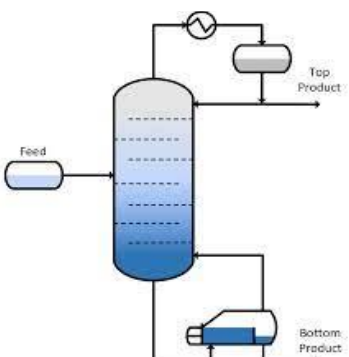
Distillation:



Distillation

- **Distillation** is a method of separating mixtures based on differences in their volatilities in a boiling liquid mixture. Distillation is a physical separation process, and not a chemical reaction.
- Uses:-

1. Crude oil
2. Water is distilled to remove impurities
3. Air is distilled to separate its components
4. Distillation of fermented solutions to produce distilled beverages with a higher alcohol content.

The premises where distillation is carried out, especially distillation of alcohol, are known as a **distillery**.

VARIOUS TYPES OF DISTILLATION

- Simple Distillation
- Molecular Distillation
- Vacuum Distillation
- Batch Distillation
- Continuous Distillation
- Flash Distillation
- Fractional Distillation
- Azeotropic Distillation

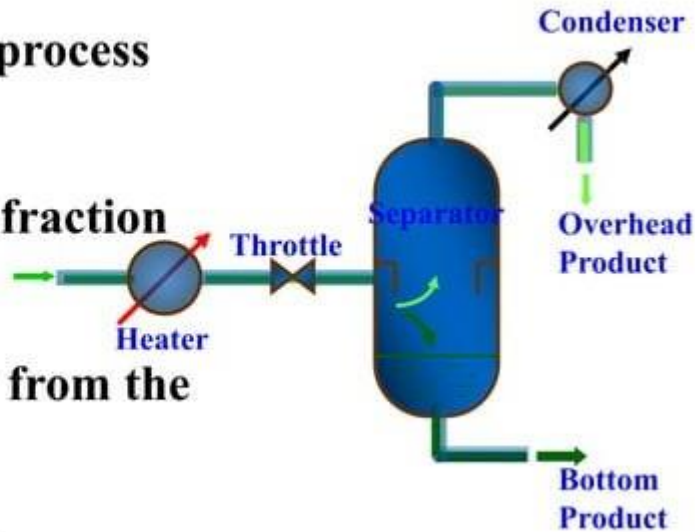
Flash Distillation

(1) The flash distillation process consists of three parts.

a. Vaporizing a definite fraction of the liquid ;

b. Separating the vapor from the liquid;

c. Condensing the vapor.



Features

a. Continuous steady state
Operating conditions (T & P)
are constant.

b. Compositions & flow rates of
feed , products of overhead
and bottom are constant.

c. There is equilibrium always
between phases of vapor and liquid .

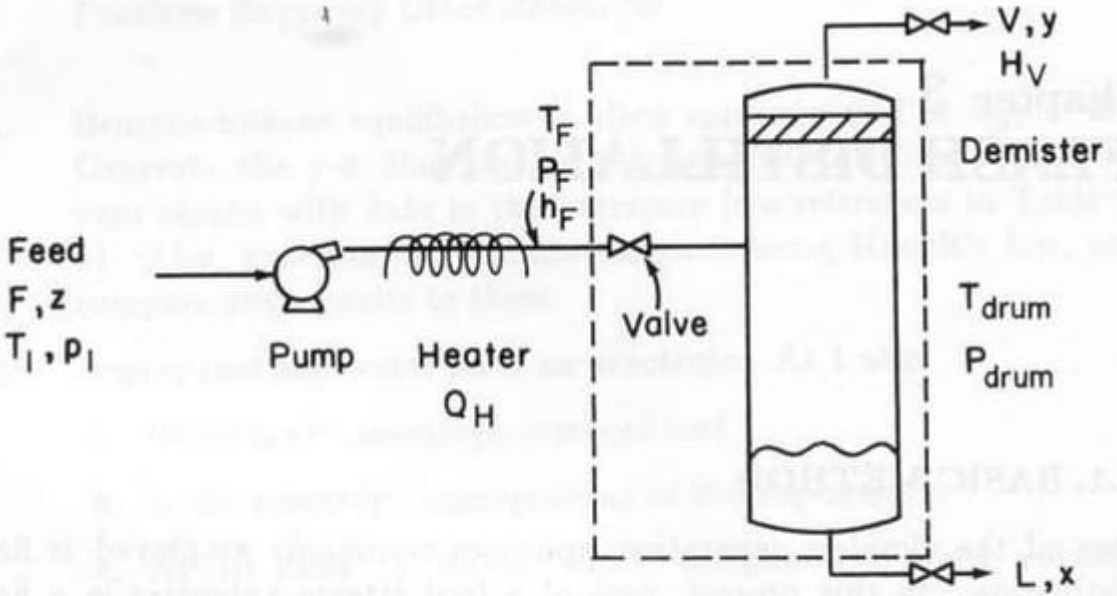


Figure 3-1. Flash distillation system.

Flash Distillation

- **Flash evaporation** is the partial vaporization that occurs when a saturated liquid stream undergoes a reduction in pressure by passing through a valve or other device. If the valve or device is located at the entry into a pressure vessel so that the flash evaporation occurs within the vessel, then the vessel is often referred to as a flash drum.
- If the saturated liquid is a single-component liquid (for example, liquid propane or liquid ammonia), a part of the liquid immediately "flashes" into vapor. Both the vapor and the residual liquid are cooled to the saturation temperature of the liquid at the reduced pressure. This is often referred to as "auto-refrigeration" and is the basis of most conventional vapor compression refrigeration systems.
- If the saturated liquid is a multi-component liquid (for example, a mixture of propane, isobutane and normal butane), the flashed vapor is richer in the more volatile components than is the remaining liquid.

Flash Distillation:

- Flash distillation (sometimes called "equilibrium distillation") is a single stage separation technique. A liquid mixture feed is pumped through a heater to raise the temperature and enthalpy of the mixture. It then flows through a valve and the pressure is reduced, causing the liquid to partially vaporize. Once the mixture enters a big enough volume (the "flash drum"), the liquid and vapor separate. Because the vapor and liquid are in such close contact up until the "flash" occurs, the product liquid and vapor phases approach equilibrium.
- Simple flash separations are very common in industry, particularly petroleum refining. Even when some other method of separation is to be used, it is not uncommon to use a "pre-flash" to reduce the load on the separation itself.

When is flash distillation used?

flash distillation = a single equilibrium stage

1. when very crude separation is needed
   e.g., oil/water separation in crude oil refining

2. when volatilities of components in the mixture are very different
   e.g., water desalination (4000 plants worldwide, producing 3.4 billion gallons potable H_2O daily)

Batch Distillation

Production of vapor by boiling the liquid mixture to be separated and condensing the vapors without allowing any liquid to return to the still.

Continuous Distillation

Based on the return of part of the condensate to the still under such conditions that this returning liquid is brought into intimate contact with the vapors on their way to the condenser.

PLATE CONTACTORS:

Cross flow plate are the most commonly used plate contactor in distillation. In which liquid flows downward and vapours flow upward. The liquid move from plate to plate via down comer. A certain level of liquid is maintained on the plates by weir.

I prefer **Sieve Plate** because:

- Pressure drop is low as compared to bubble cap trays
- Their fundamentals are well established, entailing low risk.
- The trays are low in cost relative to many other types of trays.
- They can easily handle wide variations in flow rates.
- They are lighter in weight. It is easier and cheaper to install.
- Maintenance cost is reduced due to the ease of cleaning.

FACTORS AFFECTING DISTILLATION COLUMN OPERATION

Adverse vapour flow conditions can cause:

- **Blowing**
- **Coning**
- **Dumping**
- **Raining**
- **Weeping**
- **Flooding**

BASIC DISTILLATION EQUIPMENT AND OPERATION

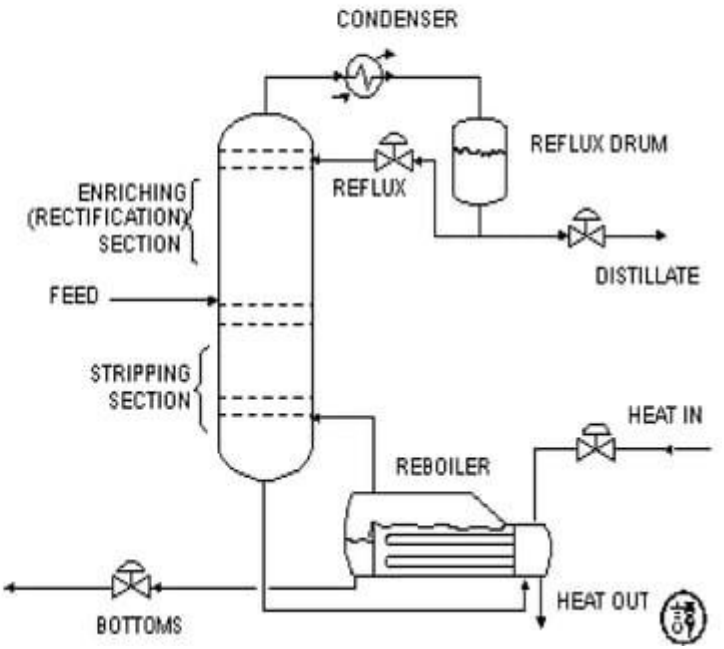
Main Components of Distillation Columns

Distillation columns are made up of several components, each of which is used either to tranfer heat energy or enhance materail transfer. A typical distillation contains several major components:

- a vertical shell where the separation of liquid components is carried out
- column internals such as trays/plates and/or packings which are used to enhance component separations
- a reboiler to provide the necessary vaporisation for the distillation process
- a condenser to cool and condense the vapour leaving the top of the column
- a reflux drum to hold the condensed vapour from the top of the column so that liquid (reflux) can be recycled back to the column

BASIC DISTILLATION EQUIPMENT AND OPERATION

The vertical shell houses the column internals and together with the condenser and reboiler, constitute a distillation column. A schematic of a typical distillation unit with a single feed and two product streams is shown below:



BASIC DISTILLATION EQUIPMENT AND OPERATION

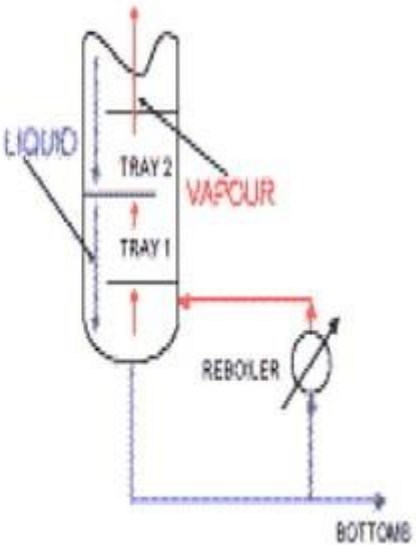
Basic Operation and Terminology

The liquid mixture that is to be processed is known as the feed and this is introduced usually somewhere near the middle of the column to a tray known as the feed tray. The feed tray divides the column into a top (enriching or rectification) section and a bottom (stripping) section. The feed flows down the column where it is collected at the bottom in the reboiler.

BASIC DISTILLATION EQUIPMENT AND OPERATION

Basic Operation and Terminology

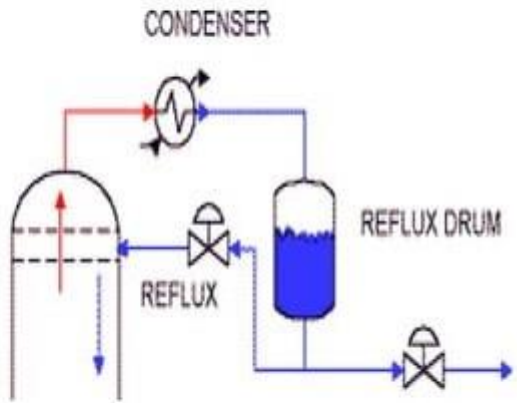
Heat is supplied to the reboiler to generate vapour. The source of heat input can be any suitable fluid, although in most chemical plants this is normally steam. In refineries, the heating source may be the output streams of other columns. The vapour raised in the reboiler is re-introduced into the unit at the bottom of the column. The liquid removed from the reboiler is known as the bottoms product or simply, bottoms.



BASIC DISTILLATION EQUIPMENT AND OPERATION

Basic Operation and Terminology

The vapour moves up the column, and as it exits the top of the unit, it is cooled by a condenser. The condensed liquid is stored in a holding vessel known as the reflux drum. Some of this liquid is recycled back to the top of the column and this is called the reflux. The condensed liquid that is removed from the system is known as the distillate or top product.



Thus, there are internal flows of vapour and liquid within the column as well as external flows of feeds and product streams, into and out of the column.

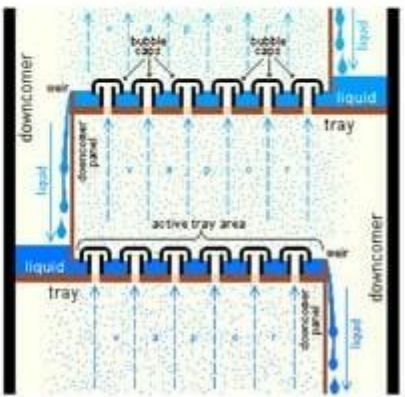
COLUMN INTERNALS

Trays and Plates

The terms "trays" and "plates" are used interchangeably. There are many types of tray designs, but the most common ones are :

Bubble cap trays

A bubble cap tray has riser or chimney fitted over each hole, and a cap that covers the riser. 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.



- Because of its high cost and complexity, most modern column designs favour the use of sieve or valve trays over bubble-cap trays. Bubble-caps should only be used where very low vapour rates have to be handled, or adequate residence time is necessary for separation and/or chemical reaction, or in applications where a positive liquid seal is essential at all flow rates.

COLUMN INTERNALS

Sieve trays

Sieve trays are simply metal plates with holes in them. Vapour passes straight upward through the liquid on the plate. The arrangement, number and size of the holes are design parameters.

Because of their efficiency, wide operating range, ease of maintenance and cost factors, sieve and valve trays have replaced the once highly thought of bubble cap trays in many applications.

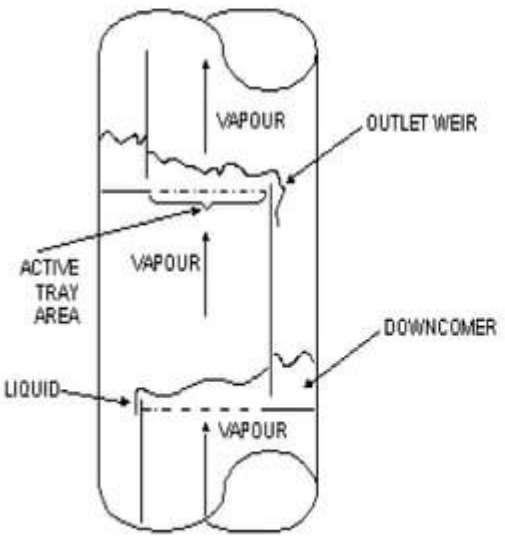
Single pass sieve tray (1600 mm dia.) constructed from stainless steel

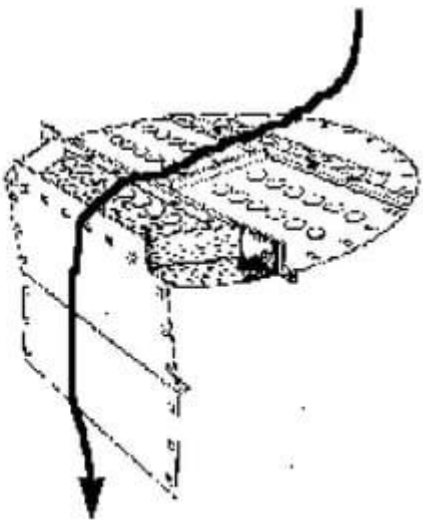
- he sieve tray was developed. Sieve tray has almost the opposite characteristics of the bubble-cap tray. It is inexpensive to male. With proper design, it has low pressure drop, fairly good capacity and efficiency. However, its turn down ratio often does not meet flexibility demanded by the operating facility.

COLUMN INTERNALS

Liquid and Vapour Flows in a Tray Column

The next few figures show the direction of vapour and liquid flow across a tray, and across a column.

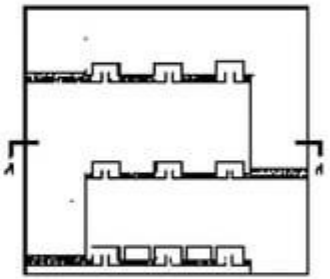




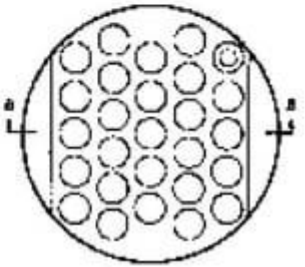
COLUMN INTERNALS

Each tray has 2 conduits, one on each side, called 'downcomers'. Liquid falls through the downcomers by gravity from one tray to the one below it. The flow across each plate is shown in the above diagram on the right.

A weir on the tray ensures that there is always some liquid (holdup) on the tray and is designed such that the the holdup is at a suitable height, e.g. such that the bubble caps are covered by liquid.



Being lighter, vapour flows up the column and is forced to pass through the liquid, via the openings on each tray. The area allowed for the passage of vapour on each tray is called the active tray area.



COLUMN INTERNALS

As the hotter vapour passes through the liquid on the tray above, it transfers heat to the liquid. In doing so, some of the vapour condenses adding to the liquid on the tray. The condensate, however, is richer in the less volatile components than is in the vapour. Additionally, because of the heat input from the vapour, the liquid on the tray boils, generating more vapour. This vapour, which moves up to the next tray in the column, is richer in the more volatile components. This continuous contacting between vapour and liquid occurs on each tray in the column and brings about the separation between low boiling point components and those with higher boiling

COLUMN INTERNALS

Tray Designs

A tray essentially acts as a mini-column, each accomplishing a fraction of the separation task. From this we can deduce that 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 maximise vapour-liquid contact by considering

- the liquid distribution and
- vapour distribution

on the tray. This is because better vapour-liquid contact means better separation at each tray, translating to better column performance. Less trays will be required to achieve the same degree of separation. Attendant benefits include less energy usage and lower construction costs.

There is a clear trend to improve separations by supplementing the use of trays by additions of packings.

COLUMN INTERNALS

Packings

Packings are passive devices that are designed to increase the interfacial area for vapour-liquid contact. The following pictures show 3 different types of packings.

These strangely shaped pieces are supposed to impart good vapour-liquid contact when a particular type is placed together in numbers, without causing excessive pressure-drop across a packed section. This is important because a high pressure drop would mean that more energy is required to drive the vapour up the distillation column.

COLUMN INTERNALS

Packings versus Trays

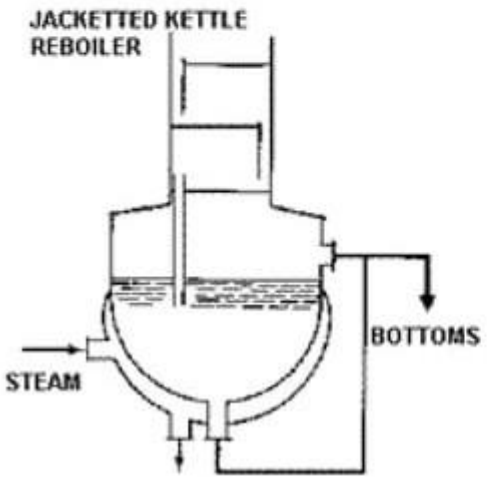
A tray column that is facing throughput problems may be de-bottlenecked by replacing a section of trays with packings. This is because:

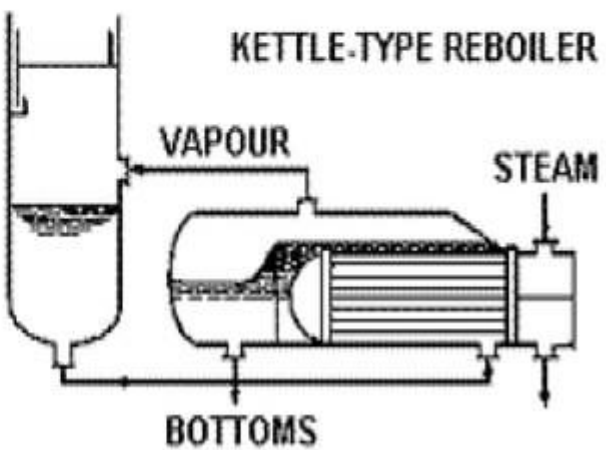
- packings provide extra inter-facial area for liquid-vapour contact
- efficiency of separation is increased for the same column height
- packed columns are shorter than trayed columns

Packed columns are called continuous-contact columns while trayed columns are called staged-contact columns because of the manner in which vapour and liquid are contacted.

COLUMN REBOILERS

There are a number of designs of reboilers. It is beyond the scope of this set of introductory notes to delve into their design principles. However, they can be regarded as heat-exchangers that are required to transfer enough energy to bring the liquid at the bottom of the column to boiling boint. The following are examples of typical reboiler types.





DISTILLATION PRINCIPLES

Separation of components from a liquid mixture via distillation depends on the differences in boiling points of the individual components. Also, depending on the concentrations of the components present, the liquid mixture will have different boiling point characteristics. Therefore, distillation processes depends on the vapour pressure characteristics of liquid mixtures.

DISTILLATION PRINCIPLES

Vapour Pressure and Boiling

The vapour pressure of a liquid at a particular temperature is the equilibrium pressure exerted by molecules leaving and entering the liquid surface. Here are some important points regarding vapour pressure:

- energy input raises vapour pressure
- vapour pressure is related to boiling
- a liquid is said to 'boil' when its vapour pressure equals the surrounding pressure
- the ease with which a liquid boils depends on its volatility
- liquids with high vapour pressures (volatile liquids) will boil at lower temperatures
- the vapour pressure and hence the boiling point of a liquid mixture depends on the relative amounts of the components in the mixture
- distillation occurs because of the differences in the volatility of the components in the liquid mixture