Crude Oil Distillation

The process of distillation is the most common method adopted for separating the constituents of crude oil into compounds or groups of compounds having industrial uses. Crude oil consists of a complex mixture of hydro-carbons widely differing in boiling points. Distillation is done to separate the crude oil into the basic fractions like motor gasoline kerosene, gas oil and fuel oil.

1. Atmospheric Distillation

Crude distillation unit (CDU) is the first and most fundamental step in the refining process, also known as topping unit, or atmospheric distillation unit. The primary purpose of the atmospheric distillation tower is to separate crude oil into its components (or distillation cuts, distillation fractions) for further processing by other processing units. It receives high flow rates hence its size and operating cost are the largest in the refinery. The capacity of the CDU ranges from 10,000 barrels per stream day (BPSD) to 400,000 BPSD. The economics of refining favours larger units. A good size CDU can process about 200,000 BPSD.

These towers can be up to 150 feet (50 meters) high and contain 20 to 40 fractionation trays spaced at regular intervals. Before entering the column distillation, desalted crude oil pass through a network of pre-heat exchangers in order to heat it initially with hot material drawn from the bottom of the distillation tower to raise its temperature up to 450°F and then to a heating furnace, which brings the temperature up to about 650°F. This part of process is essential because the carbon will be deposited inside the pipes and equipment through which it flows when the oil gets much hotter. The hot crude oil enters the column distillation and most of it vaporizes. Unvaporized heavy oil cuts and residue will drop to the bottom of the column, where it is drawn off. Inside the tower distillation column, there are the so-called trays, which are working mainly in the separation of crude oil to light the required derivatives. These trays permit the vapors from below to pass from it and contact with the condensed liquid on top of the tray that provides excellent contact between vapor and liquid. Condensed liquid flows down through a pipe to the hotter tray below, where the higher temperature causes re-evaporation. A given molecule evaporates and condenses many times before finally leaving the tower. Products are collected from the top, bottom and side of the column. In modern towers, a portion of the condensed overhead liquid product from a distillation tower that is returned to the upper part of the tower, this **reflux** plays a major role in controlling temperature at the top of the tower and further enhance separation.

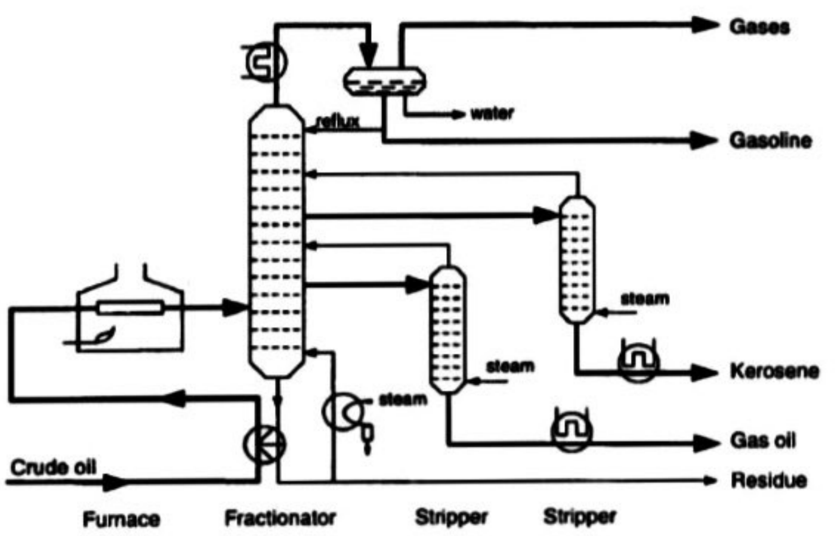

Figure 5.1: Atmospheric Distillation

Fractionation process depends on :

1- Number of Trays 2- Reflux ratio 3- Quantity of steam added to the column

As increasing in trays no. and reflux ratio, the efficiency of separation process is increasing.

Products from ADU

The light products, which have low boiling points, tend toward the top and the heavier products, with relatively higher boiling points tend toward the bottom. The product obtained from a top of ADC under atmospheric pressure is gasoline (C_5 to C_8). This fraction withdrawal as a vapor then is condensed and a part of it will be returned to the atmospheric column as a reflux.

Other products will withdrawal from several points along atmospheric column as a liquid. These products are cooled and a part of them will be returned to the column as a reflux and the remaining parts send to the stripper towers (small fractionating column like column distillation having 4-8 trays placed on each other – beside the distillation column). These stripper towers are aimed to remove the light compounds that effect on the flash point.

The other products are: Heavy straight naphtha, Kerosene, & Light gas oil.

The remaining part at the bottom of atmospheric distillation will be sent to the vacuum distillation tower.

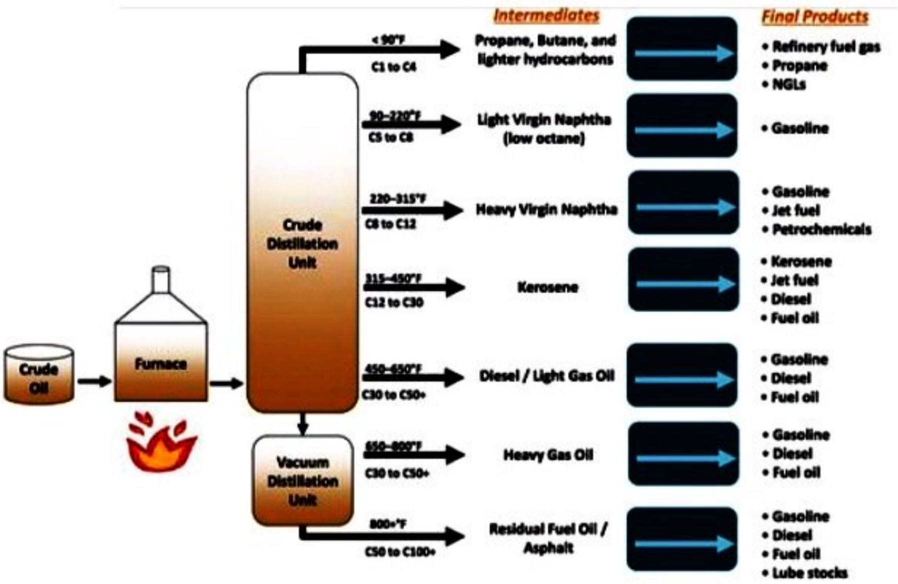

Figure 5.2 Products from Crude distillation unit.

2. Vacuum Distillation Column

The residue from an atmospheric distillation tower can be sent to a vacuum distillation tower, which recovers additional liquid. The furnace outlet temperatures required for atmospheric pressure distillation of the heavier fractions of crude oil are so high that thermal cracking would occur, and creation of unwanted by-products. These materials are therefore distilled under vacuum because the boiling temperature decreases with a lowering of the pressure. Addition of steam to the furnace inlet increases the furnace tube velocity and minimizes coke formation in the furnace as well as decreasing the total hydrocarbon partial pressure in the vacuum tower.

The main products from this unit are:

1- Heavy gas oil

2- Lubricant

3- Asphalt or vacuum residue (B.P > 1000F)

Cracking

Cracking means heating of higher boiling petroleum fractions like heavy fuel oil at high temperature and pressure to produce lower boiling lighter fractions. It is an endothermic reaction.

The process of cracking, increases the relative amounts of the lower hydrocarbons. During cracking, carbon-carbon bonds get broken, leading to various kinds of products being formed.

There are two types of cracking:

1- Thermal Cracking: Cracking at elevated temperatures in the absence of catalyst. Examples: Visbreaking, delayed coking, Fluid coking.
2- Catalytic Cracking: Cracking in presence of catalyst. Examples: FCC , Hydrocracking, DCC.

1- Thermal cracking

Breaking down large molecules by heating at high temperature and pressure is termed as thermal cracking.

There are three classes of industrial thermal cracking processes:

a- Visbreaking

The first is mild cracking (as in visbreaking) in which mild heating is applied to crack the residue just enough to lower its viscosity and also to produce some light products.

Feed : Atmospheric residue (AR) &Vacuum residue (VR)

Products : Four products are produced in the visbreaking process: gases (C4), Naphtha C5 - 166 °C (C5 -330 F), gas oil 166–350 °C (330–660 F) and residue or tar 350+ °C (660+ F).

b- Delayed Coking

The second process is delayed coking in which thermal cracking converts the residue into lighter products, leaving coke behind.

Feed: Vacuum residue, cracked residue.

Product: Gases, Naphtha, Fuel oil, Gas oil and Coke.

A schematic flow diagram of the delayed coking is shown in Figure below. The process includes a furnace, two coke drums, fractionator. Residual oil from the vacuum distillation unit is pumped into the bottom of the distillation column called the main fractionator. From there, it is pumped, along with some injected steam, into the furnace and heated to its thermal cracking temperature of about 480 °C. The injected steam helps to minimize the deposition of coke within the furnace tubes. The liquid–vapour mixture leaving the furnace passes to one of the coking drum, and cracking takes place in the drum. Coke is deposited in this drum for 24 h period. After the first drum is full of the solidified coke, the hot mixture from the furnace is switched to the second drum. While the second drum is filling, the filled first drum is steamed out to reduce the hydrocarbon content of the petroleum coke, and then quenched with water to cool it. Vapors from the top of the coke drum are returned to the bottom of the fractionator. These vapors consist of steam and the products of the thermal cracking reaction (gas, naphtha and gas oils).The top and bottom heads of the full coke drum are removed, and the solid petroleum coke is then cut from the coke drum with a high pressure water nozzle, where it falls into a pit, pad, or sluiceway for reclamation to storage.

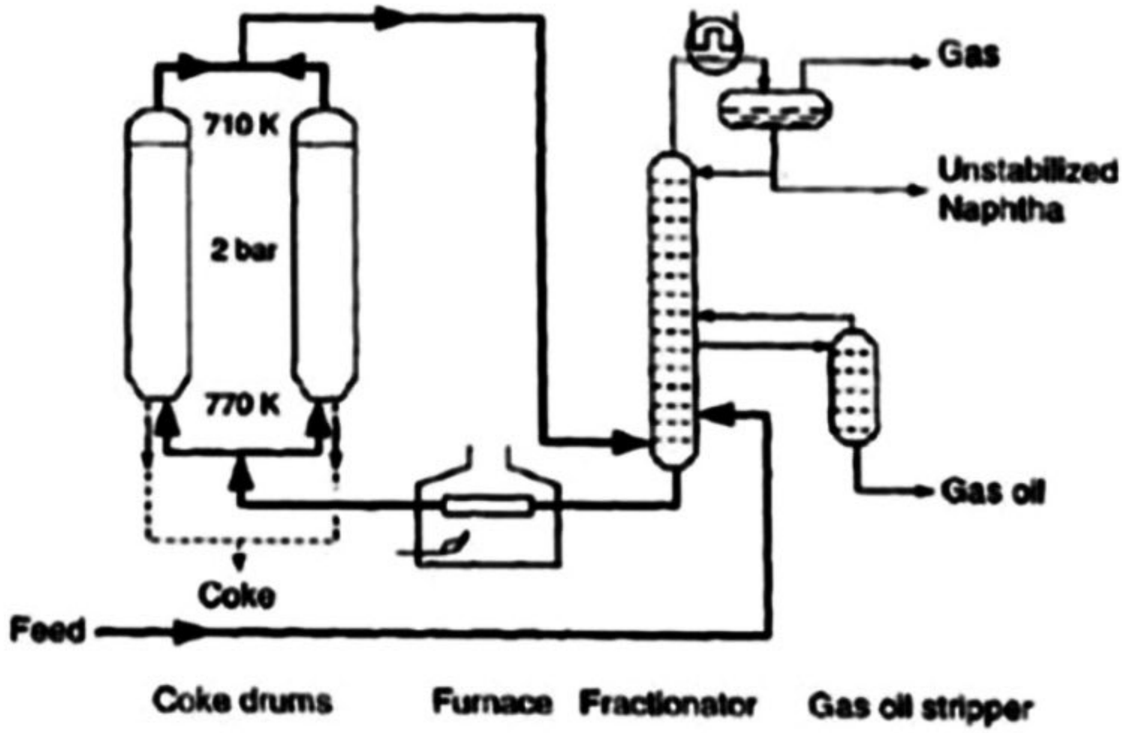

Fig 5.3: Process Flow Chart of **Delayed Coking**

c- Fluid Coking and Flexi Coking

The third process involves severe thermal cracking. Flexi coking is one of the most important processes in a refinery as only 2% of coke is produced from the residue.

It is continuous process involves thermal cracking in a bed fluidized coke and gasification of the coke produced at 870 °C.

2- Catalytic Cracking:

Higher hydrocarbons can also be cracked at lower temperature (350-650 oC) and lower pressure (2 atm) in the presence of a suitable catalyst. The feedstocks ranging from gas oil to heavy crude oil and residuum is heated in presence of catalyst (like, platinum , nickel , iron silica-alumina etc..) to produce lower boiling products and gasoline of higher octane number and therefore this method is used for obtaining better quality gasoline. Modern cracking uses zeolites as the catalyst.

Advantages of Catalytic Cracking over Thermal Cracking:

- Pressure and temperature required for catalytic cracking is lower.
- Yield and octane number of petrol production is higher.
- Petrol produced has less quantity of gum and gum forming material.
- Sulphur content of the products is low.
- The product contains a higher amount of aromatics and hence the petrol possesses better anti-knock characteristics.

Reforming

Reforming means rearrangement of molecules without much affecting the average molecular weight of feed which is generally naphtha to produce high octane number gasoline called reformate or reformat gasoline.

Feed for Reforming:

The feed is generally naphtha produced during straight run distillation of crude oil, catalytic cracking and cooking process. The best result is obtained with naphtha produced during straight run distillation having high naphtha content.

Reforming Product:

Besides the main product (reformate) or reformat gasoline, reforming also produces lighter hydrocarbons (gases), hydrogen and traces of very high boiling materials.

Types of Reforming:

Reforming can be thermal or catalytic as in the case of cracking. Catalyst apart from accelerating the process also enhances the yield and quality (octane number) of gasoline. The gasoline produced by reforming is called reformed gasoline or reformate. Thermal reforming has been almost completely replaced by catalytic reforming.

- Thermal Reforming

This is carried out in absence of catalyst and its similar to high temperature, low pressure thermal cracking. Feed is usually Naphtha and the products are mainly gas (13 -14%) and gasoline (75 -80%) of octane number 81 -86, rest being polymer (unwanted gum) and losses.

- Catalytic Reforming

Reforming in the presence of a catalyst is called catalytic reforming.

There are two types of catalyst are used:

- Non- precious metal oxide type (e.g. molybdena or chromia supported on alumina base).
- Precious metal oxide type (e.g. platinum on a silica-alumina or alumina base). Platinum is more active and selective catalyst.