Tikrit University

College of Petroleum Processes Engineering

Department of Petroleum Refining Engineering

Specialized Petroleum Processes

Fourth Class

Lecture 7

By

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Crude Oil Processing from Refinery to Market

Refinery Configuration

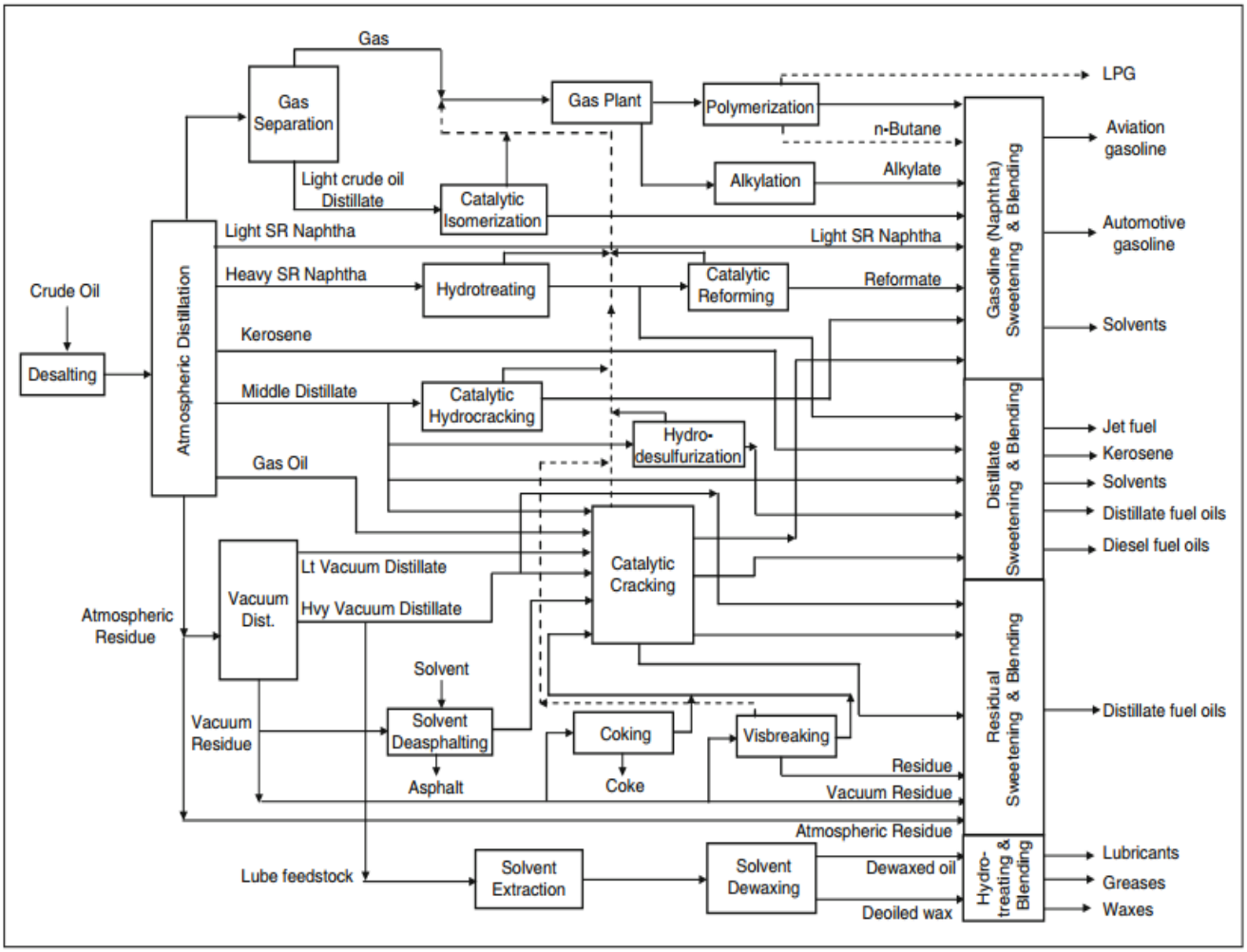

Figure 1: The Modern refinery

Classification of Refining Processes

1. Physical Separation Processes

- Crude Distillation
- Solvent Deasphalting
- Solvent E xtraction
- Solvent Dewaxing

2. Chemical Catalytic Conversion Processes

- Catalytic Reforming
- Hydrotreating
- Catalytic Hydrocracking
- Catalytic Cracking
- Alkylation
- Isomerization

3. Thermal Chemical Conversion Processes

- Delayed Coking
- Flexicoking
- Visbreaking

1. Crude Distillation

Crude distillation unit (CDU) is at the front-end of the refinery, also known as topping unit, or atmospheric distillation unit. It receives high flow rates hence its size and operating cost are the largest in the refinery. Many crude distillation units are designed to handle a variety of crude oil types. The capacity of the CDU ranges from 10,000 barrels per stream day (BPSD) or 1400 metric tons per day (tpd) to 400,000 BPSD (56,000 metric tpd). A good size CDU can process about 200,000 BPSD. The unit produces raw products which have to be processed in downstream unit to produce products of certain specifications. This involves the removal of undesirable components like sulphur, nitrogen and metal compounds, and limiting the aromatic contents. Typical products from the unit are:

- Gases
- Light straight run naphtha (also called light gasoline or light naphtha)
- Heavy gasoline (also called military jet fuel)
- Kerosene (also called light distillate or jet fuel)
- Middle distillates called diesel or light gas oil (LGO)
- Heavy distillates called atmospheric gas oil (AGO) or heavy gas oil (HGO)
- Crude column bottoms called atmospheric residue or topped crude.

Process Description

The process flow diagram of a typical crude distillation unit is shown in Figure 2. Crude oil is pumped from storage tanks where it is freed from sediments and free water by gravity. It goes through a series of heat exchangers where it is heated with hot products coming out from the distillation column and by the exchange with heat from the pumparound liquid streams. The temperature of the crude feed can reach

120–150 C (248–302 F). The crude oil contains salt in the form of dissolved salt in the tiny droplet of water which forms a water-in oil emulsion. It is separated through electrostatic water separation. This process is called desalting. The crude is further heated in product heat exchangers. The preheating of the crude using the hot products cools down the products to the desired temperature for pumping to the storage tanks. This is essential for the economics of the unit in terms of energy conservation and utilization. The furnace is required to boost the temperature to between 330 and 385 C (626 and 725 F) depending on the crude composition. The partially vaporized crude is transferred to the flash zone of the column located at a point lower down the column and above what is called the stripping section. The main column is typically 50 m (164 ft) high and is equipped with about 30–50 valve trays. At the bottom of the stripping section, steam is injected into the column to strip the atmospheric residue of any light hydrocarbon and to lower the partial pressure of the hydrocarbon vapours in the flash zone. As the hot vapours from the flash zone rise through the trays up the column, they are contacted by the colder reflux down the column. In the overhead condenser, the vapours are condensed and part of the light naphtha is returned to the column as reflux. Further reflux is provided by several pumparound streams along the column. The side draw products are usually stripped to control their initial boiling point. The strippers contain several trays and the stripping is done using steam at the bottom of the stripper or reboiler type side stream strippers. The overhead vapour is condensed at the top of the tower by heat exchange with the cool crude coming into the unit and by air and cooling ater. Down the column, other products are withdrawn, such as heavy straight run naphtha, kerosene or jet fuel, LGO and HGO. All of these products are withdrawn above the feed tray. The atmospheric residue is withdrawn from the bottom of the column. Typical designs have the trays distribution between products as shown in Table 1.

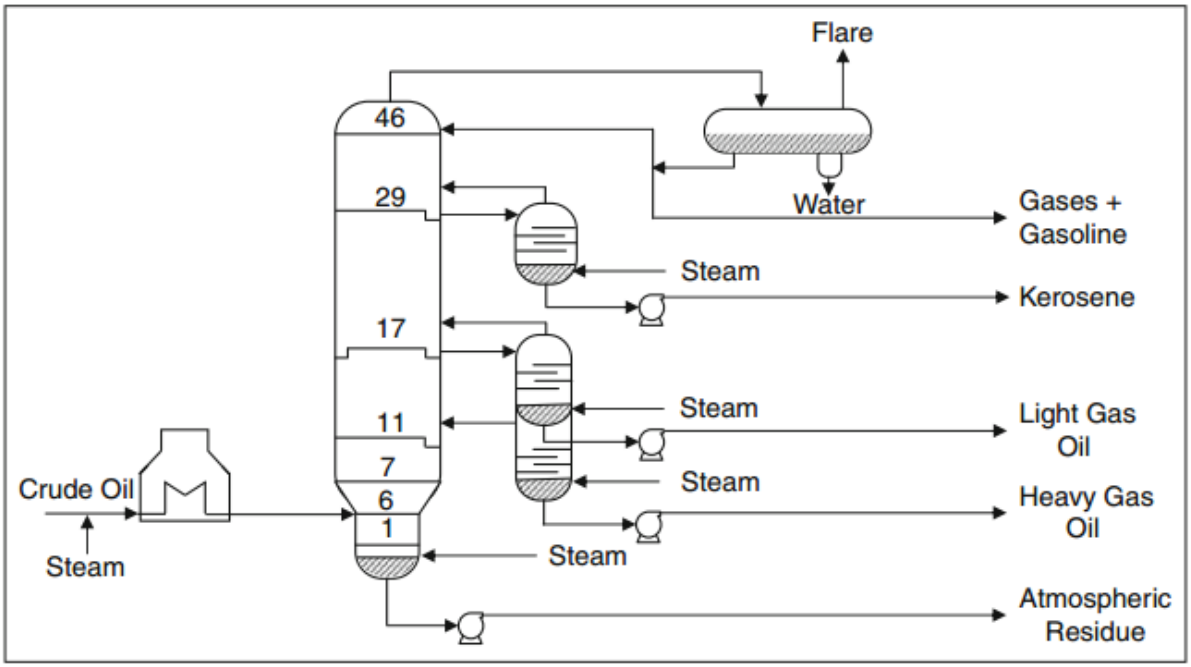

Figure 2: Process flow diagram of an atmospheric distillation unit

Table 1: Tray distribution in a crude distillation unit

Zone	Number of trays
Overhead product to kerosene	10
Kerosene to light gas oil	8
Light gas oil to heavy gas oil	6
Heavy gas oil to flash zone	6
Flash zone to atmospheric residue	6
Pumparounds	3–4

Degree of Fractionation

The fractionation quality between two consecutive streams is affected by several factors such as the vapour and liquid flow rates in the column zone between these two streams, the number of trays, and the heat extracted by the pumparound. Fractionation quality is formulated in terms of gap or overlap of the products. For perfect fractionation, zero gap and overlap are required. This means that the EBP of the light cut would be the IBP of the heavier cut and so on.

Operating Conditions

In order to fractionate the crude oil into the various products, it has to be heated to a temperature between 330 and 385C (626 and 725F), depending on the crude composition. The overhead temperature must be controlled to be 14–17 C (25–31F) higher than the dew point temperature for the water at the column overhead pressure so that no liquid water is condensed in the column. This is to prevent corrosion due to the hydrogen chloride dissolved in liquid water (hydrochloric acid). The pressure inside the CDU column is controlled by the back pressure of the overhead reflux drum at about 0.2–0.34 bar gauge (3–5 psig). The top tray pressure is 0.4–0.7 bar gauge (6–10 psig) higher than the reflux drum. The flash zone pressure is usually 0.34–0.54 bar (5–8 psi) higher than the top tray.

Example 1: If the overhead stream contains 8.5 mol % water at a pressure of 34.7 psia (2.36 bars), calculate the overhead temperature for safe operation.

Solution:

The saturation temperature of water at the partial pressure of water in the overhead vapour.
Water partial pressure = $0.085 \times 2.36 = 0.2$ bars
From the steam tables:
Saturated steam temperature at 0.2 bars = 61 °C
Safe overhead operating temperature = $61 + 17 = 78$ °C

Pre-flash Columns

To expand crude capacity, the most used technique is to introduce a pre-flash column before the crude heater. The crude oil after preheating in the hot products and pumparound heat exchangers is flashed into a column where the lightest products are removed. The bottoms from the pre-flash column are introduced into the crude heater and then to the crude column. The amounts of the light ends in the crude are now

less, and this reduces the vapour loading up the column. Although the unit throughput is increased, the furnace duty is not increased, since the crude rate going to the furnace is not affected due to the removal of the light ends. Pre-flash columns are also introduced in the original design of the CDU when the crude oil is light, and when it contains a lot of light ends in the naphtha range.