Tikrit University

The College of Petroleum Processes Engineering

Petroleum Systems Control Engineering

Department

Petroleum Refining Processes

Fourth Class

Lecture 10

By

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Petroleum Refinery

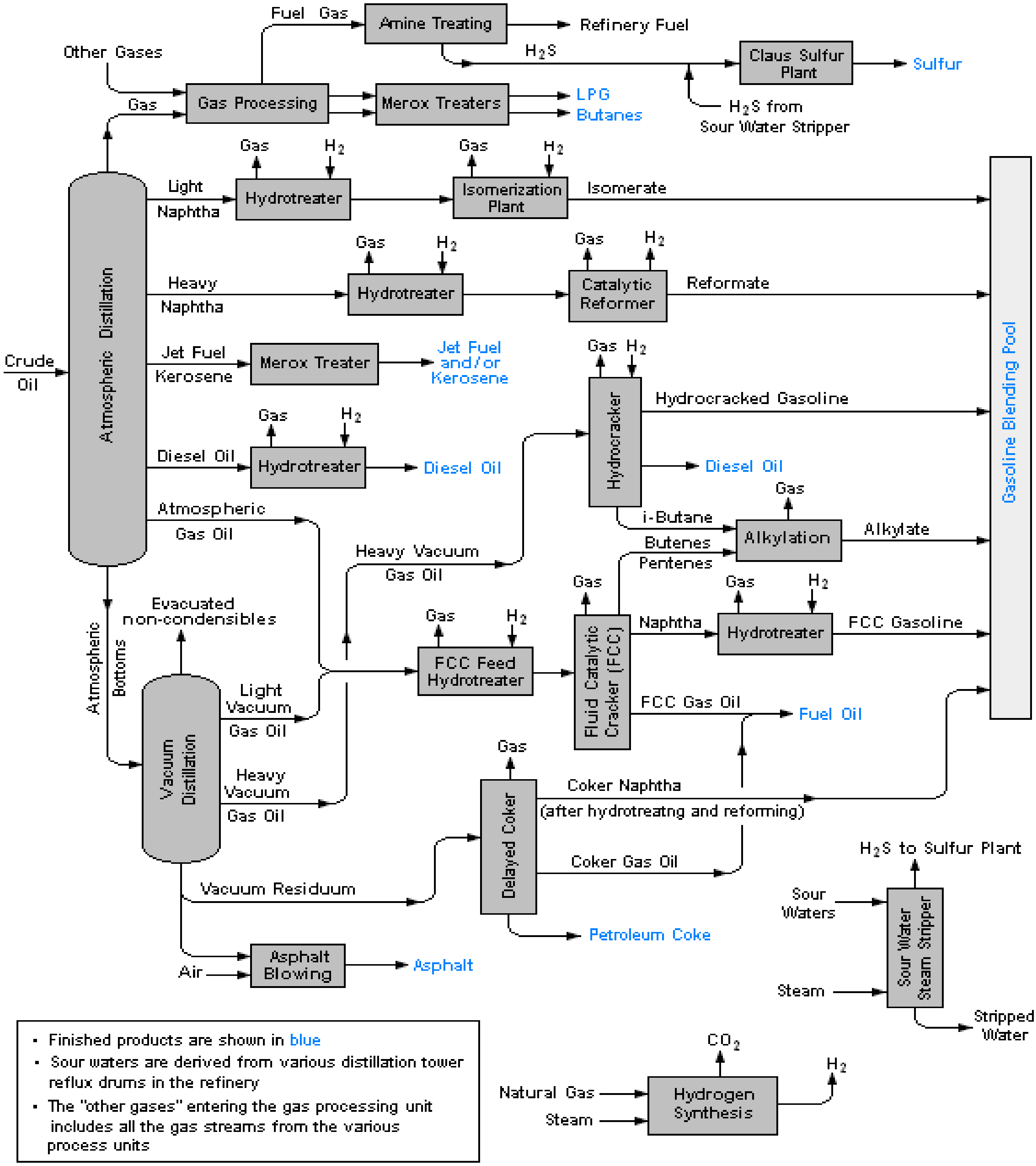


Figure 1: Petroleum Refinery.

Atmospheric Crude Distillation Unit (CDU)

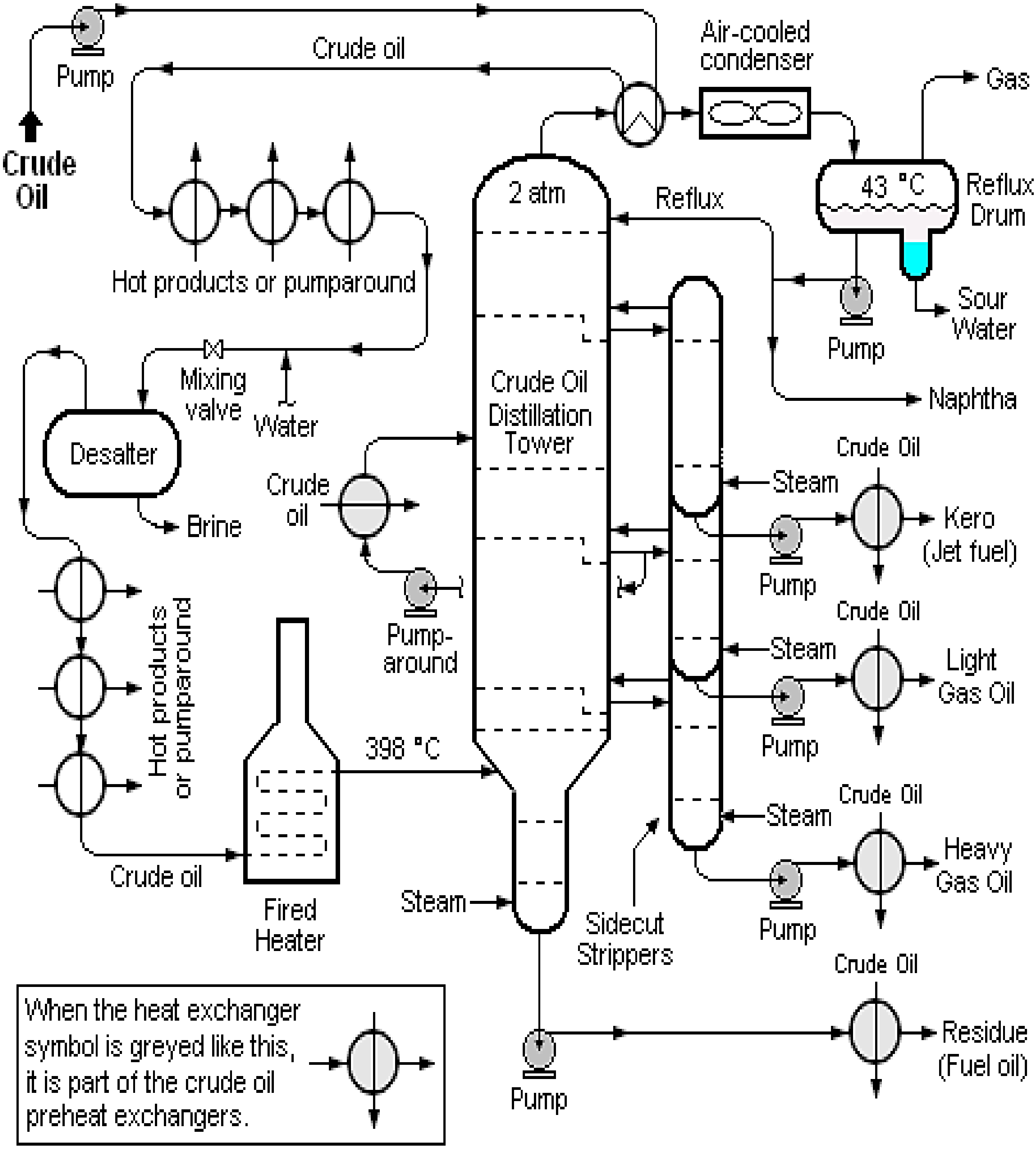


Figure 2: **A schematic Process Flow Diagram of an atmospheric CDU.**

Main equipment in CDU

- Crude storage tanks and battery limit
- Feed pumps
- Desalter
- Preheat exchangers system
- Crude heater (Direct Fired Heater)
- Atmospheric Crude Distillation Tower
- Pump around system
- Products splitters or stabilizers
- Overhead condensers and reflux drum

The crude oil is pumped from storage tanks (battery limit area) and preheated in an exchangers train by recovering heat from the pump-around and products to a temperature of between 120-160°C.

Crude Oil Desalting

It has already been studied.

Preheating Exchangers System

- Crude oil is heated from storage temperature (45ºC) to about 350ºC before it is introduced to the fractionator column.
- Heat exchangers are used to raise the temperature of the crude oil utilizing the hot products (side streams) from the fractionator in addition to the pumparounds as heating mediums for heat recovery.
- The crude is first heated using the fractionator overhead (ovhd) vapor (naphtha fraction) and top pumparound (TPA).
- This is followed by the kerosene product to insures a crude temperature of 150ºC which is the temperature required for the desalting process.

- After the Desalter, crude is heated by LGO then middle pumparound (MPA) and HGO products respectively to the temperature of 210ºC.
- The hot crude is then further heated by atmospheric residue and the bottom pumparound (BPA) and to a temperature of 260ºC.
- In most cases (but not all!) the crude probably flows through the tube side of these exchangers. The crude would be easier to clean from the tubes than the shell.

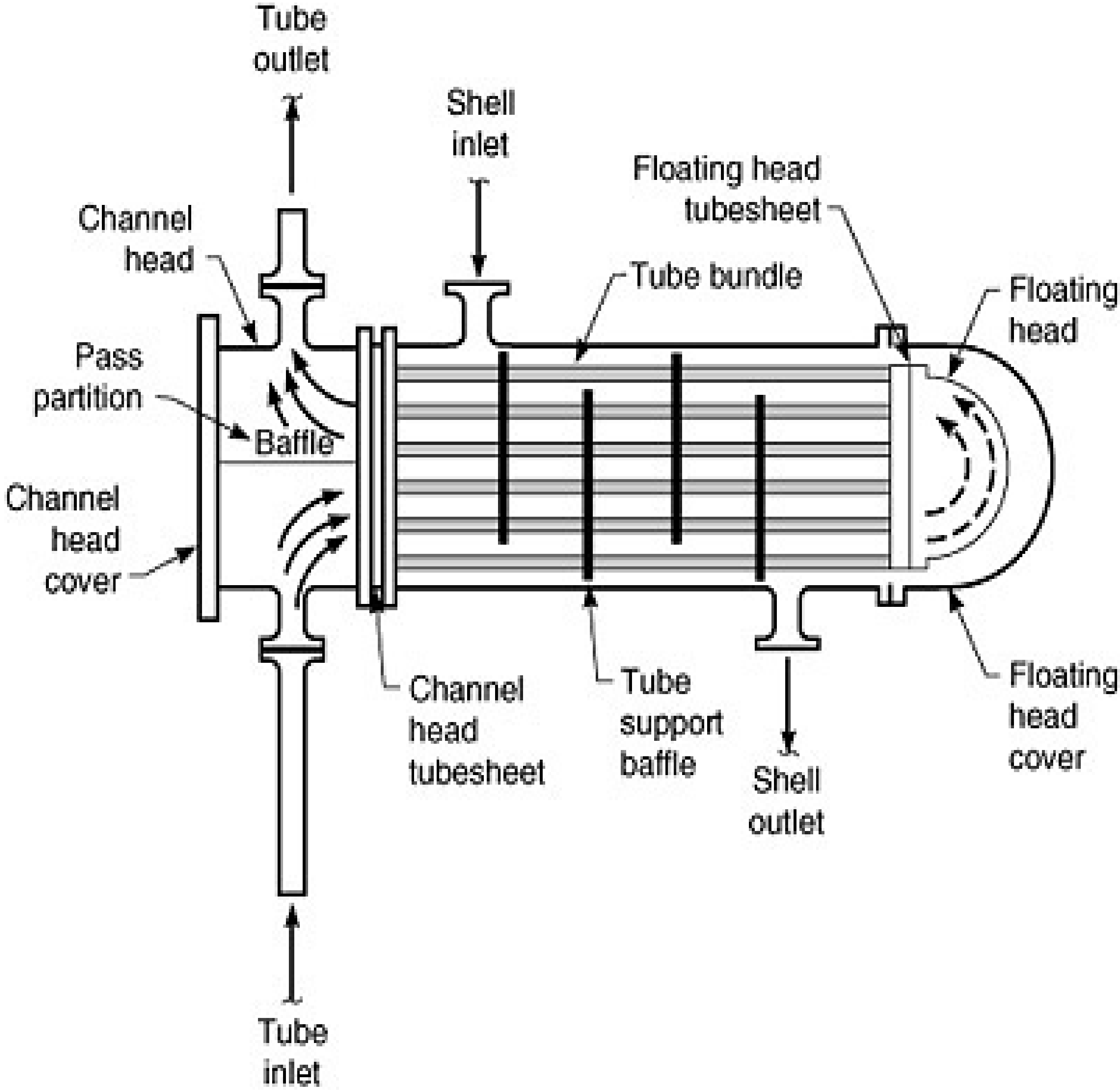
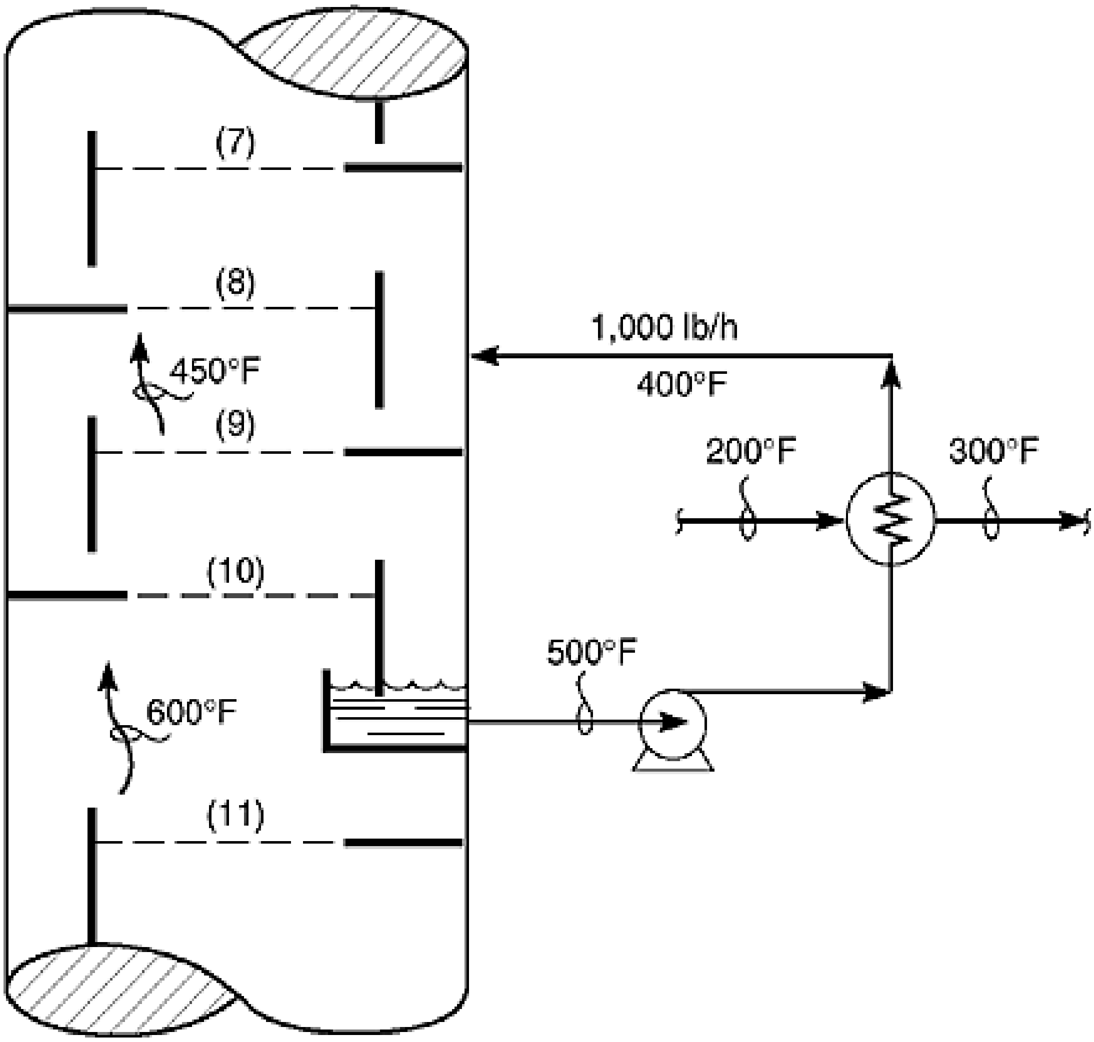


Figure 3: Typical shell and tube preheat exchanger.

Pumparounds

- Liquid is removed from the tower, (all or portion of the side stream) is cooled by heat exchangers (exchanging heat with the crude oil feed), and returned to the tower.
- The top pumparound (TPA) is withdrawn from tray X and returned after heat exchange to tray above tray X.
- The middle pumparound (MPA) is withdrawn from tray X and returned after heat exchange to tray above tray X.
- The bottom pumparound (BPA) is withdrawn from tray X and returned after heat exchange to tray above tray X.



Advantages of Pumparound

- **Better heat recovery** (at higher temperature) and better energy efficiency. (143ºC, 215ºC and 315ºC for the top, middle, and bottom pumparounds, respectively) can be recovered by preheating the feed.
- **Better fractionation between product cuts.** When a portion of the liquid flowing down through the column is removed, cooled, and routed back to the column, this cooled streams condenses more of the vapor coming up through the tower (especially the heavy material in the vapor) allowing only the light material to rise up the tower in the vapor phase, thus, fractionation (separation) is enhanced.
- **Better tower design (more proportionate diameter and smaller height)** If all the heat in the tower is to be removed in overhead condensers, the amount of liquid reflux to the tower will be huge. This would result in an inverted cone-type liquid loading which requires a very large diameter at the top of the tower.

  The tower diameter will have to be reduced below each side product draw-off point along the tower to correspond to the decrease in liquid flow to conserve materials of construction and maintain balanced V/L traffic through the tower. To reduce the top diameter of the tower and even the liquid loading over the length of the tower, intermediate heat-removal streams MPA (pumparounds) must be used.
- **Better vapor-liquid traffic along the tower.** Each side stream product withdrawal decreases the amount of internal liquid (reflux) flowing down below that point in the column. To generate uniform liquid-vapor load through the column a portion of liquid is removed, cooled, and routed back to the column, this cooled stream condenses more of the vapor coming up the tower and provides the reflux (liquid traffic) below the product draw-off point.

Crude Furnace or Crude Heater (Direct Fired Heater or Charge Heater)

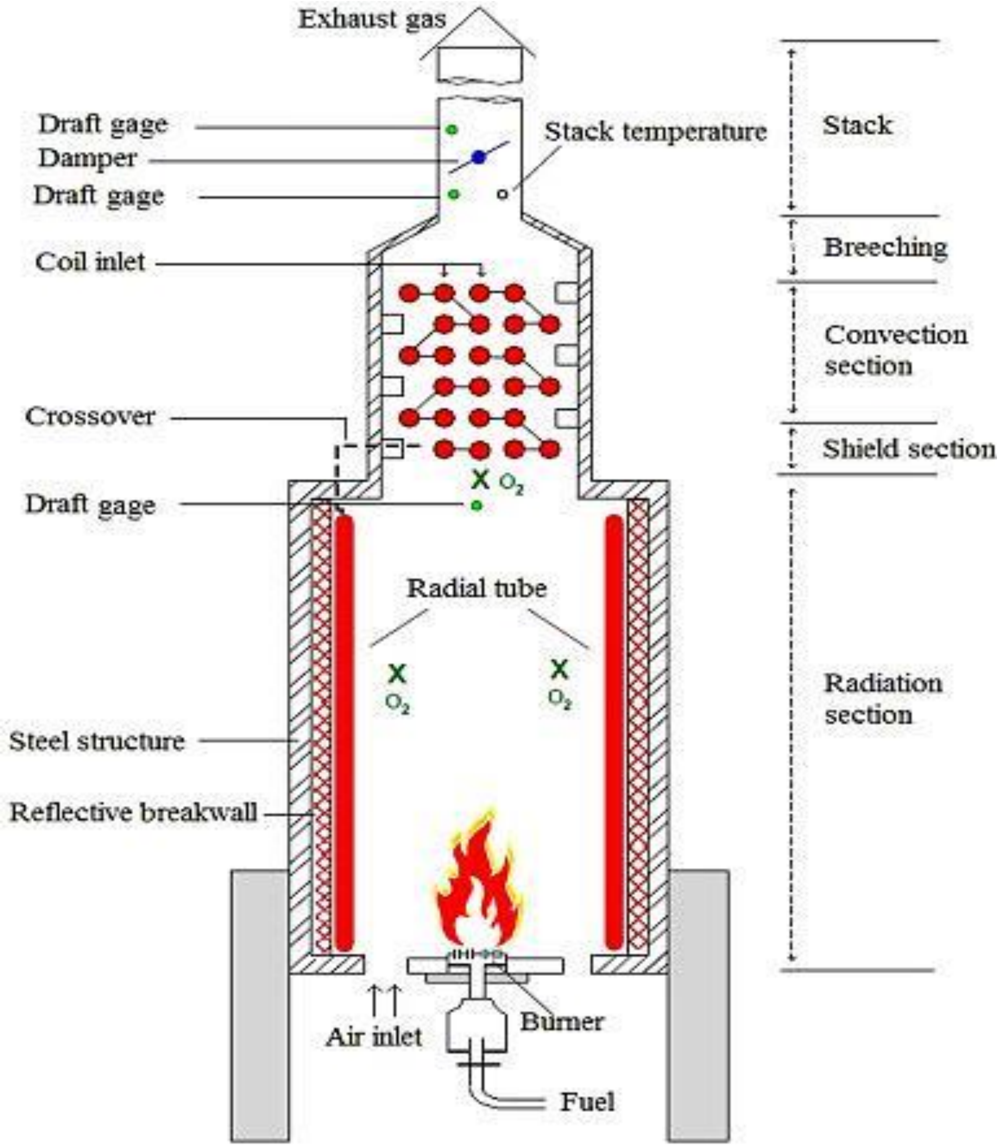


Figure 4: Typical fired heater or process furnace in CDU.

- The crude heater raises the temperature of the crude from 250 ºC to about 350 ºC to vaporize all the products withdrawn above the flash zone (total gas, naphtha, kerosene, diesel products) plus the over-flash (10 to 20% of the bottoms product).
- The crude enters the heater through four-six passes into the convection section where it is heated by the flue (combustion) gases, and then enters the radiation section for further heating.

- The passes join together at the heater outlet and enter the flash zone of the fractionator.
- The heater is equipped with an air preheat system to increase the efficiency (91.5%).
- The heater is both gas and oil fired (for flexibility).
- The skin temperature of each coil can be taken as an indication to the flow in each coil. If the skin temperature of one pass is much higher than the others, the flow in that pass is insufficient and must be increased.
- Heater outlet temperature is controlled by a temperature controller that regulates the amount of fuel (gas or oil) burned in the heater.
- This temperature should not exceed 350 °C to prevent cracking of the feed or damage to the heater tubes. A process heater operating properly will have a zero, or slightly negative draft, at the shield section. The firebox will be slightly positive (+0.5 to +2.0) water column (mmH2O) and the stack will have a range of (-0.5 to -1.0 mmH2O).

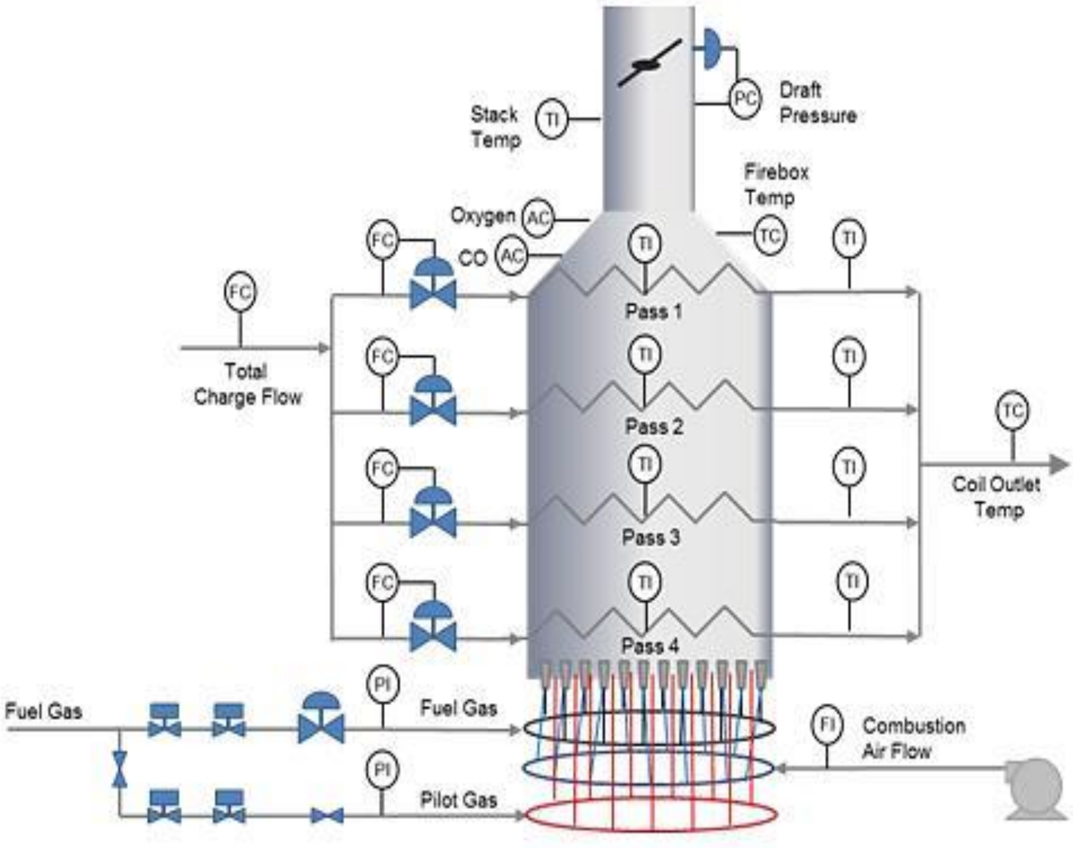
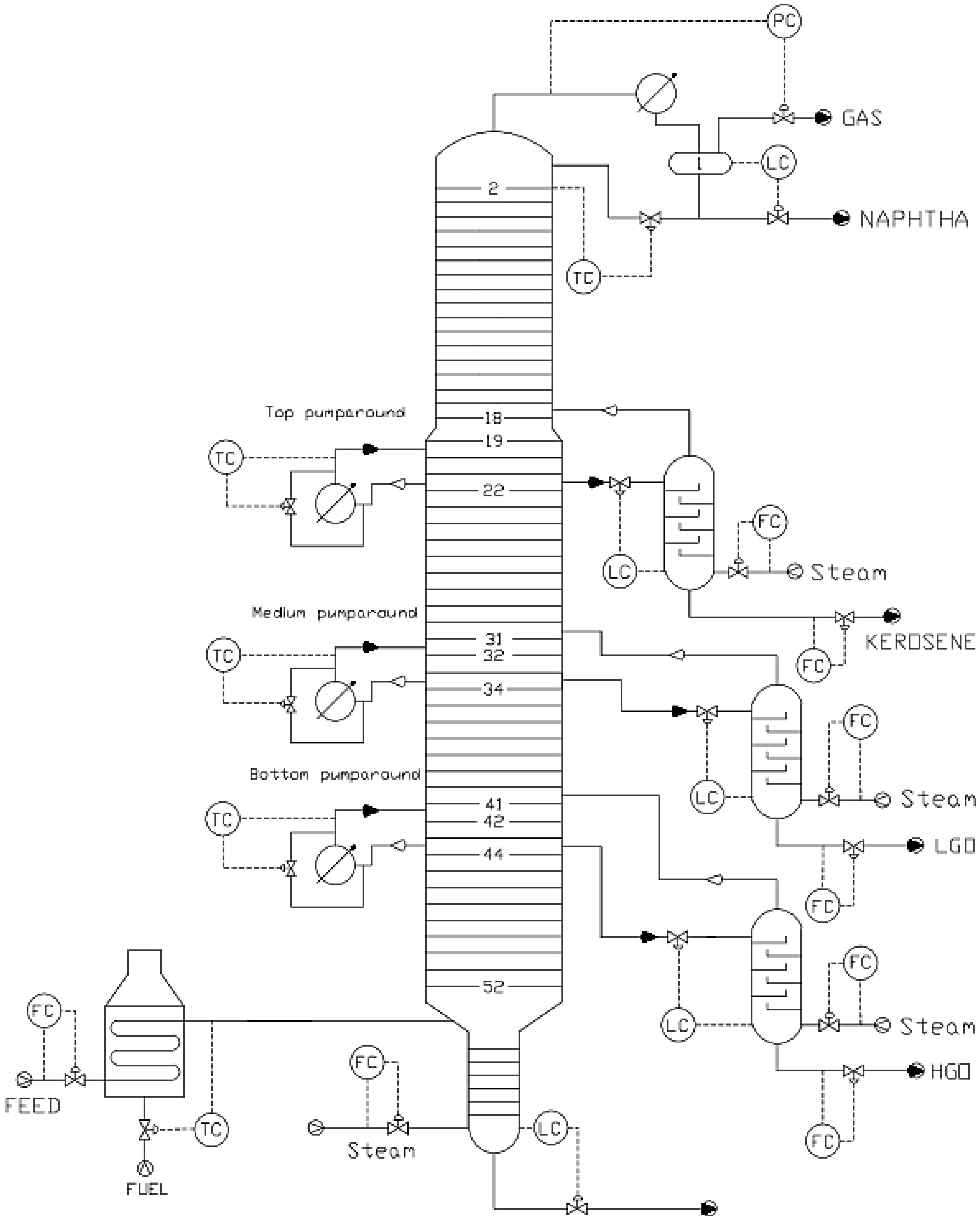


Figure 5: **A schematic flow diagram for feed dividing to fired heater in CDU**

Atmospheric Crude Distillation Tower (design and internals)

Distillation is a physical process for the separation of liquid mixtures which is based on difference in the volatilities of the components of mixture. Main sections you should know:

- **Column overhead section:** condenser (to cool and condense the vapour leaving the top of the column), receiver (reflux drum hold condensed vapour), reflux/product pump recycle back liquid to the column, pressure control.
- **Rectification section:** side reflux, side draw, side stripper.
- **Zone flash section:** feed inlet
- **Stripping section:** wash section (steam stripping addition).
- **Bottom section:** bottom product pump.
- **Separation Trays:** 30-50 trays, which are used to enhance component separations.
- **Vertical shell:** where the separation of liquid components is carried out.
- **Reboiler** to provide the necessary vaporization for the distillation process. The above components are used either to transfer heat energy or enhance mass transfer.

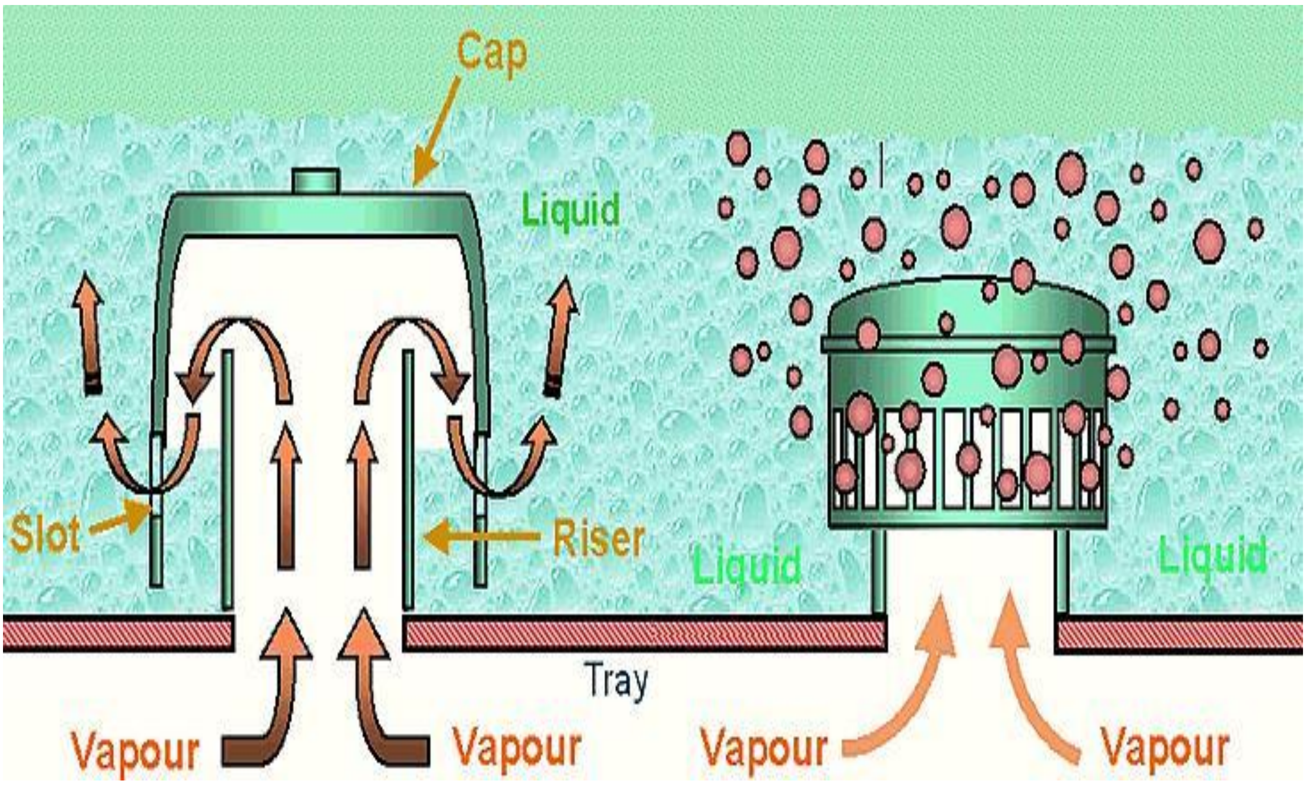


The fractionator operates at slightly above atmospheric pressure.

- 19.7 psia at the fractionator O/H reflux drum.
- 34.7 psia at the fractionator O/H.
- 39.1 psia at the flash zone.

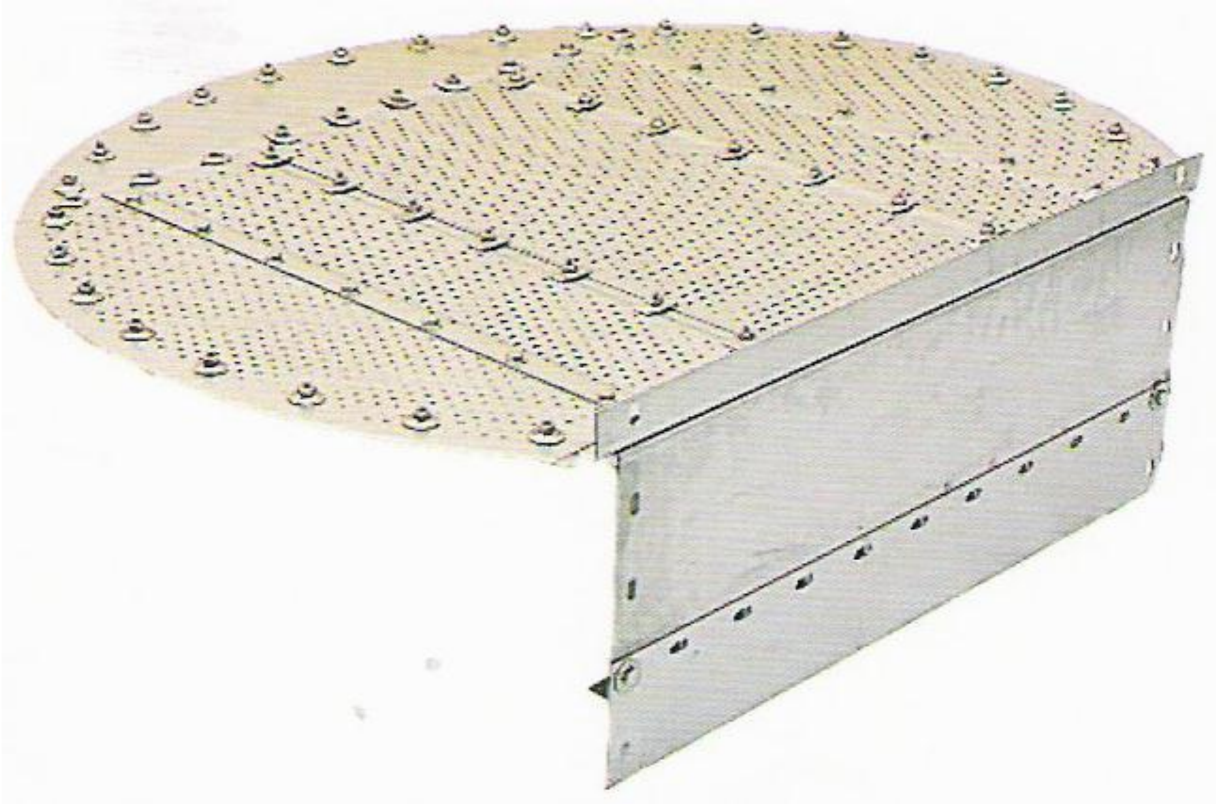
Tray Design

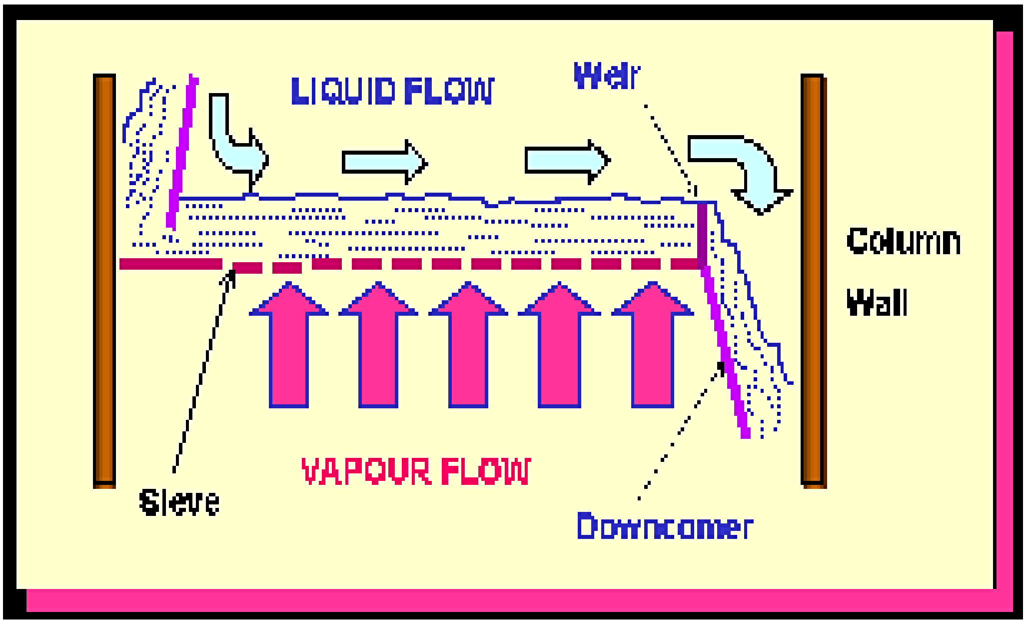
- A tray acts as a mini-column, each accomplishing a fraction of the separation task
- The more trays there are, the better the degree of separation and that overall separation efficiency will depend significantly on the design of the tray.
- Trays are designed to maximize vapour-liquid contact by considering the liquid distribution and vapour distribution on the tray.
- Better vapour-liquid contact means better separation at each tray, translating to better column performance.
- At each tray partial vaporization of light components (heat transfer from heavy liquid to light liquid) and partial condensation takes place. Bubble cap trays above the flash zone (fractionation zone or enriching section).
- Despite their higher efficiency, bubble caps are avoided in the stripping zone of crude oil fractionators because of:
- High velocity of the steam tends to rip-off the caps.
- High viscosity of the residue negligent the role of caps.
- A bubble cap tray has riser fitted over each hole. The cap is mounted so that there is a space between riser and cap to allow the passage of vapour.
- Vapour rises through the chimney and is directed downward by the cap, finally discharging through slots in the cap, and finally bubbling through the liquid on the tray.


Cap
Liquid
Slot
Riser
Liquid
Liquid
Tray
Vapour
Vapour
Vapour
Vapour

Sieve tray

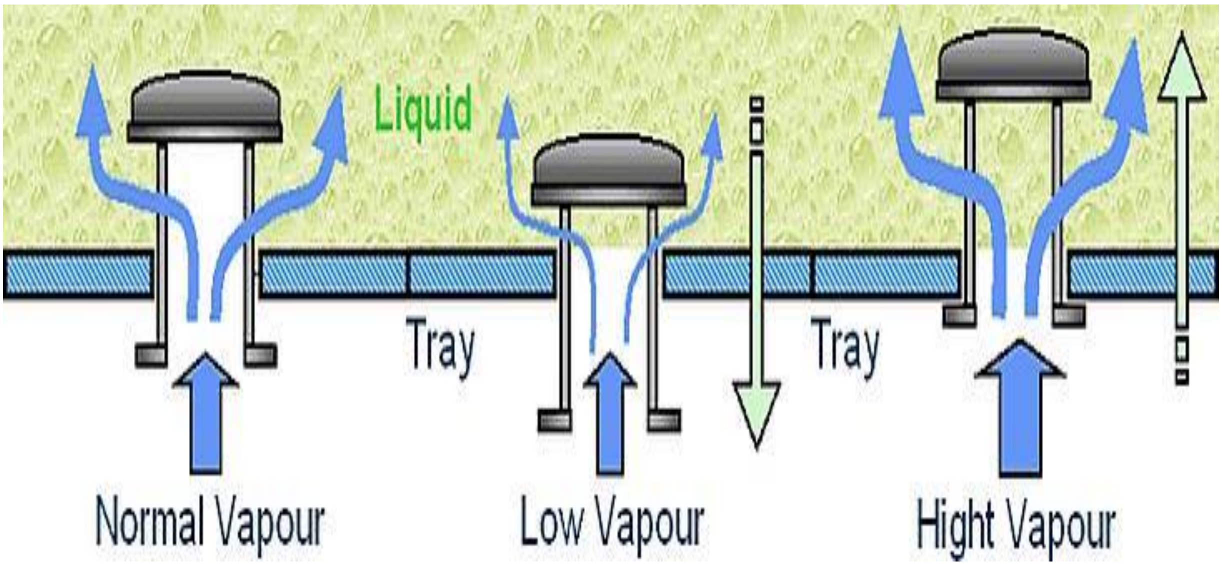
Sieve trays below the flash zone (stripping zone or stripping section).





- Sieve trays are metal plates with holes in them.
- Vapour passes straight upward through the liquid on the plate.
- Because of their efficiency, wide operating range, ease of maintenance and cost factors, sieve and valve trays have replaced the bubble cap trays in many applications.

Valve tray at the column overhead



- In valve trays, perforations are covered by lift-able caps.
- Vapour flows lifts the caps, thus self-creating a flow area for the passage of vapour.
- The lifting cap directs the vapour to flow horizontally into the liquid, thus providing better mixing than is possible in sieve trays.