आईएफटीएम विश्वविद्यालय, मुरादाबाद, उत्तर प्रदेश

IFTM University, Moradabad, Uttar Pradesh

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IFTM University, Moradabad

EVAPORATION

PHARMACEUTICAL ENGINEERING

Presented by Mrs. Sheetal Negi
School of Pharmaceutical Sciences
IFTM University, Moradabad

syllabus

- **Heat Transfer**: Objectives, applications & Heat transfer mechanisms. Fourier's law, Heat transfer by conduction, convection & radiation. Heat interchangers & heat exchangers.
- **Evaporation**: Objectives, applications and factors influencing evaporation, differences between evaporation and other heat process. principles, construction, working, uses, merits and demerits of Steam jacketed kettle, horizontal tube evaporator, climbing film evaporator, forced circulation evaporator, multiple effect evaporator& Economy of multiple effect evaporator.
- **Distillation**: Basic Principles and methodology of simple distillation, flash distillation, fractional distillation, distillation under reduced pressure, steam distillation & molecular distillation.

Evaporation

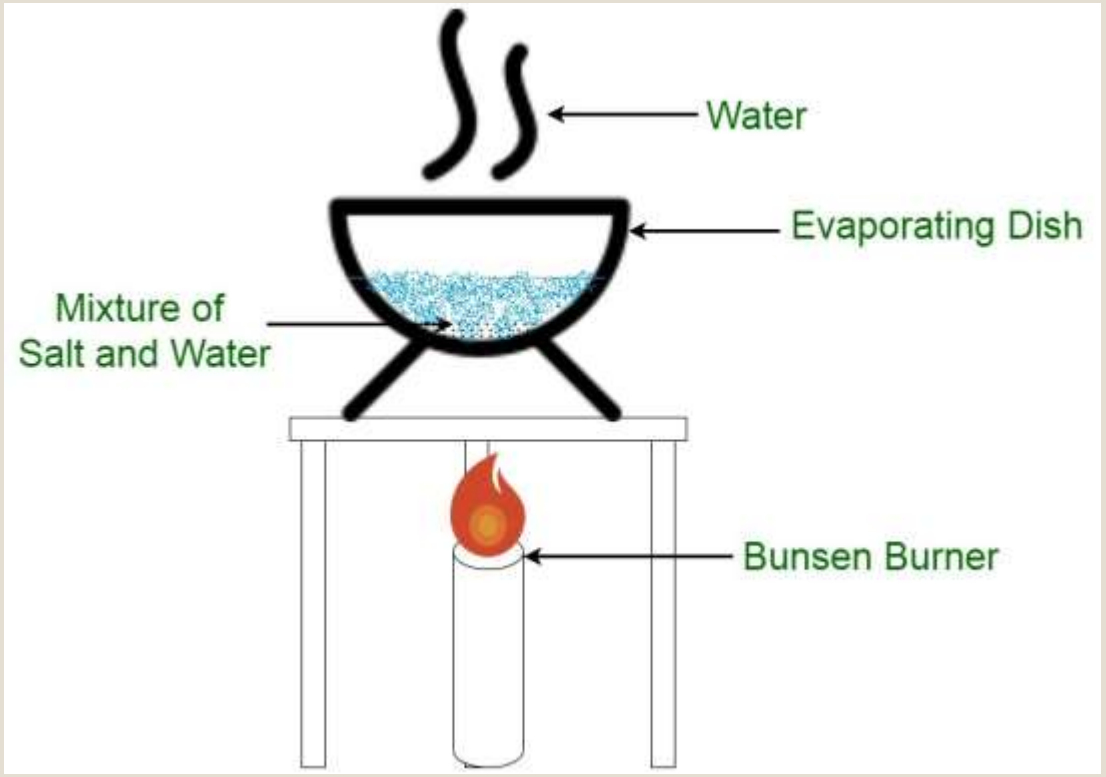
The process by which liquid atoms or molecules vaporize i.e convert into gaseous phase after gaining sufficient Energy (by boiling) is known as evaporation.

Objective & application

- It reduces the bulk and weight of fluids
- To remove large amount of moisture
- Reduce water activity by increasing the conc. Of soluble solids in food material for preservation

Applications

1. Used in concentrating pharmaceutical herbal extracts in herbal industry.
2. It is used in the bulk drug manufacturing.
3. Used in the manufacture of biological products. For example, insulin, enzymes, hormones etc.
4. Used in demineralization of water.
5. used in glucose and fructose syrup concentrations in chromatographic fractions.



Factors Affecting Evaporation

The rate of evaporation is influenced by the following factors:
1) Surface Area: Because evaporation is a surface-
based process, its rate increases as one's surface area increases.
For example, laying out damp garments enables them to dry faster.

2) Temperature: As the temperature rises, more molecules can evaporate because of t
heir increased kinetic energy, which makes it easier for them to enter the vapor state.

3) Humidity: As humidity (the amount of water vapor in the air) rises, the rate of evaporation falls.
At a certain temperature, the air can only contain a certain amount of water vapor.
Thus, the rate of evaporation decreases with increasing air humidity.

- 4) Wind Speed: As the wind picks up more speed, the evaporation rate rises and the surro unding water vapour content decreases as the water vapour particles go with the wind. For instance, wet garments dry more quickly on windy days.

- 5) Liquid Nature: In addition to outside influences, the liquid's intrinsic characteristics have an impact on the rate of evaporation.
  For instance, compared to gasoline, water vapor evaporates considerably more slowly.
  A liquid that evaporates rapidly is referred to as volatile.
  The boiling point of a liquid determines its volatility.
  A liquid has increased volatility and a higher rate of evaporation the lower its boiling point
  The forces of attraction between particles are weaker in liquids that evaporate more quic kly.

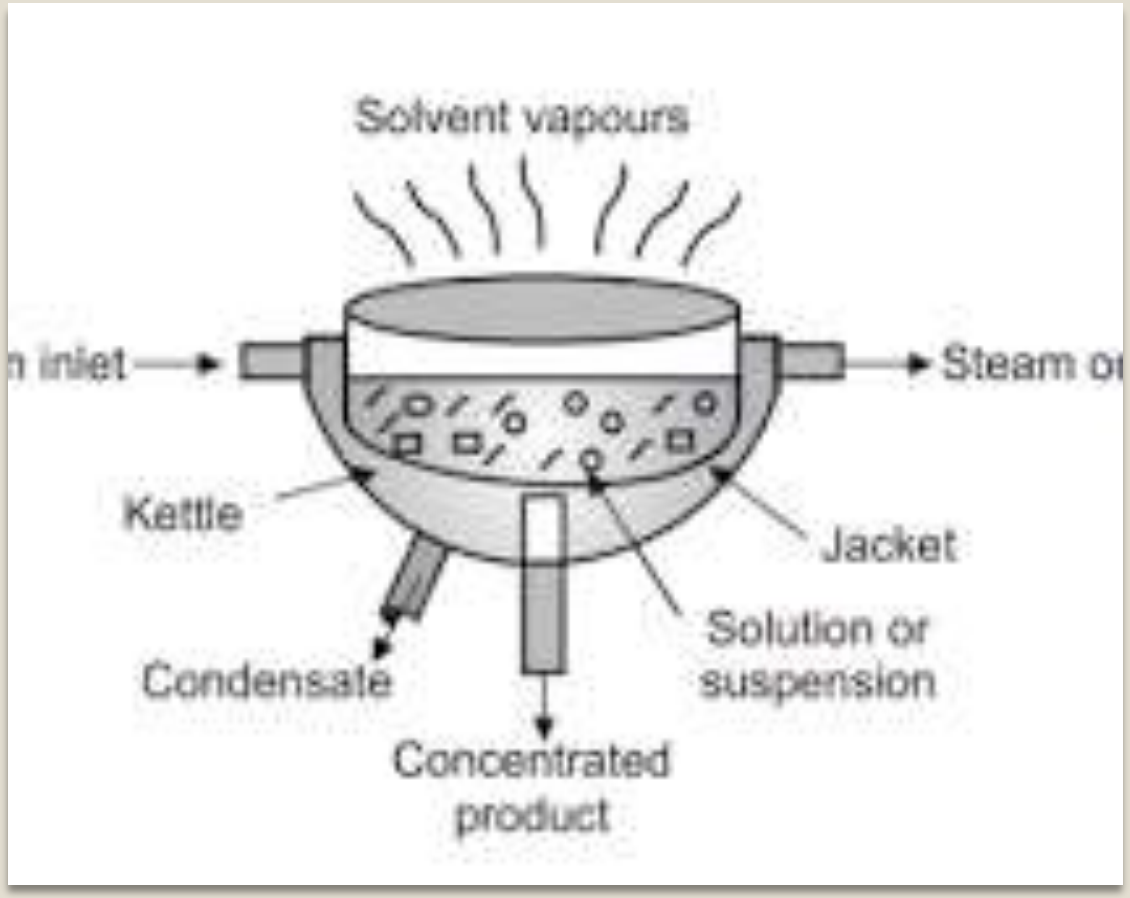
- **DIFFERENCE BETWEEN EVAPORATION AND OTHER HEAT PROCESS**

EVAPORATION	DISTILLATION
Process of transforming liquid into gas under the influence of heat	Process of obtaining gas or vapour from liquid by heating and condensing to liquid
Occurs only at the surface	does occur only at the surface
Liquid vaporizes below boiling point	Liquid vaporizes at boiling point
Slow process	Rapid process
Not a separation technique	A Separation technique

evaporation	Boiling
Takes place at all temperature	Takes place at a definite temperature
Temperature may change during evaporation	Temperature does not change during boiling
Takes place only at the liquid surface	Takes place in every region of liquid
Evaporation rate depends on the free liquid surface area	Boiling rate is independent of the liquid surface area

evaporation	Drying
Removal of large amount of water from solutions	Removal of small amount of water from solids and sometimes from liquids or gases
Concentrated Thick Syrup liquid is yielded	Solid product is yielded
Removal of water by boiling a solution	Removal of water by boiling below its boiling point
Water is removed as pure water vapour mix with other gases due to unavoidable leaks	Water is removed by circulating hot air or some other gases over the material in order to carry away the water vapour
Not the final stage of preparation	Final stage of preapartion

Steam Jacketed kettle (evaporator pan)



Principle- conduction and convection

The evaporating pan is provided with steam which gives out heat to a jacketed kettle. The temperature rises and the escaping tendency of the solvent molecules into the vapor increases and enhances the vaporization of the solvent molecules.

Construction The Steam evaporating pan consists of a hemispherical structure with an inner pan called a kettle which is enveloped with an outer pan called a jacket

To provide a space where steam can pass through, pans are connected together.

An inlet for the steam and non-condensed gases is provided near the top of the jacket through the bottom outlet, condensation exits the jacket.. The kettle is provided with an outlet for the product discharge at its bottom.

Working – firstly solution aqueous extract is placed in kettle

Condensate exits through the outlet, and steam, which provides heat to the content, enters through the inlet.

For smaller volumes the contents must be stirred manually and mechanically for larger volumes.

Products that are concentrated are collected via the bottom outlet.

Use

- it is used for concentrating aqueous extracts and thermostable liquors

Merits

- It is used on both small or large scale
- simple construction ,easy in use ,cleaning and also its maintenance
- Constructed using various mateials copper, ss and alumininum

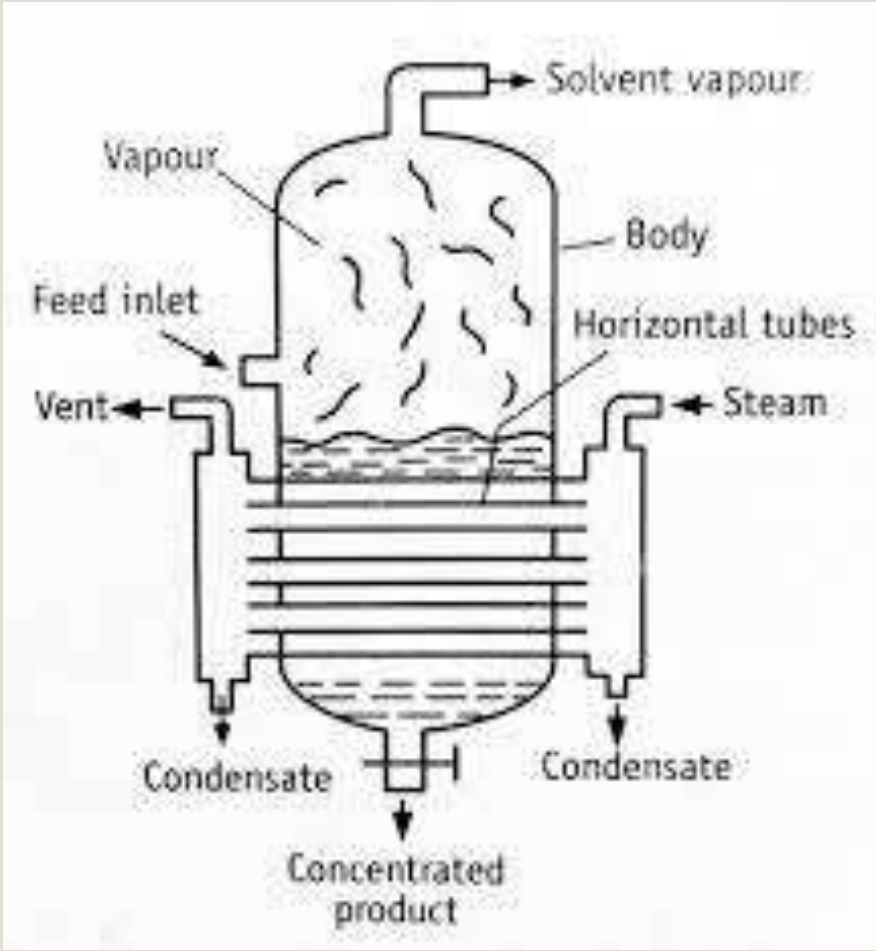
Disadvantages

Not suitable for heat sensitive material

heat economy is less

Horizontal tube evaporator

- **Principle**:
- The steam is passed through tubes arranged horizontally.
- Heating causes the feed to evaporate outside the tubes, releasing vapors from the top outlet and concentrating at the bottom.
- The vapor is removed from the top of the chamber and product circulation takes place by natural circulation over the heating coil.



- **Construction**: It is constructed from plated steel or cast iron.
- and it is about 1.8-2.4 M wide and 2.4-3.6 m long.
- One inlet feed and outlet at the downside for concentrate products
- Steam inlet from which steam enters also condensates for steam and outlet for steam
- One outlet at the top for discharge vapors
- And there are steam compartments in which 6 -8 tubes is placed horizontally and steam pass es through it.

Working

- Firstly feed enters through the inlet and steam enters from the steam inlet.
- Now steam releases heat through tubes and liquid absorbs that heat and becomes heated and starts to convert into vapors.
- Vapours is escape from the outlet at the top.

- Process continue until we get the concentrated product which we want
- And then product is collected through outlet at bottom

- **Uses**
- Use for nonviscous solution

- **Merits (advantages)**
- Easy to install and operate
- Not expensive
- Suitable for nonviscous liquid

- **Disadvantages**
- Not suitable for viscous liquid
- Heat sensitive material (not Suitable)

Climbing film evaporator

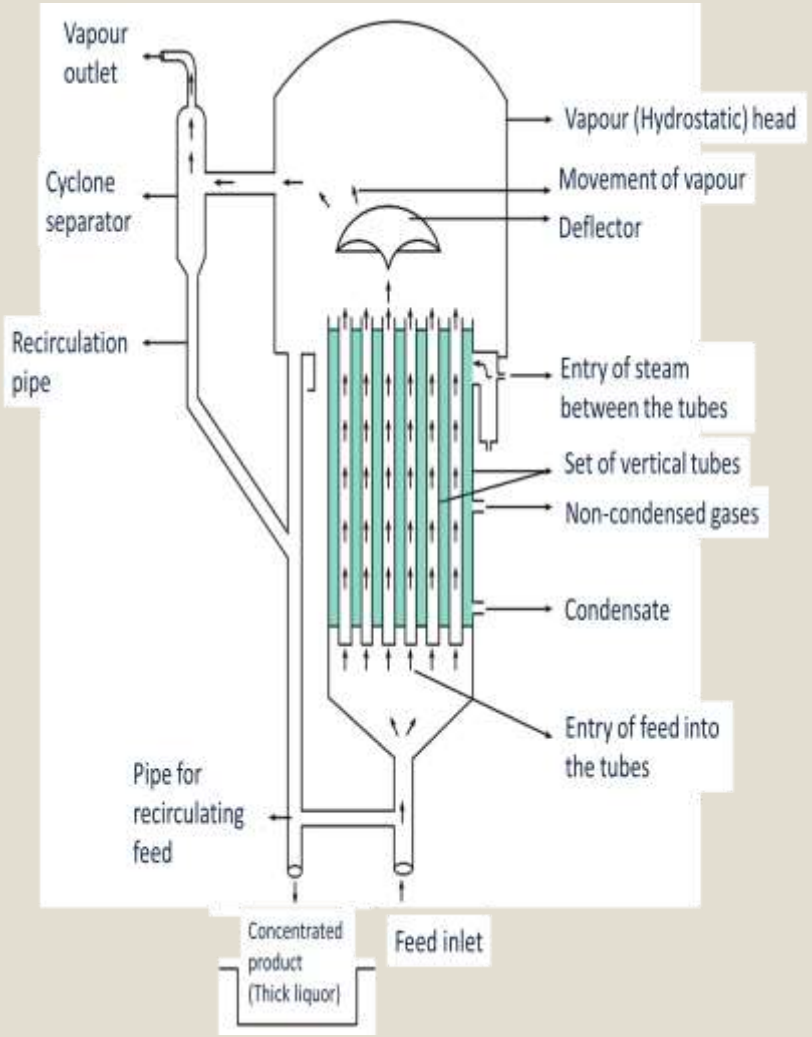
- Also known as rising film evaporator

Principle

- Evaporation takes place via tube which or vertically fitted in the cylinder
- The liquid outside the tube and steam inside the tube both absorb heat and becomes heated and convert into small bubbles which climb upward
- **And through the product outlet, concentrated liquid descends to the bottom and vapour exits (discharges) from the top.**

Construction

- **It is made out of jacketed steam tubes.**
- Additionally, an entrance separation deflector is positioned above the vapour head.



- Also condensate outlet for steam and vent outlet
- Feed inlet from bottom
- And one pipe for recirculation which circulate feed again
- And at bottom one product outlet from which we get product (concentrated)
- **Working**
- Preheated liquid feed is introduce from bottom and steam introduce (enter) into tubes
- Liquid absorb heat and started to make small bubble which started to climb up word
- Then that bubbles seperated through deflector which is present on vapour head

- And an amount of liquid is circulated through a pipe, and the vapor is directed into a separator.
- And an amount of liquid is circulated through a pipe, and the vapor is directed into a separator.
- And when liquid is concentrated (which we want) product obtained from the product outlet

- **Uses**
- Use for corrosive solutions, clear fluids, and foamy liquids.
- Also used for vitamins and insulin etc.

- **Advantage**
- Provide large area of heat transfer
- Suitable for heat sensitive material
- Suitable Foam forming liquids

- **Disadvantages**
- Expensive & construction is complicated
- Difficult to clean
- Not suitable for very viscous liquid.

Forced circulation Evaporator

- **Principle**: **In this evaporator, liquid flows via tubes at high pressure using pumps**
- Because of the high pressure, boiling does not occur because the liquid's boiling point is raised. ‘
- **Additionally, the liquid causes some sort of agitation when it exits the tubes and enters the vapors head** pressure fall suddenly
- **this causes the overheated liquor to flash, which causes evaporation to occur.**

- **Construction**
- **Includes a pump to boost circulation and pressure.**
- Steam jacketed tubes are also contained within two tube sheets in the evaporator.
- The tube is 2.5 meters long and has an internal diameter of 0.1 meters.
- The tube components, which include a deflector and are attached to a return pipe that descends and reaches the pump inlet, protrudes into the vapour head.

- **Working:**

- The calendria is filled with steam.
- The liquid is pumped into the tube at a positive velocity.
- The liquid heats up and boils as it moves up through the tube.
- Consequently, the mixture of vapor and liquid shoots out of the tubes quickly.
- This mixture hits the deflector in a way that effectively separates the liquid from th e vapor.
- After exiting the apparatus, the vapor enters the cyclone separator.
- The concentrated liquid is pumped through so that it can evaporate even more.
- Ultimately, the concentrated product is gathered at the discharge outlet's bottom .

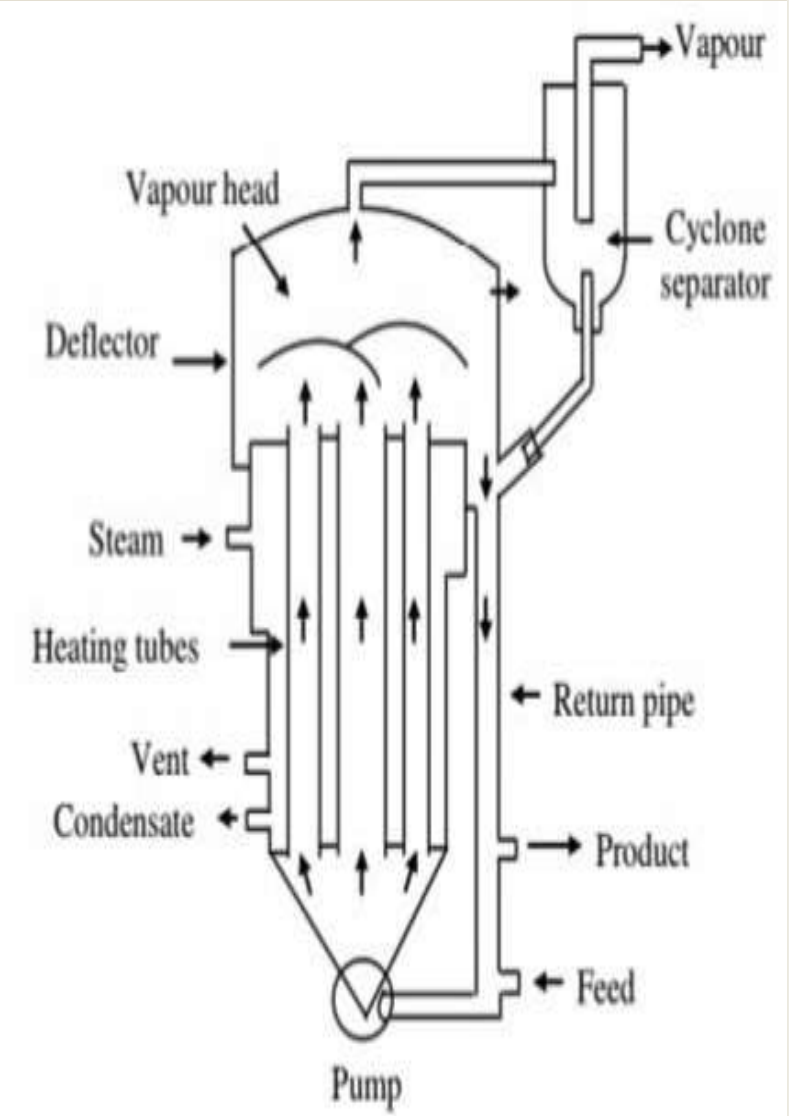


Figure 5.4: Forced Circulation Evaporator

Uses;

1) It is employed in concentration of thermolabile materials,

2) It is applied for insulin and liver extracts.

3) It is used for corrosive solutions.

4) Crystallization activities that need constant suspension of crystals can benefit from its application.

Merits

1) Because of the quick liquid movement, it has a high heat transfer Coefficient

2) Forced liquid circulation prevents fouling, scaling, and salting.

3) Because of its quick evaporation, it works well with materials that are sensitive to heat.

4) Because the liquid is circulated via a pumping mechanism, it is also utilized for highly viscous li quids.

Demerits

1) Its liquids have a lengthy residence duration.
2) The pump needed for liquid circulation contributes to its high cost.

Multiple Effect Evaporator

- It is a single effect vertical short tube evaporator. To accomplish large-scale evaporation, this evaporator can be coupled in numerous ways.

Principle

- A series of vessels are placed one after the other, each maintained at a lower pressure than the last one
- **They are used to boil water.**
- **Water in one vessel is heated in the next vessel using the vapour that remains after the water boils because water's boiling point dr ops with decreasing pressure.**
- **This suggests that the first vessel, which is under the most pressure, is the only one that boils its**

  water using an external heat source.

Construction

- Includes three evaporators.
- Similar to a vertical tube evaporator are the remaining advantageous qualities.
  Vapor from Evaporator I is used as a heating source for Evaporator II in the evaporator, while vapor from Evaporator II serves as the heating medium for Evaporator III.
- **With the final evaporator is a vacuum pump attached.**

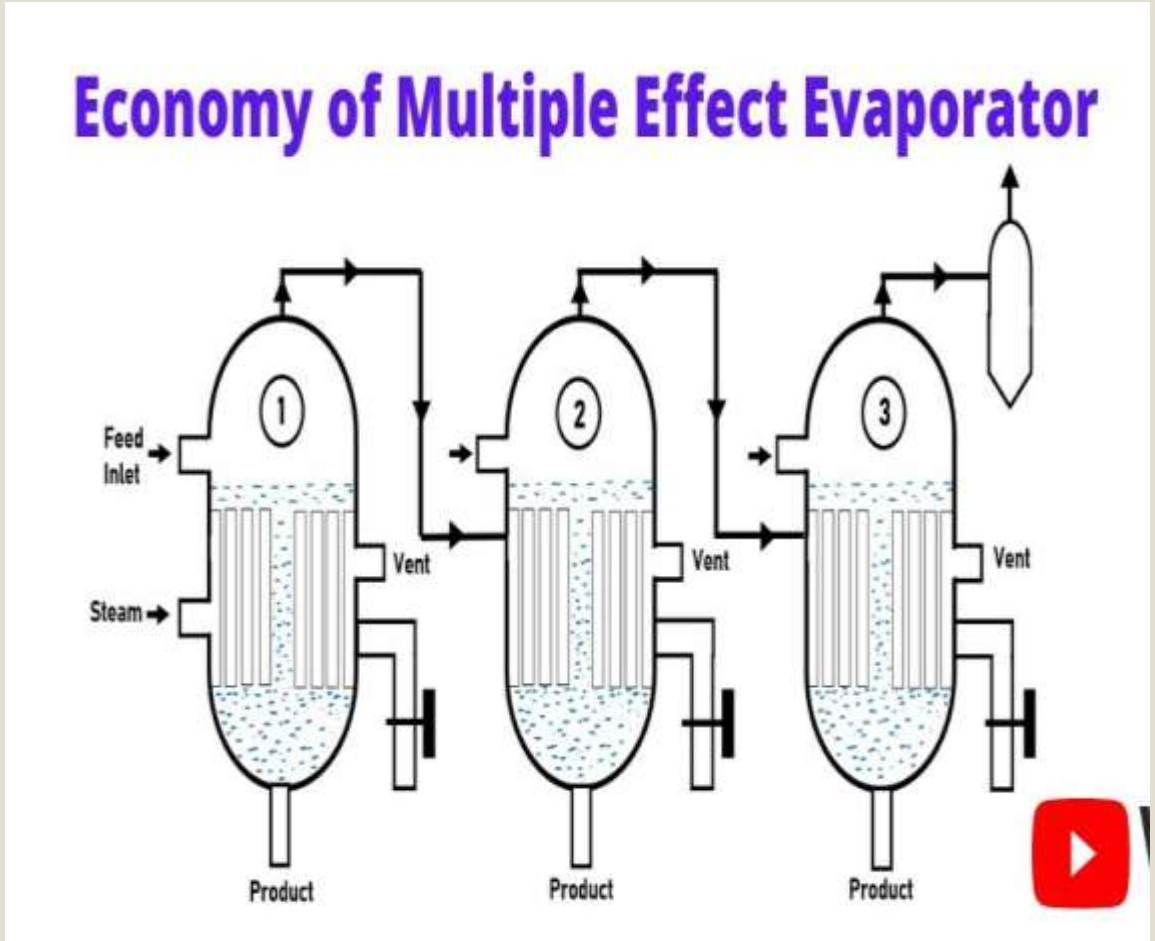
Working

First, add heated solution to each evaporator until it reaches the top of the tube sheets.

Once hot steam has been added to the first evaporator, it is kept flowing there until the appropriate pressure is reached in the steam space.

In the process of transferring heat from steam to liquid, some steam is also converted into condensati on, which is then expelled through the condensation outlet.

- The temperature of the liquid rises as a result of heat absor ption, and it begins to evaporate. These vapors then travel to the second evaporator's steam space and function as st eam there.
- Next, the liquid of the second evaporator receives the hit fr om the first evaporator's web, and the condensate is extra cted via the condensate outlet.
- The same thing occurred in three evaporators.
- **And heat is continuously applied until the three evaporators' temperatur es are the same.**
- In order to ensure a steady feed for all operators, the evap orator product output is likewise connected to the next ev aporator feed intake.
- The procedure is kept going until the liquid in the operators has the appropriate viscosity.
- Third evaporator output is where the final concentrated pr oduct is collected.
  The separator, which is connected to the third evaporator, releases or separates the remaining vapor.



Uses

1) It is also employed in the desalination of water and the manufacture of salt.
2) It heats the liquid to be flashed using sensible heat from the condensate. Advantages
3) It can operate continuously and on a huge scale.
4) When compared to a single effect, it is very cost-effective.
5) With this kind of setup, about 5 evaporators can be connected.

- Demerits

1)In comparison to the vapours produced in the preceding part, its capacity to produce an d condense vapours in the subsequent sections is restricted.
2) Inert gases have the potential to pollute the vapours generated in the evaporators' first se gment.

Economy of Multiple Effect Evaporators

- The multiple effect evaporator's economy is measured by the amount of vapour generate d per unit of steam injected.
- At a temperature equivalent to its boiling point, feed is injected into the evaporator. Consequently, the temperature of the feed can be raised without the need for a separate heating source.
- The supplied steam condenses and releases condensation heat, which is then transmitted to the liquid.
- After acquiring heat, liquid vaporizes, and this heat now acts as the latent heat of vaporiz ation. This results in a negligible loss of heat.

Economy of evaporator

- The economy of an evaporator can be expressed as:
- Economy of an evaporator = $\frac{\text{Total mass of vapours produced}}{\text{Total mass of steam supplied}}$

- Steam in a single effect evaporator produces vapour only once. Hence,
- Economy of a single effect evaporator = $\frac{\text{N units of vapours produced}}{\text{N units of steam supplied}} = 1$

- However, in multiple effect evaporators, one unit of steam produces vapour many times. This depends on the number of evaporators connected. Hence
- Economy of multiple effect evaporator = $\frac{\text{Nunits of vapour produced}}{\text{1 unit of steam supplied}} = N$

- This concludes that **economy of multiple effect evaporator is N times the economy of the single effect evaporator**.
- Many variables affect the multiple impact vaporizer's economics, including: Temperature of the feed
  2) The evaporator's temperature range,
- 3) The feed weight to product ratio, and
- 4) The pressure differential.