

**LIST OF REFINERIES IN INDIA :**

SL NO.	REFINERY NAME	YEAR OF COMISSION	INSTALLATION CAPACITY (MMTPA)	PRESENT CAPACITY (MMTPA)
1	JAMNAGAR REFINERY	1999	27	33
2	NAYARA ENERGY REFINERY	1996	20	20
3	KOCHI REFINERY	1963	15.5	15.5
4	MANGALORE REFINERY	1988	15	15
5	PARADIP REFINERY	2002	15	15
6	PANIPAT REFINERY	1998	15	15
7	GUJARAT REFINEY	1965	13.7	13.7
8	MUMBAI REFINERY	1955	7.5	12
9	GURU GOBIND SINGH REFINERY	2012	11.3	11.3
10	MANALI REFINERY	1965	10.5	10.5
11	VISHAKHAPATNAM REFINERY	1957	8.3	8.3
12	MATHURA REFINERY	1972	8	8
13	HALDIA REFINERY	1975	7.5	7.5
14	BINA REFINERY	2011	7.8	7.8
15	BARAUNI REFINERY	1964	6	6
16	NUMALIGARH REFINERY	1993	3	3
17	BONGAIGAON REFINERY	1969	2.735	2.735

18	GUWAHATI REFINERY	1962	1	1
19	NAGAPATTNAM REFINERY	1993	0.5	1
20	DIGBOI REFINERY	1901	0.65	0.65
21	TATIPAKA REFINERY	2001	0.07	0.07
22	BARMER REFINERY	2013	9	9

### **Jamnagar Refinery:**

Jamnagar refinery is a private sector crude oil refinery owned by reliance. The refinery was commissioned in 14 July 1999 with an installed capacity of 27MMTPA. The present capacity of this refinery is 33MMTPA. It is currently the largest refinery in the world.

### **Oil Field of Assam:-**

In Assam up to the cost of Myanmar, the presence of oil is very common. In the year 1825 itself seepage of oil was discovered in Makum. In the year 1867 under the guidance of Sir Madly Colt, the first oil well was dug at Makum. But after a very short production, it was abandoned as it was not economically viable.

At that time, the drillers faced the problem of transportation as most part of Assam were jungle areas. In 1889 oil first discovered in a place called Borbeel in upper Assam and it was heard that first oil well was drilled. Later the place became known as Digboi. Digboi refinery was first commission in the year 1901. Extensive exploration by different companies have led to the discovery of oil in Lakuwa, Moran, Rudrasagar, Makum, Nahorkotia and many other places of upper Assam. Many companies like ONGC, OIL, IOCL, GAIL are involved in the oil industry of Assam. Assam has 4 refineries- Noonmati refinery, Namuligarh Refinery, Bongaigaon Refinery, Digboi Refinery.

### **Different Petroleum Products & Uses:-**

**GAS & LPG:-** During the distillation of crude oil in refineries, the considerable amount of gas is produced. From this gas we generally obtain LPG. LPG is a mixture of propane and butane and has some amount of unsaturated like propylene and butylene. LPG is in liquid state ambient pressure under moderate pressure. They are marketed in steel cylinder. LPG is used for cooking purpose. It is heavier than air & it doesn't have any smell of its own but little amount of mercaptan is added to refineries for detection purposes during leakage.

**MOTOR SPIRIT (Gasoline):-** Motor spirit is the first liquid fraction obtained by crude oil distillation having a boiling range from 30-215°C. It is a straight run product from the ADU having poor octane number. Initially its octane number increased by adding TEL. So that we get gasoline having high octane number but TEL has been banned due to lead pollution. Nowadays, the octane number is increased by catalytic reforming process.

**NAPHTHA:-** Naphtha fraction is produced in the same boiling range as water spirit. It is a very important feedstock for the petrochemical industry. It contains less amount of aromatics and is also an important feedstock for fertilizer industry.

**KEROSENE:** Kerosene has a boiling range of 150-300°C. It is used as an illuminate and also as a fuel for cooking purpose. The most important taste for kerosene is smoke point test. It must have minimum aromatics and should burn without smoke. It must not have any carbon residue which could clogged the wick of lamp. It must also have a high flash point and low viscosity. Its smoked point is 18 mm.

**AVIATION TURBINE FUEL (ATF):** ATF is high grade of refined kerosene. It is used as a fuel in aviation turbine engine, jet engine. The most important test for ATF is the freezing point test. ATF must not freeze at high altitude even at -50°C. It must not any smoke. The smoke point is 21mm compared to kerosene which has a smoke point of 18mm. It must be free from water particles and corrosive sulphur. It must have a high calorific value and must remain stable even at high temperature.

**DIESEL FUEL:** The fuel used in diesel engine must be classified as high speed diesel (HSD) and LSD oil. High speed diesel is generally used in bus, truck while low speed diesel is used in generator pump. Diesel fuel has a boiling point of 200-300°C because of its use in CI engine, diesel fuel must have certain ignition quality which will enable the fuel to get ignited without much delay when injected into the combustion chamber of the diesel engine. This quality is called cetane no. diesel fuel must have high pour point and must not contain any sulphur. The cetane number may be increased by adding ethyl nitrate, amyl nitrate and isopropyl nitrate.

**LUBRICATING OIL:** Lubricating oil covers a wide range of product like low viscosity lube oil used for dedicate instrument like watches or clock and highly viscous lube oil used in gears and axles of cars and other locomotives. Lubricating oil must not deteriorates in contact with air. Lubricating oils are generally blended with additives to improve viscosity index, oxidation stability.

**WAX:** Wax is generally obtained from the residuum which we get from ADU. There are two types of wax ,paraffinic or macro crystalline or micro crystalline wax. In the market ,the wax is available as Type- 1, Type- 2, Type- 3. It refers in there oil content. The general uses of wax may be produced only from wax bearing crude and not from all crudes.

**BITUMEN PITCH AND ASPHALTS:** Bitumen is dark viscous motoring almost solid in ambient temperature. It is obtained from heaviest part of ADU as well as VDU by the method of air blowing. Because of its adhesive nature and water proof quality, it is used for build roof, bridge, roads.

Bitumen is classified based on test like penetration index, softening point, ductility test. Crude containing high quantity of wax is not suitable for manufacture bitumen.

**FUEL OIL:** Fuel oil is the residue or heavy distilled obtained from distillation unit as well as cracking of secondary operation. It is generally used as fuel for generating heat within the refinery itself. This fuel oils are highly viscous and the viscosity sometimes lowered by adding thinners for transportation purpose.

**PETROLEUM COKE:** Petroleum coke is generally obtained from secondary process or cracking process in refineries like delayed cooking unit. The end use of petroleum coke are manufacturing of carbon paper, electrodes, printer ink.

**WHITE OIL:** White oil are speciality product obtained by highly refining lubricating oil. First of all the aromatic content is remove by from the lubricating oil by solvent extraction process and then oleum is pass through it. It is then washed with alcoholic potash solution and then gives fullers earth treatment. White oils may be technical and medicinal white oil. Medical white oil is used in the preparation of hair oil, Vaseline, spray and intestinal laxative.

### **PRE-TRETEMENT OF CRUDE**

After the crude is drilled from under the earth surface it is collected in collecting station and send to different refineries through pipelines.

In the refineries, it mainly undergoes distillation process to separate the mixture of hydrocarbon from the basis of their boiling range. But the crude has to undergo certain pre-treatment process before it can be enter the distillation column. It must fulfil certain criteria like-

- The water content should be 1%.
- Salt should be removed completely.
- Pour point must be kept in minimum level and should not go up or down.

### **DEHYDRATION AND DESALTING OF CRUDE**

All crudes generally contain moisture and salt. The water present in the crude has a lot of dissolved salt which is harmful for the distillation column as it causes corrosion.

The different method of dehydration and desalting are-

1. Mechanical method

2. Chemical method
3. Electrical method

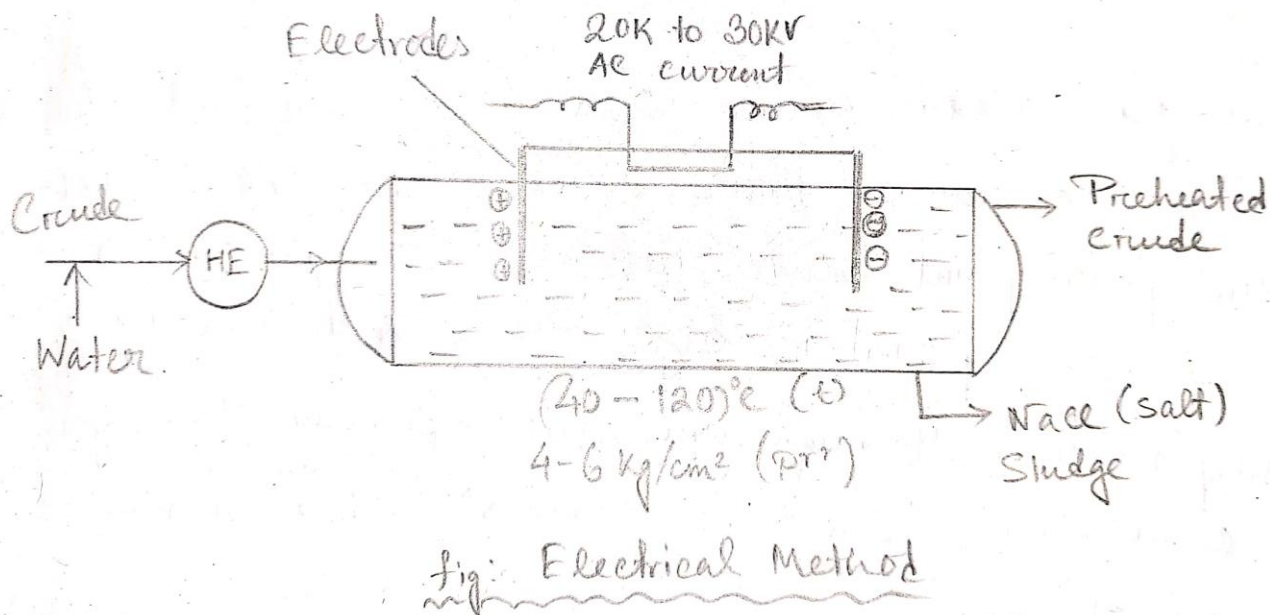
**1. Mechanical method:**

It is a settling gravity principle. The crude is allowed to settle in huge settling tank maintained at a temperature of 70-80<sup>0</sup>C and 15Kg/cm<sup>2</sup> of pressure. At this temperature the stability of the emulsified water and salt breaks down and the impurities settle at the bottom as sludge. But this method is time consuming and less effective.

**2. Chemical method:**

Chemical method is a combination of mechanical method with addition of chemicals or demulsifying agent. This chemical increase the coalescence time of the water droplet and helps them to settle faster. The temperature is maintained at 70-80<sup>0</sup>C and pressure 15Kg/cm<sup>2</sup>.

The chemicals added are NaOH , salts of fatty acid, oleum etc. The generally time taken for settling is 48-50hours.



**Fig : Electrical Method**

This method was developed much later. The crude is first mixed with water and heated in a heat exchanger to a temperature of 40-120 °C. It then enters the treatment tank maintained at a pressure of 4-6 kg/cm<sup>2</sup>. The treatment tank is filled with electrodes connected to 20000 – 30000 Volt AC. When the crude passes through the electrodes, the water particles on one end and the negatively charged ones on another side. These oppositely charged particles get attracted to each other very fast and water along with entrapped salt settle down very fast as sludge as sludge while the desalted crude is taken out from the top and goes to the distillation column. This is highly efficient method with power consumption only 0.01 KW-H barrel of crude.

Generally, Assam crude has large amount Wax and so has a pour point of 13-34°C. Generally, the pour point crude differs from place to place. If pour point is high, here is difficulty in transportation through pipeline specially during wintertime. There are two methods of depression –

- a. Physical
- b. Chemical

- a. **Physical** : In this method, crude is heated up to 95°C and then pulled down to two stages. First, cooling is done at 55°C. It is allowed to remain at that temperature for some time. Then it is again cooled to 18°C. In doing so, the structure of wax is broken down where pour point gets depressed about 5°C below 13°C. Physical process is done in Moran, upper Assam.
  
- b. **Chemical** : In this method, chemicals called pour point depressants are added to the crude. This chemical breaks down the structure of wax and lower the pour point by 15°C. For Assam crude, indigenous chemicals like flow cell developed by Axel industries and SWAT 104-105-106 developed by NEIST, Jorhat is used. This lowers the pour point by 15°C and also the viscosity by 7cP. It must be kept in mind that pour point can be depressed for only 40 hours.



### Atmospheric Distillation Unit (ADU):

The atmospheric distillation column has 30-40 trays. Out of these, four are in stripping zone and rest in the rectification zone. Conventionally, trays are fitted with bubble caps which has been replaced now by valve trays which are simpler in design, easy to install and less costly. The plates are made of cast iron and bolted on alternative sides of the tower. Trays have down comers for the liquid to flow to the next lower trays. Weirs are provided at the end of each lower plate to hold the liquid

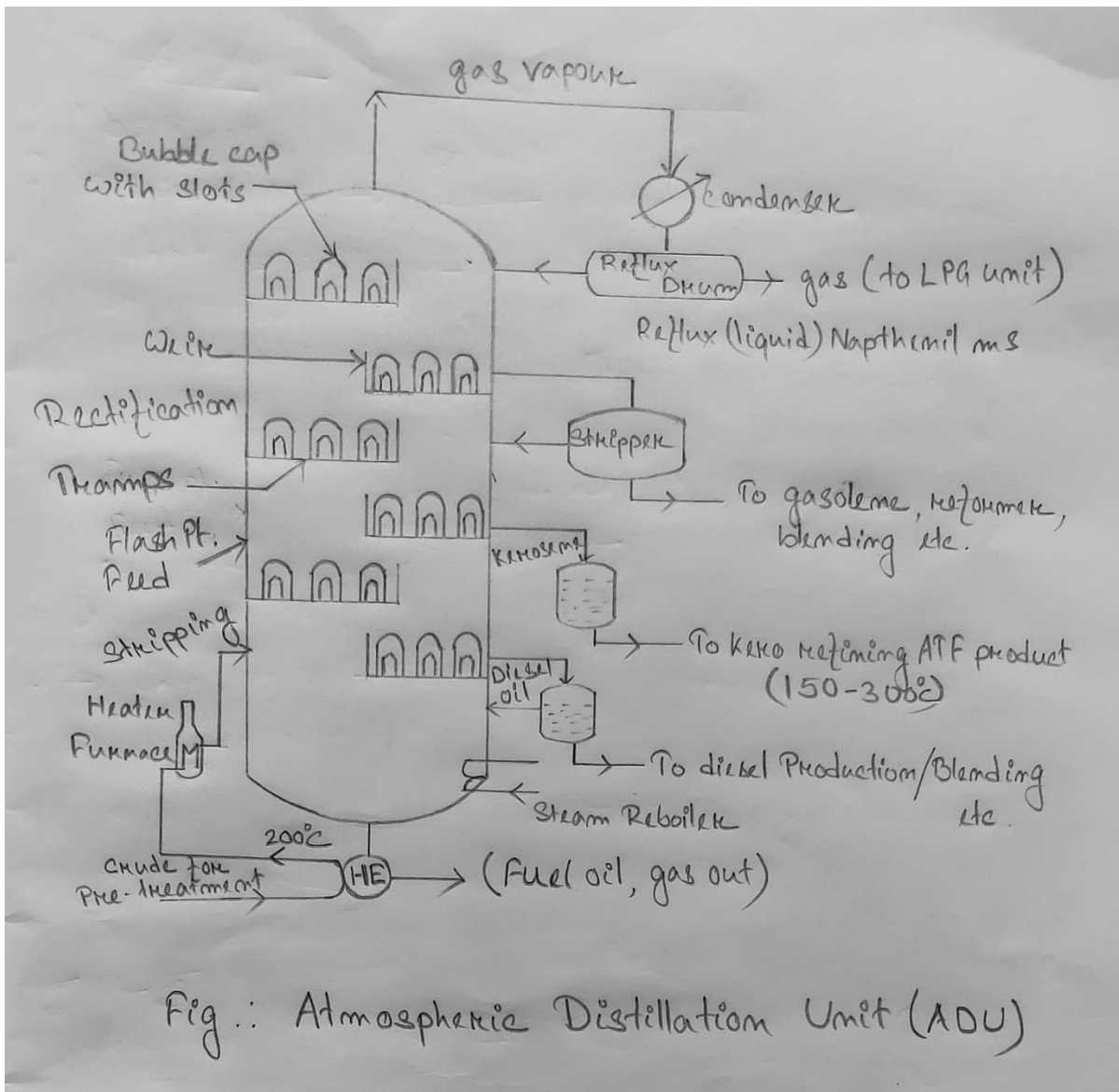


Fig.: Atmospheric Distillation Unit (ADU)

up to a certain level. Above this level, the liquid flows down. Spacing between trays is 55 cm enough for a person to travel for maintenance purpose.

### **Distillation process:**

After pre- treatment, the crude is pre- heated to 200°C by v passing through heat exchangers. Then it is further heated in a furnace at 350°C. A part of crude gas vaporizes. It is flashed into the flashing in the ADU. The hot vapours rises up passing through the slots of the bubble caps in each tray. As the vapour rises up, it is condensed to liquid and collects in the uppermost trays. As the liquid level goes above the weir, it falls to down comer to the next trays. In this way, the vapour rises up from tray to tray. Thus they are in a counter current intimate mixing between liquid and vapour. A part of the overhead vapour condense and pumped back into top of the column which is called reflux and this helps maintaining the lower top line. Some amount of liquid flows down into the stripping zone which is further heat with the help of superheated steam introduced at the bottom of the tower.

The entire distillation column is thermally insulated and coated with water proof compound and covered with metal sheet. This helps in maintaining thermo stability and the state of thermal equation is achieved. After a particular amount of time, it is observed that liquid with different boiling ranges collected in the different trays. The lighter fractions are collected towards the top of the tower and heavier fractions towards the bottom. These are the straight run products taken out as side draws. The different side draws will differ from refinery to refinery. The common side draws are ---

1. **Gas:** - which is stabilized to produce LPG.

2. ***Naphtha:*** - which is converted to motor gasoline, motor spirit etc.
3. ***Kerosene:*** - which is refined and sometimes converted to ATF.
4. ***Diesel Oil:*** - which is blended to give us heavy diesel oil, light diesel oil.
5. ***Residuum and Heavy Product:*** - from this, wax is removed and it is called bright stole and this is the feed for VDU from which we get lube oil.
6. ***Other component of distillation column:*** -
  - a. Connection section
  - b. Radiation section

The material of construction (MOC) pipe steel heater are low carbon steel or alloy steel. The size of furnace depends upon quantity of fuel or crude flowing through. The size should ensure that there is always laminar flow.

### **Heat Exchanger: -**

Generally shell and tube heat exchanger are used. Again, the size of the heat exchanger will depend on amount of fluid it will handle.

### **Different types of trays**

1. ***Valve Trays:*** Valve trays are also called perforated trays having holes of 4 mm diameter. The holes have valves that open upward due to pressure of the gas.

### ***Advantages:***

- (i) They have low pressure drop as compared to bubble cap trays.

- (ii) Less tendency of entrainment

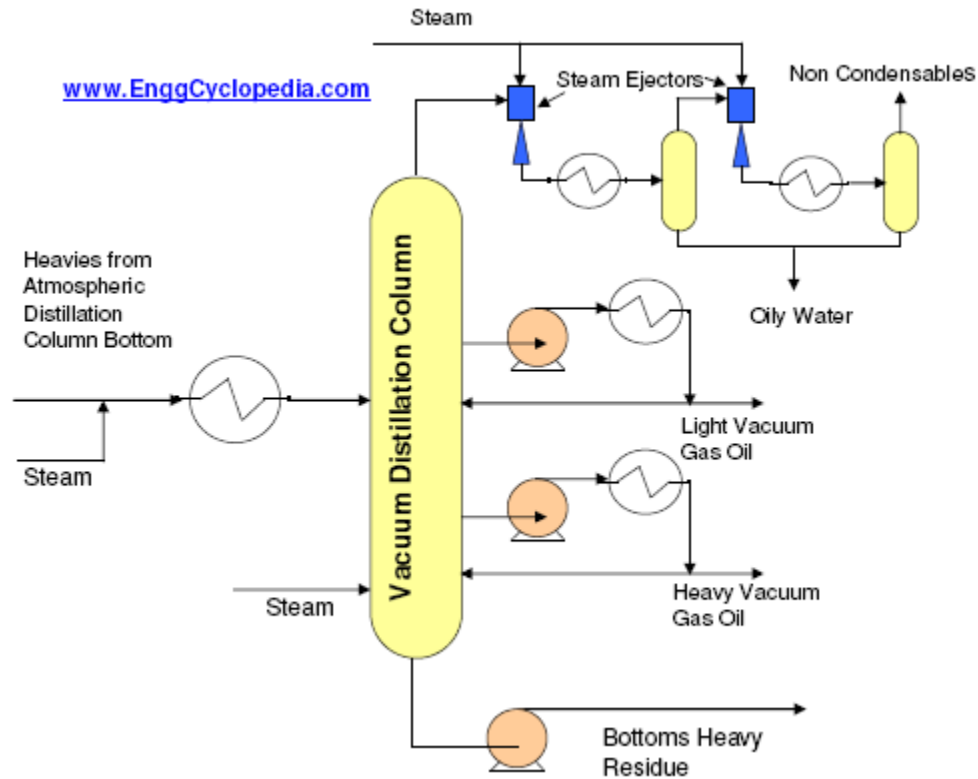
***Disadvantages:***

- (i) They are very small than bubble cap trays.
- (ii) They are very fragile and may get damaged fast.
- (iii) Corrosion occurs in the orifice of these trays.

Other different trays are used in modern refineries are flexi trays, turbo grid trays. Float valve tray, dual trays, sieve trays, etc.

***Vacuum Distillation Unit***

A VDU may not be present in all refineries. It generally used residuum from ADU as feed. In the ADU, if the temperature is increased beyond 370°C, cracking usually occurs. Therefore, residuum is redistilled in VDU at high temperature to reduce pressure. A VDU is generally employed to produce lubricating oil along with bitumen and asphalts and also feed stock for secondary operation. Vacuum is maintained in VDU by steam jet ejectors which sucks out the air from column and a very low pressure is maintained inside. A lube oil producing VDU consists of distillation column with less number of trays than VDU. It is usually a packed tower with packing materials fitted between the trays. It is generally a wet type of column that uses steam for re-boiling. There are very few side draws. From the top of the column we get gas oil, special Mobil from the side, spindle oil, light machine oil, medium machine oil and from the bottom we get bitumen and asphalts.



**Fig: Vacuum distillation unit (VDU)**

### **Secondary Process of refining:**

In our discussion we have already seen how crude oil is distilled in the A.D.U. & V.D.U. The products obtained by distillation alone make create and imbalanced in the market as majority of them are heavy products and do not have good market value.

Primary products obtained from distillation column like atmospheric residuum, vacuum gas oil, vacuum residuum are produce in large volumes but they do not have any market. Those product that have a good market value like gasoline, kerosene, diesel oil etc. are produced in comparatively lesser amount.

It is therefore necessary for secondary process to be done in refineries with the help of which heavy distillate can be converted to lighter products. This is usually done by converting vigorous size molecular weight substances called cracking. There are two types of cracking-

- 1) **Thermal Cracking**
- 2) **Catalytic Cracking**

The decomposition of high, molecular weight hydro oil breaks into smaller fraction by agency of heat alone is called thermal cracking. Again decomposition of high molecular net hydrocarbons into smaller fragments with the agency of heat in presence of a catalyst is called catalytic cracking.

Cracking is a endothermic reaction i.e. it needs external heat for the reaction to takes place. Paraffin are the easiest to crack while aromatics are the hardest.

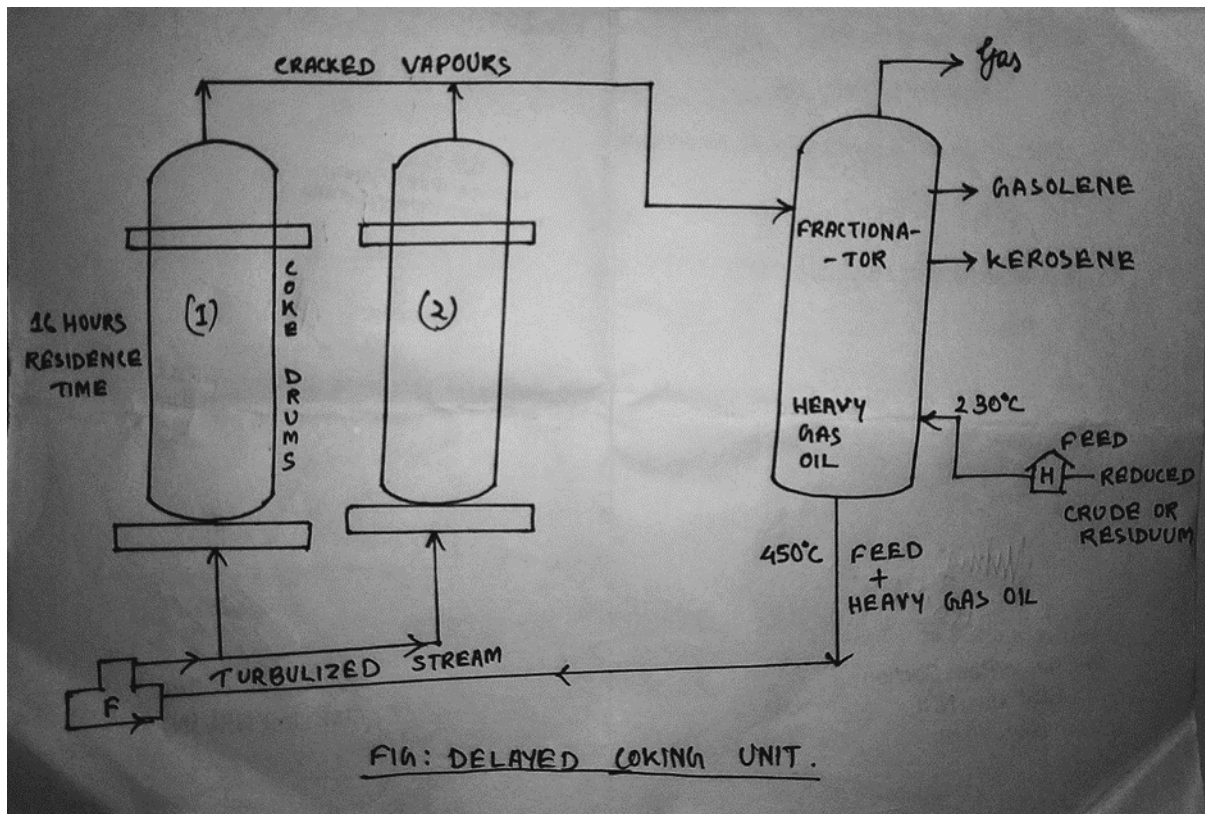
Coke formation is a polymerization mechanism that takes place side by side the cracking mechanism which is not possible to prevent. Thus coke formation is a side reaction during cracking processes.

### **DELAYED COCKING UNIT—**

Coke has very few uses but is always obtained as a bi-product from the delayed coking unit. The main aim of this unit is to convert the residue from ADU&VDU to lighter product like gas, Gasoline & Kerosene.

The feed i.e. reduced crude is heated to 230°C and enters the bottom of a fractionator where it comes into contact with heavy gas oil from the bottom of the fractionator. The combined stream of this crude reduce crude & heavy gas oil are at temperature

of 450°C. It enters the furnace where it is heated up to 500°C from this furnace it enters coke chamber 1 and 2 which provide the necessary residence time of 16 hours for cracking reaction to take place. The cracked vapours from the coke chamber goes to the fractionator from where we get lighter fraction like gas, gasoline, Kerosene etc. The bottom part is called heavy gas air which collects at the bottom of the fractionator and mixed the incoming feed i.e. reduced crude and cycle is repeated.



The furnace is the most important equipment in the DCU with heats up the feed to the required temperature. Care must be taken to prevent the pre-matured coke formation within the furnace itself. This depends upon the velocity of the incoming feed. If the velocity of the feed is quite high cracking does not occur fast but if feed entering the furnace must be increased. This is done by injecting high velocity steam into the furnace called turbulized steam. This high velocity steam helps in the

delayed coke formation inside the furnace and allows to coke to form only in the coke drums or chambers. This is why process is called delayed coking process. In the coke chamber 10-16 hours residence time is given for cracking as well as coking reaction to take place. After the coke which is formed in the chamber, it is removed by hydraulic de-coking process.

### **Hydraulic decoking**

In early days, cable decoking method was used to remove the coke from the coke drums .But now a days , more sophisticated methods are used. The method employs a hydraulically operated mechanical drill to remove the coke from the coke drums. This method uses high impact water jets operating at 2000-4000 psi is used in cutting the coke. Both boring and cutting tools are used. Each tool is provided with nozzle through which the water jet comes out and the pilot hole is first drilled. The boring and cutting tools are lowered into the coke ground attached to the drilling stem. The drill stem also rotates along with the boring and cutting tools by a motor connected to a swivel .The high pressure water supplied by a jet pump and delivered by a hose pipe connected to the swivel .This high pressure water comes out through the holes of the cutting tools. The drill stem is raised and lowered into the hole. A wire rope spelled over a shine black and the entire arrangement is supported by a drill rig.

### **Uses of coke:**

Coke is basically used for manufacturing of carbon papers and printer inks.

### ***\* The different test done as well as products:***

(1) **Viscosity:** Viscosity is the measure of resistance to flow Water has low viscosity and heavy has high viscosity. Viscosity is measured in the laboratory by allowing



known quality of oil taken in a standard tube to flow into a collecting vessel. The time taken to flow and completely empty the standard tube is note down. If less time is required viscosity is less and if more time is required viscosity is more. This is done with the help of redwood viscometer 1 and 2.

**Significance:** The test is very important for lubricating oil. At high operating temperature high viscosity oil is required and in low operating temperature low viscosity oil is required.

(2) **Viscosity Index:** It is define as the resistance to the change of viscosity with temperature. The resistance of oil to become thick when cook down and to remove then is called viscosity index. The test is done by finding viscosity at various temperature and noting it down graphically.

**Significance:** A high viscosity of oil indicates that more paraffin is present. Vi indicates the oil is naphthenic In nature.

**(3)Pour point:**

In cooling a given sample of oil, the limiting temperature at which the sample in the will ceases to flow when kept horizontally +5°F is called the pour point.

**Significance-** Pour point is very important for transportation through pipe lines especially in cold areas. In this areas pour point depressions must added to the oil. It is also important for oil used in refrigeration systems.

**Smoke point:**

It is the height in mm of a flame that will be produced by burning an oil sample in a standard lamp without causing smoke.

**Significance-** Important test for kerosene and ATF. Higher the smoke point less aromatic present.

**Gross calorific value:**

It is the number of heat unit which will be liberation when unit weight of fuel is burned on oxygen in a G. bomb calorimeter under test conditions.

**Significance:** It indicates the heat producing capacity if a fuel and it helps in comparing the heat developed from different fuels.

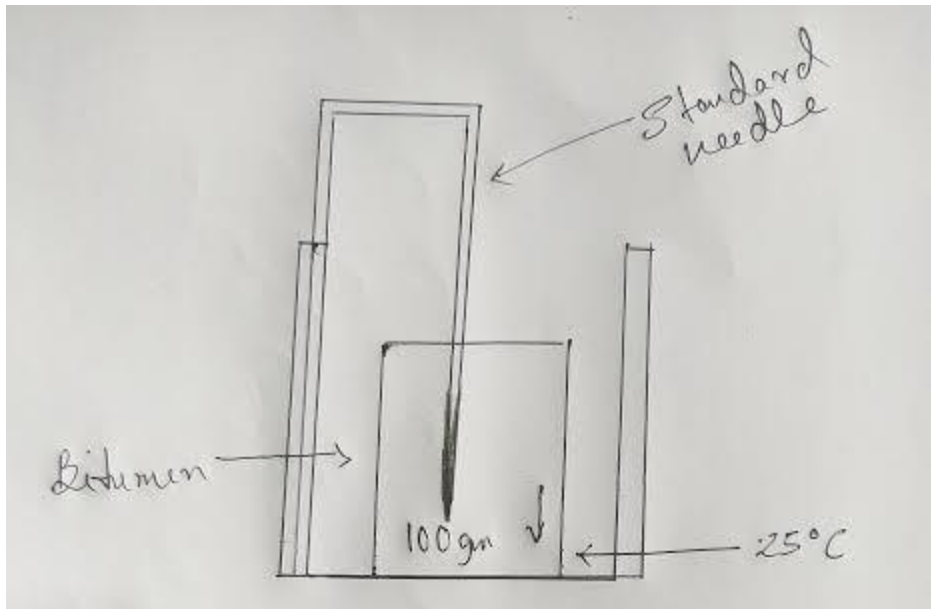
**Penetration**

Penetration is expressed as 1/10 th of distance in mm which has standard needle will penetrate vertically through a piece of bitumen under specified test.

**Conditions are –**

1. Weight of bitumen is= 100mg.
2. Time= 5 sec
3. Temperature = 25° c

If in 5sec the needle travels 25mm then penetration will be  $1/10 \times 25\text{mm}=2.5 \text{ mm}$ . Penetration indicates the hardness or softness of bitumen and its suitability for specific applications.



- ❖ **FLASH POINT** :- It is defined as the minimum temperature in which a sample of oil gives off sufficient vapour which mixes with air to form a combustible mixture that flashes with a momentary flash when it comes in contact with the naked flame.
- ❖ **FIRE POINT** :-It comes after flash point . It is the minimum temperature in which a sample of oil gives off sufficient vapour which mixes with air to form a combustible mixture that burns continuously for 5 sec when it comes on contact with a naked flame.
- ❖ **Significance** :- It indicates the degree of safety of oil under storage condition the lower the flash point the higher is the potential to fire hazard.
- ❖ **Carbon Residue** :-A known weight of the oil sample is taken and fired at high temperature until all the volatile matters go off as vapour. The residue left behind is weighed it is called carbon residue.
- ❖ **Significance** :-It shows the carbon forming tendency of oil less carbon forming tendency means more purity of oil.
- ❖ **API gravity :**

$$^{\circ}\text{API} = 141.5/\rho - 131.5$$

P= sp. Gravity of air at 60° F.

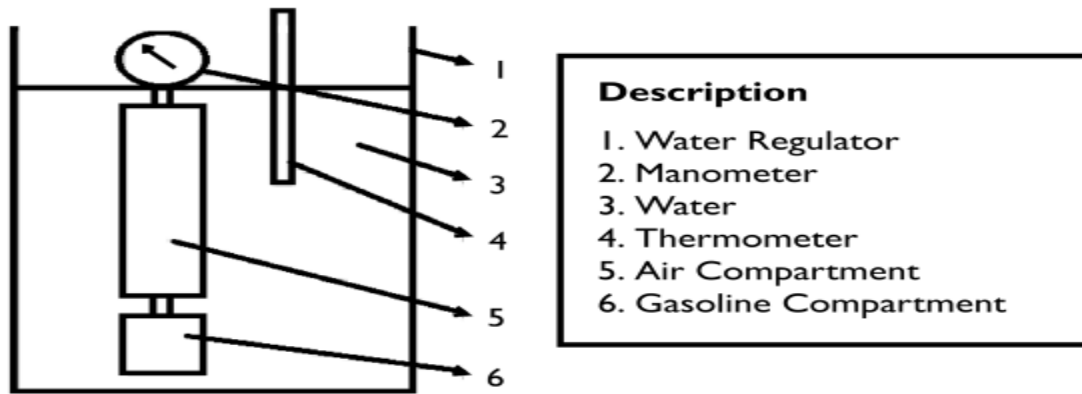
**Octane number** :- It is the percentage by volume of iso-octane in a mixture of iso-octane and n-haptane that gives the same antiknocking properties as the fuel undergoing the tests. It is the single test for gasoline for gasoline.

**Significance**:- Higher the octane number the better is the anti-knocking properly.

**Cetane number** :- It is the percentage volume normal cetane in a mixture of n-cetane and  $\alpha$ -methyl naphthalene.

It is the single important list for diesel.

**R.V.P**:- Reid Vapour Pressure:



The vapour pressure of volatile fraction are measured by RVP apparatus. The apparatus consists of two chamber. The chamber consists of two chambers the lower chamber is an the form of the cylinder which holds the sample. Above this is the air chamber the volume of which 4 times the volume of the bottom chamber. Both the chambers are connection by a narrow . At the top of air chamber is an Bourdon Gauge for pressure indication. The lower chamber is filled with the sample and is immersed in a water bath to get that 38°C temperature. As the oil sample starts to give up vapour completely fills up the upper chamber. The maximum pressure indicated by the pressure gauge is the RVP of the sample.

**Diesel index**:-  $[0.1S \text{ Aniline point} + 0.32] \times \text{°API}$

Aniline Point:- It is the maximum equilibrium temperature in which equal volume of aniline and oil sample re completely miscible.

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**Lubricating Oil** : Lubricating oil is a substance used as a film between two moving surfaces of a machine to reduce friction and increase efficiency. It is also used as a coolant to dispose heat generated by frictional moving.

**Constituents of Lubricating Oil** : The constituents of lubricating oils are paraffins (highly viscous) naphthenes, aromatics, little amount of wax, asphalts and resins. It also contains impurities like Oxygen, Nitrogen and Sulphur in very small amount. Paraffinic crude is best for producing lubricating oil as it has a high viscosity index. Wax, aromatics, asphalts and resins are undesirable in lubricating oil and hence to be removed.

**Additives Added To Straight Run Lubricating Oil** : The different additives added are

—

1. Antioxidants like phenol, naphta.
2. Viscosity index improvers like butane and methacrylic ester.
3. Pour point depressents.
4. Deforming agents like silicon.

**Finishing Treatment of Lubricating Oil** : The different types of finishing treatment are given to lubricating oil to improve its quality, color and to remove impurities. These treatments are —

1. Sulphuric Acid Treatment.
2. Clay Treatment.
3. Hydro Treatment or Hydro Finishing.

A. **Sulphuric Acid Treatment** : In this treatment 20-50 kg of Sulphuric acid is added per barrel of lubricating oil at a temperature of 60°C and allowed to remain undisturbed in a huge tank. The temperature is maintained by steam oil present in the bottom of the tank. The acid acts upon the impurities present in the lubricating oil and collects at the bottom as sludge. But the disposal of sludge is a huge problem for refinery. So this method has become almost obsolete.

B. **Clay Treatment** : Clay Treatment is followed by most of the refineries. Clay has the capacity to absorb asphalts, resins and pigments present in lube oil. There are 2 methods of Clay Treatment.

- I. Contract Treatment – In this process clay is thoroughly mixed with the lubricating oil and time is given for the reaction to complete. Clay collects all the impurities and settles down as sludge at the bottom of the reaction tank which is then deposited off.
- II. Percolation Treatment – In this process the lube oil is passed through a bed of clay. All the undesirable materials are retained by the clay and lube oil is purified. When the bed of clay is exhausted, it is regenerated by passing hot steam through the pores.

C. **Hydro treatment or Hydro Process** : In this process, hydrogen oil is allowed to pass through the lubricating oil at 300-400°C temperature at 800psi pressure in the presence of Cobalt/Magnesium catalyst. This process improves the color and thermal stability and reduces the amount of impurities like Sulphur, Nitrogen etc from lubricating oil by this process. It is possible to improve viscosity index by 5-10 points by this process.

**Different types of lubricating oil** : Lubricating oil may be classified as -

1. Low viscosity lubricating oil.
2. Intermediate viscosity lubricating oil.
3. Heavy viscosity lubricating oil.

Low viscosity lubricating oil is used for lubricating watches, clock. Intermediate viscosity lube oil is used for lubricating machineries in industries and heavy viscosity lube oil is used for lubricating gears and axel of automobile.

According to viscosity index lubricating oil is classified as -

1. Low viscosity index lubricating oil.
2. Medium viscosity index lubricating oil.
3. High viscosity index lubricating oil.

Low viscosity index lubricating oil is used for lubricating light machineries.

Medium viscosity index lubricating oil is used for lubricating different parts of petrol and diesel vehicles.

High viscosity index lubricating oil is used for lubricating parts of plane and air craft.

Another type of lube oil is called commercial crude lubricating oil, these are while turbine, textile, refrigerator oil.

### **Properties of lubricating oil :**

1. **Viscosity** : It is the property of lubricating oil which resists the flow.
2. **Viscosity Index** : It is a significant property of lubricating oil is used for different purpose.
3. **Pour Point** : The pour point of lubricating oil is desired to be very low and it is used on refrigeration and hydraulic system in specific cases.
4. **Oxidation Stability** : This is an important property for lube oil. Oxidation stability is about the deterioration characteristics of lube oil under storage condition. Major amount of lube oil has paraffin's which is easily oxidised and deteriorate fast. Thus oxidation inhibitors added to improve oxidation stability.
5. **Carbon Residue** : When a sample of lube oil is evaporated at 250°C for 20 minutes, the residue left behind is called carbon residue. Good quality lube oil has very low carbon residue.



## WAX-

Many heavy fractions of crude oil contain some amount of waxy material which is called paraffin. Wax even though some amount of naphthene. The wax is removed from wax bearing residuum obtained from ADU.

Broadly speaking there are two types of wax.

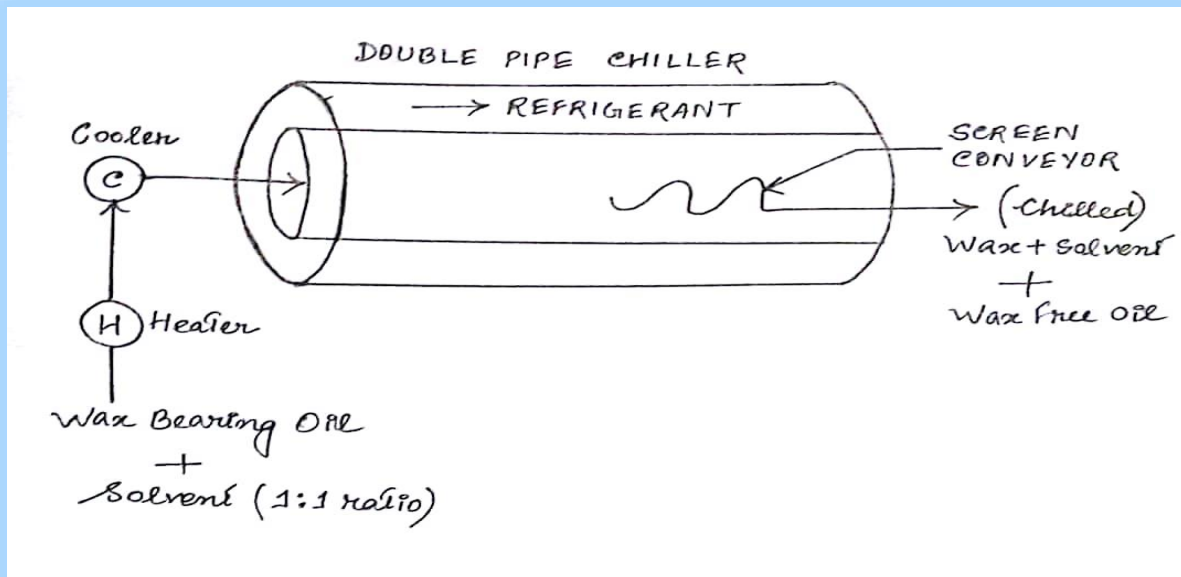
- **PARAFFIN/MICROCRYSTALLINE WAX:** It contains C atom from C20-C30. It is also plate type of wax or needle type of wax. This type of wax is straight chain & its molecular weight ranges 300-500 grams.
- **AMORPHOUS/MACROCRYSTALLINE WAX:** It contains C atom above C30. It is generally a branch chain & its molecular weight ranges to 580-700 grams.

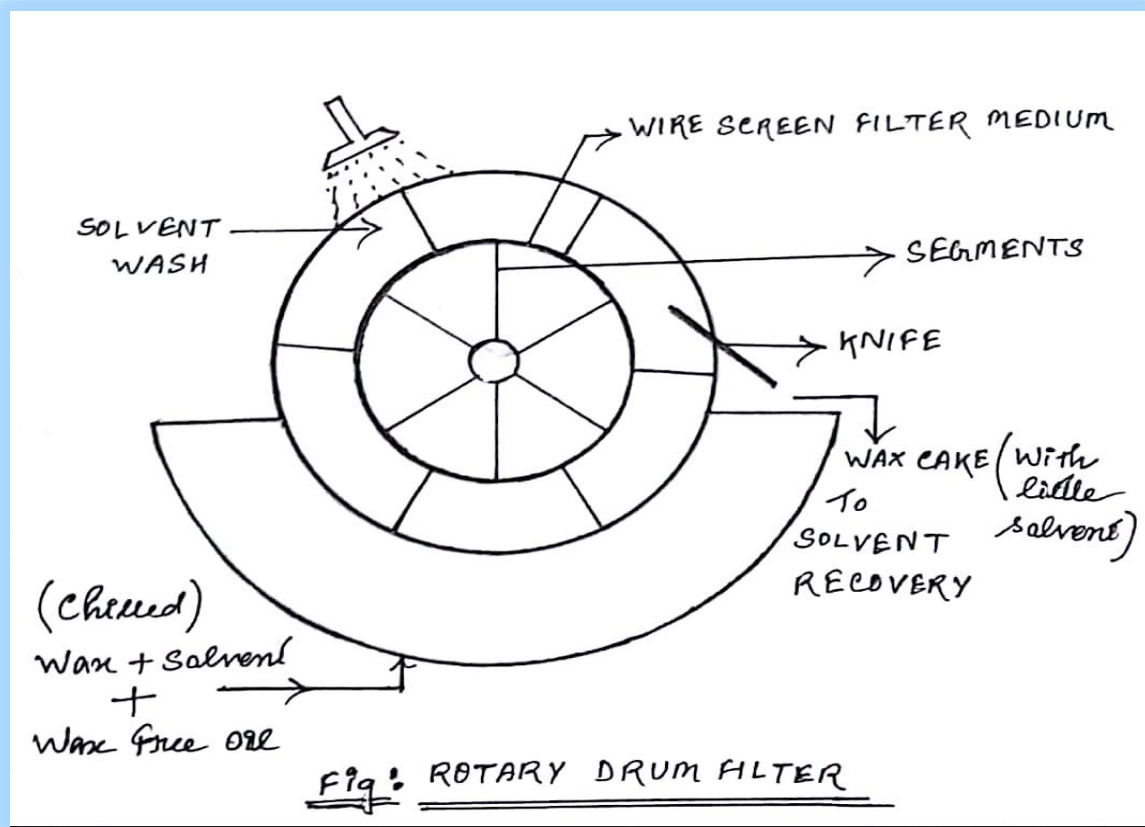
Wax that contains 70% oil is called **PETROLACTUM**.

## Important Property of Wax-

1. **Specific Gravity:** - Specific gravity is the ratio of the density of a substance to the density of a given reference material. The specific gravity of wax is 0.910.
2. **Viscosity:** - Viscosity governs the effectiveness of application of wax. The viscosity of wax is below 37°C
3. **Penetration index:** - A measure of wax hardness, higher penetration index value indicates a softer wax.
4. **Colour:** - Colour is given while the wax is in melting state.
5. **Melting point:** - Point at which wax melts which is 37°C

## MANUFACTURING OF WAX BY SOLVENT PROCESS-





In this case we take the help of hydrocarbon solvent to separate out the wax from the wax bearing oil. The wax bearing oil and solvent are taken in the ratio 1:1 and introduced into a heater where it is warmed to initiate proper mixing. The mixture is then cooled in a cooler and subjected to chilling in a double pipe chiller. It is introduced into the inner pipe of chiller while through the outer pipe any refrigerant say  $\text{NH}_3$  is allowed to pass. This chiller is filled with a screw conveyor to scrap out the chilled wax along which wax free oil and solvent. This is taken to a rotary drum filter.

The rotary drum filter is a horizontal cylindrical drum operating under vacuum. The outer periphery of which is covered with a filtering medium with fine wire screen. The entire drum is divided into segments as shown in the figure. Because of this vacuum, suction is maintained towards the central of the drum as the drum

rotates. As the bottom is the entrances through which the feed is introduced. As the feed rotates along with the drum, the oil and solvent easily passes through the filtering medium and goes towards centre of drum which the wax is deposited on the surface of the filtering medium in the form of wax cake. As the filter rotates the wax, the cake is scrap off with the help of Doctor's knife present near the discharge line.

In order to facilitate the removed of wax cake, solvent wash is given along the edge of the drum. This wax cake contains little amount of solvent and this is taken to a solvent recovery unit. The wax free oil and solvent collected from the centre of the drum also goes to the recovery unit.

## **SOLVENT RECOVERY**–

The wax cake and wax free oil and solvent are subject to following treatment to recover back the solvent:-

- The wax cake is 1<sup>st</sup> taken to a evaporator from which the solvent is evaporated as solvent vapours are then distilled in a distillation column and solvent is recovered and maybe reused again. The wax cake is subjected to steam stripping to remove any traces of solvent and obtain pure wax.
- The wax free oil and solvent is heated in a heat exchanger and subjected to distillation in a distillation column. From this tower, most of the solvent

goes out as solvent vapour which is distilled and maybe used again from the bottom of tower. The wax free oil is obtained which is called bright stock. It is sent to VDU to produce lube oil.

## **DIFFERENT RANGE OF WAX–**

There are 3 different ranges of wax.

1. **TYPE 1 WAX**–It is pure form of wax as it well refined. It is used for making candles, wax paper and in processing. It has 0.25% oil content.
2. **TYPE 2 WAX** – It is less refined and has 0.5% oil content. It is used to produce match stick.
3. **TYPE 3 WAX** – It is least refined and has 3.5% oil content. It is used in manufacturing decorative items, water proof product, etc.

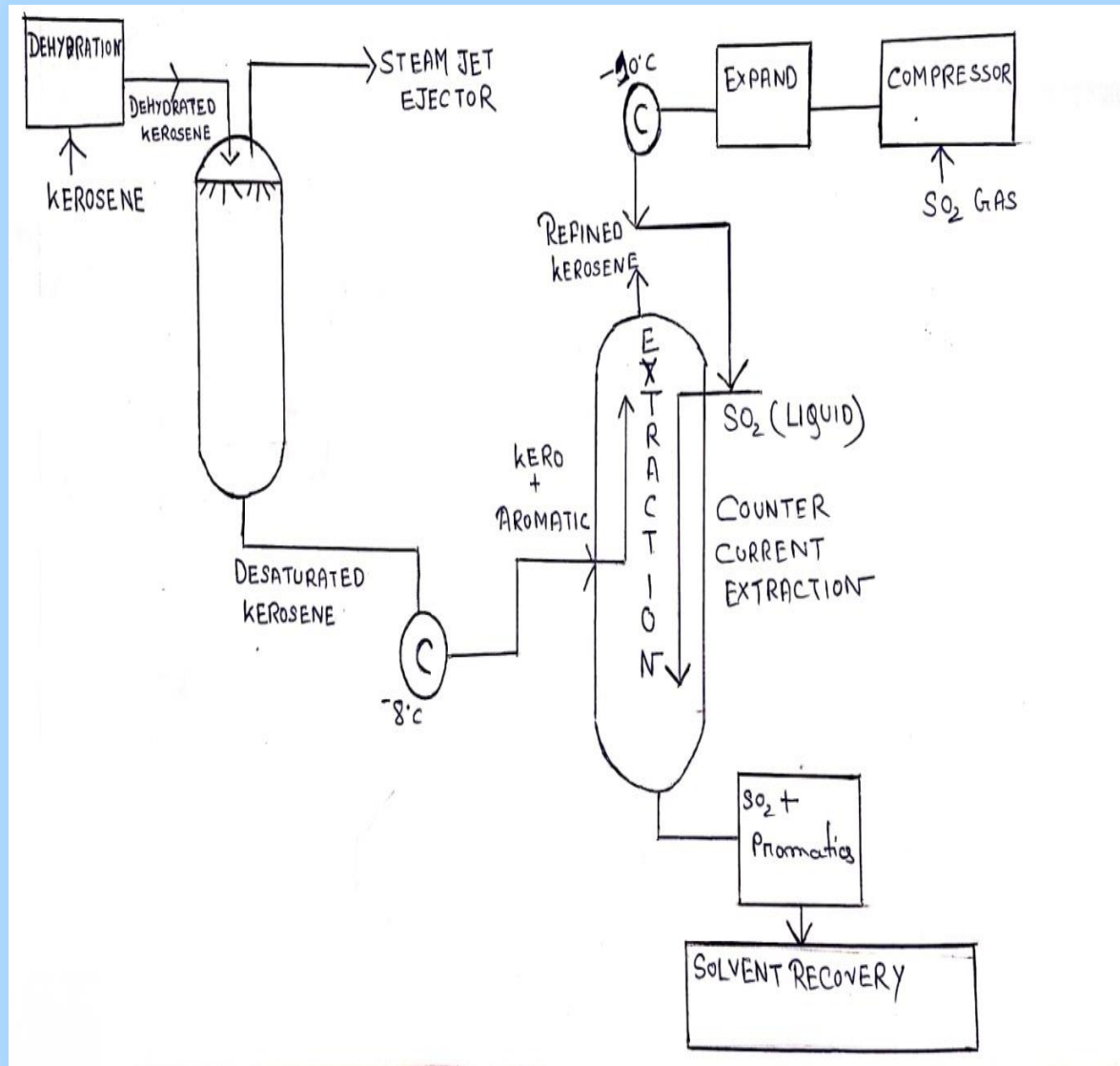
## **PROPERTIES OF DIFFERENT TYPES OF WAX**

Properties	Type I	Type II	Type III
1) Melting point	45°-75°C	45°-75°C	45°-75°C
2) Ash content	0.03	0.03	0.03
3) Oil content	0.25%	0.5%	3.5%
4) Colour (by Pinto meter)	0.5 γ	2 γ	3 γ
5) Inorganic content	0.02	0.02	0.02
6) Saponification	1	1	1

## KEROSENE REFINING BY SOLVENT EXTRACTION

### PROCESS OR EDE LEANU PROCESS-

*Fig: KEROSENE REFINING AND ALSO TRANSFERRED TO PRODUCE AVIATION TURBINE FUEL*



Solvent treatment or solvent extraction of kerosene means the removal of aromatics from kerosene by extracting with the help of a solvent. It was discovered in 1907 by Dr. Edeleanu. Almost 20% aromatics may be removed by this process.

The process requires the following steps:-

- PREPARATION OF CHARGE STOCK OR KEROSENE BY REMOVAL OF WATER FROM IT.
- REMOVAL OF AIR FROM KEROSENE.
- COOLING THE KEROSENE.
- LIQUEFACTION OF SO<sub>2</sub>
- EXTRACTION OF AROMATICS BY SO<sub>2</sub> IN THE MAIN EXTRACTOR COLUMN.
- SOLVENT RECOVERY

### **1. PREPARATION OF KEROSENE BY DEHYDRATION–**

Water may be present in kerosene which has to be removed to prevent corrosion of equipments. This may be done by allowing the kerosene to settle down in huge settling tanks without being disturbed. Gradually, the water particles along with any other impurities settle down at the bottom as sludge and kerosene free from water is taken out from the top.

### **2. REMOVAL OF AIR FROM KEROSENE–**

The dehydrated kerosene is then de-aerated by exposing it to vacuum. It is sprayed into a perforated tray column which is connected to an ejector or vacuum pump. The pressure in this column is maintained at 150 mm Hg. From the bottom, we get the de-aerated kerosene.

### **3. COOLING OF THE KEROSENE–**



The kerosene then enters heat exchanger where it exchanges heat with the outgoing bottom part of the extraction column 2, than it is further cooled to a very low temperature of  $-8^{\circ}\text{C}$ .

#### **4. LIQUEFACTION OF $\text{SO}_2$ –**

We know that  $\text{SO}_2$  exist in the gaseous state. In order to use it in the extraction column it is first converted to liquid state. The  $\text{SO}_2$  gas is compressed to a very high pressure, than allowed to expand to a low pressure and at the same time it is cooled to  $-10^{\circ}\text{C}$  to get liquefied  $\text{SO}_2$  which is used in the extraction column.

#### **5. EXTRACTION OF AROMATICS FROM KEROSENE BY $\text{SO}_2$ –**

The  $\text{SO}_2$  is allowed to enter from top of the extraction column while kerosene containing aromatics from the bottom. Intimate contact between the two streams takes place to counter current extraction occurs. The  $\text{SO}_2$  extracts aromatics from the kerosene and goes out from the bottom of the extract column. It is known as extract. The extract contain maximum amount of  $\text{SO}_2$  and aromatics. The aromatic from kerosene goes out from the top of the column and is known as raffinate.

#### **6. SOLVENT RECOVERY FROM BOTH THE RAFFINATE AND EXTRACT–**

Rich extract from the bottom of the column combines maximum solvent and maximum aromatics. It enters four evaporators kept in series one after another. The extract first enters evaporator 1 which has a top temperature of  $65^{\circ}\text{C}$ , bottom temperature of  $75^{\circ}\text{C}$  and pressure  $13\text{kg/cm square}$ . A part of sulphur dioxide goes out as vapour from the top of the evaporator. The bottom part enters evaporator 2 having top temperature  $45^{\circ}\text{C}$ , bottom temperature  $145^{\circ}\text{C}$ , pressure  $7\text{kg/cm}$

square. More sulfur dioxide vapour goes out from the top while the bottom part enters evaporators called condenser pressure evaporator having tower top temperature of 9°C and bottom temperature 131°C and pressure 1.5kg/cm square. More sulfur dioxide vapour goes out from top and bottom part is introduced to a low pressure evaporator with top temperature 26°C, bottom temperature 145°C and pressure 0.6kg/cm square. From the bottom, of this evaporator we get aromatics while from the top, more sulfur dioxide vapour goes out.

Similar operations are carried out to recover sulfur dioxide solvent from the raffinate. In this case there are three evaporators. The raffinate first enters the condenser pressure evaporator having top temperature 75°C, bottom temperature 145°C and pressure 7kg/cm square. From the top of this evaporator sulfur dioxide vapours goes out while the bottom parts enters the low pressure evaporator having top temperature 12°C, bottom temperature 132°C and pressure 1.1kg/cm square. More amount of SO<sub>2</sub> goes out from the top of this evaporator while from the bottom the raffinate enters the vacuum pressure evaporator; the lower top temperature is 44°C, bottom temperature 135°C and pressure 0.5 kg/ cm square. From the top of the lower, more SO<sub>2</sub> vapours goes out while from the bottom, we get refined kerosene.

The SO<sub>2</sub> vapours from both the raffinate and extract recovery section are compressed, liquefied, cooled to get liquid SO<sub>2</sub> which is used again in the extraction column. The kerosene obtained by the above process has a high smoke point since it completely free from aromatics.

## **CHEMICAL TREATMENT OF CRUDE & PETROLEUM FOR REMOVING THE SULPHUR–**

In general all crudes as well as products contain  $H_2SO_4$  & other impurities like O, N, heavy metals etc up to a certain amount. When sulphur is present in crude it is called sour crude. The sulphur has to be removed because it causes corrosion during various refining processes.

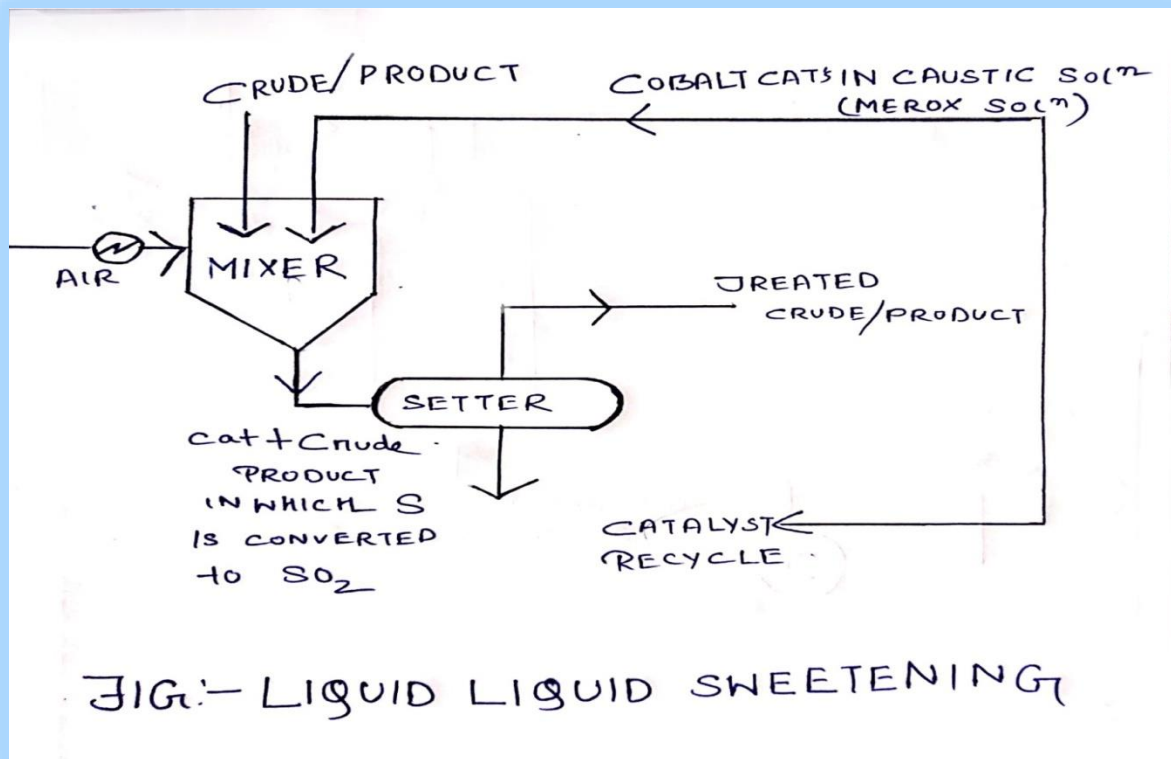
There are three methods of sulphur removal.

- ❖  $H_2SO_4$  ACID TREATMENT PROCESS: (DISCUSSED IN LUBE OIL)
- ❖ CLAY TREATMENT PROCESS: (DISCUSSED IN LUBE OIL)
- ❖ MEROX SWEETNING PROCESS: When we remove sulphur completely from the crude or the product it is called merox extraction process. In merox sweetening process however the sulphur is not removed completely but it's converted to  $SO_3$  which is harmless as it doesn't cause corrosion.

**There are two types of merox sweetening processes.**

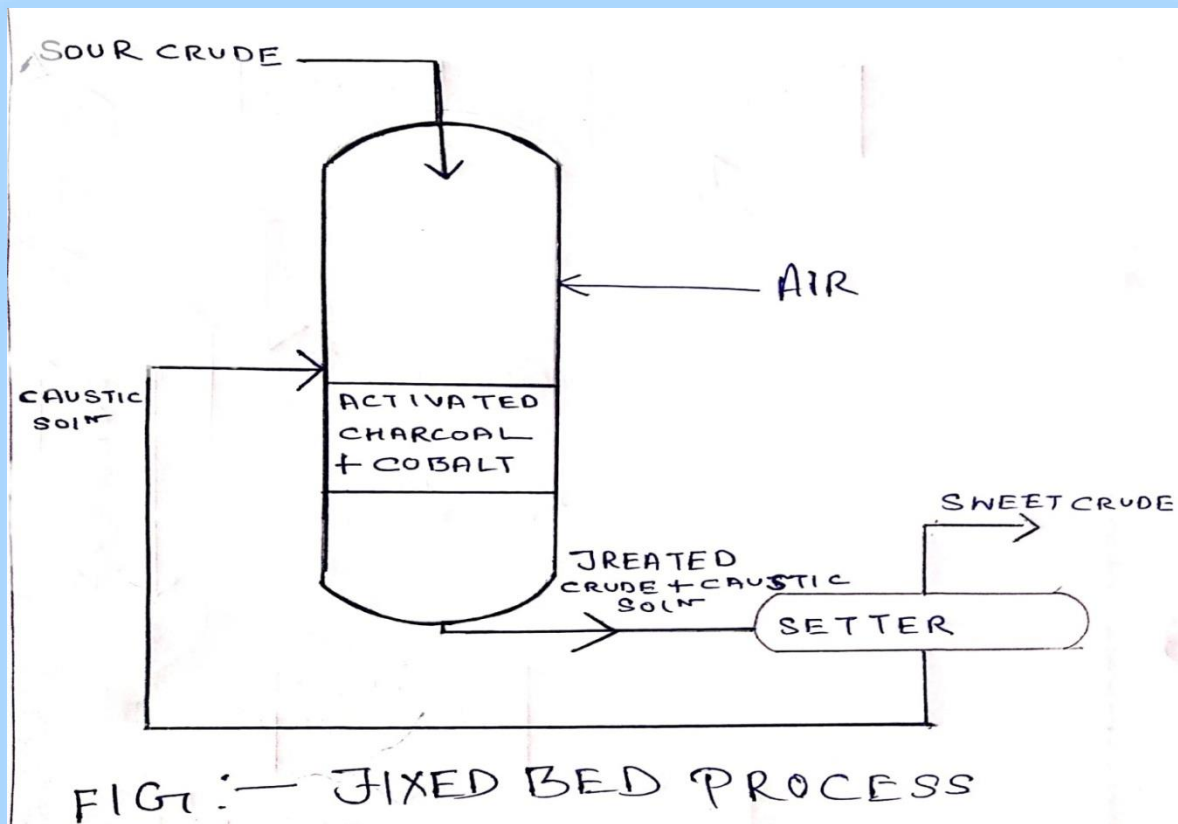
### **LIQUID-LIQUID SWEETENING:**

In this case the hydrocarbon feed-crude, gasoline, LPG or kerosene etc is mixed together in a mixture with the catalyst cobalt in caustic solution which is called merox solution. Excess of air is let into the mixer. Inside the mixer the sulphur present in the feed gets oxidised to  $SO_2$ . Treated feed along with the catalyst then comes out from the bottom of the mixer. It then goes to a separator or settler. In the settler since the catalyst is solution is heavier than the treated fraction, it settles down at the bottom from where it is taken out and recycled. The treated fraction containing less harmless  $SO_2$  goes out from the top.



### FIXED BED SWEETNING PROCESS:

The fixed bed process consists of reactor which contains a bed of activated charcoal and cobalt catalyst. A solution of caustic is passed through the bed so that we get a mercox solution as catalyst in the bed itself. The sour feed is introduced from the top of the reactor while excess of air is injected from the side into the reactor. As the feed passes through the bed it is oxidised by air and the sulphide present in it are converted to disulphide. At the same time the charcoal present in the bed adsorbs any gums, pigments, asphalt and other impurities present in it. The effluent coming out from the bottom of the reactor contains treated fraction and caustic solution. It is directed to a settler and the caustic solution being heavier settled at the bottom from where it is removed and recycled while the treated crude or product is taken out from the top.

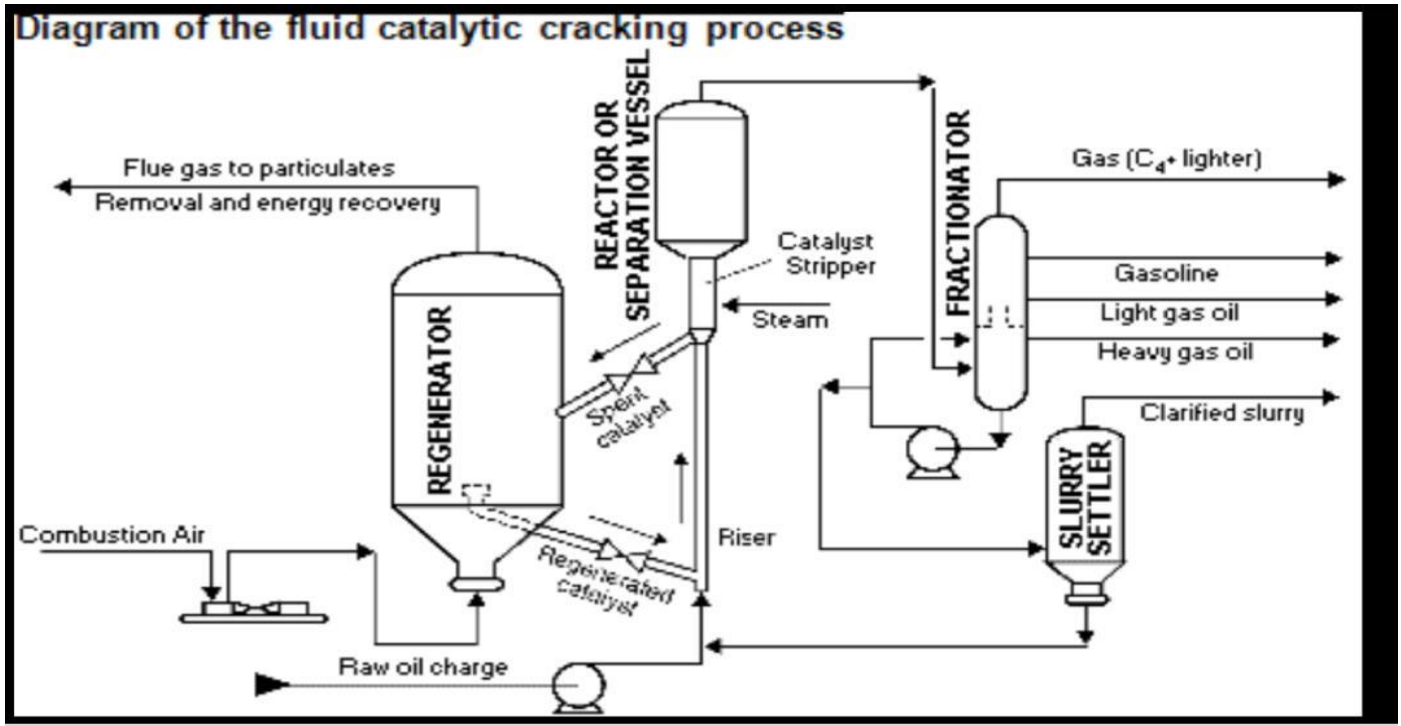


**Merox treatment is usually done:**

- ▼ To remove sulphur content.
- ▼ To improve the odour of the crude or product.
- ▼ To prevent gum formation during storage.

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## Fluidized catalytic cracker :



A fluidized catalytic cracker is used to decompose high molecular hydrocarbons into smaller fragments by using heat and a catalyst. The FLC process is a continuous process and there are various designs by different refineries. A common FLC unit is described here. In this FLC unit there is a Reactor and the regenerator and it factors rapid transportation of the catalyst between the reactor Chamber and the regeneration unit. The regenerated catalyst is fine Zeolite particles in the fluidised state who is this very hot from the regenerator comes through the side valve and meets the incoming feed vacuum gas oil in the bottom of the reactor. The heat from the catalyst is utilised in vaporising and cracking the incoming feed. The cracking reaction takes place within the riser itself within the contact time of 5 seconds. The temperature of the reactor is 452-510° Celsius and pressure is 2 atm. It is desirable that all the cracking and cooking reactions must be completed within the riser itself and not in the reactor which may result in unwanted secondary reactions. The reaction products of the cracked hydrocarbon vapours and the catalyst is separated from each other in the disengaging vessel. The hydrocarbon vapours goes up and passes through a cyclone separator to

remove it from impurities, before entering the fractionator. The catalyst on the other hand is coated with a coating of Coke and is called a spent catalyst. It falls downward and gets through a slide valve at the bottom of the reactor and it enters the regenerator. In regenerator it comes in contact with very hot air burns off the coke deposits on the catalyst surface; this is an exothermic reaction. As the coke is turned off the hot air is covered with soot and is called blue gas which rises up the riser along with the regenerated catalyst. The blue gas and the regenerated catalyst are separated from each other in the discharging vessel, the blue gas goes upward through a cyclone separator and out through an exit at the top of the regenerator this blue gas may be utilized for generation of steam in other units of the refinery . The regenerated catalyst falls down and passes through a slide valve at the bottom of the refrigerator and gets to the reactor where it mix the incoming feed at every point the incoming feed utilizes the heat from the hot catalyst and vaporizes and goes up the riser and the cycle is repeated

The cracked vapours from the reactor goes to a fractionator or distillation column .From which we get products like gas, gasoline, light gas oil, heavy gas oil and column bottom

**Char Value:** It is the amount of charcoal oil deposition on the wick obtained from kerosene after burning in a standard wick lamp at a standard Hall for 24 hours. the weight of char is estimated form that present in the upper portion of the wick after washing wick light petroleum and drying 100- 110°C char value of a good quality kerosene should be less the 20mg/kg

Ignition temperature: it is the minimum temperature at which the fuel ignites in a oxidising atmosphere without any external source of fire.

Diesel index: an alternative method of expressing the quality of diesel is by use of the diesel index.

$$DI = (\text{Aniline Point} \cdot F \times \text{API}) / 100$$

$$DI = \text{Cetane No.} + 3$$

Cetane number: it is a characteristic property of diesel and is used to indicate its quality and performance in compression, ignition engine. It is defined as the volume percentage of cetane in a mixture of n-cetane and 110°C

.Which gives ignition delay and performance when tested in a standard ignition engine as that of the fuel where number of cetane taken is 100 and  $\alpha$ -methyl naphthalene is 0.

**Specification of different refinery products**

Characteristics	Requirements
<b>1.Motor gasoline</b>	
i. Colour	Orange
ii. Copper strip corrosion test done for three hours at 50°C	Not more than 1
iii .Distillation	10% volume
Recovery at 40°C	50%
Recovery at 125°C	90%
Recovery at 185°C	215°C
iv. Final boiling point	93



v. Octane number	360 minutes		
vi. Oxidation stability test	4mg/100 mg		
vii. Residue left after evaporation	0.25% of weight		
viii. Sulphur content	0.7kg/cm <sup>2</sup>		
ix. Reid vapour pressure test			
<b>2. Kerosene</b>			
i. Burning quality	20 mg/kg of oil		
Char value	Must not be darker than grey		
Bloom on the chimney	Not more than 1		
ii. Copper strip corrosion test for three hours at 50 <sup>0</sup> C	20% volume		
iii .Distillation	300 <sup>0</sup> C		
Recovery at 200 <sup>0</sup> C	35 <sup>0</sup> C		
iv. Final boiling point	18 mm		
v. Flash point	.25% of weight		
vi. Smoke point			
vii. Sulphur content	Low viscosity	Medium viscosity	
	High viscosity		
<b>3. Fuel oil</b>			
i. Acidity	Nil	Nil	
	Nil		
ii. Ash content	0.1% of wt of wt	0.1% of wt	0.1%
iii. Flash point	66 <sup>0</sup> C	66 <sup>0</sup> C	
iv. Kinematic viscosity at 50 <sup>0</sup> C	66 <sup>0</sup> C		
v. Sulphur content			

vi. Water content	80 CS 170 CS  3.5% 4.5%  1% by vol by vol	125 CS  4%  1% by vol  1%
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