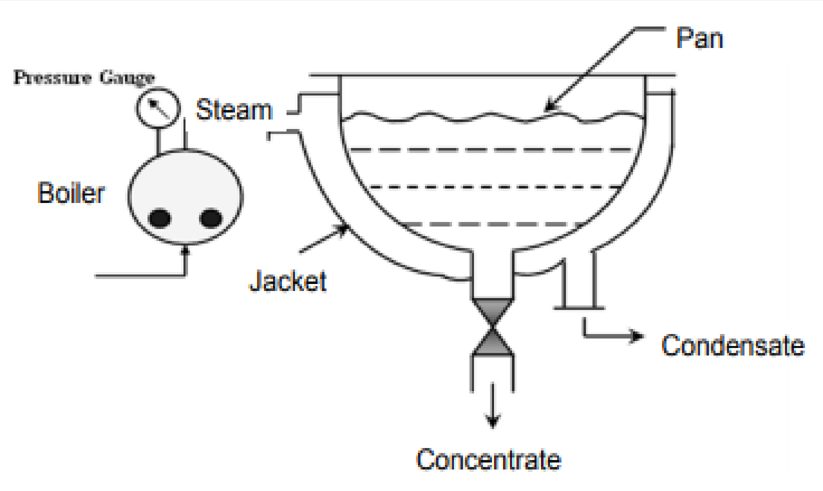
Evaporation

Types of Evaporators

- Most evaporators are broadly classified as (i) Natural circulation and (ii) Forced circulation
- If the *circulation of the solution through the tubes is by density gradient* then the evaporator is a **natural circulation evaporator**
- If the *circulation is by an external means such as a pump*, the evaporator is a **forced circulation evaporator**
- Some common types of evaporators are:

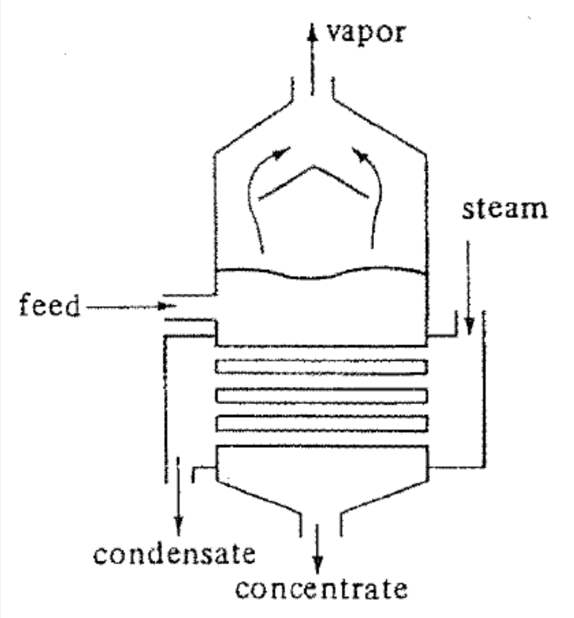
Open kettle or pan

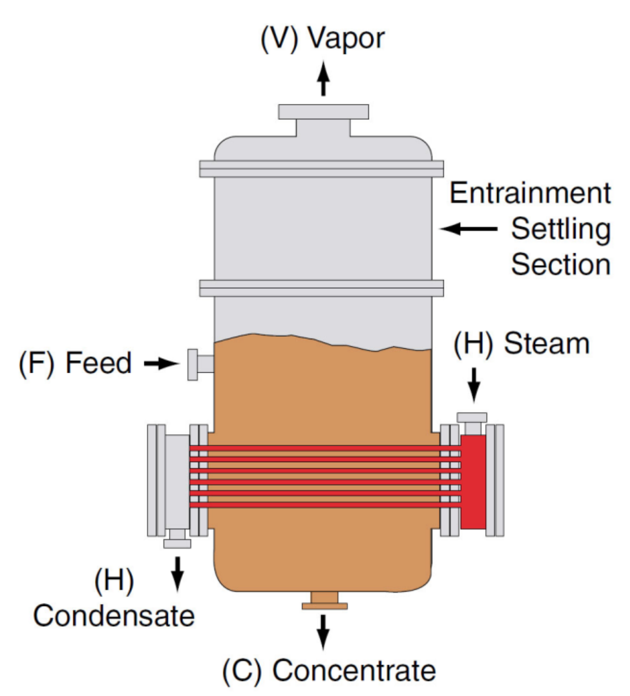
- This is the simplest form of evaporator and consists of an open pan or kettle in which the liquid is boiled
- The heat is supplied by condensation of steam in a jacket or in coils immersed in the liquid
- In some cases the kettle is direct-fired
- These evaporators are inexpensive and simple to operate, but the heat economy is poor
- In some cases, paddles or scrapers for agitation are used
- Heat transfer is improved by agitation within the vessel
- Low surface areas together with low coefficients generally limit the evaporation capacity of such a system



Horizontal-tube natural circulation evaporator

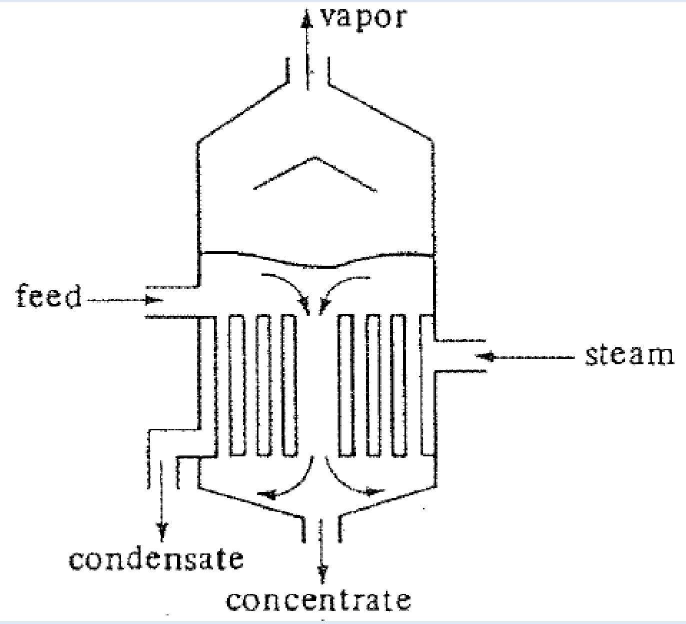
- A horizontal-tube natural circulation evaporator has horizontal bundle of heating tubes similar to the bundle of tubes in a heat exchanger
- The *steam enters into the tubes, where it condenses*. The steam condensate leaves at the other end of the tubes.
- The boiling liquid solution covers the tubes
- The vapour leaves the liquid surface, often goes through some de-entraining device such as a baffle to prevent carry over of liquid droplets, and leaves out the top
- This type of evaporator is relatively cheap and is used *for non-viscous liquids having high heat-transfer coefficients and liquids that do not deposit scale*
- Since liquid circulation is poor, they are unsuitable for viscous liquids
- In almost all cases, this evaporator is operated continuously, where the feed enters at a constant rate and the concentrate leaves at a constant rate

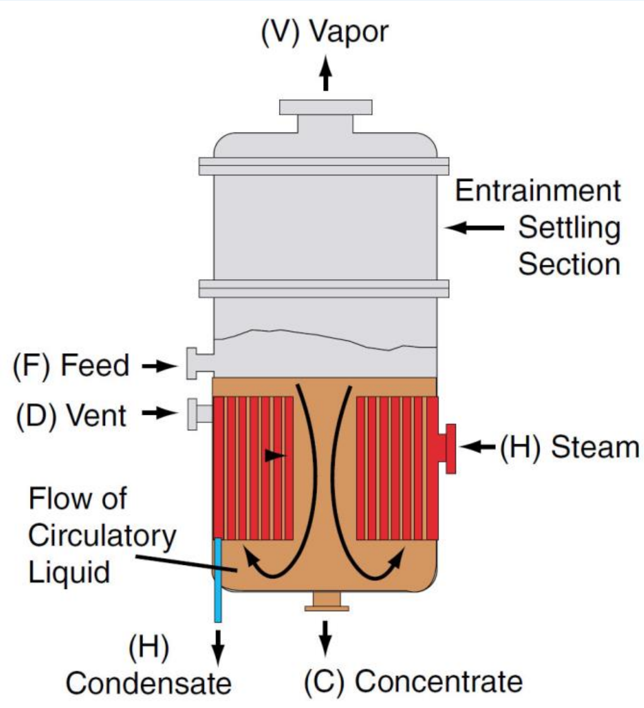




Short tube vertical natural circulation evaporator (Calendria type)

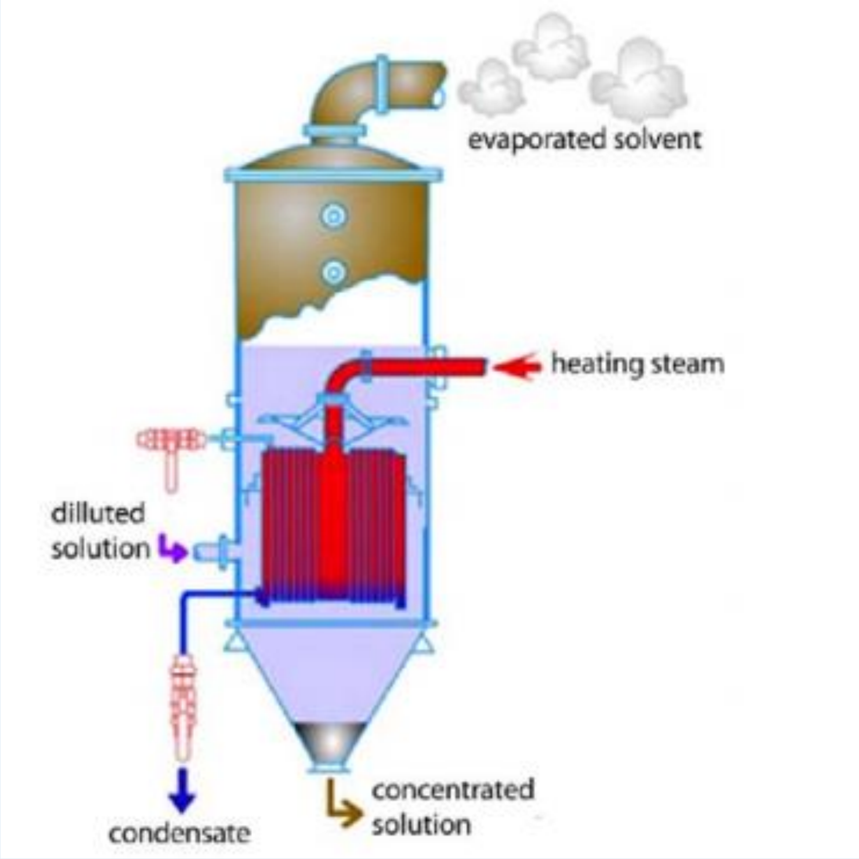
- This type of evaporator is often called the *short-tube evaporator or calendria*
- In this type of evaporator, vertical tubes are used
- The *liquid is inside the tubes and the steam condenses outside the tubes*
- The liquid rises in the tubes by natural circulation because of boiling and decrease in density, and flows downward through a large central open space or downcomer
- The natural circulation increases the heat transfer coefficient
- This is a standard evaporator but not suitable -
  - ✓ for viscous liquids (as heat transfer coefficient is low)
  - ✓ for solutions containing precipitates (natural circulation cannot keep the particles in suspension)





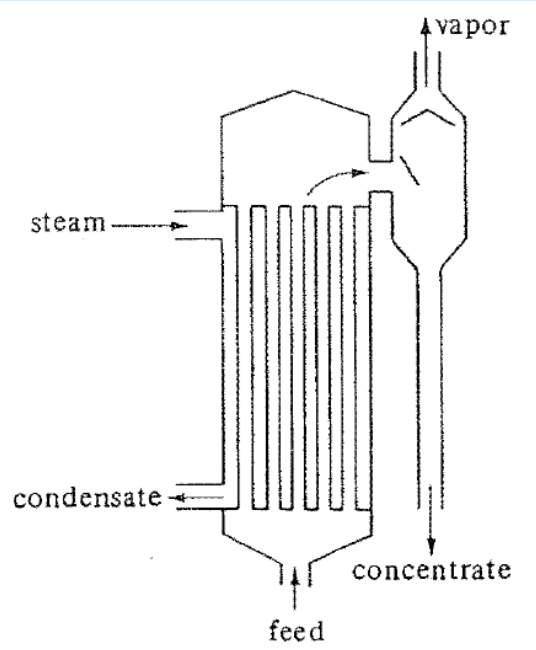
Basket type vertical evaporator

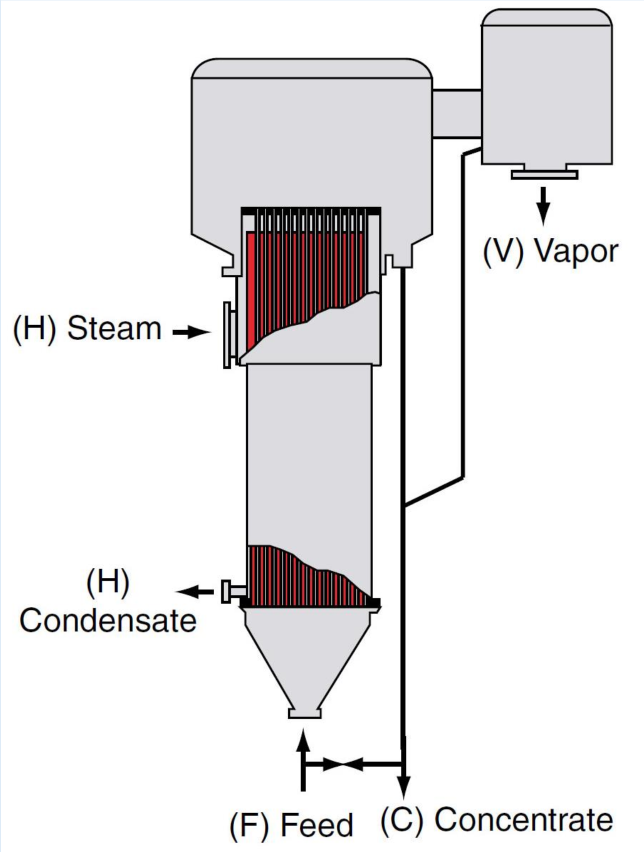
- A variation of the short tube vertical evaporator is the basket type
- Here vertical tubes are used, but the *heating element is held suspended in the body so there is an annular open space as the downcomer*
- The basket type differs from the vertical natural circulation evaporator, which has a central instead of annular open space as the downcomer.
- Movement of the solution is through the annular space
- This type is widely used in the sugar, salt, and caustic soda industries
- This evaporator is not suitable for viscous liquid as natural circulation forces are not strong enough to circulate such viscous liquids
- This type is better than the calendria type *for scale forming solutions, as cleaning is easier*



Long tube vertical evaporator

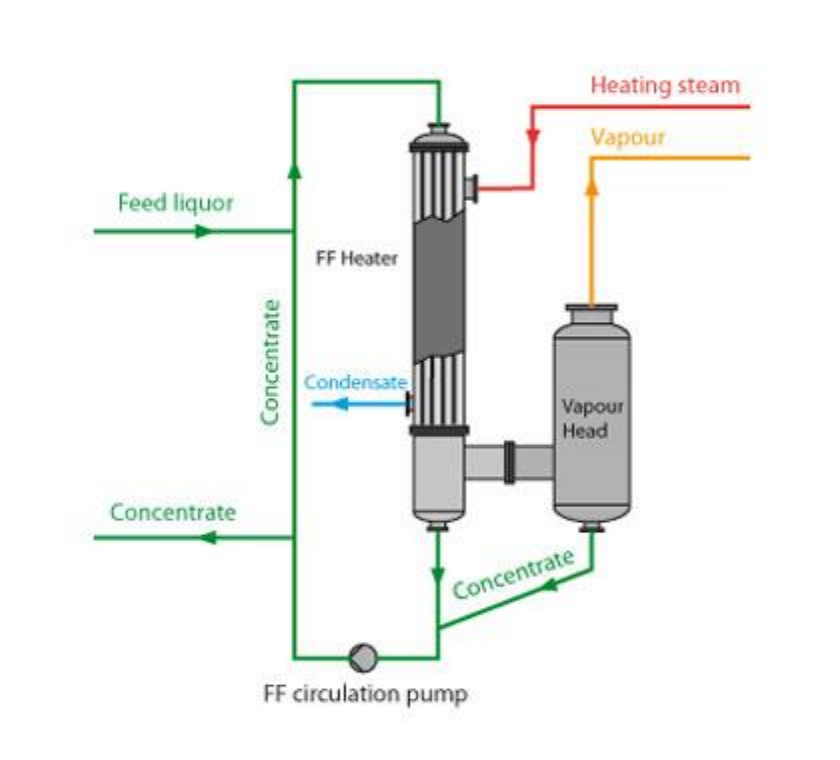
- This is a natural circulation evaporator with a long vertical tube bundle fitted with a shell
- Since the heat-transfer coefficient on the steam side is very high compared to that on the evaporating liquid side, high velocities are desirable in the liquid side to obtain high heat transfer coefficients
- In a long-tube vertical-type evaporator, the *liquid is inside the tubes*
- The tubes are 3 to 10 m long and the *formation of vapor bubbles inside the tubes causes a pumping action which leads to high liquid velocities*
- Generally, the liquid passes through the tubes only once and is not recirculated
- Contact times can be quite low in this type
- Though the tubes are long, the liquid level in the tubes is not more than 1 m
- Advantages of this type include *high heat transfer coefficient, low cost, low liquid hold-up and less floor space requirement*
- Disadvantages are high head room requirement, and unsuitable for viscous and scale forming materials





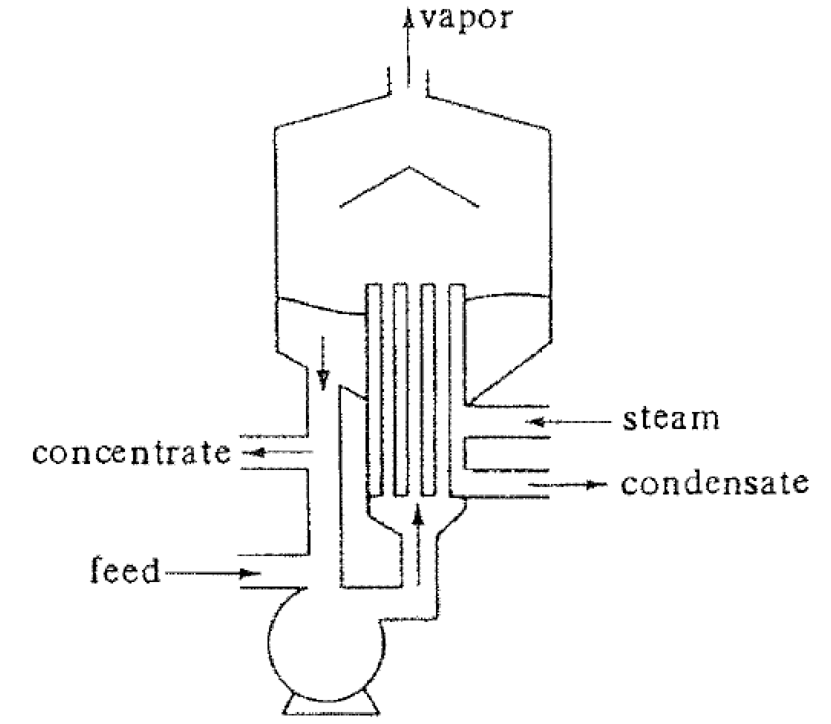
Falling film evaporator

- This is a variation of the long-tube type is the falling-film evaporator, where the *liquid is fed to the top of the tubes and flows down the walls as a thin film*
- Feed enters at the top of the evaporator, where specially designed distributors evenly distribute the feed into each of the tubes
- This evaporator has the advantage of gravity pulling the film downward which results in a *thinner, faster-moving film and gives high heat-transfer coefficients and short residence times in the heating zone*
- It is useful in applications where the *temperature driving force* between the heating medium and the liquid *is small* (less than 15°F).
- The combination of the ability to function at low temperature differences and short residence times makes the falling-film evaporator *suitable for use with temperature-sensitive products* (concentrating heat-sensitive materials such as orange juice and other fruit juices)
- Vapor-liquid separation usually takes place at the bottom



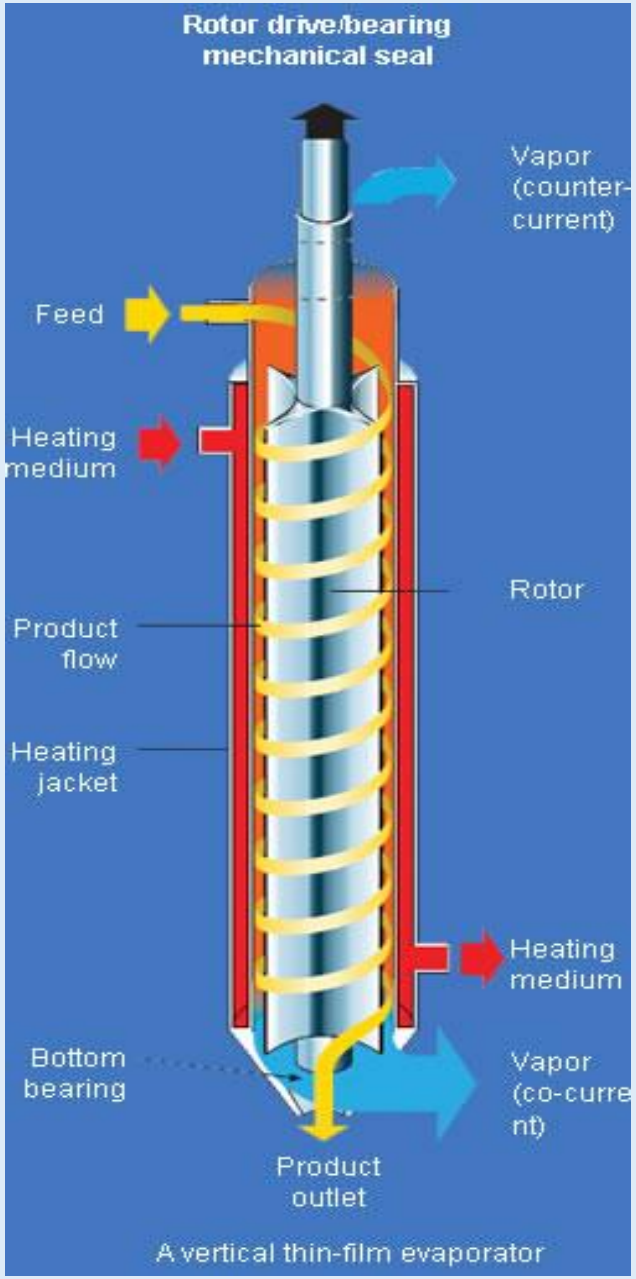
Forced circulation evaporator

- In case of liquids which are viscous (resulting in low natural circulation velocity) and those containing particulates (settling may occur due to natural circulation) and for heat sensitive materials (which require low contact times), a natural circulation evaporator cannot be used
- These problems may be overcome when the liquid is circulated at high velocity through the heat exchanger tubes to enhance the heat transfer rate and inhibit particle deposition
- Any evaporator that *uses pump to ensure higher circulation velocity* is called a **forced circulation** evaporator
- The pump is used between the outlet concentration line and the feed line to circulate the liquid
- Using the pump for circulation of liquid in the tubes leads to an *increase in the liquid-film heat-transfer coefficient*
- Usually in a forced-circulation type, the vertical tubes are shorter than in the long-tube type
- Forced circulation evaporator is commonly used for concentration of caustic and brine solutions and also in evaporation of corrosive solution



Agitated-film evaporator

- In an evaporator the main resistance to heat transfer is on the liquid side.
- One way to increase turbulence in this film, and hence the heat-transfer coefficient, is by actual mechanical agitation of this liquid film
- This is done in a modified falling-film evaporator with only a single large jacketed tube containing an internal agitator
- *Liquid enters at the top of the tube and as it flows downward, it is spread out into a turbulent film by the vertical agitator blades*
- The concentrated solution leaves at the bottom and vapor leaves through a separator and out the top
- This type of evaporator is very *useful with highly viscous materials, since the heat-transfer coefficient is greater than in forced-circulation evaporators*
- It is used with heat-sensitive viscous materials such as rubber latex, gelatin, antibiotics, and fruit juices
- However, it has a high cost and small capacity



Evaporator Accessories or Auxiliaries

The evaporator often contains several accessories such as:

(i) ***Vacuum producing device***: Vacuum conditions are maintained in evaporators (especially the last one or two effects) by means of a *vacuum pump* or a *steam-jet ejector* with a barometric condenser

A reciprocating vacuum pump can produce reasonably high vacuum and has good efficiency while a centrifugal pump is suitable for higher capacities

A steam ejector with a barometric condenser for condensing of vapours is a simple and cheaper method of maintaining vacuum

(ii) ***Surface condensers to condense the vapour****:* A surface condenser is a heat exchanger where the vapours are condensed as they are in indirect contact with the cooling water

If the vapor being condensed is below atmospheric pressure, the condensed liquid leaving the surface condenser can be removed by pumping and the non-condensable gases by a vacuum pump

Surface condensers are much more expensive and use more cooling water, so they are usually not used in cases where a direct-contact condenser is suitable

In *direct-contact condensers such as a barometric condenser* cooling water directly contacts the vapours – the vapour enters the condenser and is condensed by rising upward against a shower of cooling water droplets

(iii) ***Steam trap to remove condensate from steam chest***: A steam trap is an automatic valve that allows the condensate to discharge but traps (or prevents the flow of) steam

(iv) ***Entrainment separator to remove entrained liquid droplets from the vapour***: An entrainment separator is a device that retains the liquid droplets when the vapour containing some entrained liquid passes through it. This helps in preventing loss of liquid or solution before the vapours leave the system