EVAPORATION – PRINCIPLES, TYPES OF EVAPORATORS

Evaporation is an operation used to remove a liquid from a solution, suspension, or emulsion by boiling off some of the liquid. It is thus a thermal separation, or thermal concentration, process. We define the evaporation process as one that starts with a liquid product and ends up with a more concentrated, but still liquid and still pumpable concentrate as the main product from the process. There are actually a few instances where the evaporated, volatile component is the main product.

EVAPORATION

Evaporation can be defined as the process where liquid is transformed into a gaseous state. Evaporation can occur only when water is available. Evaporation requires that the humidity of the atmosphere is less than the evaporating surface. Kinetic energy is the collective motion of water molecules in the water. The kinetic energy of the molecules measures the water temperature. Molecules have the highest kinetic energy. So, it can break the hydrogen bonds and escape the water surface. Reducing the water temperature, average kinetic energy is reduced.

Principle:

Evaporation and vapouration are two processes in which simultaneous heat and mass transfer process occurs resulting into separation of vapour from a solution. Evaporation and vapourization occur where molecules obtain enough energy to escape as vapour from a solution. The rate of escape of the surface molecules depends primarily upon the temperature of the liquid, the temperature of the surroundings, the pressure above the liquid, surface area and rate of heat propagation to product.

Factors affecting Evaporation:

The rate of evaporation is depended on the following:

Vapour Pressure

EL = C (ew – ea)

Where, EL = rate of evaporation (mm/day)

C = a constant

ew = the saturation vapour pressure at the water temperature in mm of mercury

ea = the actual vapour pressure in the air in mm of mercury

This equation is known as Dalton's law of evaporation.

Temperature

The rate of evaporation increases with the increase in water temperature.

Wind

The rate of evaporation increases with the wind speed. The critical speed beyond which any further increase in the wind speed has no influence on the evaporation rate.

Atmospheric Pressure

Decrease in the barometric pressure with high altitudes, increases evaporation.

Soluble Salts

Solute is dissolved in water, the vapour pressure of the solution is less than that of pure water and hence causes reduction in the rate of evaporation.

Heat Storage in Water Bodies

Deep-water bodies have more heat storage than surface ones.

Types of Evaporators:

In most cases it is essential that the product be subject to minimal thermal degradation during the evaporation process, requiring that temperature and time exposure must be minimized. This and other requirements brought on by the physical characteristics of the processed product have resulted in the development of a large range of different evaporator types. Additional demands for energy efficiency and minimized environmental impact have driven development toward very innovative plant configurations and equipment design.

In the field of thermal separation / concentration technology, evaporation plants are widely used for concentration of liquids in the form of solutions, suspensions, and emulsions. The major requirement in the field of evaporation technology is to maintain the quality of the liquid during evaporation and to avoid damage to the product. This may require the liquid to be exposed to the lowest possible boiling temperature for the shortest period of time. This and numerous other requirements and limitations have resulted in a wide variation of designs available today. In almost all evaporators the heating medium is steam, which heats a product on the other side of a heat transfer surface.

The following list contains the descriptions of the most common types of evaporators as they may be classified on the following bases;

1.Short tube Evaporator

2.Method of operation of evaporator

(a)Single Effect Evaporators

(b)Forward Feed-Multiple effect Evaporators

(c)Backward-Feed-Multiple Effect Evaporators

(d)Parallel-Feed-Multiple Effect Evaporators

3.Circulation Mechanism

(a)Natural Circulation evaporator

(b)Forced Circulation evaporator

4.Heating Mechanism

(a)Direct Heating Evaporator

(b)Steam Heating evaporator

5.Number of Pass through tubes

(a)Once through evaporation

(b) Multipass evaporation

Short Tube Evaporator

Short-tube vertical evaporators are the oldest type evaporator widely used in sugar industry for evaporation of cane-sugar juice. These are also known as **Calandria or Robert evaporators**. It became so common in process industry; this evaporator is sometimes known as standard evaporator. Short-tube vertical evaporators contain of a short tube bundle (about 4 to 10 ft. in length) enclosed in a cylindrical shell. The feed is introduced above the upper tube sheet and steam is introduced to the shell or steam container of the calandria. Solution is heated and vaporized in tubes. The central tube in a calandria is of longer diameter. Typically, it's down comer area is taken as 40 to 70% of the total cross-sectional area of tubes. The circulation rate through the down comer/down take is many times the feed rate. The flow area of the down take is approximately equal to the total tubular flow area.

Natural Circulation Evaporators

In these evaporators, the liquor flows through the tubes without any external ageny.It flows due to convection currents arising from the heating surface and flows through the tubes due to density differences.

Forced Circulation Evaporators

Forced circulation evaporators are usually costlier than natural circulation evaporators. However, the natural circulation evaporators are not suitable under some situations such as:

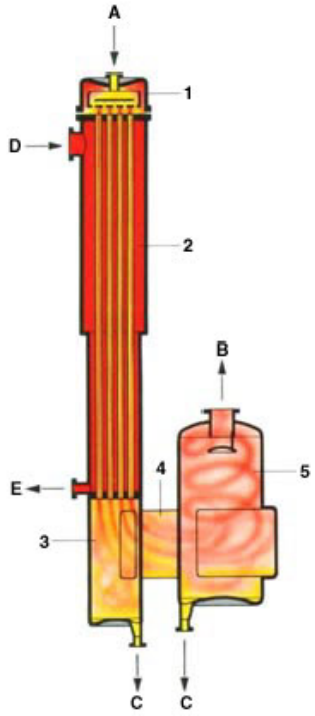
1. Highly viscous solutions due to low heat transfer coefficient,
2. Solution containing suspended particles,
3. For heat sensitive materials.

Problems may be occurred when the liquid is dispersed at high velocity in the heat exchanger tubes to improve the heat transfer rate and prevent particle deposition. Evaporator that can use pump to ensure higher circulation velocity is known as forced circulation evaporator. The main components of a forced circulation evaporator are a tubular shell and tube heat exchanger (horizontal or vertical), a flash chamber (separator) mounted above the heat exchanger and a circulating pump. The solution is heated in the heat exchanger without boiling and the superheated solution flashes off at lower pressure are reduced in the flash chamber. The pumps feed and liquor from the flash chamber and force it through the heat exchanger tubes back to the flash chamber. It is commonly used for concentration of caustic and brine solutions. It can also use in evaporation of corrosive solution.

Falling Film Evaporators

In the falling film evaporator, liquid is fed on the top of the tubes in the vertical tube bundle. The liquid is allowed to flow down through the inner wall of the tubes as a film. As the liquid travels down the tubes, the solvent vaporizes and the concentration slowly increases. Vapor and liquid are generally separated at the bottom of the tubes and the thick liquor is taken out. Evaporator liquid is recirculated in tubes by pump below the vapor-liquid separator. The circulation of liquid in the inner wall of the tubes affects the performance of this type of evaporator. The falling film evaporator is largely used for concentration of fruit juices and heat sensitive materials because of

the low holdup time. The device is suitable for scale-forming solutions as boiling occur on the surface of the film.



A: Product
B: Vapor
C: Concentrate
D: Heating Steam
E: Condensate

1: Head
2: Calandria
3: Calandria, Lower part
4: Mixing Channel
5: Vapor Separator

Fig. 1. Falling Film Evaporator

Wiped (Agitated) Film Evaporators

Agitated thin film evaporator involves a vertical steam-jacketed cylinder. The feed solution flows down as a film beside the inner surface of large diameter jacket. Liquid is circulated on the tube wall by a rotating assembly of blades mounted on shaft placed co-axially with the inner tube. The blades maintain the close clearance of around 1.5 mm or less from the inner tube wall. The main advantage is that rotating blades permits handling of extremely viscous solutions.