UNIT-IV
FUEL TECHNOLOGY

Definition

A fuel is defined as naturally occurring or artificially manufactured combustible carbonaceous material which serves particularly as source of heat and light and also in few cases as a source of raw material.

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Classification of fuels Fuels are classified into a two types.

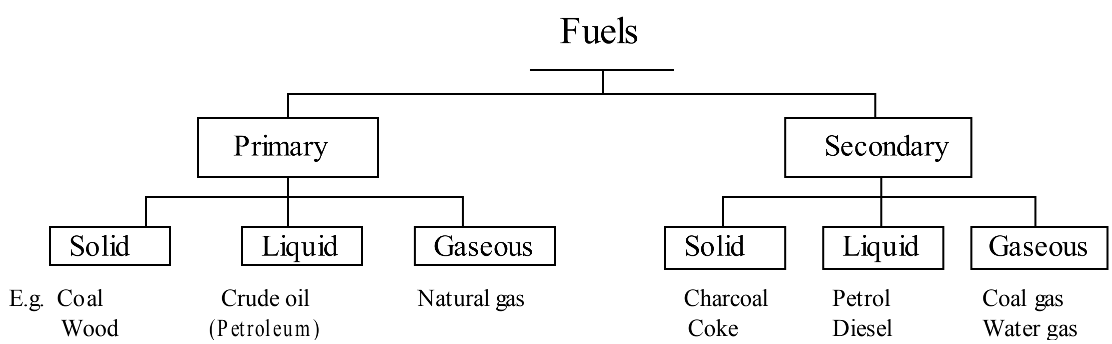
1) Based on their origin they are classified into
   a) Primary fuels
   b) Secondary fuels.

a) **<u>Primary Fuels</u>:** There are naturally occurring fuels which serves as source of energy
without any chemical processing.
Ex: Wood, Coal, Crude oil, Natural gas, Peat, Lignite, Anthracite.

b) **<u>Secondary Fuels</u>: -** They are derived from primary fuels & serves as source of energy
only after subjecting to chemical processing.
Ex: Charcoal, Coke, produsergas, Petrol, Diesel etc.,

Bases on their physical state fuel are classified into

a) Solid
b) Liquid
c) Gaseous fuels.



Liquid Fuels:

Liquid fuels are the important commercial and domestic fuels used in our daily life. Most of these fuels are obtained from the naturally occurring petroleum or crude oil called as primary fuel.

Advantages:

(a) They posses higher calorific value per unit mass than solid fuels.
(b) They burn without dust, ash, clinkers, etc.
(c) Their firing is easier and also fire can be extinguished easily by stopping liquid fuel supply.
(d) They are easy to transport through pipes.
(e) They can be stored indefinitely without any loss.
(f) They are clean in use and economic to handle.
(g) Loss of heat in chimney is very low due to greater cleanliness.
(h) They require less excess air for complete combustion.
(i) They require less furnace space for combustion.

Disadvantages:

(a) The cost of liquid fuel is relatively much higher as compared to solid fuel.
(b) Costly special storage tanks are required for storing liquid fuels.
(c) There is a greater risk of five hazards, particularly, in case of highly inflammable and volatile liquid fuels.
(d) They give bad odour.
(e) For efficient burning of liquid fuels, specially constructed burners and spraying apparatus are required.

Petroleum (crude oil)*:*

The crude oil or petroleum is also known as rock oil or mineral oil. It is dark colour liquid found well deep in the earth. It is mainly composed of hydrocarbons which may be solids, liquids or gases. Some optically active compounds having
S and N are also present. On the average the composition of
Petroleum is; C = 79.5 – 87.1%
H = 11.5 – 14.8%
S = 0.1 – 3.5%
N and O = 0.1 – 0.5%

Refining of petroleum:

Crude oil obtained from the mine is not fit to be marketed. It contains a lot of soluble and insoluble impurities, which must be removed. Previously the purification of crude oil is done by simple fractional distillation. Further treatment of the products is done by refining.

Definition:

"The process by which petroleum is made free of impurities, followed by the separation of petroleum into different fractions having different boiling points, and their further treatment to impart specific properties" can be called as Refining of petroleum.

Various stages during the refining process are explained below

1. Removal of solid impurities.
2. Removal of water.
3. Removal of harmful impurities.
4. Fractional distillation.

1. Removal of solid impurities:

The crude oil is a mixture of solid, liquid and gaseous substances. This is allowed to stand undisturbed for some time, till the heavy solid particles settle down and gases evaporate. The supernant liquid is then centrifuged where in the solids get removed.

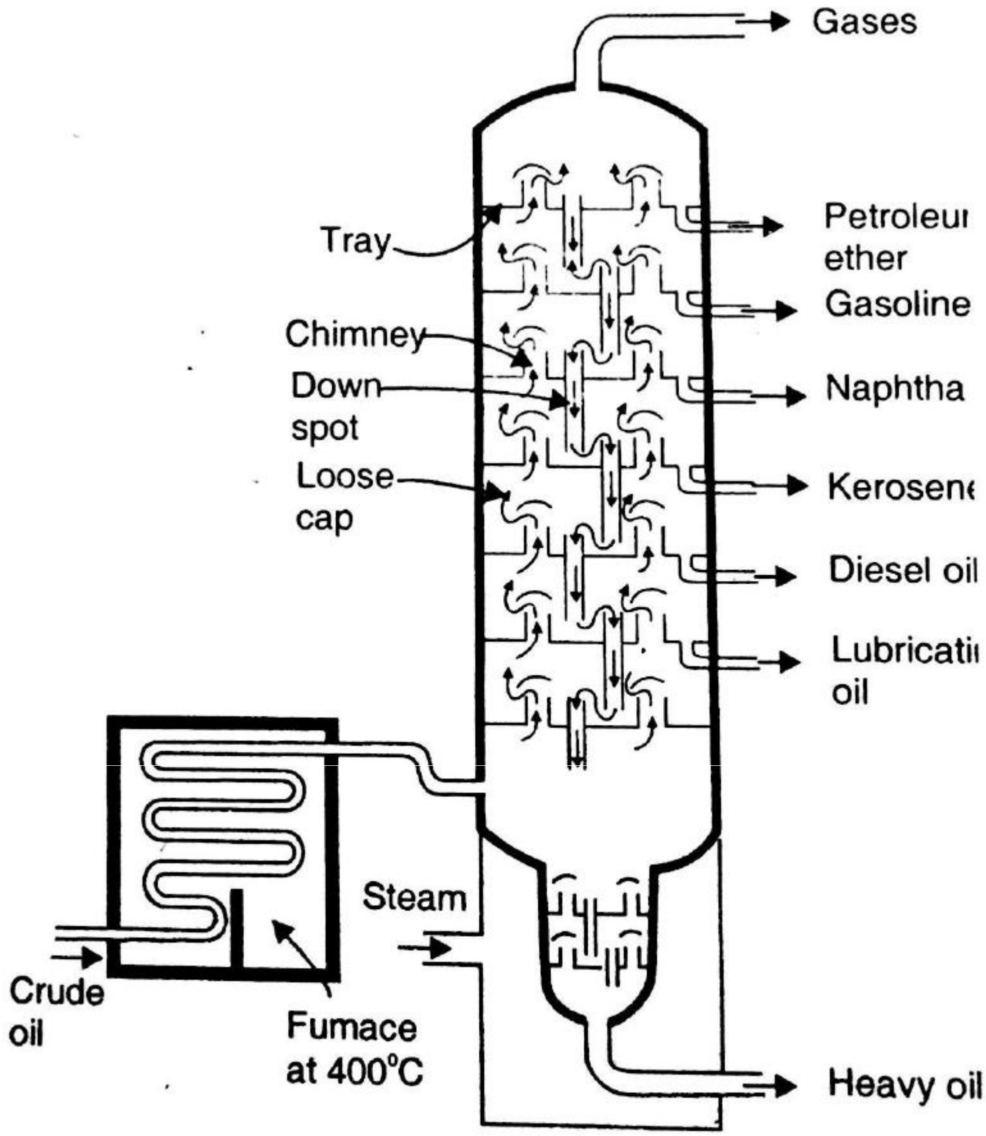
2. Removal of water by Cottrell's process:

The crude oil obtained from the earth's crust is in the form of stable emulsion of oil and brine. This mixture, when passed between two highly charged electrodes, destroy the emulsion films and the colloidal water droplets coalesce into bigger drops and get separated out from the oil.

3. Removal of harmful impurities:

In order to remove sulphur compounds in the crude oil, it is treated with copper oxide. Then, the sulphur compounds get converted to insoluble copper sulphide, which can be removed by filtration Substances like NaCl and $MgCl_2$, if present will corrode the refining equipment and result in scale formation. These can be removed by techniques like electric desalting and dehydration

Fractional distillation:



The crude oil is fractionally distilled in a fractionating still, which is a tower like structure having a bubble tower laid inside. The crude oil or the petroleum enters through the bottom of the still by an inlet. This is made to pass through a pre-heater or it can heated with steam inside the still to a temperature of about 400^0C. As we move to the top fractionating still the temperature goes on decreasing. A number of side pipes are fitted at different heights of the column or still, to collect the fractions. As petroleum enters the still, it gets vaporized and the vapours move up the bubble tower. The bubble tower consists of number of horizontal trays, and each tray is provided with a number of small chimneys through which the vapours rise. The chimneys are covered with loose caps so that the vapours bubble through and get condensed, dropping back into the trays. So as the vapours go up, they become cooler and cooler and fractional condensation of the crude oil takes place at different levels of the bubble tower.

The vapours of the liquid having the highest boiling point are the first to condense and go out and those which have the lowest boiling points go last, along with the uncondensed gases. The constituents of each fraction and the temperature at which they are obtained is given in the table.

Name of fraction	***Boiling range***	***Composition***	***Uses***
1. Uncondensed gases	Below 30^{0}C	C_1 to C_4	As domestic or industrial fuel under the name L.P.G.
2. Petroleum ether	30 – 70^{0}C	C_5 to C_7	As a solvent
3. Gasoline or petrol(11,250 kcal/kg)	40 – 120^{0}C	C_5 to C_9	As a motor fuel in I.C. engine
4. Naphtha (11,000 kcal/kg)	120 – 180^{0}C	C_9 to C_{10}	As a solvent in dry cleaning
5. Kerosene oil (11,100 kcal/kg)	180 – 250^{0}C	C_{10} to C_{16}	As domestic fuel and jet engine fuel
6. Diesel oil	250 – 320^{0}C	C_{10} to C_{18}	Diesel engine fuel
7. Heavy oil This on refraction gives; (a) Lubricating oil (b) Petroleum jelly (Vaseline) (c) Grease (d) Paraffin wax	320 – 400^{0}C	C_{17} to C_{30}	 As lubricant In cosmetics and medicines. As lubricant In candles and wax paper
8. Residue may be either; (a) Asphalt Or	Above 400^{0}C	C_{30} and above	 Water proofing of roofs As a fuel

(b) Petroleum coke			

Synthetic petrol:

Petrol can be synthesised by any of the following methods.

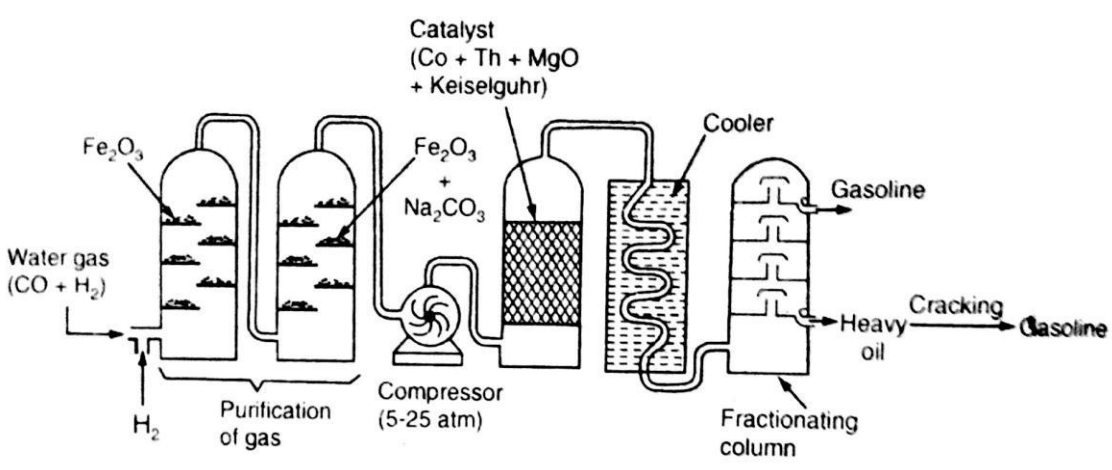
1. Fischer – Tropsch method.

2. Bergius process.

Fischer – Tropsch method:

Water gas ($CO + H_2$), produced by passing steam over heated coke, and is mixed with hydrogen. The gas is purified by passing through Fe_2O_3 to remove H_2S and then into a mixture of Fe_2O_3. Na_2CO_3 to remove organic sulphur compounds. The purified gas is compressed to 5 to 25 atm and then led through a converter, containing a catalyst.

Catalyst: It consists a mixture of 100 parts of Cobalt, 5 parts of thoria, 8 parts of magnesia, and 200 parts of keiselguhar earth. It maintained at about 200- 300^{o}C.



Then a mixture of saturated and unsaturated hydrocarbons results as follows;

$$n\,CO + 2n\,H_2 \text{--------}\rightarrow C_nH_{2n} + n\,H_2O$$

$$n\,CO + (2n+1)\,H_2 \text{--------}\rightarrow C_nH_{2n+2} + n\,H_2O$$

The reaction is exothermic, so out coming hot gaseous mixture is led to a cooler, where a liquid resembling crude oil is obtained. The crude oil thus obtained is then fractionated to yield (i) gasoline and (ii) heavy oil. The heavy oil is reused for cracking to get more gasoline.

Bergius process:

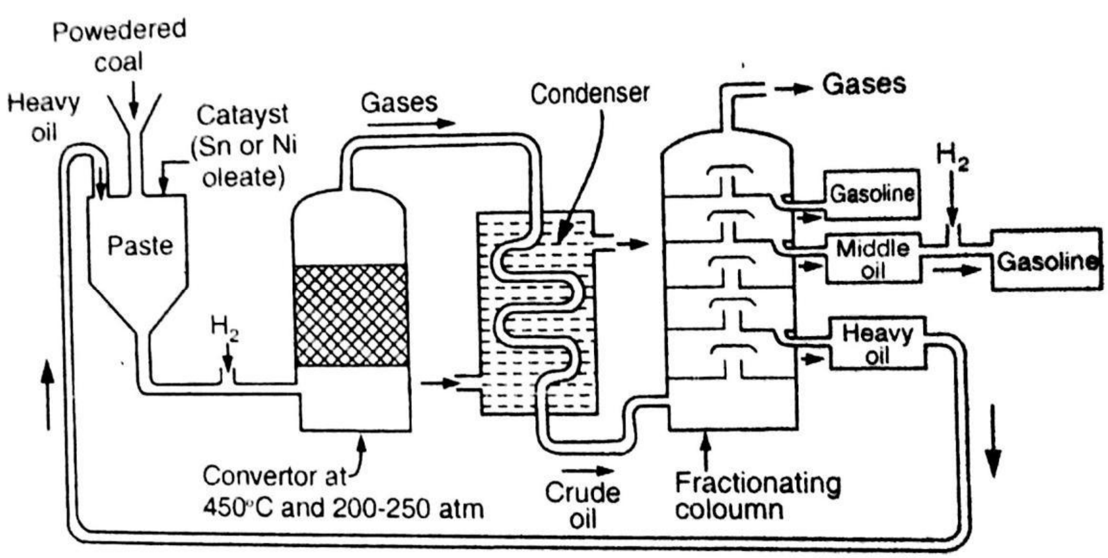
1. The low ash coal is finely powdered and made into a paste with heavy oil and then
 a catalyst composed of tin or nickel oleate is incorporated

2. The whole is heated with hydrogen at 450$_{o}$C and under a pressure 200-250 atm for
 about 1.5 hours, during which hydrogen combines with coal to form saturated hydrocarbons, which decompose at prevailing high temperature and pressure to yield low boiling liquid hydrocarbons.

3. The issuing gases are lead to condenser, where a liquid resembling crude oil is obtained, which is then fractionated to get (i) gasoline (ii) middle oil (iii) heavy oil.

4. The heavy oil is used again for making paste with fresh coal dust.

5. The middle oil is hydrogenated in vapour-phase in presence of a solid catalyst to
 yields more gasoline.



Gaseous fuels:

Gaseous fuels occur in nature, besides being manufactured from solid and liquid fuels.

The advantages and disadvantages of gaseous fuels are given below :

Advantages:

Gaseous fuels due to erase and flexibility of their applications, possess the following advantages over solid or liquid fuels :

(a) They can be conveyed easily through pipelines to the actual place of need, thereby eliminating manual labour in transportation.

(b) They can be lighted at ease.

(c) They have high heat contents and hence help us in having higher temperatures.

(d) They can be pre-heated by the heat of hot waste gases, thereby affecting economy in heat.

(e) Their combustion can readily by controlled for change in demand like oxidizing or reducing atmosphere, length flame, temperature, etc.

(f) They are clean in use.

(g) They do not require any special burner.

(h) They burn without any shoot, or smoke and ashes.

(i) They are free from impurities found in solid and liquid fuels.

Disadvantages:

(a) Very large storage tanks are needed.

(b) They are highly inflammable, so chances of fire hazards in their use are high.

Some important gaseous fuels:

Here we are going to discuss about the following gaseous fuels.

1. Natural gas 2.Water gas 3. Producer gas 4. Bio gas

5.Liquid Petroleum Gas(L.P.G.)

1. Natural gas:

It is obtained from the wells dug in the earth during mining of petroleum. It is mainly composed of methane and small quantities of ethane along with other hydrocarbons.

If the lower hydrocarbons are present, the gas is called dry gas or lean gas, but if the hydrocarbons having the higher molecular weights are present the gas is known as rich gas or wet gas.

The calorific value of this gas varies from 12000 to 14,000 kcal/m^3

Composition:

Methane – 88.5%   Ethane – 5.5%
Propane – 3.7%   Butane – 1.8%
Pentane, hydrogen, CO and higher hydrocarbons – 0.5%

Uses:

1. It is an excellent domestic fuel and can be conveyed over very large distances in pipelines.
2. It has recently been used in the manufacture of a number of chemicals by synthetic processes like carbon black, ammonia, methanol and formaldehyde.
3. Methane on microbiological fermentation gives synthetic proteins which are used as animal feed.
4. It is also used for generation of electricity in fuel cells as a source of hydrogen.

Producer gas: ($CO + N_2 + H_2$)

It is a mixture of combustible gases, carbon monoxide and hydrogen associated with large percentageof non-combustible gases, N_2, CO_2 etc.

Composition:

CO – 22 to 30% N_2 – 52 to 55% H_2 – 8 to 12% CO_2 – 3%

Preparation:

It is prepared by passing air mixed with little steam (about 0.35 kg/kg of coal) over a red hot coal or coke bed maintained at about 1100^{o}C in a special reactor called ‘gas producer’. It consists of a steel vessel about 3 m in diameter and 4 m in height. The vessel is lined inside with fire bricks. It is provided with a cup and cone feeder at the top and a side opening for the exit of producer gas. At the base it has an inlet for passing air and steam. The producer at the base is also provided with an exit for the ash formed.

LPG (Liquified Petroleum Gas)

Nowadays LPG has been a common fuel for domestic work and also in most of the industries. The main components of LPG or cooking gas are n-butane, isobutene, butylene and propane (traces of propene and ethane).The hydrocarbon are in gaseous state at room temperature and at atmospheric pressure but can be liquified under higher pressures. The gas can be compressed under pressure in containers and sold under trade names like Indane, Bharat, Petroleum gas, HP gas, etc.

LPG is kept in metallic cylinder attached with burner through pipe. It has two stoppers, one at the cylinder and other at burner. LPG has special odour due to the presence of organic sulphides which are added specially for safety measure. The gas is obtained from natural gas or as a by-product in refineries during cracking of heavy petroleum products.

Characteristics of LPG:

1. It has high calorific value: 27800 kcal/m_3, it is colourless.
2. It gives less CO and least unburnt hydrocarbons. So it causes least pollution.
3. It gives moderate heat which is very good for cooking.
4. Its storage is simple. It is colourless.
5. It has the tendency to mix with air easily.
6. Its burning gives no toxic gases though it is highly toxic.
7. It neither gives smoke nor ash content.
8. It is cheaper than gasoline. It burns with little air pollution and leaves no solid residue. Hence, it is used as fuel in auto vehicles also.
9. It is dangerous when leakage is there. It is highly knock resistant.
10. LPG can be extracted from natural gases and also from refining of crude oil. Cryogenic process is best for the extraction for natural gas.

Advantages of LPG:

1. LPG is used as domestic fuel and as a fuel for internal combustion engines.
2. It is used as a feedstock for the manufacture of various chemicals and olefins by pyrolysis.
3. LPG is used in industries as portable blow lamps, welding, annealing, hardening, steelcuttings, etc.

Knocking:

In an internal combustion engine, a mixture of gasoline vapour and air is used as a fuel. After the initiation of the combustion reaction, by spark in the cylinder, the flame should spread rapidly and smoothly through the gaseous mixture, thereby the expanding gas drives the piston down the cylinder.The ratio of the gaseous volume in the cylinder at the end of the suction-stoke to the volume at the end of compression-stoke of the piston, is known as the 'compression ratio'.

The efficiency of an internal combustion engine increases with the increase in compression ratio, which is dependent on the nature of the constituents present in the gasoline used. In certain circumstances (due to the presence of some constituents in the gasoline used), the rate of oxidation becomes so great that the last portion of the fuel-air mixture gets ignited instantaneously, producing an explosive violence, known as "knocking". The knocking results in loss of efficiently.

Chemical structure and knocking:

The tendency of fuel constituents to knock is in the following order.

Straight-chain paraffins > Branched-chain paraffins > olefins > Cyclo-paraffins > Aromatics

Thus olefins of the same carbon chain length possess better anti-knock properties than the corresponding paraffins and so on.

The knocking is maximum in open chain straight paraffins and least in aromatics. Therefore a fuel to be called a good fuel for the internal combustion engine should have least knocking.

Antiknocking agents

These are the substances added to petrol in order to prevent knocking in I.C. Engines.

Ex: TEL Tetra Ethyl led.
TML Tetra Methyl led.
MTBE Methyl Tertiary Butyl Ether.

Leaded Petrol:

The petrol containing TEL or TML as anti knocking agents is called leaded petrol. TEL or TML are the very good anti knocking agents but has some disadvantages as follows.

a) After combustion lead is deposited as lead oxide on piston and engine walls it leads to mechanical damage.
b) Lead is a poisonous air pollutant.
c) It spoils the catalyst used in catalytic converter.

Unleaded Petrol:

The petrol, which contains antiknocking agent other than lead, is known as unleaded petrol.

Ex: MTBE is used, as an antiknocking agent in place of TEL or TML and the petrol is known as unleaded petrol.

octane number.

Octane number is defined as the percentage of isooctane present in a standard mixture of isooctane and n-heptane, which knocks at the same compression ratio as the petrol being tested.

Isooctane is the branched chain hydrocarbon has least knocking rate, hence its octane number is arbitrarily fixed as 100. N-heptane a straight chain hydrocarbon has highest tendency to knock hence its octane number is fixed as zero. Octane number of petrol is 80 means it contains 80% by volume isooctane and 20% by volume n- heptane.

Cetane number.

It is defined as the percentage of cetane present in standard mixture of a cetane and Alfa- methylnaphthalene, which knocks at the same compression ratio as the diesel fuel being tested.

Power alcohol

A mixture of ethyl alcohol and gasoline blend, which can be used as fuel in internal combustion engine, is known as power alcohol or gasohol.

Absolute alcohol is mixed with ether, benzene etc compounds and one volume of this is mixed with four volumes of petrol and is used as a fuel.

Advantages:

1. The power out put is good.
2. It has better antiknock property.
3. Ethanol is biodegradable; hence it is environmental friendly fuel.
4. The use of ethanol in alcohol increases the oxygen content of the fuels and promotes more and complete combustion of hydrocarbons in gasoline.
5. It reduces carbon monoxide emission.

Calorific value

Calorific value is defined as the amount of heat liberated when a unit mass of fuel is burnt completely in presence of air or oxygen.

Calorific value is of two types as follows:-

1) Higher calorific value. (HCV) or Gross calorific value. (GCV)
2) Lower calorific value. (LCV) or Net calorific value. (NCV)

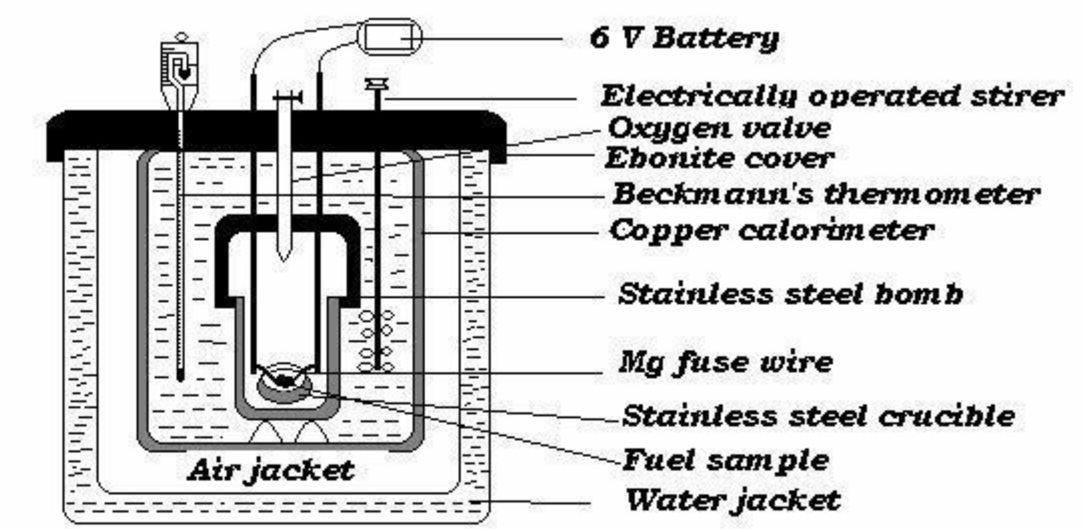
1) HCV: - It is the amount of heat liberated when a unit mass of fuels burnt completely in the presence of air or oxygen and the products of combustion are cooled to room temperature. Here it includes the heat liberated during combustion and the latent heat of steam. Hence its value is always higher than lower calorific value.

2) LCV: - It is amount of heat liberated when a unit mass of fuel is burnt completely in the presence of air or oxygen and the product of combustion are let off completely into air. It does not include the latent heat of steam. Therefore it is always lesser than HCV.

NCV = HCV – Latent heat of steam.

= HCV –0.09X % H_2 X 587 cal/g

Determination of calorific value of solid fuel using Bomb Calorimetric method



Bomb Calorimeter

A small quantity of a fuel is weighed accurately (M Kg) and is placed in the Bomb. The bomb is placed in known amount water taken in a copper calorimeter. The initial temp of water is noted as a $t_1\,^0C$ with the help of thermometer. Oxygen gas is pumped under pressure 20 to 25 atm through the O_2 valve provided.

The fuel is ignited by passing electric current through the wires provided. As the fuel undergoes combustion and liberates heat, which is absorbed by surrounding water. The water is stirred continuously to distribute the heat uniformly and the final temp attained by water is noted $t_2\,^0C$. & gross calorific value of the fuel is calculated as follows

Calculation:

Mass of the fuel = M Kg.
Initial temp of the water = $t_1\,^0C$
Final temp of the water = $t_2\,^0C$
Change in temp = $\triangle t = (t_2 - t_1)^0\ C$
Specific heat of water = S
Water equivalent of calorimeter = W Kg.

$$GCV = \frac{W \times S \times t \triangle}{M} \quad J/Kg \qquad \text{or}$$

$$GCV = \frac{(W+w) \times S \times \triangle t}{M} \quad J/Kg$$

NCV = GCV – 0.09 x %H_2 x 587 cal/g

PROBLEMS:

1) Calculate calorific value coal samples from the following data.

Mass of the coal = 1g.
Water equivalent of calorimeter = 2 Kg.
Specific heat of water = 4.187 J/Kg/c.
Rise of temperature = $4.8\,^0C$.

SOLUTION: $$GCV = \frac{W \times S \times \triangle t}{M}\ J/Kg$$

$$= \frac{2 \times 4.187 \times 4.8}{0.001}$$

= **40195.2 KJ/Kg**.

2) A coal sample with 93% carbon, 5% of Hydrogen and 2% Ash is subjected to combustion in a bomb calorimeter. Calculate GCV and NCV Given that. **6 Marks** Mass of the coal sample = 0.95g

Mass of water in copper calorimeter = 2000g.
Water equivalent wt of calorimeter = 700g.

Rise in temp = 2.8^0C
Latent heat of = 587 cal/g. Specific heat of water = 1 $cal/g/^0C$

$$GCV = \frac{(W+w) \times S \times \triangle t}{M}$$

$$= \frac{(2000+700) \times 10^{-3}\ kg \times 1\ cal/g/^0C \times 2.8^0C \times 4.184}{0.95 \times 10^{-3}\ kg}$$

$$= 33295.83\ J/kg.$$

NCV = GCV – 0.09 x $\%H_2$ x 587x4.184 J/kg.
= 33295.83 J/kg – 0.09 x 5 x 587 x4.184 J/kg.
= **32190.62 J/kg**

3) When 0.84g of coal was burnt completely in Bomb calorimeter the increase in temp of 2655 grams of water was 1.85^0C if the water equivalent calorimeter is 156g Calculate GCV.

$$GCV = \frac{(W+w) \times S \times \triangle t}{M}$$

$$= \frac{(2655+156) \times 1.85 \times 10\text{-}3 \times 4.187}{0.84 \times 10\text{-}3}$$

= 25921.26 J/Kg

4) Calculate GCV and NCV of a fuel from the following data. Mass of fuel=0.75g, W=350g $\triangle t = 3.02^0C$, Mass of water = 1150, % H_2=2.8.

$$GCV = \frac{(W+w) \times \triangle t \times S}{M}$$

$$= \frac{(1150+350) \times 10^{-3} \times 3.02 \times 4.184}{0.75 \times 10^{-3}}$$

GCV = **25271. 36 KJ/Kg**

NCV = GCV –0.09 x H x 587 x 4.184
= 25271.36 – 0.09 x 2.8 x 587 x 4.184

NCV = **24652.44 KJ/Kg**

5) Calculate calorific value of a fuel sample of a coal form the following data. Mass of the coal is 0.6g. Water equivalent wt of calorimeter is 2200g. Specific value 4.187 Kg/KJ/C rise in temperature = 6.52^0C.

$$GCV = \frac{(W_1+W_2) \times S \times \triangle t}{M}$$

$$= \frac{(2200) \times 10\text{-}3 \times 4.184 \times 6.52}{0.6 \times 10\text{-}3}$$

$$= \mathbf{100025.49\ KJ/Kg}.$$

6) Calculate GCV and NCV of a fuel from the following data.

Mass of fuel =0.83g, W=3500g. , W = 385 g, t1 =29.2^{0}C, t_2 = 26.5$_0$C, % H_2 = 0.7 and S = 4.2 kj/kg/c

$$GCV = \frac{(W+w) \times \triangle t \times S}{M}$$

$$= \frac{(3.5 + 0.385) \times (29.2 - 26.5) \times 4.2}{0.83 \times 10^{-3}}$$

GCV = 53079.39 KJ/Kg

NCV = GCV –0.09 x H x 587 x 4.184

= 53079.39 – 0.09 x 0.7 x 587 x 4.2

NCV = **52924.07 KJ/Kg**

UNIT II

POLYMERS

Polymers

Polymers are the high molecular weight compounds obtained by repeated union of simple molecules. (Monomers).

Ex: Starch, Polyvinyl chloride, Polyethylene, Nylon 6, 6 and etc.

Classification of polymers.

Polymers are classified into two types as follows:
i) Natural Polymers.
ii) Synthetic (artificial) polymers.

i) Natural polymers: These are the polymers obtained naturally by plants and animals.

Ex: Silk, wool, natural rubber, protein, starch, cellulose, etc.

ii) Synthetic Polymers: These are artificially prepared polymers also known as man made polymers.
Ex: PVC, Nylon 6.6, Polythene, Phenol, Formaldehyde, Resin etc.,

Monomers

Monomer is a simple repetitive unit which when joined together in large numbers which give rise to a polymer. These are the building blocks of Polymer

Ex: Vinyl chloride, ethene, propylene etc.

Polymerization

Polymerization is a process of chemical union of large number of monomers to form a polymer. During polymerization the monomers are linked through covalent leakages to give raise to polymer.

Based on the type of polymerization reaction, it is classified into two types as follows.

i) Addition Polymerization
ii) Condensation Polymerization

i) Addition Polymerization: It is process in which the monomers undergo simple addition reactions to give raise to a polymer without eliminating by products. Alkenes and substituted alkenes readily undergo addition polymerization reactions.

Ex: When large number of ethene molecules undergoes addition polymerization reactions, polyethylene polymer is obtained.

[redacted]

ii) Condensation Polymerization:- It is a process in which the monomers undergoes intermolecular condensation reactions to form a polymer with the elimination of simple molecules like water, HCl, ammonia, phenol etc.,

Ex: When adepic acid and hexamithylene diamine undergoes condensation polymerization reaction to form Nylon 6,6 polymer.

n.NH_2–$(CH_2)_6$-NH_2+ n.HOOC–$(CH_2)_4$–COOH Hexa methylene di amine Adipic acid $\longrightarrow$

(NH – $(CH_2)_6$- NH -OC – $(CH_2)_4$ – CO-)n + n H_2O
Nylon 6,6

7.4 What is degree of polemerization (DP). 2 Marks

Degree of polymerization is a number, which indicates the number of repetitive units (monomers) present in the polymer. By knowing the value of DP, the molecular weight of the polymer can be calculated.

[Molecular wt of the polymer] = DP x Molecular wt of each monomer. DP is represented as ‘n’.

Ex: $(CH_2 – CH_2)_n$
Polythene

Here ‘n’ is the DP.

i) Calculate the molecular weight of the polythene polymer given DP is 100.

Molecular weight of the polythene = DP X Molecular weight of Polethene
= 100 X 28

= 2800.

7.5 Explain the free radical mechanism addition polymerization by

N Nagarjuna Sarma

UNIT – IV

Lubricants and Fuel Technology

Syllabus:

Fuel Technology

Introduction:

"Fuel is a combustible substance, containing carbon as main constituent, which on proper burning
gives large amount of heat, which can be used economically for domestic and industrial purpose".
E.g. Wood, charcoal, coal, kerosene, petrol, diesel, producer gas etc.
During the process of combustion of a fuel, the atoms of carbon, hydrogen etc. combine with oxygen
with the simultaneous liberation of heat at a rapid rate. This energy is liberated due to the 'rearrangement of valence electrons' in these atoms, resulting in the formation of new compounds
(like CO_2, H_2O etc). These new compounds have less energy in them and, therefore, the energy
released during the combustion process is the difference in the energy of the reactants and that of the
products formed.

Fuel + O_2 Products + Heat

The primary or main source of fuels are coals and petroleum oils, the amounts of which are dwindling
day-by-day. These are stored fuels available in earth's crust and are, generally, called 'Fossil fuels'.

Classification:

Fuels can be classified into 2 types based
(a) On the basis of their occurrence.
(b) On the basis of physical state of aggregation.
(a) On the basis of occurrence, the fuels are further divided into two types.
(i) Natural or primary fuels:

Lubricants:

Definition, Functions of Lubricants, Mechanism of Lubrication, Classification of Lubricants, Properties of

Lubricants – Viscosity, Flash and Fire points, Cloud and pour points, Aniline Points, Neutralization number
and mechanical strength.

Fuel Technology:

Introduction, classification, characteristics of a good fuel, calorific value, liquid Fuels, petroleum, Refining of
petroleum, knocking, octane number, power alcohol, Synthetic petrol, Gaseous fuels, Important gaseous
fuels.

N Nagarjuna Sarma

Fuels which found in nature are called as natural fuels.
E.g. Wood, coal, peat, petroleum and natural gas.

(ii) Artificial or secondary fuels:

Fuels which are prepared artificially from primary fuels are called artificial or secondary fuels.
E.g. Kerosene, petrol, coal gas, coke etc.

(b) On the basis of physical state of aggregation the fuels are divided into solids, liquids and
gases.

Fuels

Characteristics of a good fuel:

1. **High calorific value**:

A fuel should possess high calorific value, since the amount of heat liberated and temperature attained
thereby depends upon the calorific value of the fuel.

2. Moderate ignition temperature:

Ignition temperature is the lowest temperature to which the fuel must be pre-heated so that it starts
burning smoothly. Low ignition temperature is dangerous for storage and transport of fuel, since it
can cause fire hazards. On the other hand, high ignition temperature causes difficulty in igniting the
fuel, but the fuel is safe during storage, handling and transport. Hence, an ideal fuel should have
moderate ignition temperature.

3. Low moisture content:

The moisture content of the fuel reduces the heating value and involves in a loss of money, because
it is paid for at the same rate as the fuel. Hence, fuel should have low moisture content.

Primary / Natural fuels Secondary / Artificial fuels

ASynthetfuels

Calorific value:

The prime property of a fuel is its capacity to supply heat. Fuels essentially consist of carbon, hydrogen, oxygen and some hydrocarbons and the heat that a particular fuel can give is due to the oxidation of carbon and hydrogen. Normally when a combustible substances burns the total heat depends upon the quantity of fuel burnt, its nature, air supplied for combustion and certain other conditions governing the combustion. Further the heat produced is different for different fuels and is termed as its calorific value.

Definition:

The calorific value of a fuel can be defined as "the total quantity of heat liberated when a unit mass of the fuel is completely burnt in air or oxygen".

There are different units for measuring the quantity of heat. They are;

1. Calorie:

It is the amount of heat required to increase the temperature of 1 gram or water through one degree centigrade.

2. Kilocalorie:

This is the unit of heat in metric system, and is defined as "the quantity of heat required to raise the temperature of one kilogram of water through one degree centigrade".

1 k.cal = 1000 cal

3. British thermal unit (B.Th.U.):

This is the unit of heat in English system. It is defined as "the quantity of heat required to increase the temperature of one pound of water through one degree Fahrenheit.

4. Centigrade heat unit (C.H.U.):

It is the quantity of heat required to raise the temperature of one pound of water through one degree centigrade.

Inter conversion of various units:

1 k.cal = 1000 cal = 3.968 B.Th.U. = 2.2 C.H.U.

Units of calorific value:

The calorific value is generally, expressed in "calorie / gram (cal/g)" or "kilocalorie / kg (kcal/kg)" or "British thermal unit / lb (B.Th.U/lb)" in case of solid or liquid fuels.

In case of gaseous fuels the units used are "kilocalorie / cubic metre (kcal/m^3)" or "B.Th.U/ft^3".

There are two types of calorific values of a fuel.

Higher calorific value or Gross calorific value (HCV or GCV):

Usually all fuels contain some hydrogen and when the calorific value of hydrogen containing fuel is determined experimentally, the hydrogen gets converted to steam. If the products of combustion are condensed to the room temperature, the latent heat of condensation of steam also gets included in the measured heat, which is then called 'Higher or Gross calorific value'.

Definition:

"The total amount of heat liberated, when unit mass or unit volume of the fuel has been burnt completely and the products of combustion are cooled down to room temperature."

The calorific value determined by Bomb calorimeter gives the gross or higher calorific value.

Lower calorific value or Net calorific value (LCV or NCV):

Whenever a fuel is subjected to combustion, the water vapour and moisture etc. escape along with the hot combustion gases and hence there is no chance for their condensation.

So the net or lower calorific value (LCV) is defined as "the net heat produced, when unit mass or unit volume of the fuel is burnt completely and the combustion products are allowed to escape".

LCV = HCV – Latent heat of water vapour formed

Since 1 part by mass of hydrogen produces 9 parts by mass of water as given by the equation below

$$H_2 + \frac{1}{2} O_2 \quad H_2O$$

Hence,

LCV = HCV – mass of hydrogen x 9 x latent heat of steam

Latent heat of steam is 587 k.cal/kg

Therefore,

$$NCV \text{ (or LCV)} = HCV \text{ (or GCV)} - 9 \times \frac{H}{100} \times 587 = HCV - 0.09 \times H \times 587$$

Where, H = % of hydrogen in the fuel.

Theoretical calculation of calorific value:

The calorific value of fuel can be approximately computed by noting the amount of the constituents of the fuel.

The high calorific value of some important main combustible constituents of fuel such as hydrogen is 34,000 kcal/kg, carbon is 8080 kcal/kg and sulphur is 2240 kcal/kg.

The oxygen, if present in the fuel, is assumed to be present in combined form with hydrogen, i.e. in the form of fixed hydrogen (H_2O). So, the amount of hydrogen available for combustion

= Total mass of hydrogen in fuel – Fixed hydrogen

= Total mass of hydrogen in fuel – ($\frac{1}{8}$) Mass of oxygen in fuel

($\because$ 8 parts of oxygen combine with one part of hydrogen to for H_2O)

Dulong's formula for calorific value from the chemical composition of fuel is;

$$HCV = \frac{1}{100}\left[8080\ C + 34{,}500\left(H - \frac{O}{8}\right) + 2240\ S\right] \text{ kcal/kg}$$

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.

$$LCV = [HCV - 0.09 \times H \times 587] \text{ kcal/kg}$$

This is based on the fact that 1 part of H by mass gives 9 parts of H_2O, and latent heat of steam is 587 kcal/kg.

2 g
1 g
18 g
9 g

Experimental determination of calorific value:

The calorific value of a fuel is determined by the combustion of the fuel in a special type of the apparatus called calorimeter. The different types of calorimeters are

1. The Bomb calorimeter
2. The Boy's calorimeter and
3. The Junker's calorimeter

The Bomb calorimeter is used in finding the calorific value of solid and liquid fuels. The Boy's
calorimeter and Junker's calorimeter are used for the determining the calorific values of gaseous
fuels and those liquid fuels which are easily vaporized.

Liquid Fuels:

Liquid fuels are the important commercial and domestic fuels used in our daily life. Most of these
fuels are obtained from the naturally occurring petroleum or crude oil called as primary fuel.

Advantages:

(a) They posses higher calorific value per unit mass than solid fuels.
(b) They burn without dust, ash, clinkers, etc.
(c) Their firing is easier and also fire can be extinguished easily by stopping liquid fuel supply.
(d) They are easy to transport through pipes.
(e) They can be stored indefinitely without any loss.
(f) They are clean in use and economic to handle.
(g) Loss of heat in chimney is very low due to greater cleanliness.
(h) They require less excess air for complete combustion.
(i) They require less furnace space for combustion.

Disadvantages:

(a) The cost of liquid fuel is relatively much higher as compared to solid fuel.
(b) Costly special storage tanks are required for storing liquid fuels.
(c) There is a greater risk of five hazards, particularly, in case of highly inflammable and volatile
liquid fuels.
(d) They give bad odour.
(e) For efficient burning of liquid fuels, specially constructed burners and spraying apparatus are
required.

Petroleum (crude oil)*:*

The crude oil or petroleum is also known as rock oil or mineral oil. It is dark colour liquid found well
deep in the earth. It is mainly composed of hydrocarbons which may be solids, liquids or gases. Some
optically active compounds having S and N are also present. On the average the composition of
petroleum is; C = 79.5 – 87.1%
H = 11.5 – 14.8%
S = 0.1 – 3.5%