32} to $C_{18}H_{38}$.
- Calorific value: 11,000 kcal/kg.
- Used as a very good diesel engine fuel.

5. Heavy oil or Residual fuel oil (C_{17}-C_{30}):

- The left over portion of petroleum after distilling off all the lighter fractions are called fuel oil.
- **Composition:**

C = 86% : H = 12% : S = 1%

H_2O = 0.6% Sediments = 0.4%

Calorific value = 9200 kcal / kg.

Light fuel oil → 350-420°C

Heavy neutral oil → 420-500°C

- Used as fuel for ship's and also used in metallurgical furances.

6. Asphalt:

Obtained by the oxidation of heavy oil m presence of air at higher temperature.

- Asphalts have the highest viscosity of all the petroleum refining products. Asphalts are available in the market in liquid, semi-solid and solid forms.
- Used for road making and in making water proofing roofs.
- Used also for making water proofing concrete & water proofing paints.