Evaporation

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

Evaporation

Practical definition

- **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."

- It is the removal of solvent from a solution (**by heating**) to obtain a thick liquor (**conc. solution**).

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

Industrial applications of Evaporation

- In sugar industry
- In dehydrating milk, which is then used in many food products
- In fertilizer plants

Evaporation is not only removing water

- In the production of refined petroleum products,
- more volatile compounds are evaporated off to separate the more crude components

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

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

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) Lillie film evaporator

iii)Long Tube Evaporator

a) Climbing film evaporator

b) Falling film evaporator

iv) Horizontal 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

1- Evaporating Pans

On a manufacturing scale,

liquid extracts containing water are evaporated in open pans called **evaporating pans**.

Construction:

The evaporating pan consists of

- **Hemispherical shallow made of**

Copper

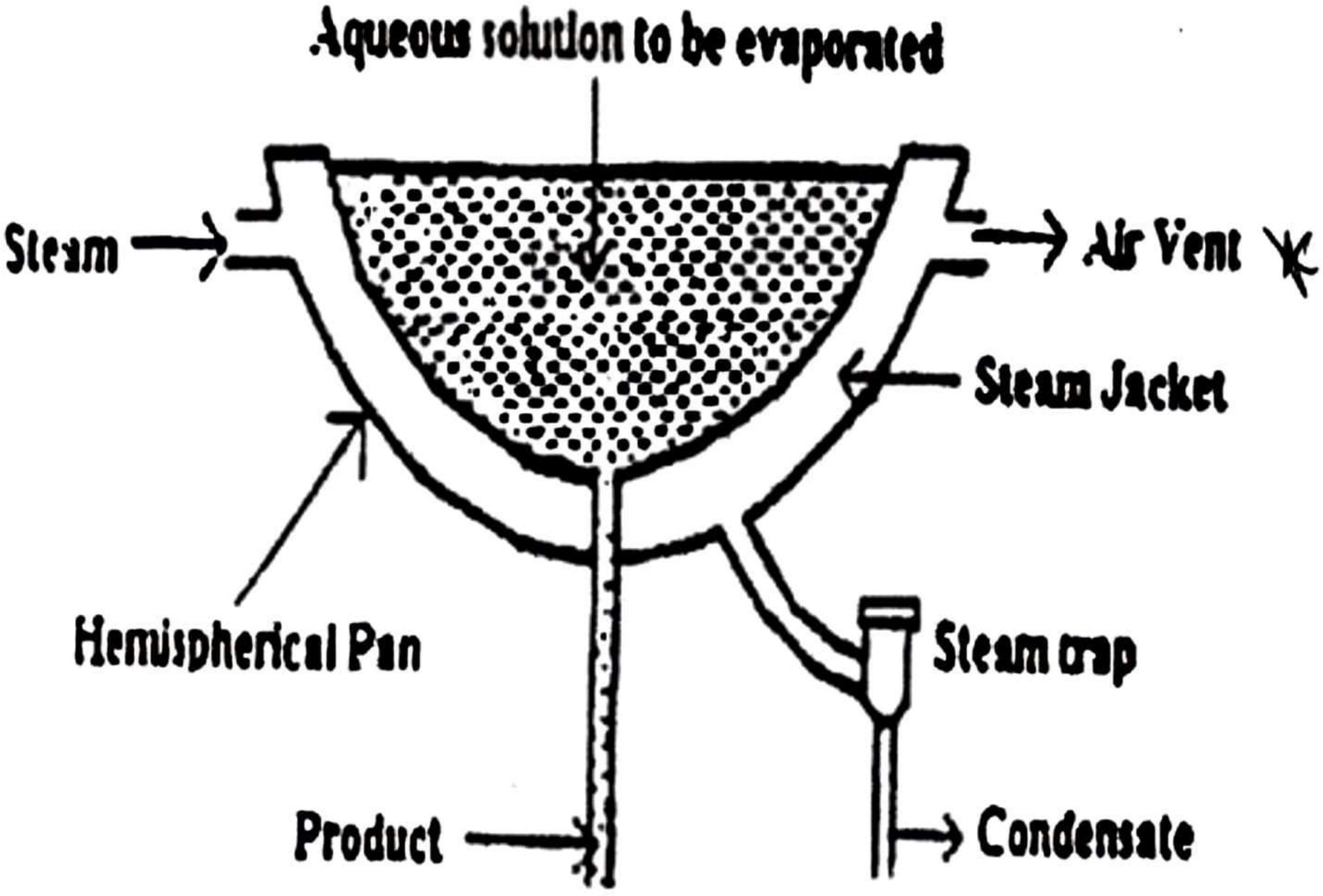
Stainless steel

Alluminium

Enameled iron

- **Steam jacket**

➢ The hemispherical shape gives the best surface\volume ratio for heating and the largest area for the disengagement of vapour.

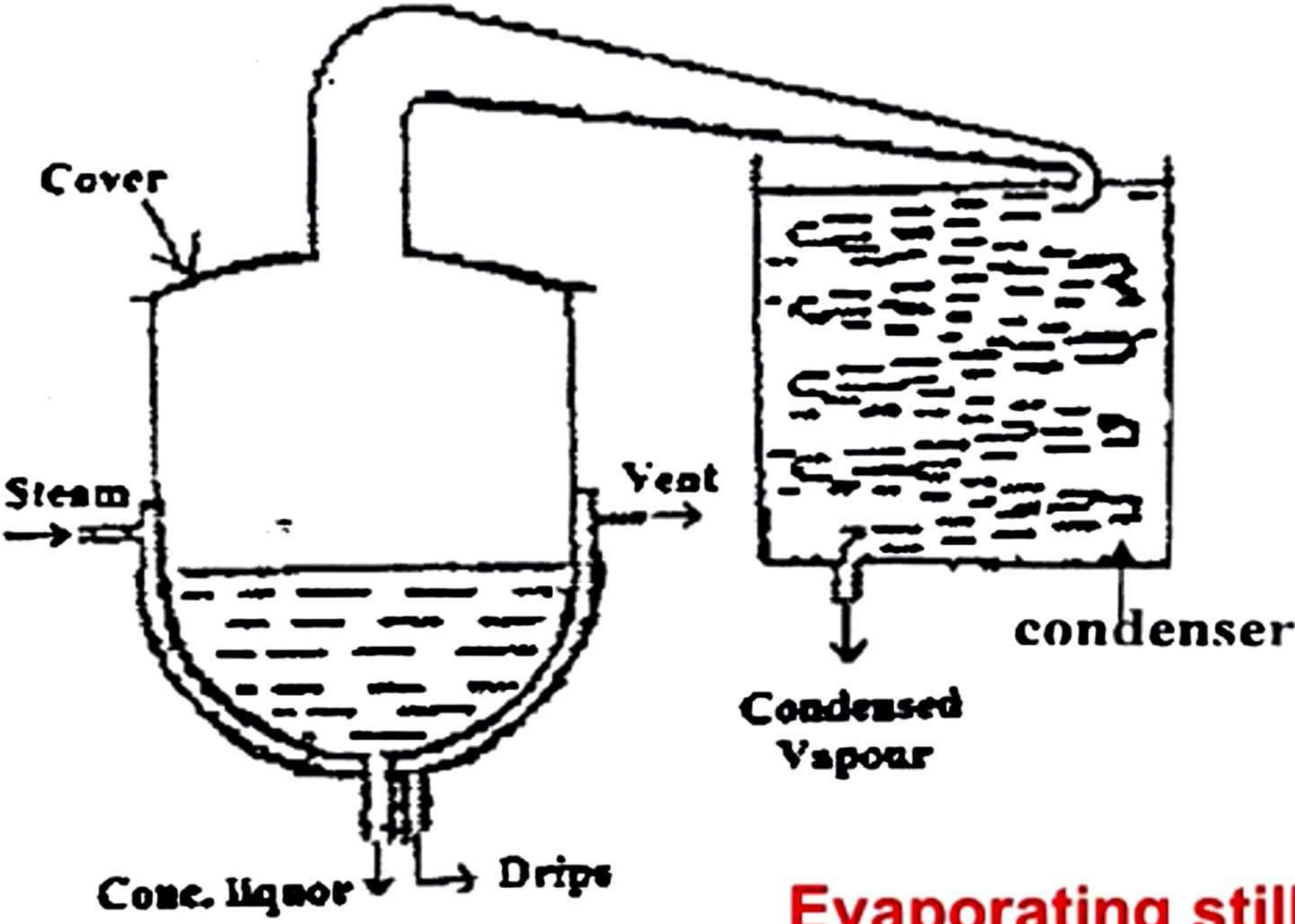


Evaporating Pans

2- 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.



Evaporating still

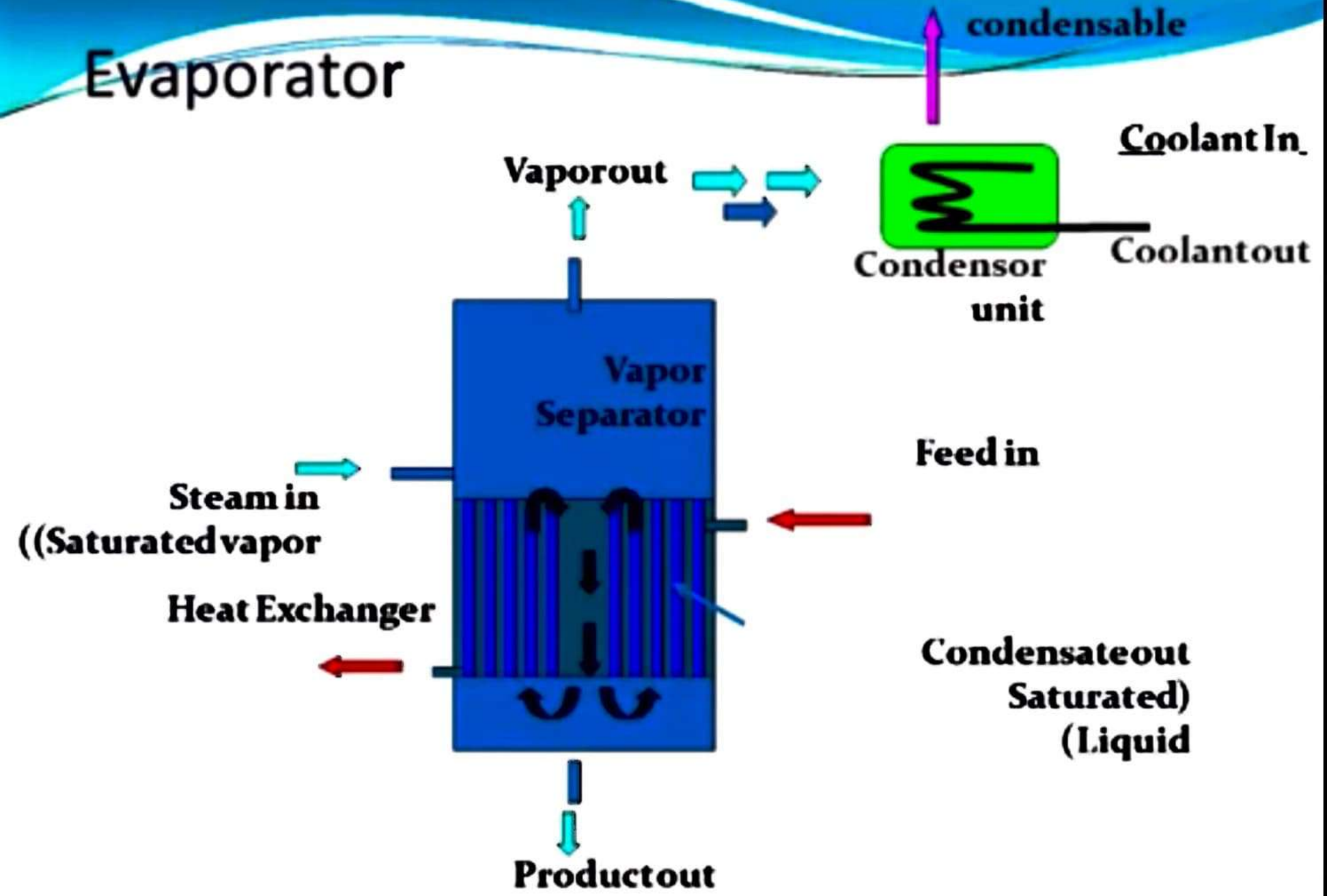
3- Vertical tube evaporator

(short tube or Calandria evaporator)

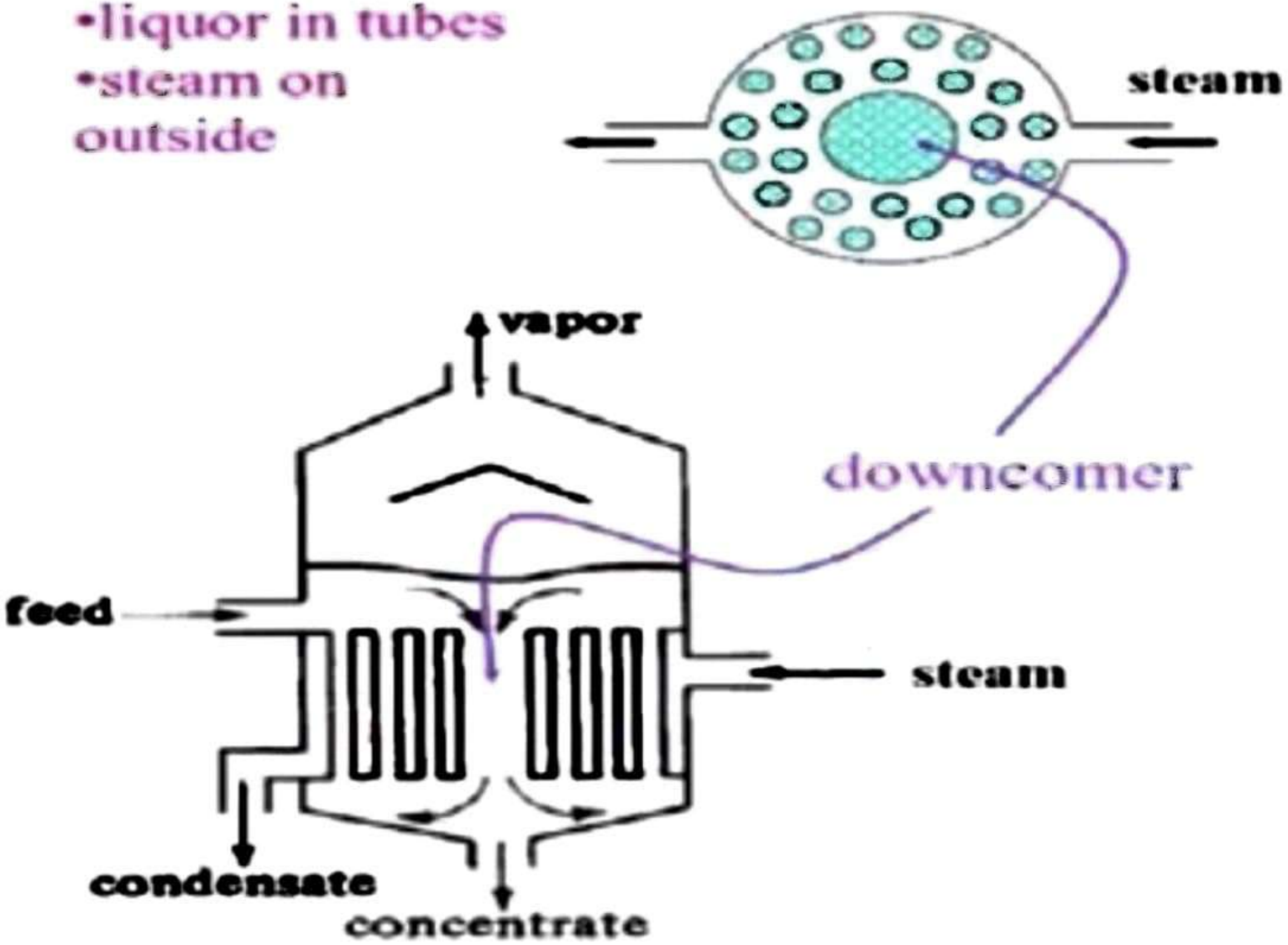
Construction:

- 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 *calendria*.
- **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 calandria.
- The product outlet is placed at the bottom of the evaporator. Steam
- Inlet and outlet is placed from the side of the calendria.

Evaporator


condensable
Coolant In
Vaporout
Coolantout
Condensor
unit
Vapor
Separator
Feed in
Steam in
((Saturated vapor
Heat Exchanger
Condensate out
Saturated)
(Liquid
Product out

- liquor in tubes
- steam on outside



Calandria type Evaporator

4- Horizontal tube evaporator

Construction:

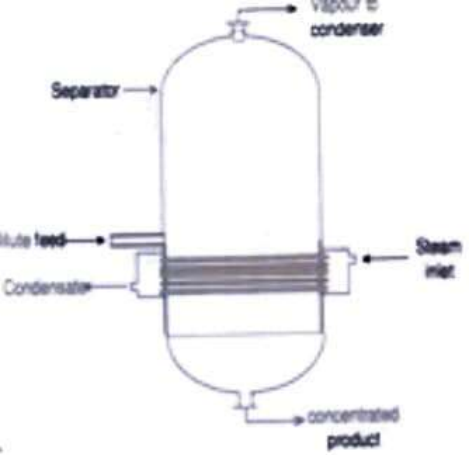
- It consists of series of horizontal tubes heated Internally by steam
- Feed enters at middle point over the tubes.
- Vapors escape from the top.

Advantage:

1. Low initial cost and require low head space.
2. Used as batch or continuous evaporation.

Disadvantages:

1. Poor circulation (natural).
2. Not for crystallizable solution.
3. Not for viscous liquids.
4. Not suitable for thermolabile due to long evaporation time



Vapour

Sight glass

Feed

Steam

Vent

Drips

Drips

Thick Juice

Horizontal tube evaporator

5- Multiple effect Evaporator

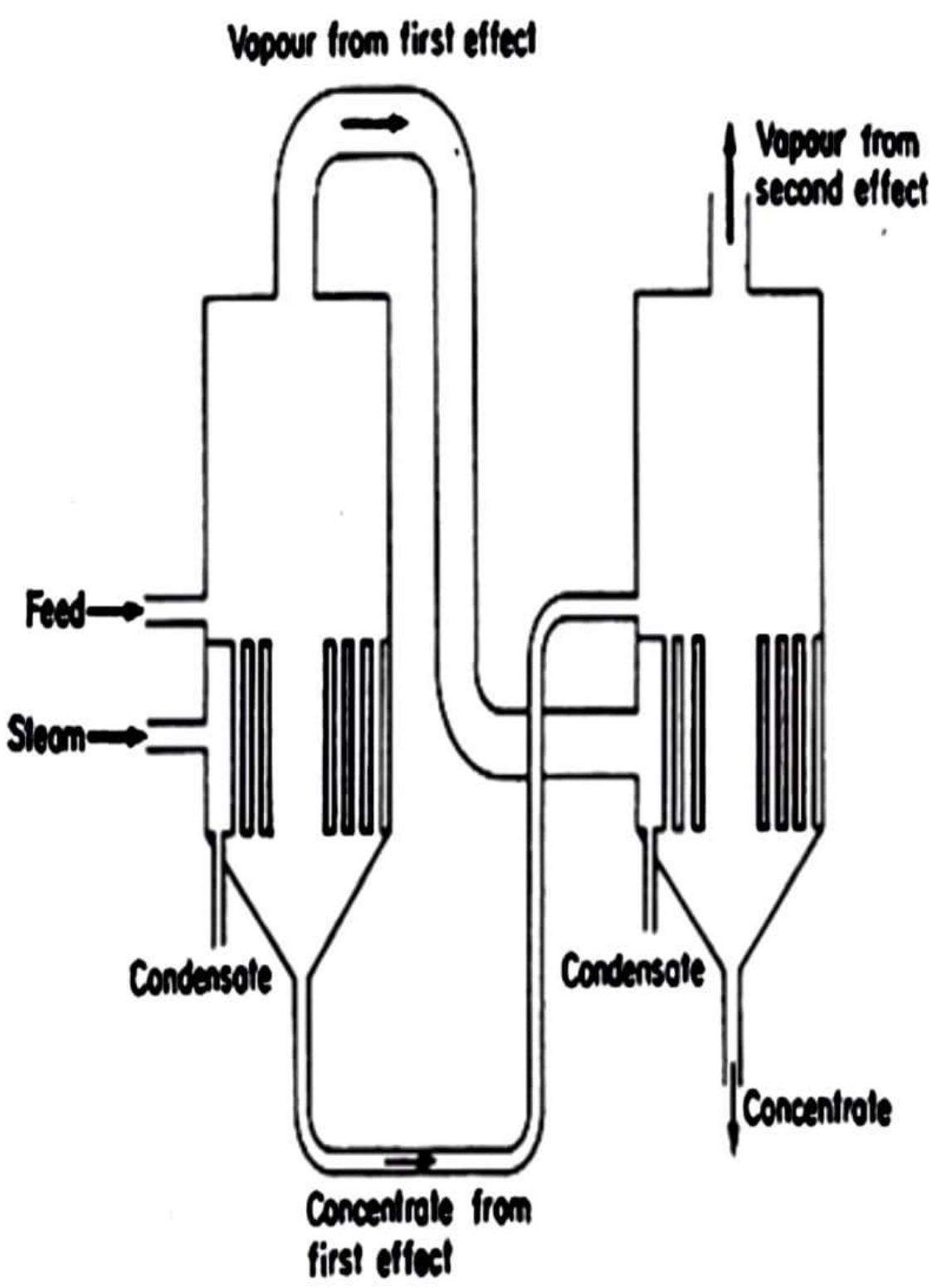
- If the vapor from one evaporator is fed into the steam chest of a second evaporator and the vapor from the second is sent to the condenser, the operation becomes double effect.

- The heat in the original steam is reused in the second effect and the evaporation economy increased.

- Also useful one the feed temp is very low, preheating

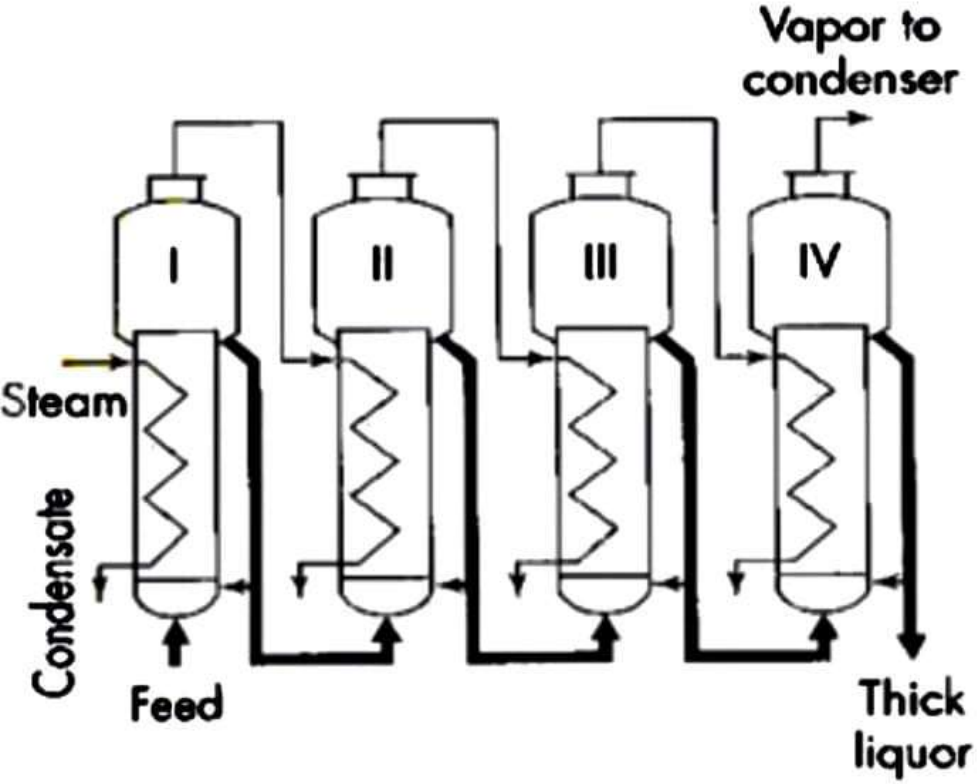
Methods of feeding

1. Forward feed
2. Backward feed
3. Mixed feed
4. Parallel feed



Multiple effect Evaporator

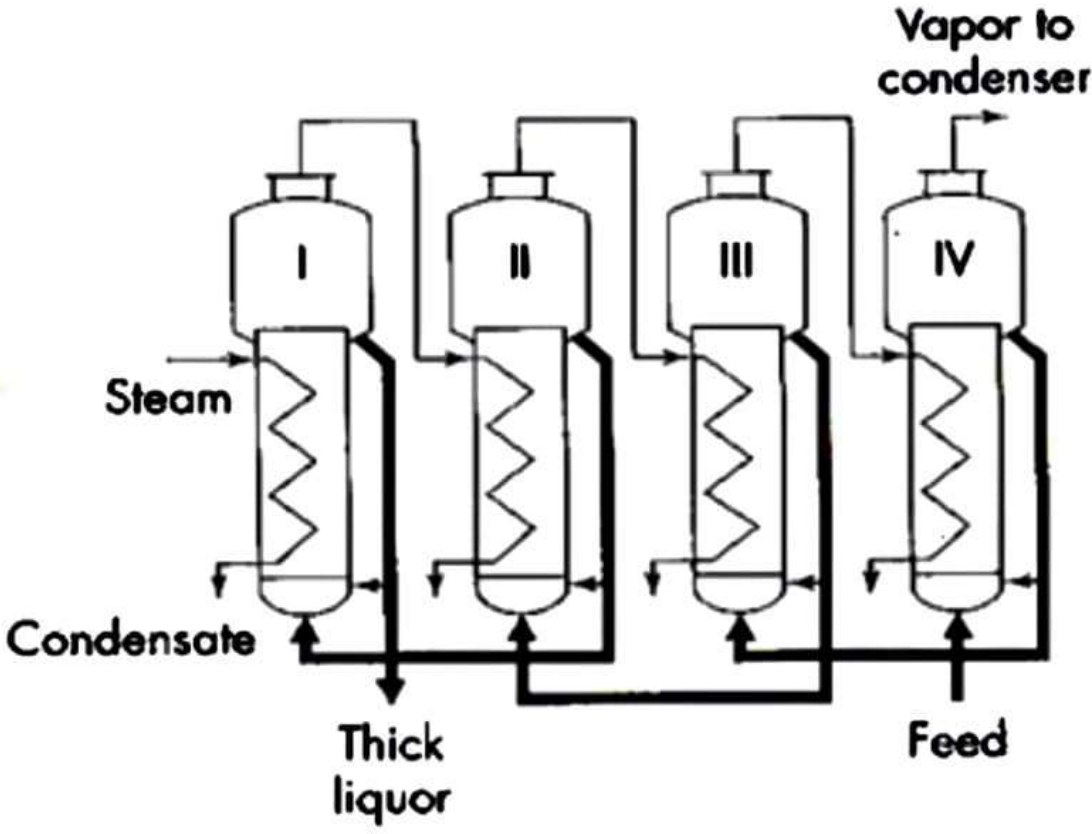
a- Forward feed



(a)

- This arrangement is simplest and no need of any pump to transfer liquid from effect to effect as the liquid flows in the direction of decreasing pressure.

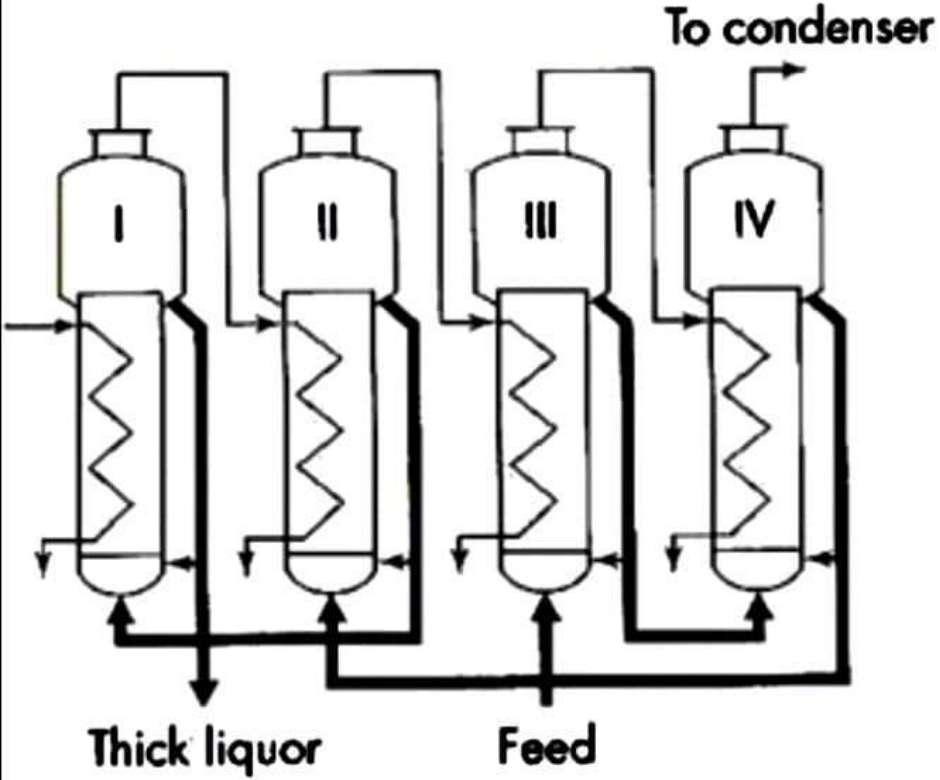
b-Backward ..



(b)

- This method requires a pump between each pair of effects since the flow is from lower pressure to the higher pressure.
- If the liquid is very viscous then we have to adopt this arrangement for better capacity.

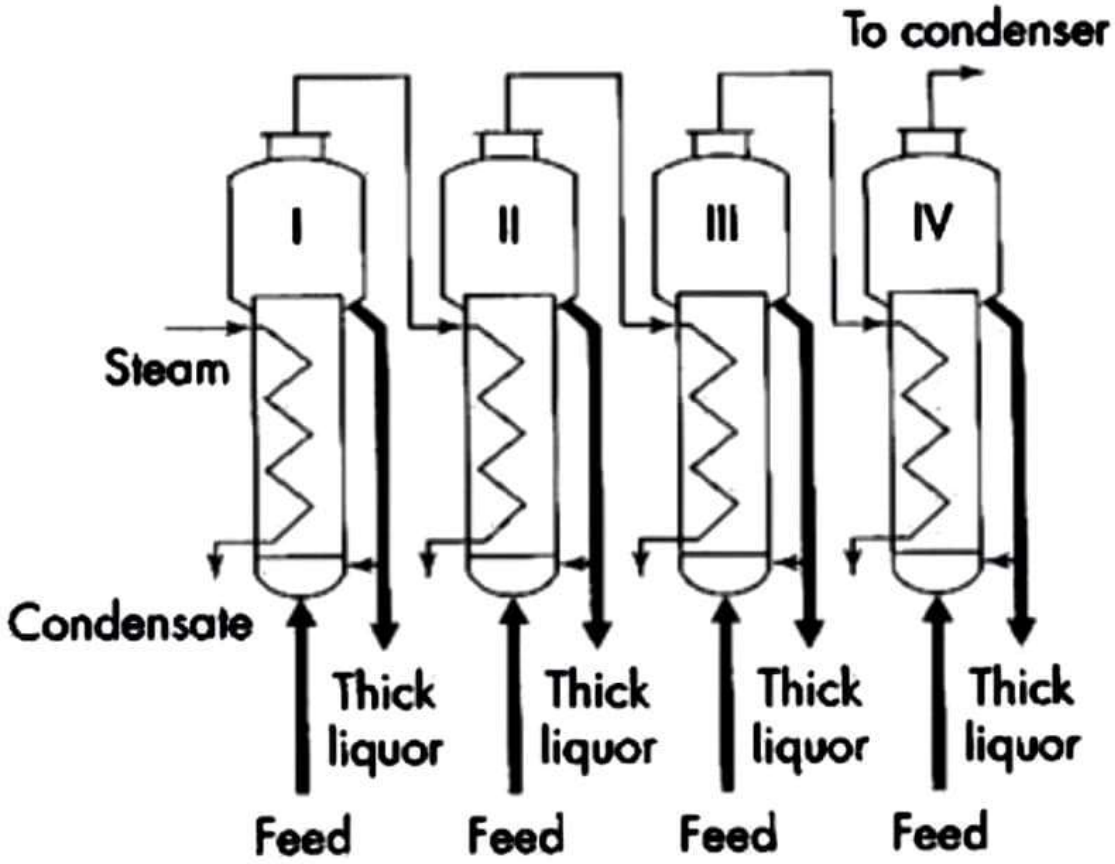
c- Mixed feed



(c)

- This arrangement is combination of forward and backward feed adopted for best overall performance

d- Parallel feed



(d)

- The fresh feed is fed to each effect simultaneously and the thick liquor is taken out from the same effect separately.
- In this arrangement there is no transfer of liquid from one effect to another effect

Multiple effect Evaporator

2) Forced circulation evaporators

Construction:

- The evaporator consists of a short tube calendria 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.

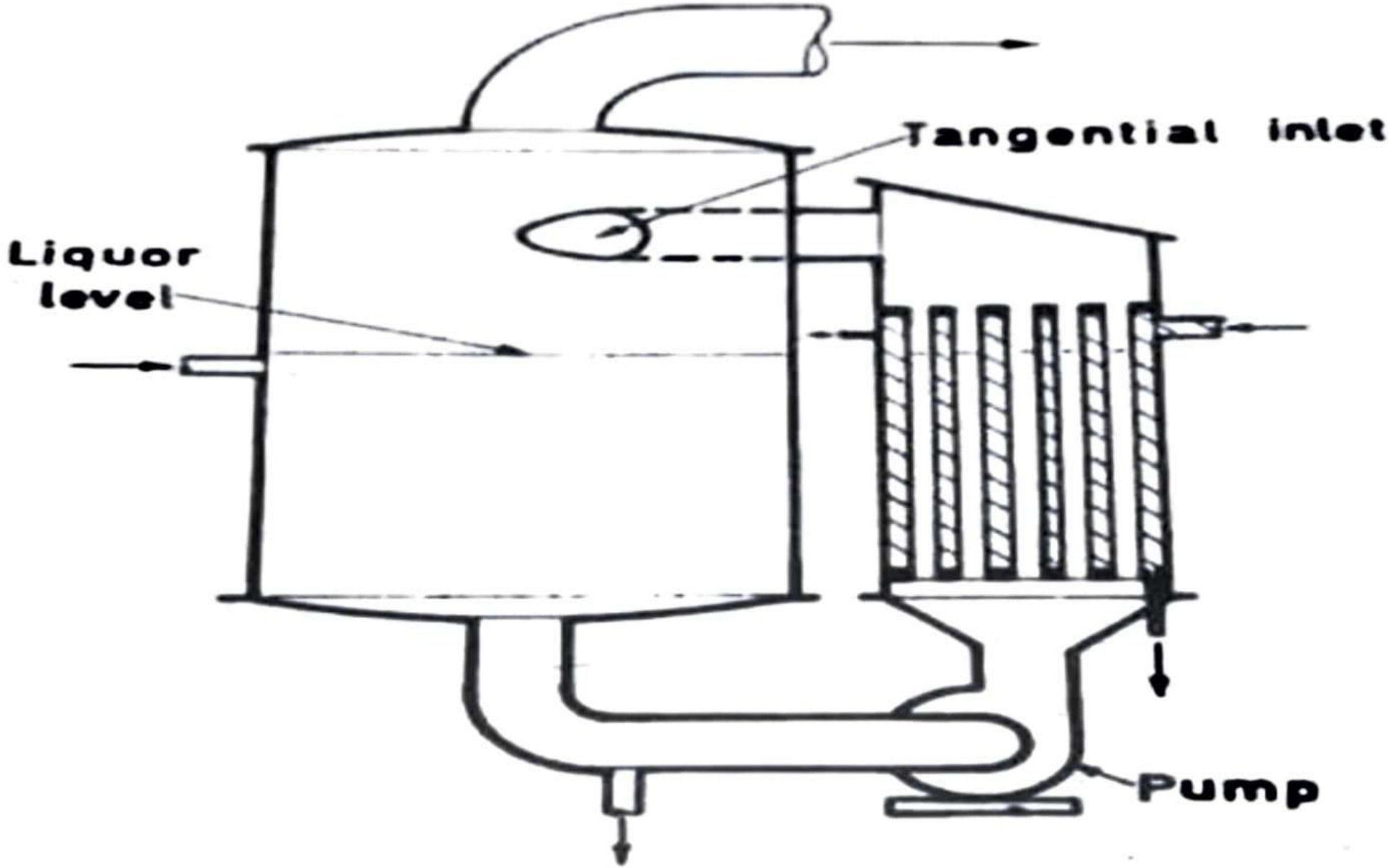
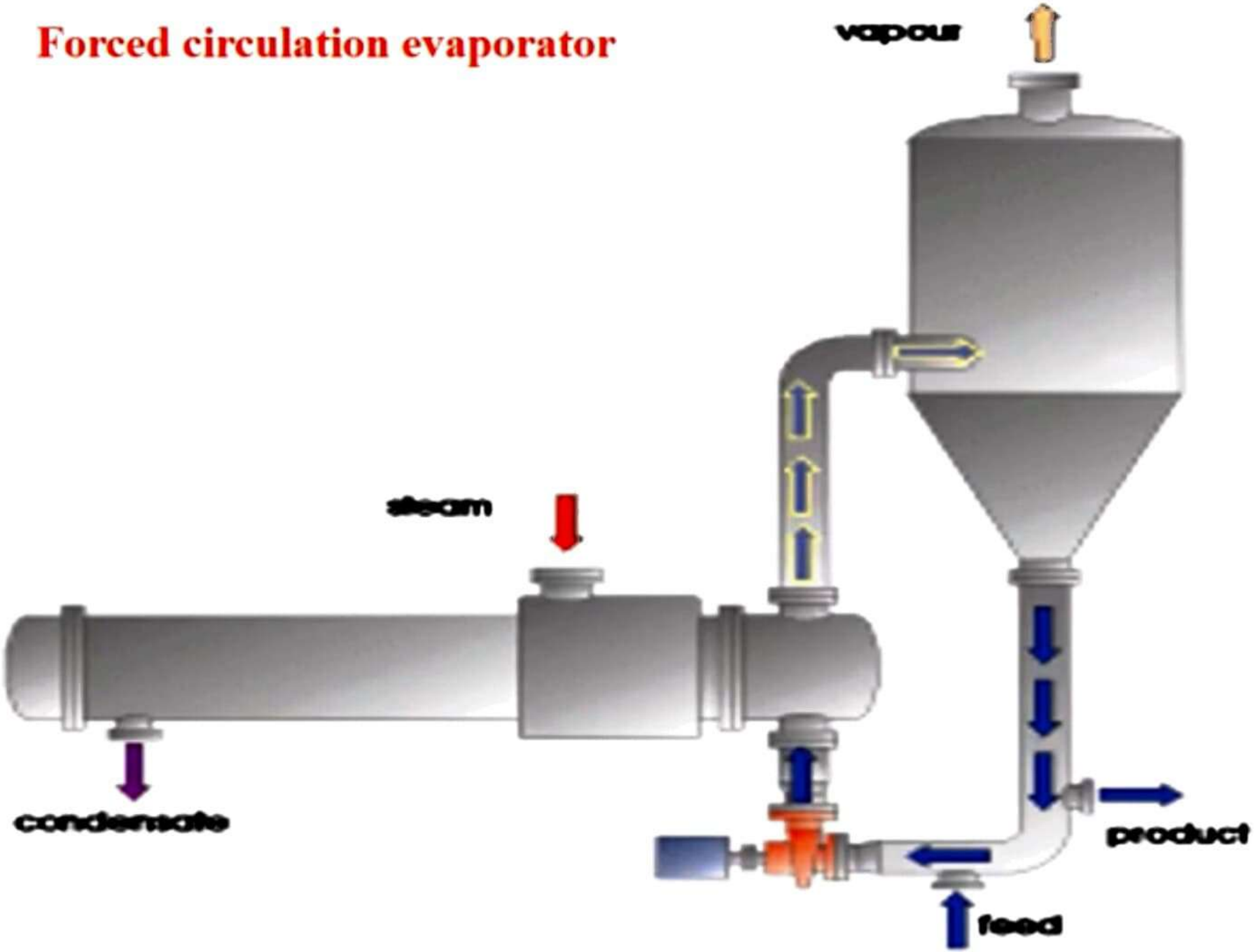


***Fig.* 14.4 Forced circulation evaporator**

(i) Forced circulation evaporator with vertical heating element

Forced circulation evaporator



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) Lillie film evaporator

iii) Long Tube Evaporator

  a) Climbing film evaporator

  b) Falling film evaporator

iv) Agitated-film evaporator

v) Horizontal film evaporator

i) Wiped film evaporators

Construction:

- A form of film evaporator coming into increasing use is the wiped film evaporator or rotary film evaporator,
- Which contains of a single, short tube of wide diameter,
- Better described as a narrow cylindrical vessel,1 or 2 meters in length.
- A section across the evaporator is shown here where it will be seen that the vessel is surrounded by a heated jacked.
- Through the vessel is a bladed rotor, with a clearance of the order of 1mm between the tips of the rotor blades and the wall of the vessel.

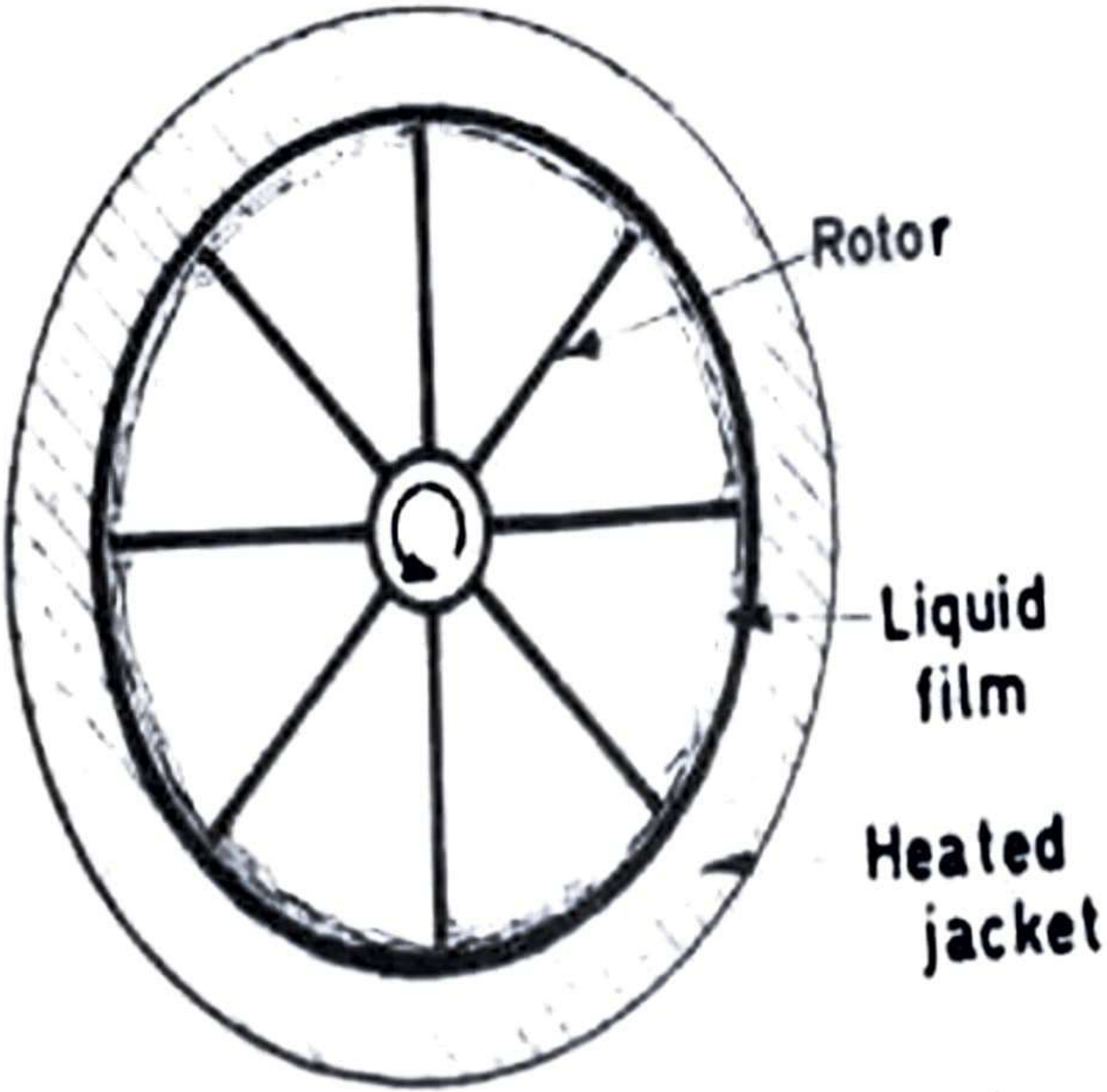
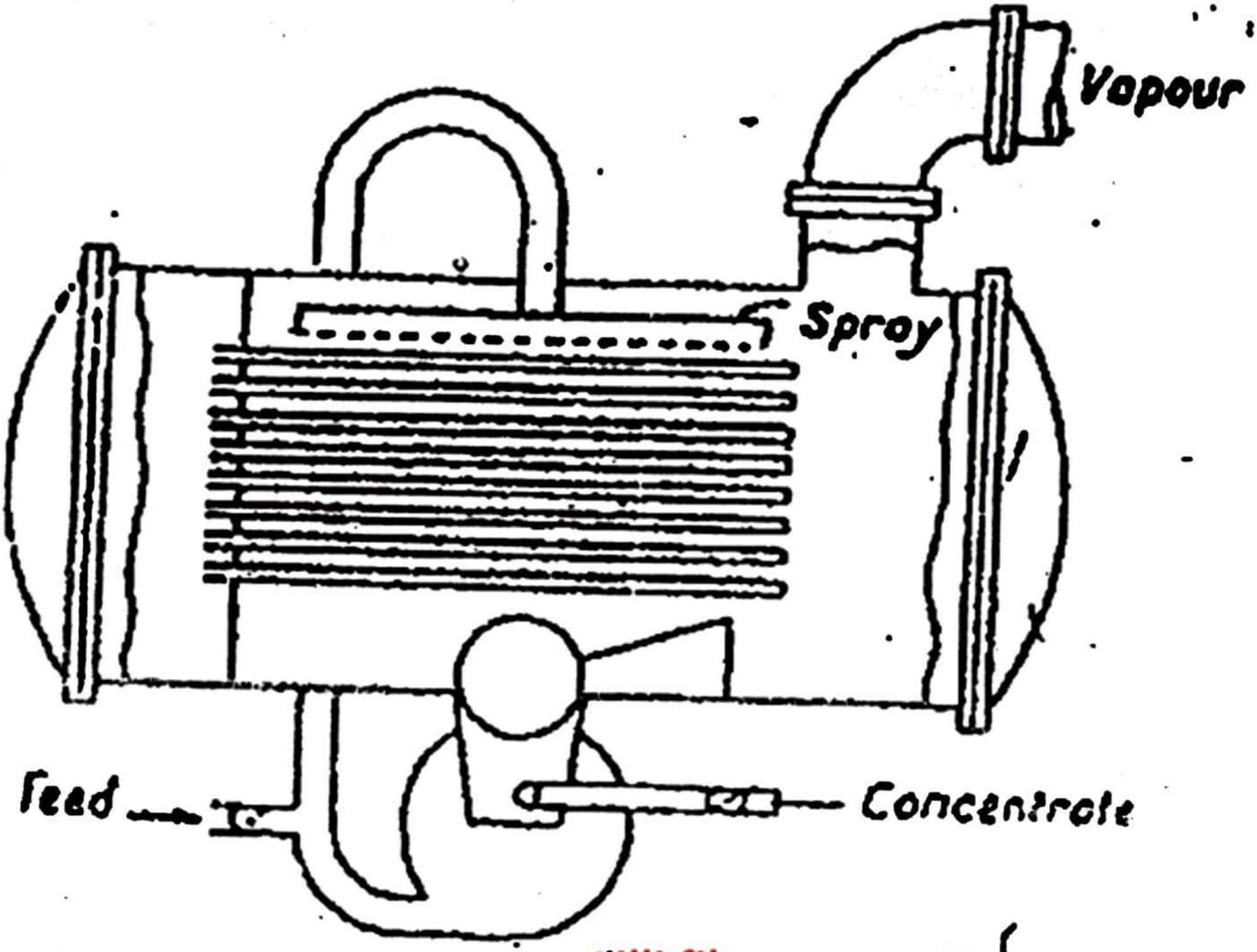


Fig. 14.9 Section through wiped film evaporator

ii) Lilli film evaporator

- liquid is sprayed as a film over a series of horizontal tubes heated internally by steam.

- The concentrated liquid collected at the bottom and can be circulated.



Lilli film evaporator

iii) Long tube evaporators

a- (Climbing film evaporators)

Construction:

- The heating unit consists of steam-jacketed tubes, having a length to diameter ratio of about 140 to 1, so that a large evaporator may have tubes 50 mm in diameter and about 7 m in length.

- The liquor to be evaporated is introduced into the bottom of the tube, a film of liquid forms on the walls and rises up the tubes, hence it is called climbing film evaporator.

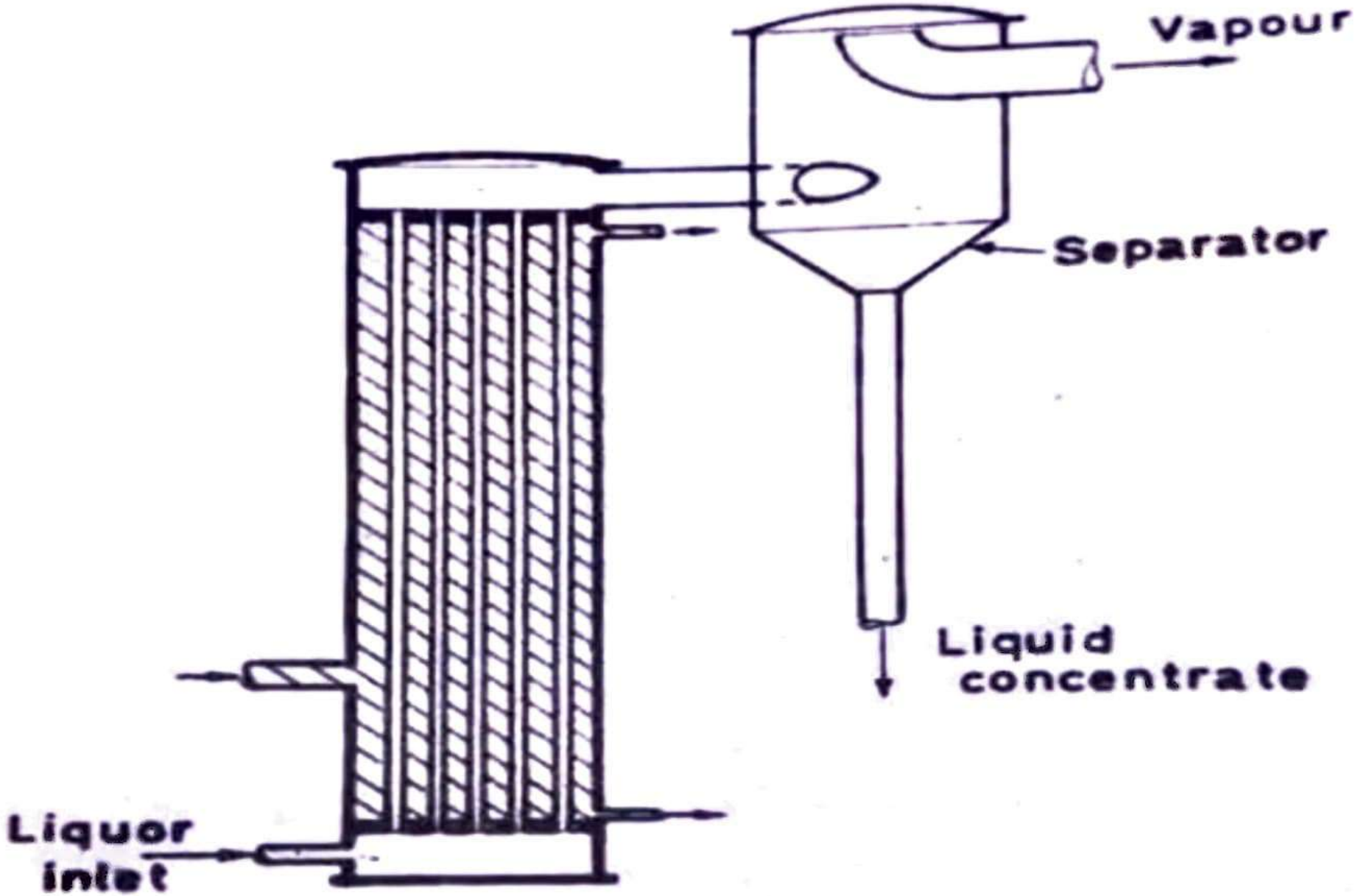


Fig. 14.5 Climbing film evaporator

iii) Long tube evaporators

b- (Falling film evaporators)

Construction:

- The heating unit consists of steam-jacketed tubes, having a length to diameter ratio of about 140 to 1,

- So that a large evaporator may have tubes 50 mm in diameter and about 7 m in length.

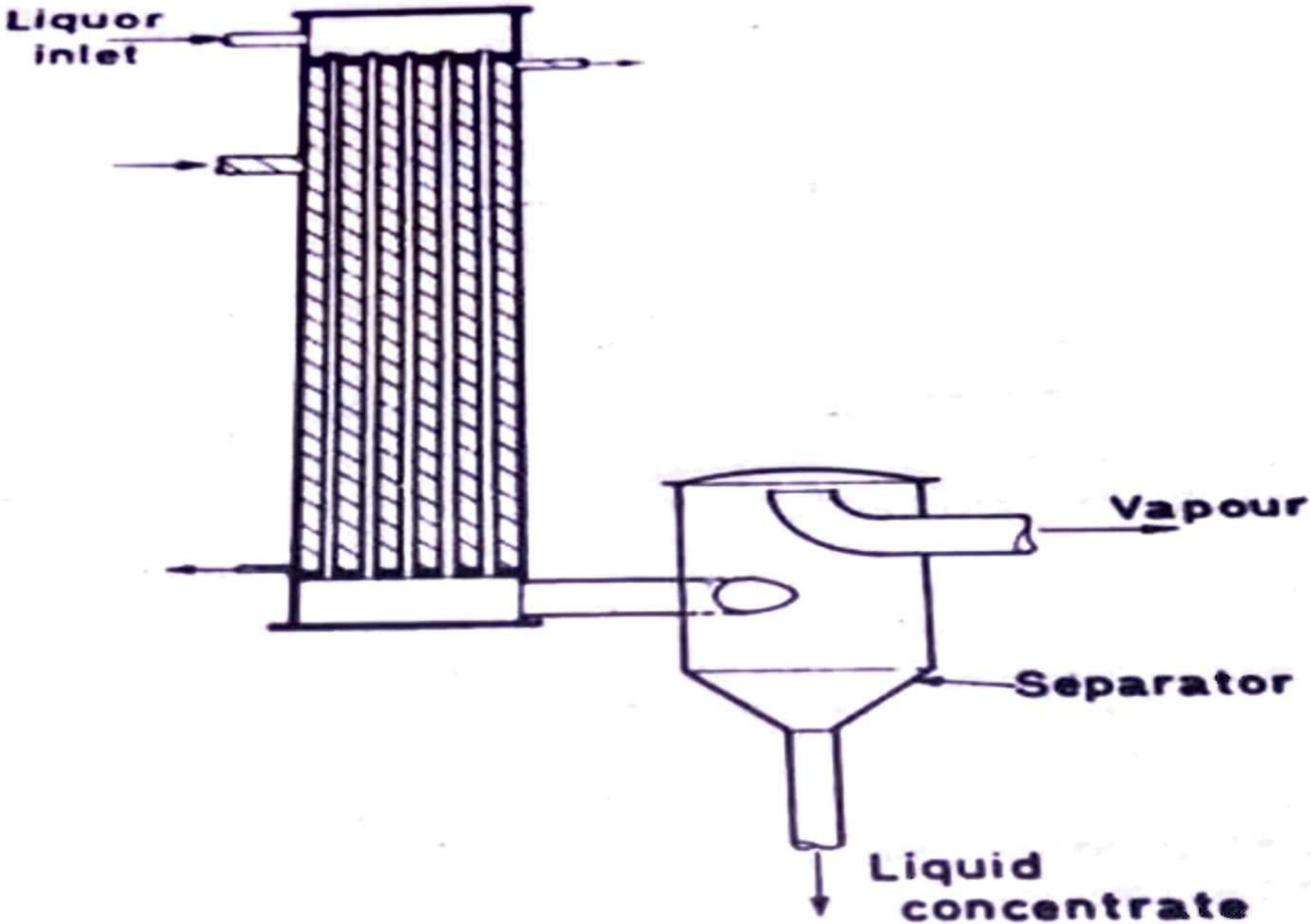
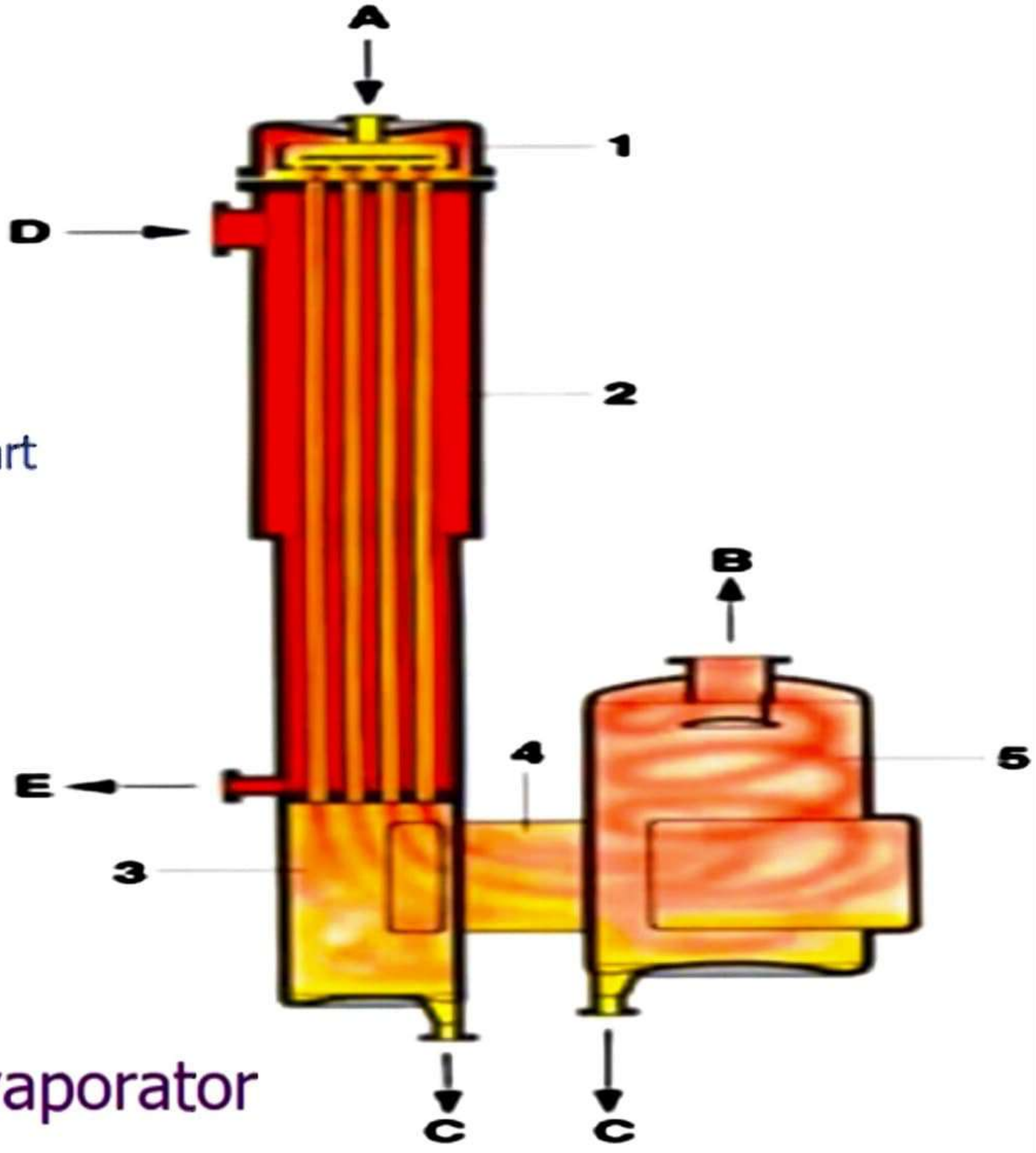


Fig. 14.7 Falling film evaporator

A: Product
B: Vapor
C: Concentrate
D: Heating Steam
E: Condensate
1: Head
2: Calandria
3: Calandria, Lower part
4: Mixing Channel
5: Vapor Separator



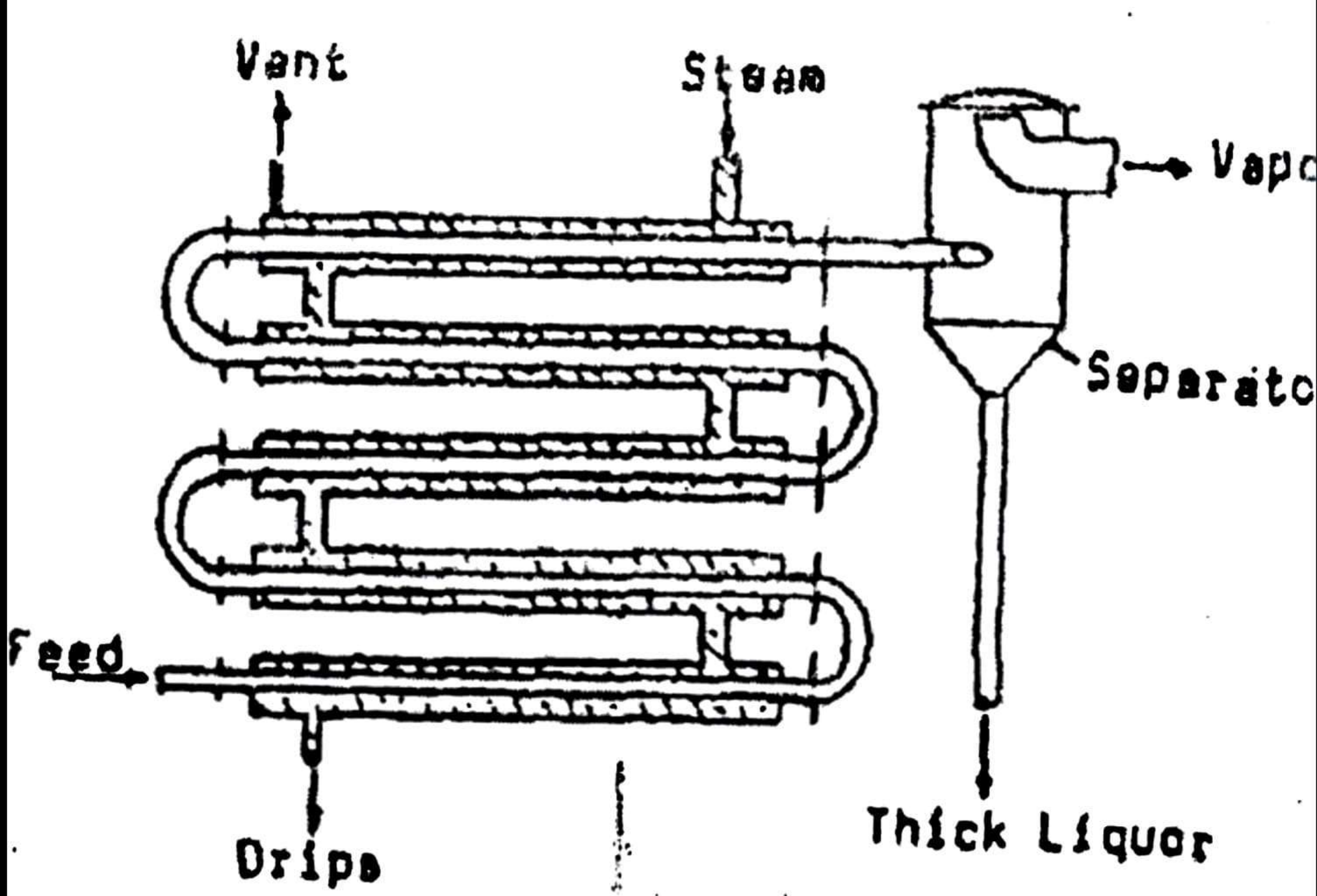
Falling Film Evaporator

iv) Agitated-film evaporator

- Resistance to heat transfer lies on the liquid side.
- By mechanical agitation of liquid we can reduce the resistance.
- It is a modified falling film evaporator with a single jacked tube containing an internal agitator

v) Horizontal film evaporator

- It overcomes the difficulty of high head space as in climbing film Evaporator (6-7 m)
- It consists of several parallel tubes 2-5 m joined together.
- Each tube is enclosed in an outer tube through which steam is passed in counter currently.
- The feed passes in the inner tube.



Horizontal film evaporator