

# Evaporation

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# EVAPORATION

## Defination:-

Theoretically,

- “Evaporation means simply vaporization from the surface of a liquid. Vaporization of a liquid below its boiling point is called evaporation.”
- Thus, no boiling occurs and the rate of vaporization depends on the diffusion of vapour through the boundary layers above the liquid.



- Thus a practical definition of evaporation is
- “The removal of liquid from a solution by boiling the solution in a suitable vessel and withdrawing the vapour, leaving a concentrated liquid residue.”
- This means that heat will be necessary to provide the latent heat of vaporization and, in general the rate of evaporation is controlled by the rate of heat transfer.
- Evaporators are designed, therefore, to give maximum heat transfer to the liquid, with the largest possible area, a suitable temperature gradient.



# Mechanism

- When heat applied in solution the motion of molecules increase and molecules present in the surface overcome the surface tension of the liquid and it evaporates because surface molecules have less cohesive force than others.



# Factors affecting the Evaporation

- There are seven factors to affect evaporation.
  1. Temperature
  2. Surface area
  3. Agitation
  4. Atmospheric aqueous vapour pressure
  5. Atmospheric pressure on the liquid under evaporation
  6. Type of product required
  7. Economic factors



- 1) Temperature:** The rate of evaporation is directly proportional to the temperature.
- 2) Surface area:** The rate of evaporation is directly proportional to the surface area of the vessel exposed to evaporation.
- 3) Agitation:** is necessary for evaporation.
- 4) Atmospheric aqueous vapour pressure:** The rate of evaporation is inversely proportional to the atmospheric aqueous vapour pressure.



- 5) **Atmospheric pressure on the liquid under evaporation:** The rate of evaporation is inversely proportional to the atmospheric pressure on the liquid under evaporation.
- 6) **Type of product required:** The selection of the method and apparatus to be used for evaporation depends upon type of product required.
- 7) **Economic factors:** When selecting the method and apparatus the economic factors are important



# Principles

- Steam heat is used for transfer of heat for subsequent vessels. Steam has a very high heat content Heat is given up at constant temperature.
- It can be used at high pressure to generate electric power and low-pressure exhaust steam is used for process heating.
- Evaporation is a process of vaporizing large quantities of volatile liquid to get a concentrated product.
- Evaporation is a surface phenomenon, i.e., mass transfer takes place from the surface.



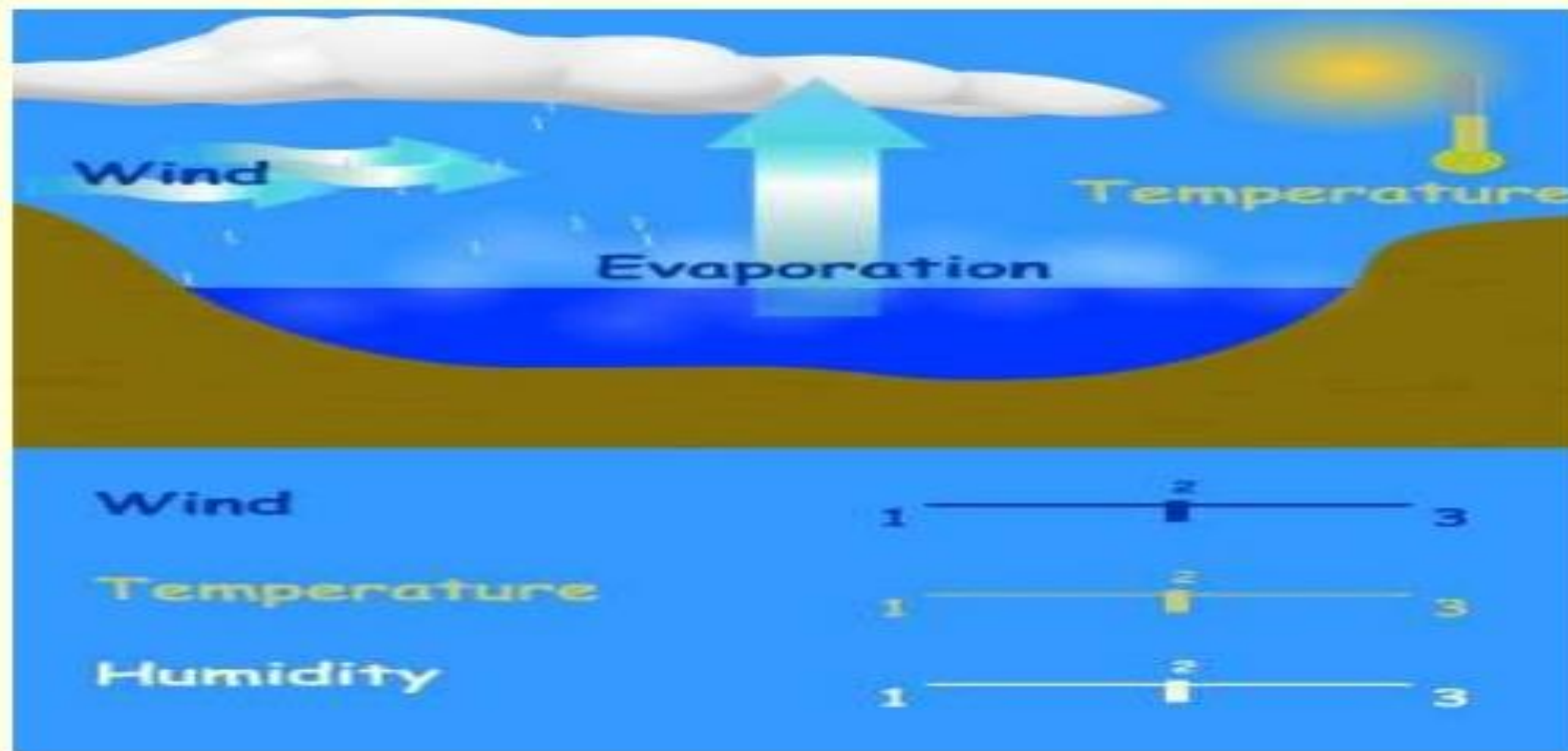
# Why we need evaporation

Reduces transportation cost

- Storage costs
- Prepare for the next Unit operation – drying, crystallisation etc.
- Reduces deteriorative chemical reactions
- Better microbiological stability
- Recovery of solvent



## EXAMPLE OF EVAPORATION PROCESS



# THANK YOU



# EVAPORATION UNDER REDUCED PRESSURE

- At reduced pressure evaporation increases.

## **Advantage:**

1. Evaporation occurs at low temperature, with less risk of damage to heat sensitive materials.
2. A lower operating temperature gives higher temperature gradients, without the need of excessive steam pressures.
3. The lower the operating, temperature the lower the steam pressure that can be used.

# EQUIPMENT USED FOR EVAPORATION

- Equipments which are used for evaporation are called Evaporators.

## **Types of Evaporator:**

- Evaporators are divided mainly into three groups.

### 1. Natural circulation evaporator

#### ❖ Types:

- i) Evaporating pans
- ii) Evaporating stills
- iii) Short tube evaporator.

2) Forced circulation evaporator.

3) Film evaporator

Types:

i) Wiped Film evaporator

ii) Long Tube Evaporator

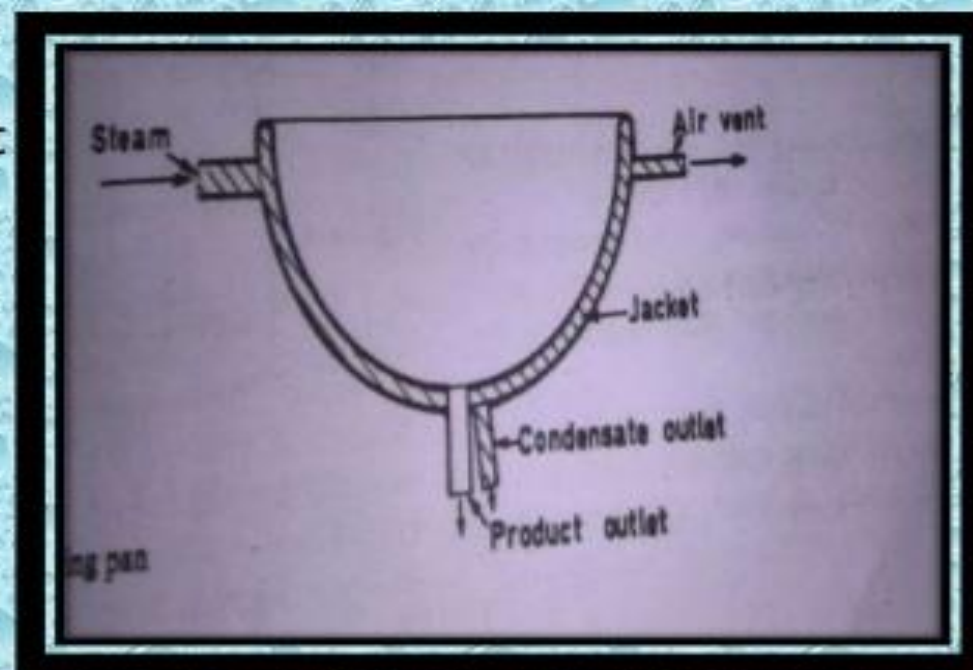
a) Climbing film evaporator

b) Falling film evaporator

# 1) NATURAL CIRCULATION EVAPORATORS

- **Working principle:**
- The movement of the liquid results from convection currents set up by the heating process.
- **Convection currents:** The process in which heat moves through a gas or liquid as the hotter parts rises and the cooler part sinks.

- **Working:**
- The dilute solution is taken in the pan. Steam is introduced through the steam inlet into the jacket to heat the pan. In these evaporators the movement of the liquid results from convection currents set up by the heating process. The concentrated liquid is collected through the outlet placed at the bottom of the pan.



## Advantages

- 1) They are simple, easy and cheap to construct.
- 2) They are easy to use and clean.
- 3) Stirring of the evaporating liquids can be done easily.

## Disadvantage

- 1) The whole of the liquid is heated all the time which may lead to decomposition of the components.
- 2) On the evaporating surface foam is rapidly formed which decreases evaporation. Solids may be deposited at the bottom which make the stirring necessary.
- 3) This pan can only be used for evaporating aqueous and thermostable liquid extracts.
- 4) They can not be used for evaporating extracts containing organic solvents like alcohol etc.

## ii) Evaporating still

- **Construction**
- It consists of a jacketed-evaporating pan with a cylindrical *cover* that connects it to a condenser. The over all assembly is called *still*. The cover is clamped with the evaporating pan.

## Working :

- The dilute liquid is fed into the still, the cover is clamped. Steam is introduced into the jacket. The liquid is evaporated and condensed in the condenser and collected. The product (i.e. concentrated liquid) is collected through the product outlet.

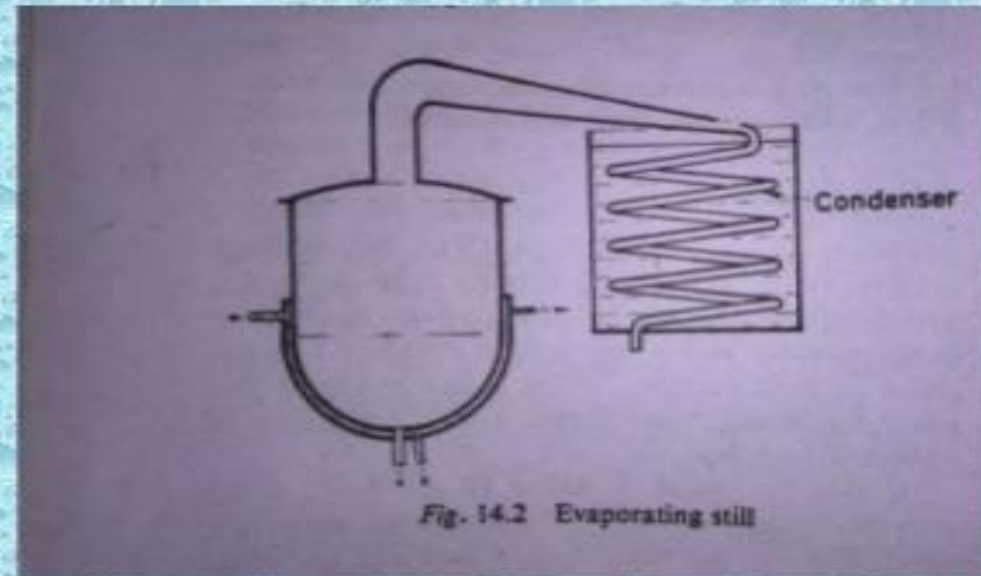


Fig. 14.2 Evaporating still

### **Advantages:**

- Easy to clean and maintain.
- Allow the equipment to be used for solvents other than water. E.g. ethanol.

### **Disadvantages:**

- All the liquor is heated all the time.
- The heating surface is limited.

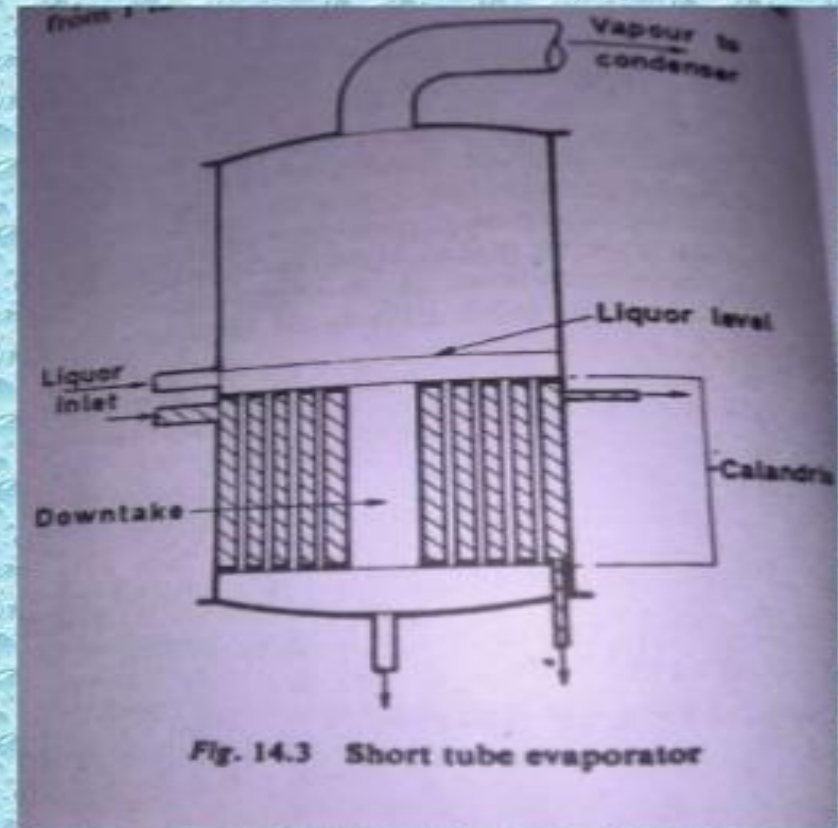
### iii) Short tube evaporator

#### Construction:

- The evaporator is a cylindrical vessel. The lower portion of the vessel consists of a nest of tubes with the liquor inside and steam outside— this assembly is called *calendra*.
- The specifications of calendria are as follows:
  - Tube length: 1 – 2 m
  - Tube diameter: 40 – 80 mm
  - Diameter of evaporator: 2.5 m
  - Number of tubes: 1000
- The feed inlet is at the top of the calendra. The product outlet is placed at the bottom of the evaporator. Steam inlet and outlet is placed from the side of the calendria.

### Working:

- The liquor in the tubes is heated by the steam and begins to boil, when the mixture of liquid and vapor will shoot up the tubes (in a similar manner to that of a liquid that is allowed to boil to vigorously in a test-tube).
- The product is collected through the product outlet.



- **Advantages**

- 1. Use of tubular calandria increases the heating area, possibly by a factor of 10 to 15 compared to that of an external jacket.
- 2. Increasing the rate of heat transfer.
- 3. Condenser and receiver can be attached to run the evaporation under vacuum with nonaqueous solvents.

- **Disadvantages**

- 1. Since the evaporator is filled to a point above the level of the calandria, a considerable amount of liquid is heated for a long time. The effect of this continual heating can be reduced to some extent by removing concentrated liquor slowly from the outlet at the bottom of the vessel.
- 2. Complicated design, difficult for cleaning and maintenance.

## 2) Forced circulation evaporators

### Construction:

- The evaporator consists of a short tube calandria and a large cylindrical vessel (body of the evaporator) for separation of vapor and liquid takes place.
- The liquor inlet is provided at the side of the cylindrical vessel.
- A pump is fitted in between the calandria and the body of the evaporator.
- A tangential inlet for liquid under high pressure is placed at neck of the body of the evaporator.
- The vapor outlet is placed at the top of the body and it may be passed through a condenser to collect the condensed liquid.

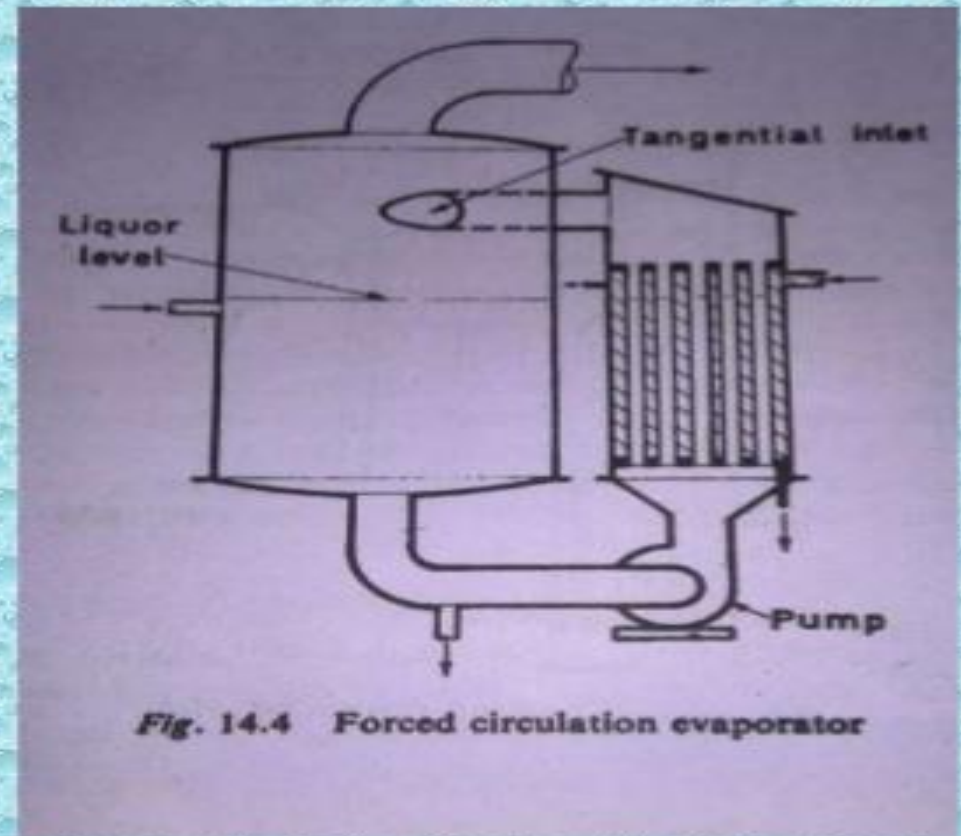
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- The vapor outlet is placed at the top of the body and it may be passed through a condenser to collect the condensed liquid.

### Working principle:

- Feed is introduced through the liquor inlet. Pump will force the liquid through the calandria. Steam heats the liquid inside the calandria. As it is under pressure in the tubes the boiling point is elevated and no boiling takes place. As the liquor leaves the tubes and enters the body of the evaporator through the tangential inlet there is a drop in pressure and vapor flashes off from the superheated liquor. The concentrated liquid is pumped out through the product outlet and the vapor is collected through the vapor outlet.



## Advantages

- 1) These have a great advantage over natural circulation evaporators in that the rapid liquid movement improves heat transfer, especially with viscous liquids or materials that deposit solids or foam readily.
- 2) The equipment is suitable for operation under reduced pressure due to the capacity of the process to overcome the effect of greater viscosity of liquids.
- 3) These evaporators possess rapid evaporation rate.

- 4) These evaporators are mainly used for thermolabile materials.
- 5) These can also be used in practice for the concentration of insulin and liver extracts.

**Disadvantage:**

- Corrosion-erosion can occur, due to high circulation velocities.
- Salt deposits detach and accumulate at the bottom.

### **3) FILM EVAPORATORS**

- Film evaporators spread the material as a film over the heated surface, and the vapor escapes the film.
- Following are the types of film evaporators.
  - i) Wiped Film evaporator
  - ii) Long Tube Evaporator
    - a) Climbing film evaporator
    - b) Falling film evaporator

# APPLICATION OF EVAPORATION

- Evaporation is one of the most important processes in the manufacture of pharmaceuticals.
- It is used in the preparation of
  1. Liquid extracts, soft extracts & dry extracts.
  2. In the concentration of blood plasma & serum.
  3. It is also used in the manufacture of drugs containing, antibiotics, enzymes, hormones & many other substances.

- 4) Used in purification of vitamins.
- 5) Concentration of proteins.
- 6) Concentration of biological products.
- 7) Stripping of solvents from vegetable & plant or herbal extracts.
- 8) Removal of water & solvents from fermentation broths.
- 9) Concentration of penicillin & related products