EVAPORATION

Evaporation is a process that occurs when a liquid turns into a gas, and it has several characteristics.

Evaporation characteristics

Rate: The rate of evaporation depends on the vapor pressure of the liquid, the temperature, surface area, and wind speed.

Surface phenomenon: Evaporation occurs at the surface of the liquid.

Dynamic equilibrium: The process of evaporation and condensation occur at the same rate, so there is no net change in the system.

Thermal flow: There is thermal flow at the interface level.

Evaporative cooling: As faster-moving molecules escape, the remaining molecules have lower average kinetic energy, and the temperature of the liquid decreases.

Factors affecting evaporation

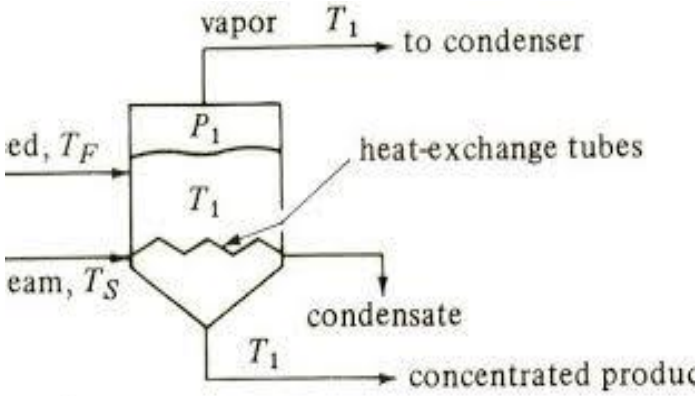
Temperature: Evaporation occurs more quickly at higher temperatures.

Surface area: The greater the surface area of the liquid, the greater the rate of evaporation.

Wind: Evaporation proceeds more quickly with higher flow rates between the gaseous and liquid phase.

Humidity: Atmospheric pressure determines the percent humidity.

SINGLE AND MULTIPLE EFFECT EVAPORATORS



Single-effect evaporators are used

1. when the throughput is low,
2. when a cheap supply of steam is available,
3. when expensive materials of construction must be used as is the case with corrosive feedstocks
4. when the vapour is so contaminated so that it cannot be used

- The feed and saturated steam with temperature at TF and TS respectively enter the heat- exchange section
- Condensed steam leaves as condensate or drips.
- The solution in the evaporator is assumed to be completely mixed.
- Hence, the concentrated product and the solution in the evaporator have the same composition.
- Temperature T1 is the boiling point of the solution.
- The temperature of the vapor is also T1, since it is in equilibrium with the boiling solution.
- The pressure is P1, which is the vapor pressure of the solution at T1
- If the solution to be evaporated is assumed to be dilute and like water, then 1 kg of steam condensing will evaporate approximately 1 kg of vapor (if the feed entering has TF near the boiling point)
- Single-effect evaporators are often used when the required capacity of operation is relatively small and/or the cost of steam is relatively cheap compared to the evaporator cost.
- However, for large-capacity operation, using more than one effect will markedly reduce steam costs
- The heat requirements of single-effect continuous evaporators may be obtained from mass and energy balances.

Advantages:

1. **Simple Design & Operation** – Easier to construct, operate, and maintain.
2. **Lower Initial Cost** – Requires less capital investment compared to multiple effect evaporators.

3. **Effective for Small-Scale Operations** – Suitable for applications where small volumes of liquid need to be concentrated.
4. **Can Handle High Solid Content** – Useful for solutions with high viscosity or solid content.

Disadvantages:

1. **Low Energy Efficiency** – Consumes more steam per unit of evaporated water, leading to higher operational costs.
2. **Higher Steam Consumption** – More expensive to run due to increased fuel usage.
3. **Limited Industrial Use** – Not suitable for large-scale operations where energy efficiency is a priority.

MULTIPLE EFFECT EVAPORATORS

The single effect evaporator uses rather more than 1 kg of steam to evaporate 1 kg of water.

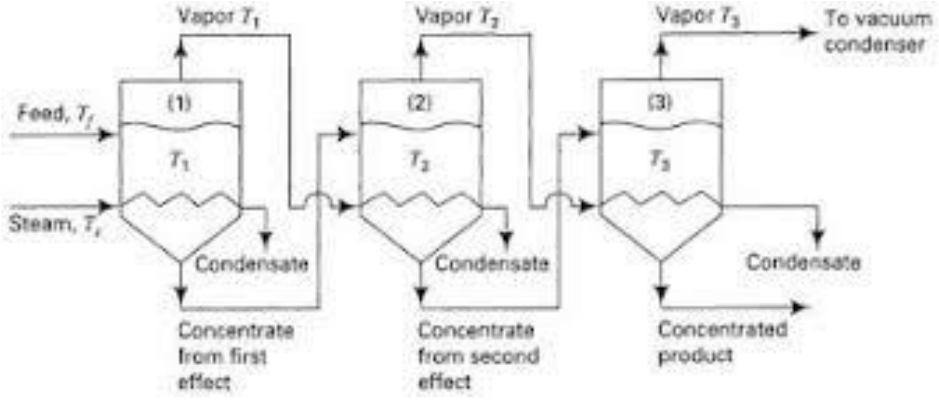
The latent heat of the vapor leaving in single effect evaporator is not used but is discarded.

Much of this latent heat, however, can be recovered and reused by employing a multiple - effect evaporator, that is, vapor from one effect serves as the heating medium for the next.

The economy of the system, measured by the kilograms of water vaporized per kilogram of steam condensed, increases with the number of effects.

in multiple effect evaporator, the pressure in each effect is lower than that of the effect to which it receives steam and higher than that of the effect to which it supplies vapors

Each effect, in itself, act as a single effect evaporator, and each has a temperature drop across its heating surface corresponding to the pressure drop in that effect.



Multiple Effect Evaporator

A **multiple effect evaporator (MEE)** consists of multiple evaporators (effects) connected in series to reuse steam from one stage to the next, improving efficiency.

Advantages:

1. **Higher Energy Efficiency** – Steam is reused in multiple stages, reducing overall steam consumption.
2. **Lower Operating Costs** – Saves fuel and energy costs by utilizing latent heat from previous stages.
3. **Ideal for Large-Scale Production** – Commonly used in industries such as sugar, paper, and chemical processing.
4. **Reduced Environmental Impact** – Lower fuel consumption results in reduced emissions.

Disadvantages:

1. **Higher Initial Investment** – Requires significant capital investment due to complex design and multiple effects.
2. **Complex Maintenance & Operation** – More challenging to maintain and operate compared to single effect evaporators.
3. **Limited for High-Solid Concentration Liquids** – Can face difficulties with highly viscous or solid-rich solutions, leading to scaling and fouling.