

Study of Evaporators

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Steam Jacketed Kettle Or Evaporating Pan

Principle: Steam is supplied to a jacketed kettle (evaporating pan) in which aqueous extract is placed. Steam gives out heat to the kettle. The heat is transferred to the aqueous extract by conduction and convection. The temperature raises and the escaping tendency of the solvent molecules into vapour increases.

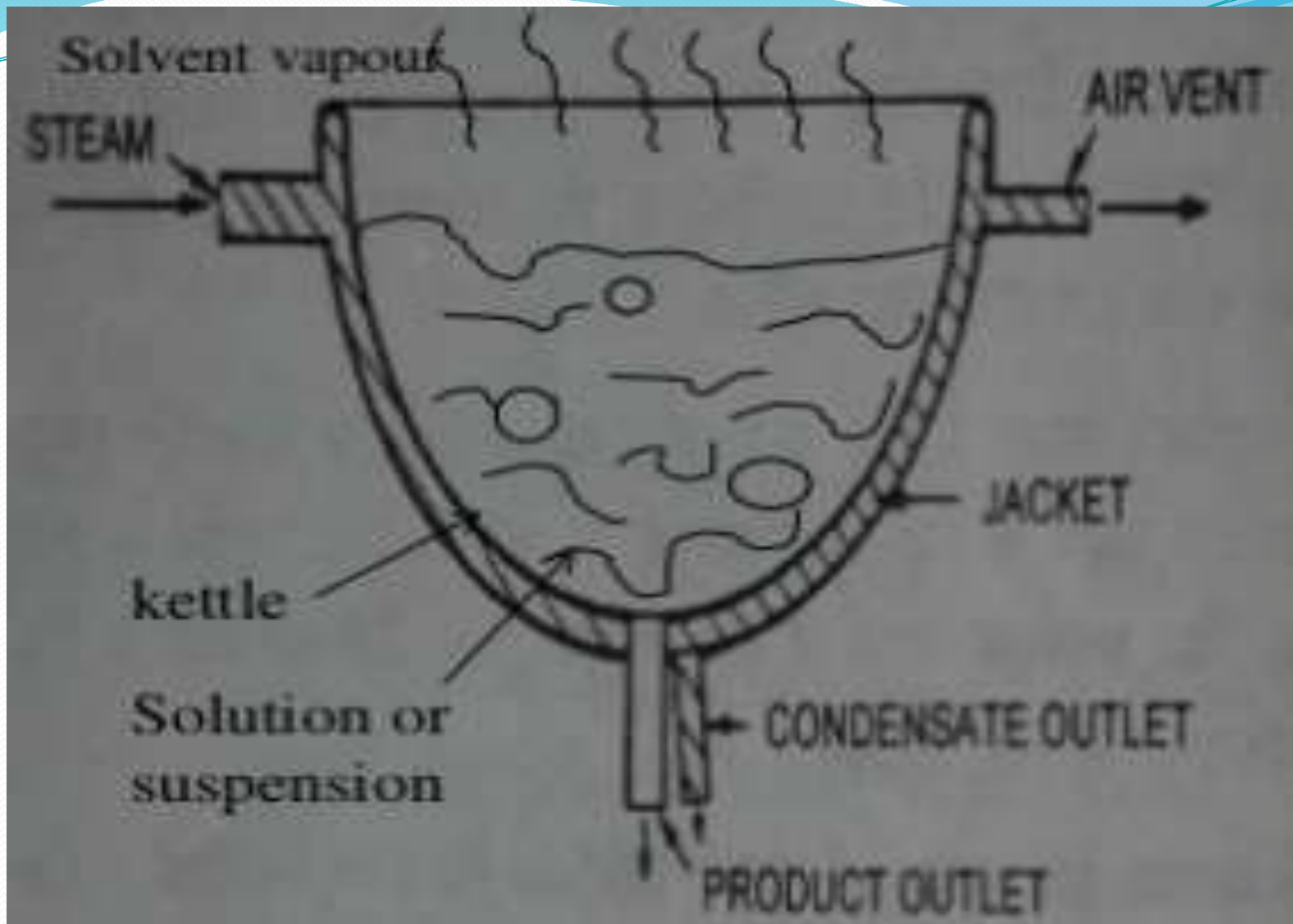
Construction:

- It is a hemispherical structure consisting of an inner pan called kettle
- It is enveloped with an outer pan called jacket
- The two pans are joined to enclose a space through which steam is passed • Kettle is made up of a single sheet of metal (for smaller quantities) or sheets are welded (for larger capacities).
- For practical purposes copper is an excellent material for the kettle because of its good conductivity (acidic materials- some quantities of copper would dissolve).
- Tinned copper is used for acidic material.
- Iron is used for the construction of the jacket because it has minimum conductivity.
- To prevent rusting of the jacket, the iron is either tinned or enamelled on inner surface.

- An inlet for steam and an outlet (vent) for noncondensed gases are provided near the top of the jacket.
- Condensate leaves the jacket through the outlet provided at the bottom.
- The kettle is provided with one outlet for product discharge at its bottom.

Working

- Aqueous extract placed in the kettle.
- Steam is supplied through the inlet.
- Contents stirred continuously.
- The rate of evaporation is fast in the initial stages & decreases gradually as the liquid gets concentrated.
- Provide ventilation for removing the vapour .
- The bottom outlet is used to collect the concentrated product.



Uses: for concentrating aqueous and thermostable liquors

Ex: liquorice extract

Advantages

1. Used for both small scale and large scale operations
2. Simple in construction and easy to operate, clean and maintain
3. Low maintenance and installation cost

Disadvantages

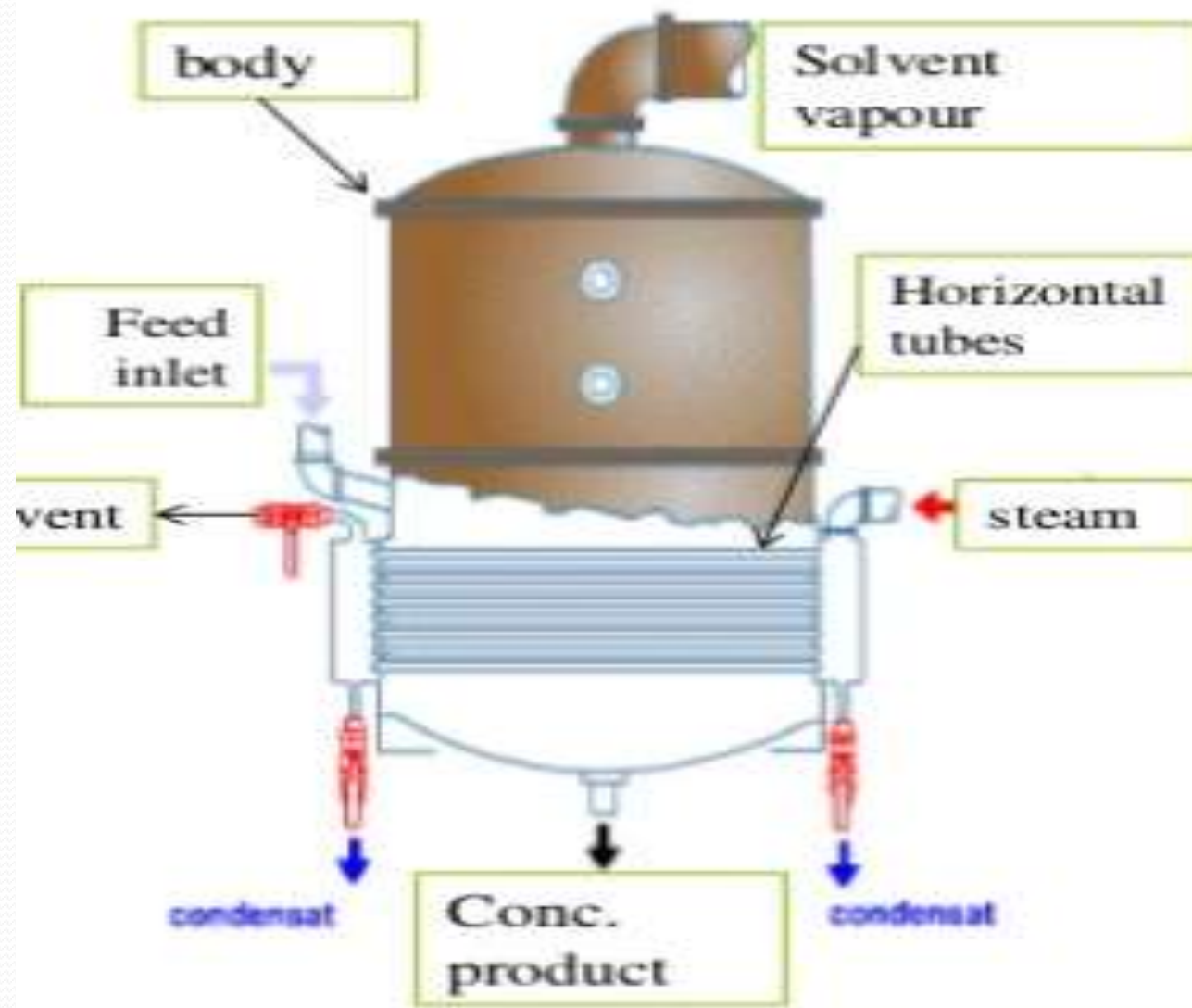
1. Heat economy is less
2. Not suitable for heat sensitive materials
3. Heat transfer rate decreases drastically when the conc. increased

Horizontal Tube Evaporator

Principle: In horizontal tube evaporator, steam is passed through the horizontal tubes, which are immersed in a pool of liquid to be evaporated. Heat transfer takes place through the tubes and liquid outside the tubes gets heated. The solvent evaporates and escapes from the top of the evaporator. The concentrated liquid is collected from the bottom.

Construction

- It consists of a large cylindrical body with conical or dome-shaped top & bottom .
- It is made up of plate steel or cast iron.
- Average size of the body ranges from 1.8 to 2.4 meters diameter & from 2.4 to 3.6 meters height.
- Lower part of the body consists of a steam compartment with an inlet for steam at one end & a vent for noncondensed gases on the other end.
- A condensate outlet is provided at the bottom of the horizontal tubes are placed.
- In the steam compartment, 6-8 stainless steel horizontal tubes are placed.



Working

- Feed is introduced into the evaporator
- Steam is introduced into the steam compartment
- The horizontal tubes receive heat from the steam
- Steam condensate passes through the corresponding outlet
- The feed absorbs heat & solvent gets evaporated
- The vapour the escapes through the outlet placed at the top
- This process is continued until a thick liquid is formed
Which can be collected from the bottom outlet

Uses: for non-viscous solutions that do not deposit scales or crystals on evaporation Ex: cascara extract

Advantage:

1. Low cost
2. Easy to install
3. Require less space for installation
4. Suitable for liquids that not crystallize
5. Can be used for batch/continuous operation

Disadvantages:

1. Not suitable for viscous liquids

Climbing Film Evaporators (rising film evaporator)

Principle:

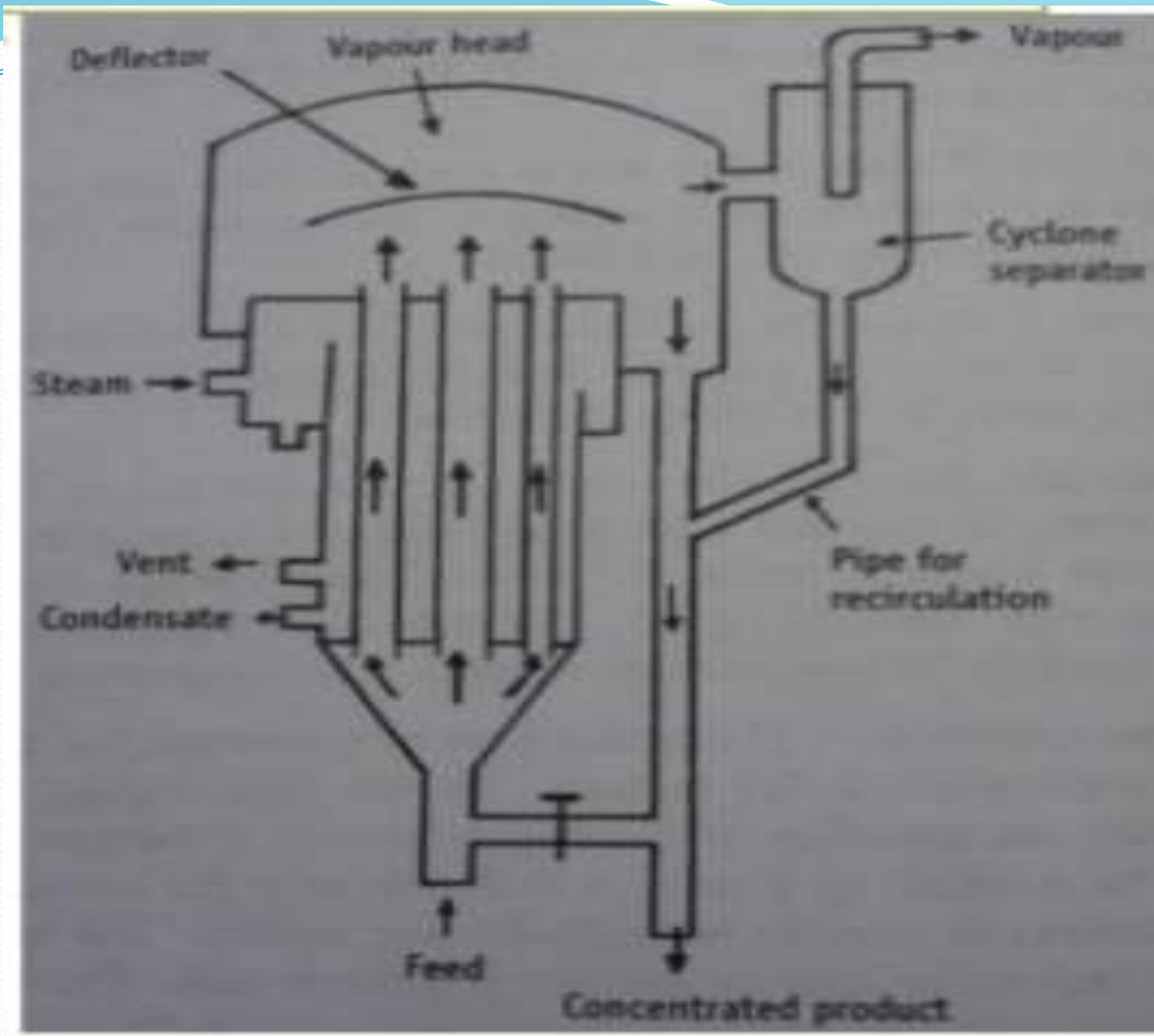
- In climbing film evaporator, tubes are heated externally by steam.
- The preheated feed enters from the bottom and flows up through the heated tubes.
- The liquid gets heated rapidly due to enhanced overall coefficient of the preheated feed.
- The liquid near the wall becomes vapour and forms small bubbles.
- These tend to fuse to larger bubbles, which travel up in the tubes along with entrapped slug.
- The liquid films are blown up from the top of the tubes and strikes entrainment separator (deflector) kept above.
- This throws the liquid concentrate down into the lower part from where it is withdrawn.

Construction

- The heating unit consists of steam jacketed tubes
- Here, the tubes (long and narrow) are held between two plates.
- An entrainment separator (deflector) is placed at the top to the vapour head.
- The evaporator carries steam inlet, vent outlet & condensate outlet
- The feed inlet is from the bottom of the steam compartment

Working

- The preheated liquid feed is introduced from the bottom of the unit
- The height of the liquid column is maintained low, i.e., 0.6 or 1.2 meter above the bottom tube sheet
- Steam enters into the spaces outside the tubes through the inlet
- Heat is transferred to the liquor through the walls of the tubes
- The liquid becomes vapour & forms smaller bubbles, which tend to fuse to larger bubbles
- These are of the width of the tubes, thereby the bubbles trap a part of the liquid (slug) on its way up
- The mixture of liquid concentrate & vapour eject at a high velocity from the top of the tubes
- The vapour leaves from the top, while conc. is collected from the bottom



Uses: For thermolabile substances such as insulin, liver extracts & vitamins can be concentrated

Advantages:

1. Large area for heat transfer is provided employing long & narrow tubes
2. The time of contact between the liquor & the heating surface is very short
3. Suitable for foam-forming liquids, because foam can be broken by an entrainment separator
4. It requires low hold up & small floor space

Disadvantages:

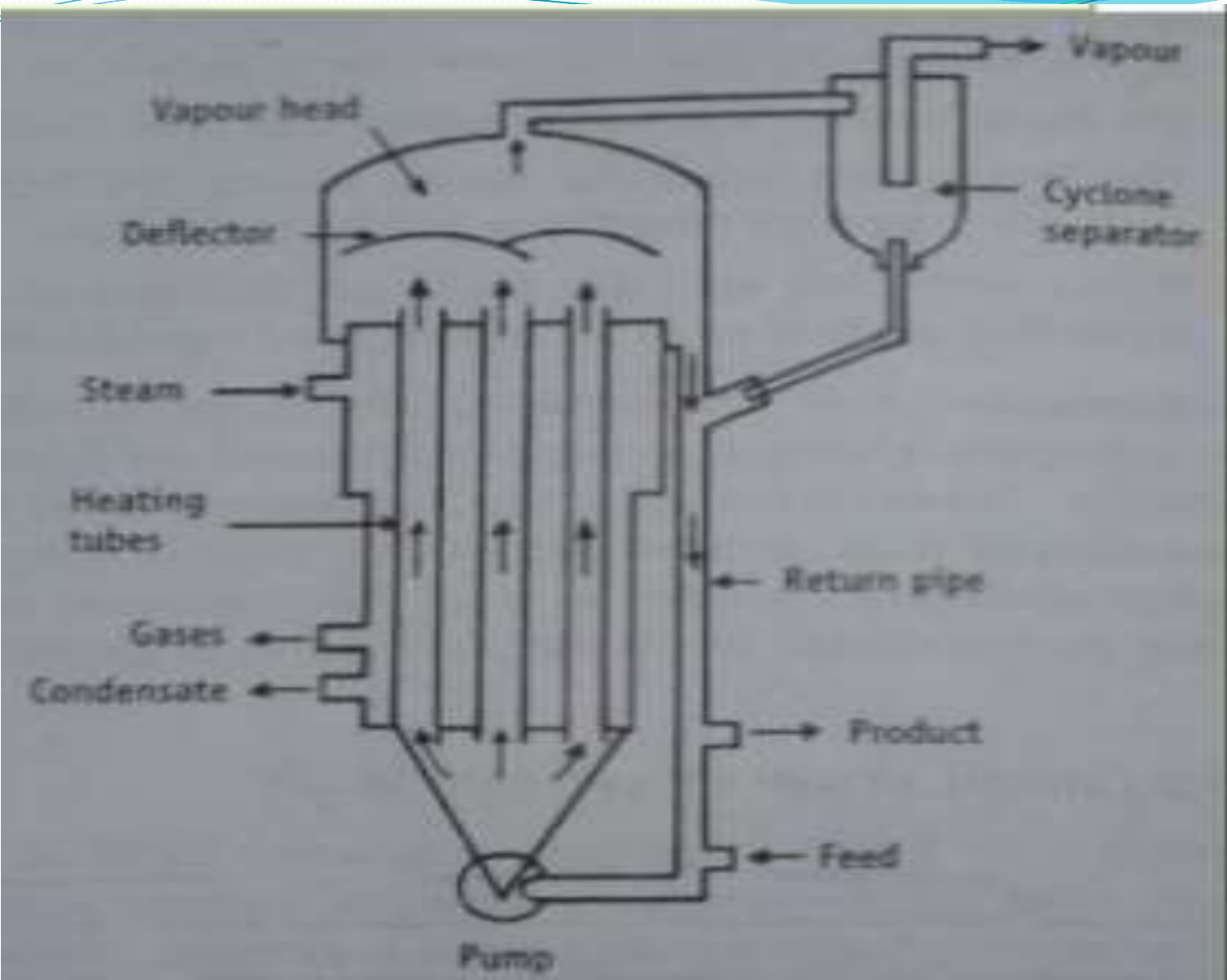
1. expensive, construction is quite complicated
2. It is difficult to clean & maintain
3. Very viscous liquids, salting liquids & scaling liquids are not used

Forced Circulation Evaporator

Principle: In Forced Circulation Evaporator, liquid is circulated through the tubes at high pressure by means of a pump. Hence, boiling does not take place because boiling point is elevated. Forced circulation of the liquid also creates some form of agitation. When the liquid leaves the tubes and enters the vapour head, pressure falls suddenly. This leads to the flashing of super heated liquor. Thus evaporation is effected.

Construction

- The steam jacketed tubes are held between two tube sheet
- The tube measures 0.1 meters inside diameter & 2.5 meters long
- The part of the tubes projects into the vapour head which consists of a deflector
- The vapour head is connected to a return pipe, which runs downwards & enters into the inlet of a pump



Working

- Steam is introduced into calandria
- Pump sends the liquid to the tubes with a positive velocity
- The liquid moves up through the tubes, it gets heated and begins to boil
- As a result the vapour and liquid mixture rushes out of the tubes at a high velocity
- This mix. strikes the deflector, which throws the liquid downward
- This results in an effective Separation of liquid & vapour
- The vapour enters the cyclone separator & leaves the equipment
- The concentrated Liquid returns to the pump for further evaporation
- Concentrated Product collected

Uses: Used for the concentration of insulin & liver extracts
Also used for crystallizing operations where crystals are to be suspended at all times

Advantages:

- 1.The heat transfer coefficient is high due to rapid liquid movement
- 2.It is suitable for thermolabile substances because of rapid evaporation
- 3.Suitable for high viscous preparations because pumping mechanism is used

Disadvantages:

- 1.The hold-up liquid is high
- 2.Expensive

Multiple-effect Evaporator

- Its also known as triple effect evaporator
- The vapour from first evaporator serves as a heating medium for the 2nd evaporator
- Similarly, vapour from 2nd evaporator serves as a heating medium for the 3rd evaporator
- Last evaporator is connected to a vacuum pump
- Parallel feed: Hot saturated solution of the feed is directly fed to each of the three effects in parallel without transferring the material from one effect to the other.
- The parallel feed arrangement is commonly used in the conc. of salt solutions, where the solute crystallizes on conc. Without increasing the viscosity

- Operations: Liquid feed is introduced to all the 3 evaporators up to the level of the upper tube sheets
 1. The vent valves V1, V2 & V3 are kept open & all other valves are closed
 2. High vacuum is created in the liquid chambers of evaporators
 3. The steam valve S1 & condensate valve C1 are closed Steam is supplied Steam first replaces cold air in the steam space of 1st evaporator When all the cold air is removed, the valve, V1 is closed
 4. The supply of steam is continued
 5. Steam give its temp. to the liquid feed in the 1st evaporator & gets condensed Condensate is removed through the valve C1
 6. Due to heat transfer, the liquid temperature increases & reaches the boiling point During this process, vapour will be generated from the liquid feed
 7. So formed vapour displaced air in the upper part of 1st evaporator The vapour also displaces the air in the steam space of the 2nd evaporator
 8. After complete displacement of air by vapour in the steam compartment of 2nd evaporator, the valve V2 is closed
 9. The vapours of 1st evaporator transmits its heat to the liquid of 2nd evaporator & gets condensed Condensate is removed through the valve C2

Advantages:

1. It is suitable for large scale & for continuous operation
2. It is highly economical when compared with single effect
3. About 5 evaporators can be attached

