Energy sources and Applications

The energy sources may be classified as primary and secondary. Primary energy sources are those which may be directly obtained from the natural resources without involving any conversion processes. These include fossil fuels such as coal, crude oil, natural gas, sun, heat in the rock (geothermal energy), flowing water (hydroenergy) wind and tides (tidal energy). Secondary energy sources do not occur in nature but derived from primary energy sources. These include derived fuels such as petrol, diesel, coke etc and electricity generated by burning of fossil fuels. The primary energy sources may be further classified as renewable and non-renewable energy sources.

The conventional energy sources for power generation such as fossil fuels and hydro power are far from adequate in meeting the increasing energy demand. To ensure the future energy demands are met with quality and pollution – free the use of non-conventional or renewable power was recognized. They include hydro, solar, wind, geothermal, ocean thermal and biomass energy.

Hydro energy/Energy from water:

Electricity generated from the energy of water is called Hydro power.

The amount of power produced depends upon the rate of flowing water, and height from which the water falls.

Hydro power schemes are classified into four types based on power output.

They are

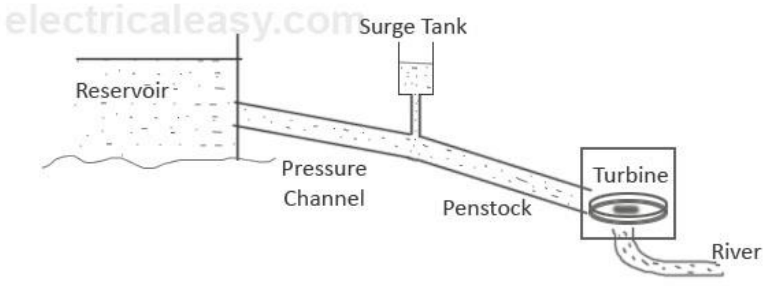
1. LARGE SCALE: power output is 2MW and above.
2. MINI SCALE: Power output is 100KW TO 200KW.
3. MICRO SCALE: Power output is 5KW to 100KW.

4. PICO SCALE: Power output is less than 5KW.

Power is generated by the rotation of turbines and they are different for different flow rates of water.

1. FRANCIS TURBINES: Used for high flow waters.
2. PELTON TURBINES: Used for low flow waters.
3. PROPELLER TURBINES: Used for very high flow waters.

It is the energy generated from flowing & falling water. Water is stored in damsbuilts across flowing rivers. This raises the water level there by increasing its potential energy. Water falls on hydraulic turbines which convert pressure & kinetic energy of water into rotational kinetic energy. The rotating shaft of the turbine drives the generator which transforms mechanical energy into electrical energy.



Advantages:

1) Hydropower is non-polluting and renewable source of energy.

2) Use of dams provides a constant supply of water for irrigation, agriculture electricity also.

3) Does not cause pollution.

Disadvantages:

1) Building of dams is very expensive.

2) Loss of forest & agricultural land.

3) Need to rehabilitate people living in submerged zones.

Solar energy:

Solar energy is the radiant energy due to illumination of the sun. It can be converted into various forms of energy like thermal and electrical energies. The main advantage of using solar energy as an energy source is that it is readily available, free of cost and eco-friendly.

Applications of solar energy:

This energy source is harnessed to provide basic necessities like domestic water supply and irrigation in villages done by using solar pumps. It is also used as solar lamps, solar street lights, solar heaters and solar cookers.

Conversion of solar energy:

Solar energy may be converted into more useful forms of energies by two path ways – thermal conversion and photo conversion.

1) In thermal conversion, the heat from direct rays of sun is absorbed in the form of infra red radiation by the surface air or water and put to many uses.

Eg: Flat plate collector's i.e. solar heater

2) In photo conversion, sunlight is used to generate electricity by the photo electric effect.

Eg: photo voltaic or solar cells.

Physical and Chemical properties of silicon:

1.	Color	Pure silicon is a hard, dark gray solid
2.	Phase	Solid
3.	Luster	A metallic shine or glow
4.	Allotropic	Silicon has two allotropic forms, a brown amorphous form, and a dark crystalline form
5.	Solubility	Soluble in hydrofluoric acid and alkalies
6.	Melting point	Melts at 1417°C
7.	Boiling point	Boils at 2600°C
8.	Conductivity	It is a semi-conductor

Chemical properties of silicon

1.	Chemical Formula	Si.
2.	Compounds	Silicon forms compounds with metals (silicides) and with non-metals.
3.	Oxidation	Combined with oxygen as silica (silicon dioxide, SiO2) or with metals as silicate minerals. It is stable in air even at elevated temperatures owing to the formation of a protective oxide film.
4.	Flammability	Dark-brown crystals that burn in air when ignited.
5.	Reactivity with acids	Dissolves only in a mixture of nitric acid and hydrofluoric acid.

Preparation of semiconductors:

In the preparation of semiconducting material following steps are involved

i) Preparation of ultrapure silicon

ii) Preparation of single crystal of silicon

iii) Doping

i) Preparation of ultrapure silicon:

Elemental silicon is abundantly available in the form of silicon dioxide (band or quartz). Elemental silicon can be obtained from sand (SiO_2) by heating with carbon (metallurgical coke) in an electric arc furnace.

$$SiO_2 (s) + 2C(s) \rightarrow Si + 2CO$$

Carbon monoxide combines with atmospheric oxygen to form carbondioxide which is discharged into the atmosphere and silicon is collected at the bottom of the furnace. To obtain semiconductor grade silicon, it is purified further. It is combined with hydrochloric acid (HCl) to form trichlorosilance ($SiHCl_3$) and small amount of tetrachlorosilane ($SiCl_4$)

$$Si + 3HCl \rightarrow SiHCl_3 + H_2$$

$$Si + 4HCl \rightarrow SiCl_4 + 2H_2$$

$SiHCl_3$ which is a liquid at room temperature is purified by fractional distillation to remove impurities like iron, copper and also $SiCl_4$. $SiHCl_3$ is reduced by H_2 in a reactor containing high purity silicon rods.

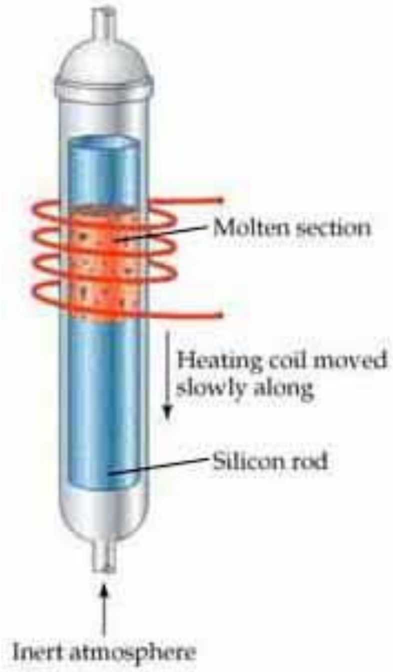
$$SiHCl_3 + H_2 \rightarrow Si + 3HCl$$

Solid silicon deposits on heated 'silicon rods' which grow radially. This process produces rods of semiconductor grade polycrystalline silicon.

Zone refining: Silicon and germanium can be purified by this method

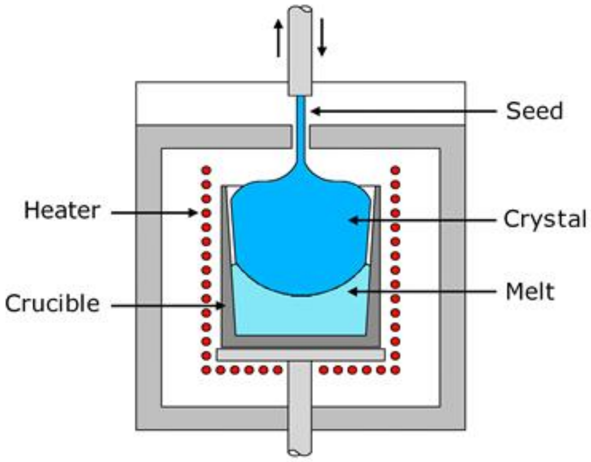
Principle: When an impure metal is solidified after melting, crystals of pure metal separate out and the impurities are left behind in the melt.

In this method the metal to be purified is cast into a thin rod. One zone of the rod is melted by a circular heater in an inert atmosphere of argon at about 1000^0C. The metal melts at the heated zone. The heater gradually moves from top to bottom and the impurities are swept into the adjacent molten part and are finally discarded. The molten pure metal in the upper region gradually solidifies yielding metal of very high purity.



Single crystal formation (Czochralski process)

Crystal growth method is used to produce single crystal of silicon.



This method converts polycrystalline material into an crystalline material.

This apparatus consists of a crucible, heating element, power supply, seed shaft, rotating mechanisms and vaccum systems.

The semiconductor grade polycrystalline silicon is melted in a quartz lined graphite crucible. The melt is maintained at a temperature of 1690K. A single silicon crystal of desired orientation is attached on the rod to act as the seed crystal and made to touch the surface of the melt. The rod is rotated in the molten material and the crystal is pulled out of the melt. The molten semiconductor solidifies on the seed crystal with an identical structure and orientation.

Wafer manufacture:

The diameter of the obtained crystals is nearly 20-30 cms. These crystals are removed and ground to be perfectly round and then they are cut into thin discs called wafers.

Doping techniques:

Calculated quantity of dopant (B,P,As or Sb) is added to the melt before the crystal pulling stage. It is carried out by epitaxy, diffusion and implantation techniques.

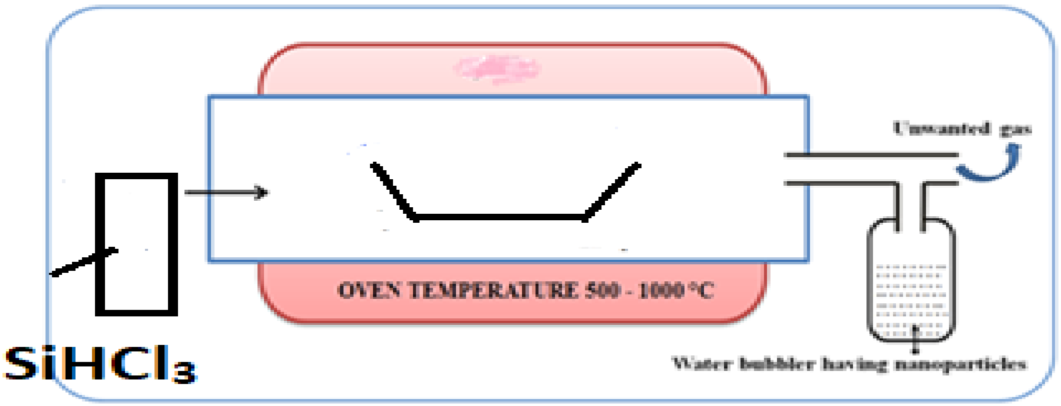
a) Diffusion: In this process the vapours of the dopant atoms are deposited at the silicon surface at a high temperature of 1000^0C.

b) Ion implantation: The semiconductor material is bombarded with an electrically controlled beam having high energy of 10,000ev containing impurity ions like Boron or phosphorous.

c) Epitaxy: Chemical vapour deposition (CVD) process is employed for epitaxial growth. Silicon wafers are placed in a boat shaped crucible made up of graphite. The boat is placed in a cylindrical quartz tube reactor which is heated using heating coils. The gases containing compounds of Germanium or Silicon mixed with calculated quantities of the dopant are introduced into the reactor. The epitaxial layer is grown from the vapour phase onto silicon which is in solid state.

Manufacturing of Photovoltaic cell using Chemical vapour Deposition technique:

Thin films of semiconducting material have proven to be easy to process into photovoltaic cell (PV) devices. A coating of silicon in solar cells is deposited through chemical vapour deposition (CVD) processes. Silicon wafers are placed in a boat shaped crucible made up of graphite. The boat is placed in a cylindrical quartz tube reactor which is heated using heating coils. The gases containing compounds of Germanium or Silicon mixed with calculated quantities of the dopant are introduced into the reactor. By some mechanical methods deposition of thin wet silicon film takes place. This wet film then dries usually at standard pressure and low temperatures (less than 120^{0}C) to create a solid film of desired thickness. Dry films are formed when thermally annealed at high temperature in oven to remove residual solvent.



Chemical vapour deposition [CVD]

Photovoltaic or solar cells (or) PV devices:

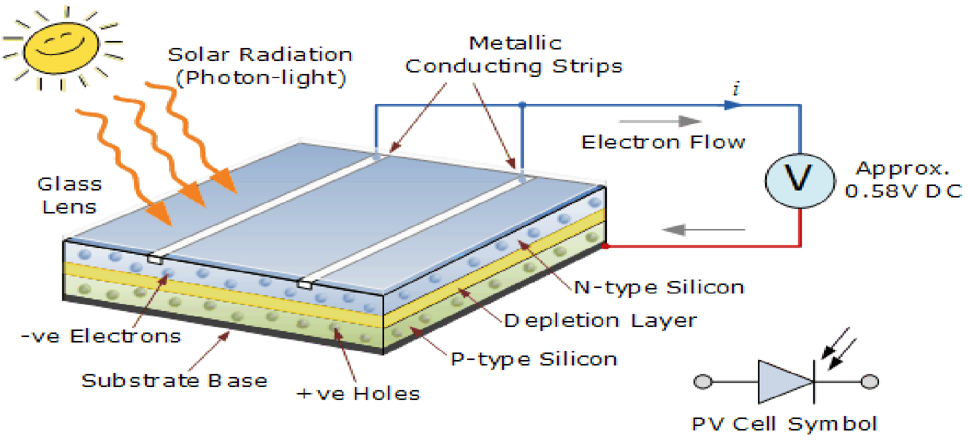
It changes sunlight directly into electricity. Individual PV cells are grouped into panels and arrays of panels that can be used in wide range of applications ranging from single small cells that charges calculators to large power plants covering many acres.

Working:

These are made up of semiconductors such as crystalline silicon or various thin film materials.

Sunlight is composed of photons or particles of solar energy. These photons contains various amount of energy corresponding to different wavelengths of solar spectrum.

When photons strike a photovoltaic cell, they may be reflected, pass right or absorbed. When enough sunlight is absorbed by the materials, electrons are dislodged from the material. Special treatment of the material surface during manufacturing makes the front surface of cell more receptive to free electrons. So, the electrons migrate to the surface. When electrons leave their position holes are formed. When many electrons each carrying a negative charge travel towards the front surface of the cell, resulting imbalance of the charge between the cells front and back surfaces creates a voltage potential like the negative & positive terminal of the battery. When the two surfaces are connected through an external load, electricity flows.



To increase power output, cells are electrically connected into a packaged weather tight module. Modules can be further connected to form an array.

LIQUID FUELS

Liquid fuels are used extensively in industrial and domestic fuels. Use of liquid fuels in internal combustion engine makes them very important fuels. The single largest source of liquid fuels is petroleum or crude oil. The term petroleum means rock oil (derived from latin – petram means rock; oleum means oil) is a dark, greenish – brown viscous oil found deep inside the earth's crust. It is a mixture of hydrocarbons such as straight chain paraffins, cycloparaffins or naphthalene, olefins and aromatics along with small amount of organic compounds containing oxygen, nitrogen and sulphur.

Classification of petroleum:

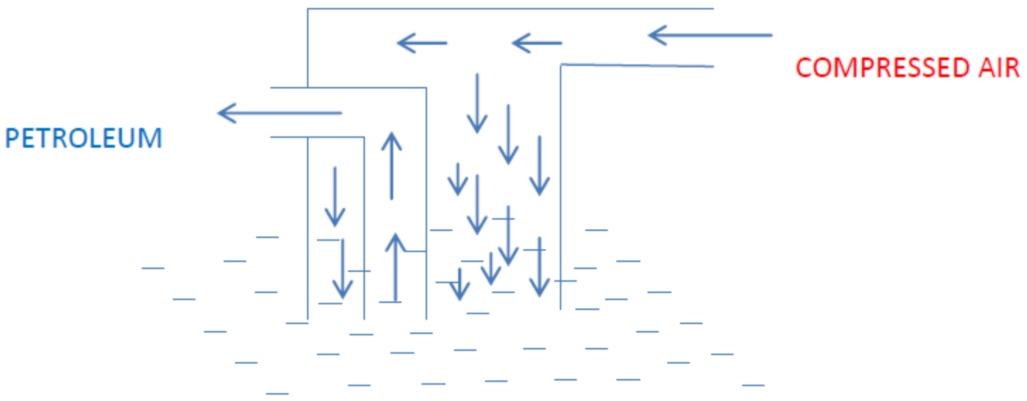
Petroleum is classified into three categories according to its composition

1. **Paraffinic base petroleum:** It is mainly composed of straight chain saturated hydrocarbons from CH_4 to $C_{35}H_{72}$ alongwith small amounts of naphthenes and aromatic hydrocarbons.
2. **Naphthenic or asphaltic base petroleum:** It contains mainly cycloparaffins or naphthenes as main constituent along with smaller amount of paraffin's and aromatic hydrocarbons.
3. **Mixed base petroleum:** It contains both paraffin's and asphaltic hydrocarbons.

Mining of petroleum:

Petroleum is found deep below the earth's crust. The oil is found to be floating over salt water or brine often associated with natural gas, which exerts pressure on the oil surface.

Mining of oil is carried out by drilling holes in the earth's crust and sinking pipes up to the oil bearing porous rocks. Oil rushes through these holes because of the pressure of natural gas. As the pressure of natural gas decreases, oil is pumped out with help of airlift pumps.



Refining of petroleum:

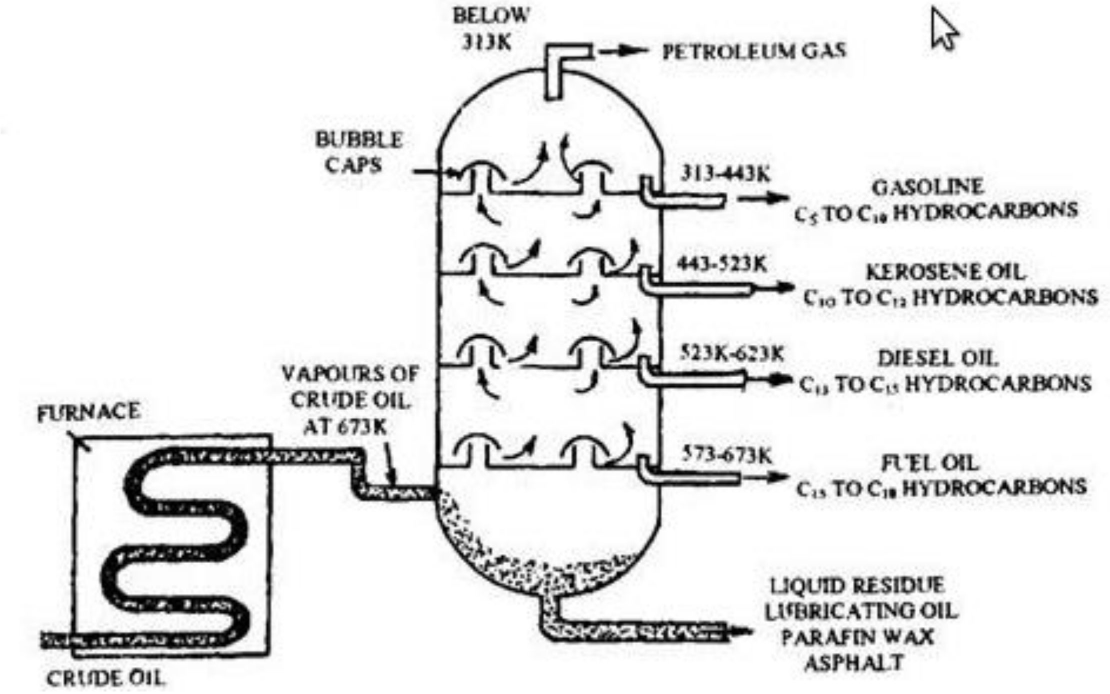
Crude oil coming out from the oil well is a mixture of solid, liquid and gaseous hydrocarbons containing sand and water in suspension. After removal of dirt, water, sulphur and other impurities, this oil is subjected to fractional distillation. This process of dividing petroleum into fractions with different boiling ranges and free from undesirable impurities, is termed Refining. The process of refining involves the following steps

1) Separation of water: [Cottrell's process] : Crude oil is an emulsion of oil and water. Water is separated by allowing crude oil to flow through the charged electrodes. Colloidal water is separated from oil in the form of big droplets, they can be separated from out from the oil.

2) Removal of Sulphur compounds: Crude oil is treated with copper oxide, which gives a black precipitate of copper sulphide, which can be removed by filtration.

3) Fractional distillation: Crude oil obtained from 1 and 2 steps is then heated at about 400^0C in an iron retort. The entire volatile constituent is evaporated leaving behind residue [asphalt or petroleum coke].

The hot vapours are passed through different fractional columns. The apparatus is a long cylindrical vessel with several trays, each having chimney covered with a loose cap. As the vapours go upward, they gradually become cool and their fractional condensation takes places at different levels in the column.



Different fractions obtained at different levels are given below:

Name of the fraction	**Boiling range**	**Approximate composition in terms of Hydrocarbon containing 'C' atoms**	**Uses**
Uncondensed gas	Below 30^0C	C_1 to C_4 [such as ethane, propane, isobutene]	As domestic or industrial fuel under the name of LPG
Petroleum Ether	$30 – 70^0C$	C_5 toC_7	As a solvent

Gasoline or petrol or motor spirit	40 – 120^0C	C_5 to C_9	As motor fuel, solvent & dry cleaning
Naptha (or) solvent spirit	120 – 180^0C	C_9 to C_{10}	As solvent for points and in dry cleaning
Keresone oil	180 – 250^0C	C_{10} to C_{16}	As an illuminant, jet engine fuel and preparing laboratory gas
Diesel oil	250 – 320^0C	C_{10} to C_{18}	Diesel engine fuel
Heavy oil this on refractionation produces a) Lubricating oil b) Petroleum Jelly c) Grease d) Paraffax wax	320 – 400^0C	C_{17} to C_{30}	It is used as lubricants, cosmetics candles & shoes.
Residue	Above 400^0C	C_{30} & above	Fuel for ships, in metallurgical furnaces and in conversion to gasoline by cracking. Water proofing, as a fuel in mouldings.

Cracking: The crude oil on fractionation yield approximately 20-30% gasoline, 30-35% middle oil and 20-25% heavy oil. Among all these fractions, gasoline is in maximum demand because of its use as fuel in automobile industry. This is achieved by cracking. Cracking is a process of conversion of bigger hydrocarbon molecules into smaller hydrocarbons of lower molecular weights

$$C_9H_2O \rightarrow C_5H_{12} + C_4H_8$$

(nonane) n-pentane butane

Cracking is carried out in two ways.

- Thermal cracking

- Catalytic cracking

Thermal cracking: Breaking of bigger hydrocarbon molecules into low boiling fractions by use of temperature and pressure is called thermal cracking. This process is carried out either in liquid phase or in vapour phase.

a) Liquid phase thermal cracking:

By this method, any type of oil (residue, fuel oil or gasoline) can be cracked by applying high pressure of the range 100 kg/cm^2 at a suitable temperature of 475 – 530^{0}C.

b) Vapour phase thermal cracking:

The oil is first vaporized and then cracked at about 600 – 650^{0}C and under a low pressure of 10-20kg/cm^2.

Catalytic cracking:

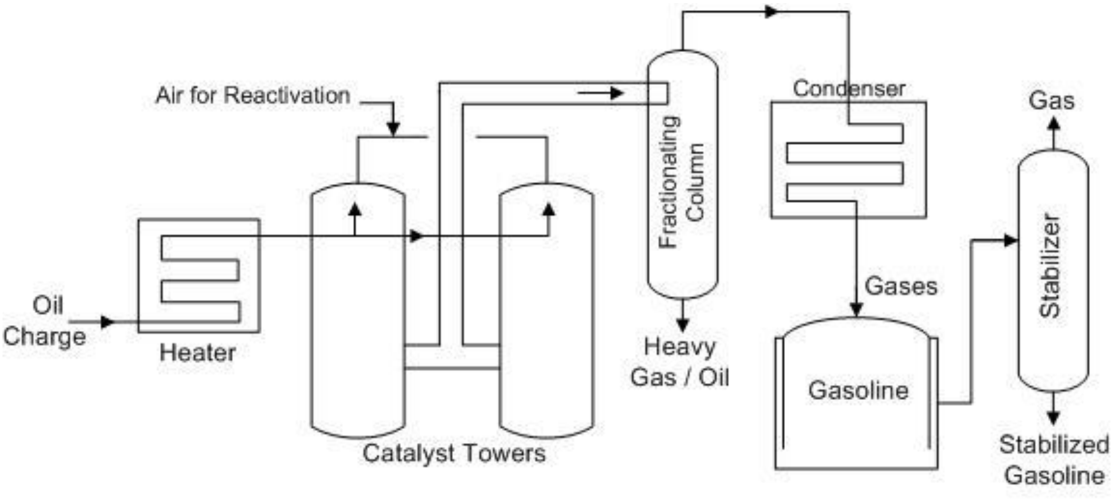
In this type a catalyst is used which are Al_2O_3 and $Al_2(SiO_3)_3$. It is of two types

1) Fixed – bed cracking
2) Fluid – bed cracking or moving bed cracking

Fixed bed cracking:

1) In this method, heavy oil is heated in a pre-heater to cracking temperature of 425-450^{0}C.
2) The hot vapours are forced to catalytic chamber (containing artificial clay) maintained at 425-450^{0}C at 1.5 kg/cm^2 pressure.
3) The vapour produced is then passed through a fractional column, where heavy oil fractions are condensed.
4) The vapours are then led through a cooler, where some of the gases are condensed along with gasoline.
5) Gasoline vapours are purified with stabilization.

6) After 8-10 hours of reactivation of the catalyst is carried out by burning of the deposited carbon.



Fixed Bed Catalytic Cracking

Moving Bed Cracking: [Fluidized Cracking]

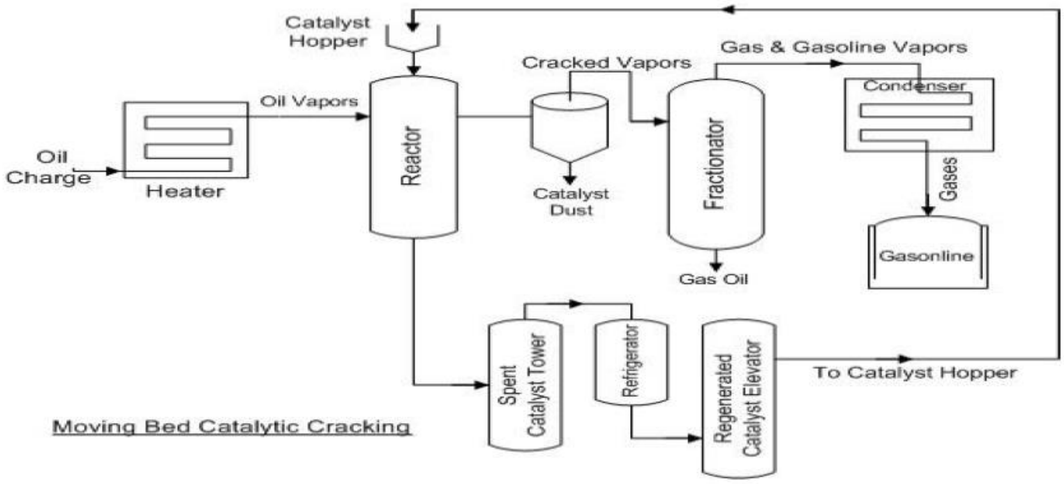
1) The vapours of higher hydrocarbons are mixed with fluidize catalyst (catalyst in the form of fine powder charged into catalytic chamber so that catalyst particles moves free in a chamber like a fluid) and forced into a reactor at 500^0C.

2) After cracking vapour are passed into the fractional column.

3) Gasoline vapours are purified by the stabilization process

4) After sometime catalytic particles settle down to the bottom of the catalytic chamber due to deposition of carbon on the surface of the catalyst.

5) The particles are collected and carbon deposited on the surface of the catalyst is burnt off in regenerator. Now the catalyst particles are charged into catalytic chamber.

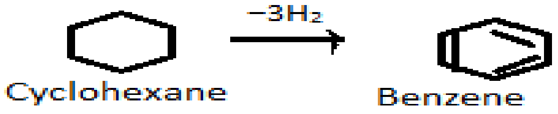


Moving Bed Catalytic Cracking

Reforming in chemistry processing technique by which the molecular structure of a hydrocarbon is rearranged to alter its properties. The process is frequently applied to low-quality gasoline to improve their combustion characteristics.

The main reactions involved in reforming process are:

1. Dehydrogenation (removal of hydrogen)



2. Hydrocracking (breaking of the molecule in presence of hydrogen)

$$\underset{\text{n-decane}}{CH_3 - (CH_2)_8 - CH_3} + H_2 \longrightarrow 2\ \underset{\text{n-pentane}}{CH_3 - (CH_2)_3 - CH_3}$$

- Reforming can be carried out either thermally or in the presence of a catalyst.

- i. Thermal reforming alters the properties of low-grade naphthas by converting the molecules into those of higher-octane number by exposing the materials to high temperatures and pressures.

ii. Catalytic reforming uses a catalyst, usually platinum, to produce a similar result. Mixed with hydrogen, naphtha is heated and passed over pellets of catalyst in a series of reactors, under high pressure, producing high-octane gasoline

Gaseous fuels

They posses high calorific value, transported easily, combustion can be controlled. Gaseous fuels are highly inflammable and chances of hazards are more during their use. Some of the important gaseous fuels are

1. LPG (Liquefied Petroleum Gas):

It is obtained as a by- product during cracking of heavy oil or from Natural gas.

1. It is supplied under pressure in containers after treating with “mercaptins” to detect the leakage of gases
2. It is highly volatile, colourless liquid under pressure
3. It is highly inflammable and consists of hydrocarbons that can be readily liquefied under pressure and exist as gas in atmospheric pressure.
4. Composition of LPG is n-butane, iso-butane, butylene and propane.
5. Calorific value is 27,800 Kcal/m^3

Uses:

1. Largest use as domestic fuel.
2. Used in industries for welding, steel cutting etc

Disadvantages:

Handing has to be done extremely carefully to avoid hazards.

3. CNG [Compassed Natural Gas]:

1. Natural gas contains mainly CH_4

2. When natural gas is compressed at high pressure [1000 atm] or cooled at -160^0C it is converted to CNG.

3. It is stored in cylinder made up of steel.

4. releases less pollutants during its combustion

Advantages:

1. Due to higher temperature of ignition, CNG is better fuel than petrol or diesel.
2. Operating cost is less, it can be stored easily.
3. Releases less pollutants like CO and unburnt hydrocarbons.

Uses:

1. As fuels in automobiles like car, truck, buses etc

2. It is also used as fuels in diesel generators to generate electricity that drives motors of trains.

Disadvantages:

1. Faint smell [odour] so leakage cannot be detected easily
2. CNG tank requires large space