EVAPORATION

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Evaporation

- It may be defined as the vaporization of a portion of solvent from a solution of a solid, leaving a concentrated liquid residue.
- **Objectives:**

1. Liquid, soft and dry extracts are prepared employing evaporation process.
2. It is also used in the concentration of blood plasma and serum.
3. Used in the preparation of medicaments containing enzymes, hormones, antibiotics and many other agents.

Differences between Evaporation, Distillation & Drying

EVAPORATION	DISTILLATION	DRYING
Components are heated below their boiling points	Components are heated at their respective boiling points	Components are heated above their boiling points
Vaporization takes place from surface of liquid	Vaporization takes place from entire body of liquid	Vaporization takes place from entire solid bed
Condensation of vapors are not required	Condensation of vapors are required to get purified product	Condensation of vapors are not necessary

General Principles of Evaporation

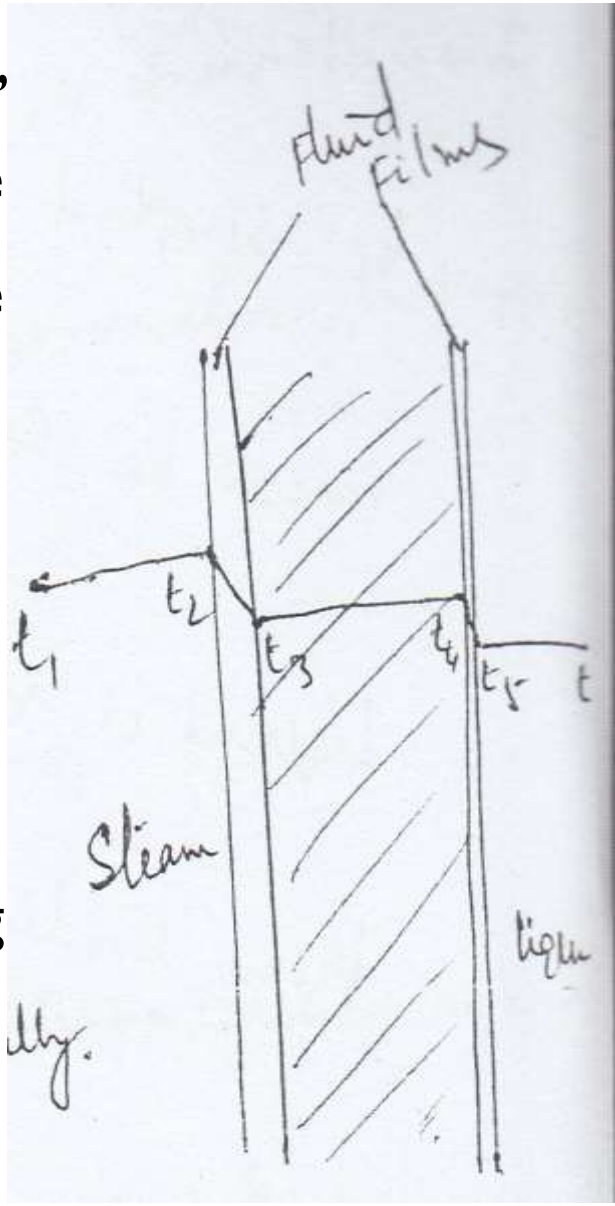
- Various factors influencing the heat transfer co-efficient of an evaporator are;

1. Vapor pressure
2. Boiling point
3. Effect of dissolved substances
4. Heat supply and vapor removal
5. Heat transfer

Heat Transfer

- When steam is used as a source of heat, there are three obstructions to the transfer of heat from the steam to the substance being heated. They are;

1. The Wall of the evaporator.
2. The film of condensed steam on steam side of wall.
3. The liquid film of substance being heated on the other side of the wall.



Film Co-efficients

- The general equation for heat transfer can be expressed as follows;

$$q = UA\Delta t$$

- Flow of heat through a solid can be represented by equation;

$$\frac{q}{A} = \frac{\Delta t K}{L}$$

- Flow of heat through a fluid film is expressed by equation;

$$\frac{q}{A} = \Delta th$$

- Flow of heat through fluid films is expressed by equations;

$$\frac{q}{A} = \Delta th1 \qquad \frac{q}{A} = \Delta th2$$

- The total resistance per unit of cross sectional area is the summation of fluid film resistances, the wall resistances and equals;

$$\frac{1}{h1}+\frac{1}{K}+\frac{1}{h2}$$

Where h1 and h2 are the film coefficients of the steam film and the liquid film respectively.

- The reciprocal of this resistance can be treated as a conductance U, so that

$$\frac{1}{U}=\frac{1}{h1}+\frac{1}{K}+\frac{1}{h2}$$

- The rate of heat flow from the steam side to liquid side is

$$\frac{q}{A}=\frac{t6-t1}{1/U}=(\mathrm{t6}-\mathrm{t1})\mathrm{U}$$

U is over all heat transfer coefficient

Factors influencing Rate of Evaporation

- Various factors influencing the rate of evaporation are;

1. Temperature
2. Temperature and time of evaporation
3. Temperature and moisture content
4. Type of product required
5. Effect of concentration

Classification of Evaporators

- They are classified based upon the movement of heat transfer. They are;

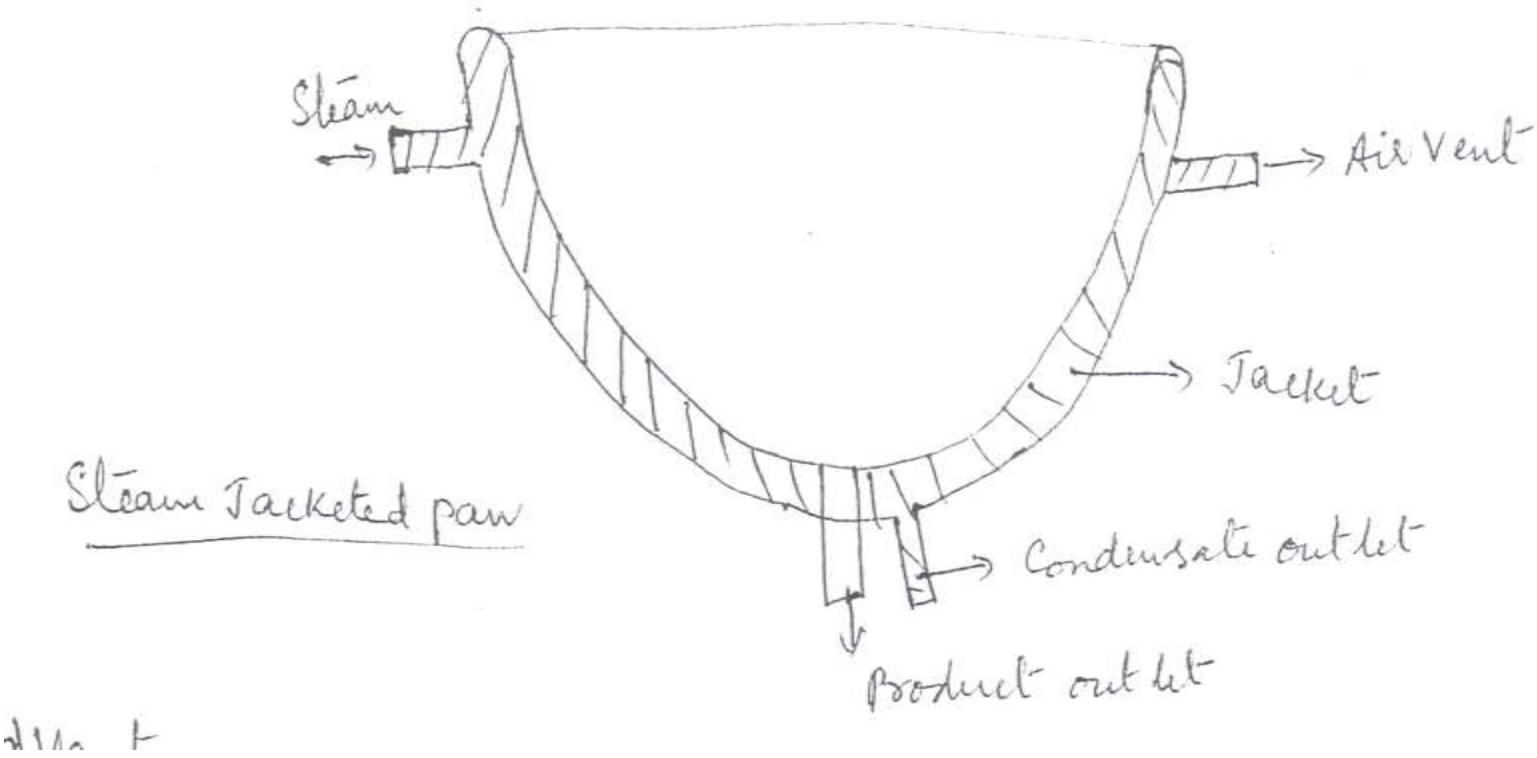
1. Natural circulation evaporators
2. Forced circulation evaporators
3. Film evaporators

Natural Circulation Evaporators

- They are of three types;

1. Evaporating pans or Steam jacketed pans
2. Evaporating stills
3. Short tube evaporator

Evaporating pans or Steam jacketed pans



- **Advantages:**

1. It is simple and cheap to construct.
2. It is easy to use, clean and maintain.

- **Disadvantages:**

1. Heat transfer in these pans is very poor and solids are likely to deposit on the surface, leading to decomposition of the product. Also many products give rise to foaming when boiled under conditions of natural convection.
2. The entire liquid is heated all the time, which is not suitable for thermolabile materials.
3. The heating surface is limited and decreases proportionally as the size of the pan increases. Further more the heating area will decrease as concentration of the product occurs.

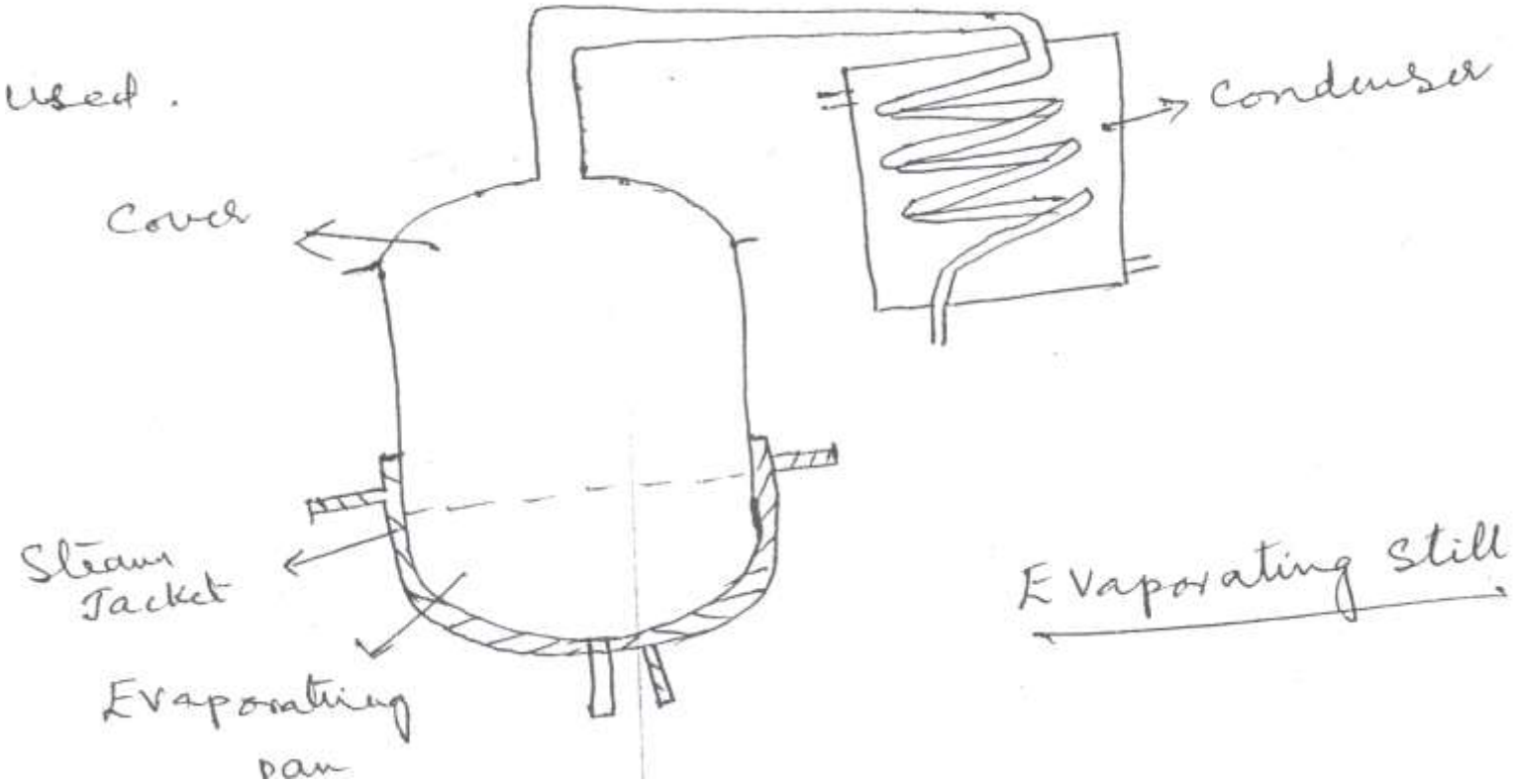
- **Disadvantages:**

4. The pan is open, so that the vapor passes to the atmosphere which can lead to the saturation of the atmosphere and pollution cannot be controlled.
5. These pans are limited only to aqueous liquids evaporation.
6. Vacuum cannot be used with these pans, so that the temperature of boiling cannot be lowered.

- **Applications:**

1. It is used for the concentration of aqueous and thermostable liquors. Eg: Extract of Liquorice
2. It is used for the preparation of final stage process of soft extracts.

Evaporating Stills



- **Advantages:**

1. It is quite simple to construct and easy to clean and maintain.
2. The vapor is condensed, which speeds evaporation and allows equipment to be used for any type of solvents. Eg: Ethanol
3. A receiver and vacuum pump can be fitted to the condenser, permitting operation under reduced pressure and hence at lower temperatures.

- **Disadvantages:**

1. Natural convection only.

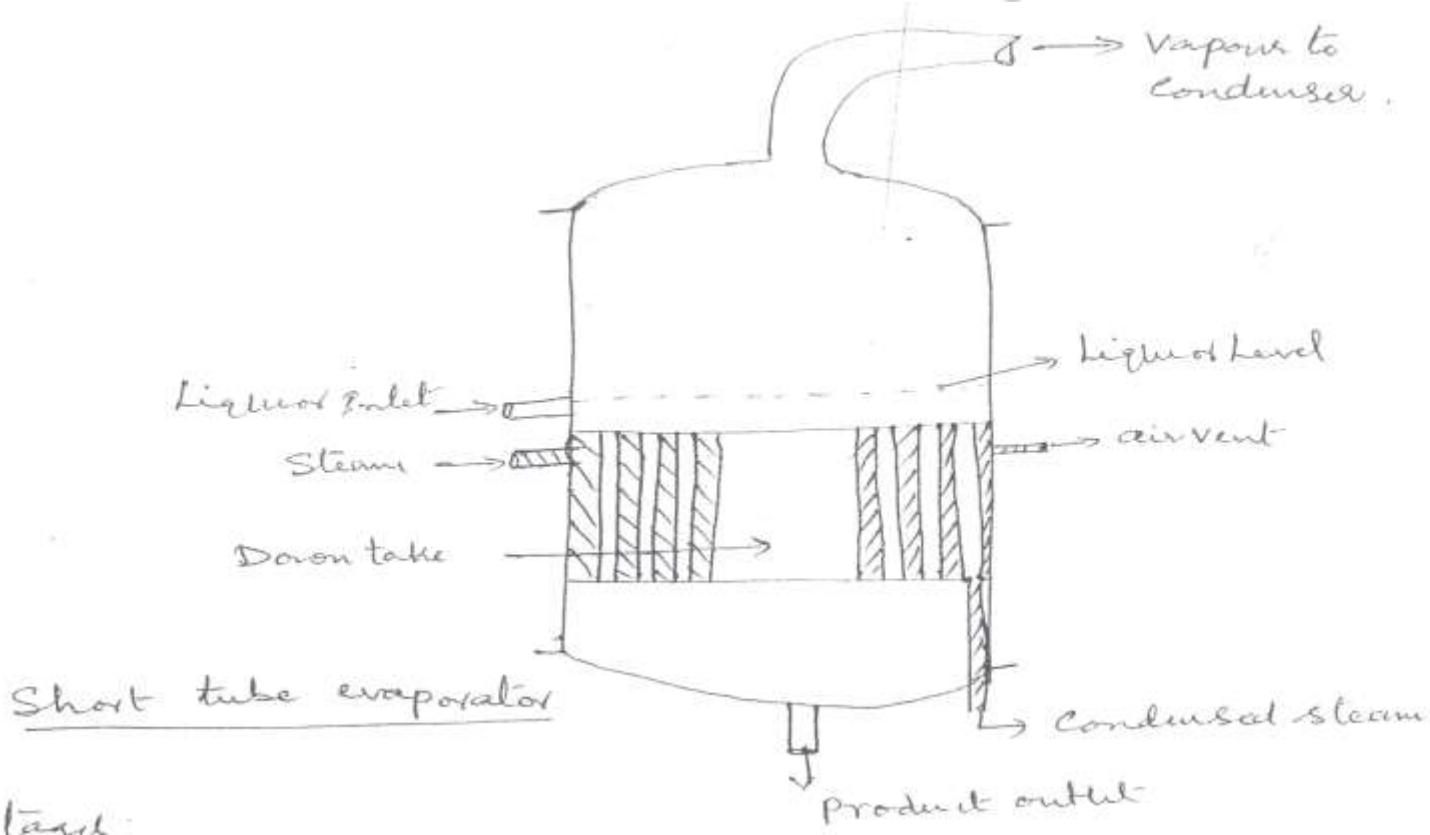
2. All the liquid is heated all the time.

3. The heating surface is limited.

- **Applications:**

1. The still can be used for evaporating liquors in general, with aqueous or other solvents.
2. Thermolabile materials can be evaporated under reduced pressure.
3. Easy removability of the still head makes it convenient for evaporating extracts to dryness.
4. This plant can be useful to deal with small batches of variety of materials.

Short Tube Evaporator



- **Advantages:**

1. It increases the heating area, possibly by 10 to 15 times when compared with that of an external jacket.
2. Vigorous circulation reduces boundary layers and keeps solids in suspension, so increases the arte of heat transfer. As a result, over all coefficients of heat transfer are from 3 to 5 times greater than those founding in evaporating pans.

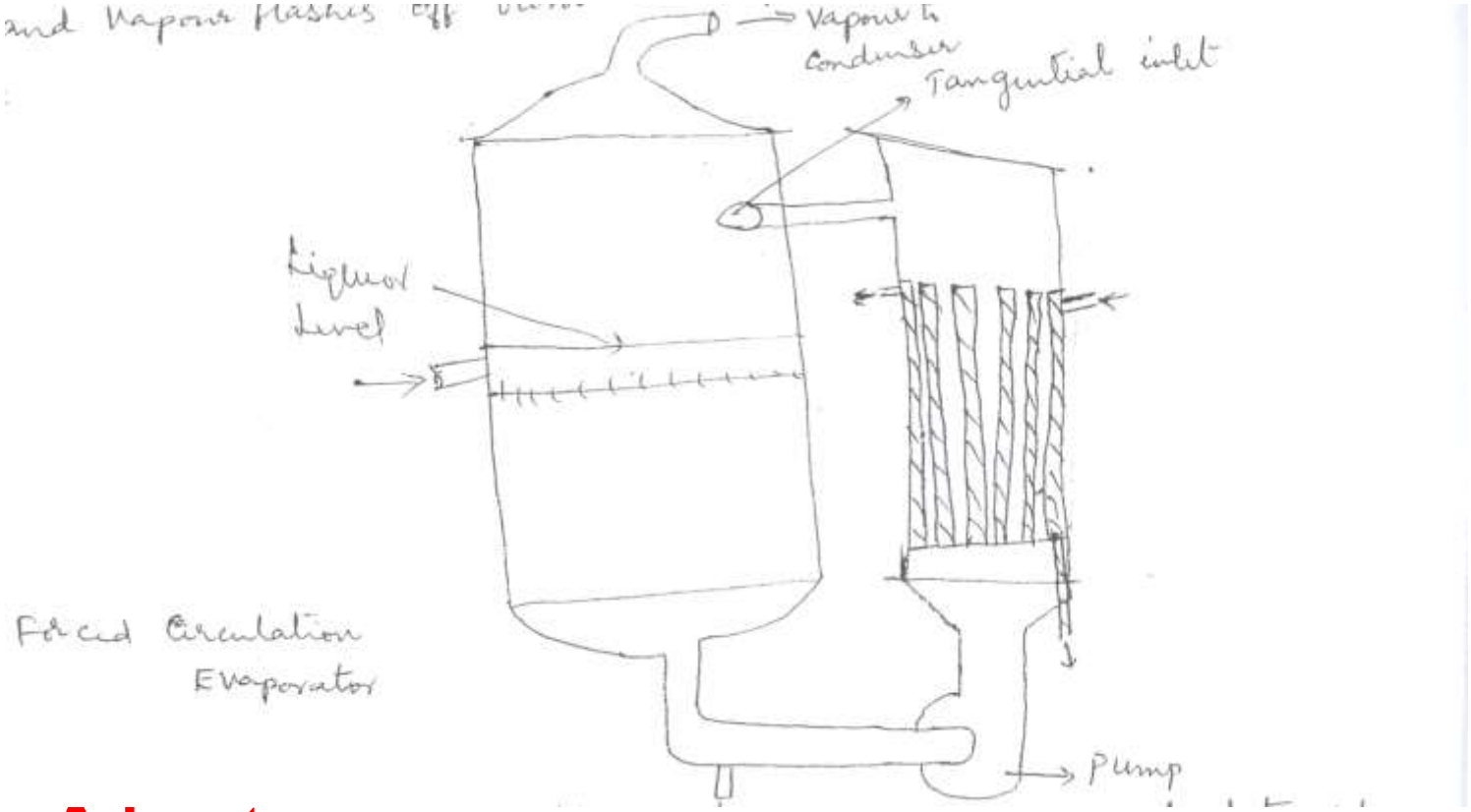
- 3. Like the still, a condensor and receiver can be attached, to collect the condensed liquid.
- **Disadvantages:**

1. Since the evaporator is fitted to a point above the level of the calandria, a considerable amount of the liquid is heated for a long time.
2. The plant is much more complicated, making it expensive to construct and increasing the difficulty of cleaning and maintenance compared with the simple still.
3. The head of liquor increases the pressure at bottom of vesel especially in large evaporators where the liquor depth may be 2m, which may give pressure of about 0.25 bars, leading to elevation of boiling point by 5 or 6 degrees.

- **Applications:**

1. This equipment is most useful for products manufactured on large scale, where the process can be operated continuously on one type of material.
2. This method is used for extracts manufactured in large quantities such as cascara, sugar, salt or caustic soda.

Forced Circulation Evaporator



- **Advantages:**

1. The rapid liquid movement improves heat transfer, especially with viscous liquids or materials that deposit solids of foam readily.
2. This equipment is particularly suitable for operation under reduced pressure.
3. The evaporation rate is rapid.

- **Applications:**

1. This is more suitable for thermolabile materials.

   Eg: It is used in practice for the concentration of insulin and liver extracts.

FILM EVAPORATORS

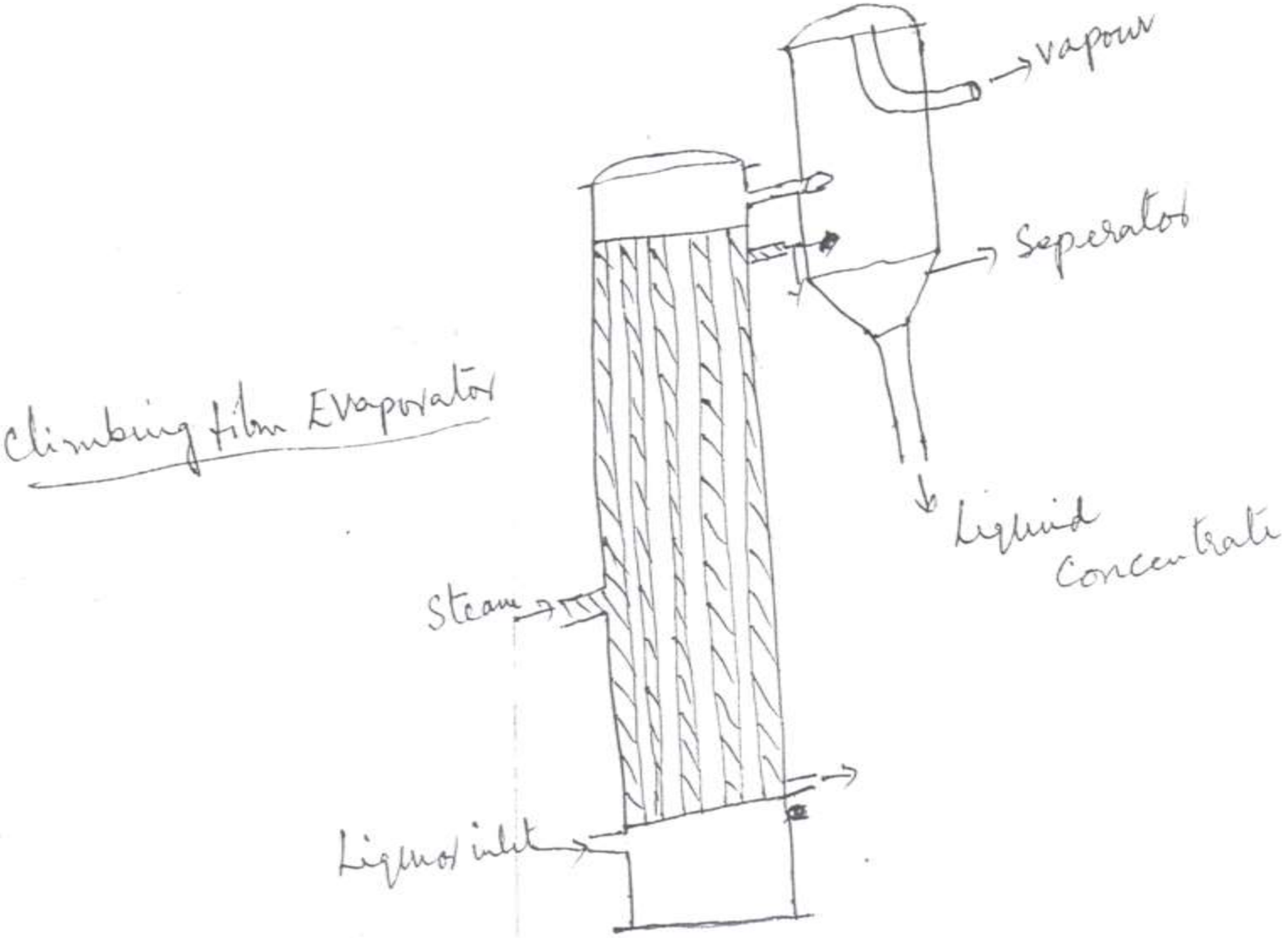
They are of several types.

(a) Long tube evaporators – Climbing film evaporators
– Falling film evaporators
– Horizontal film evaporators

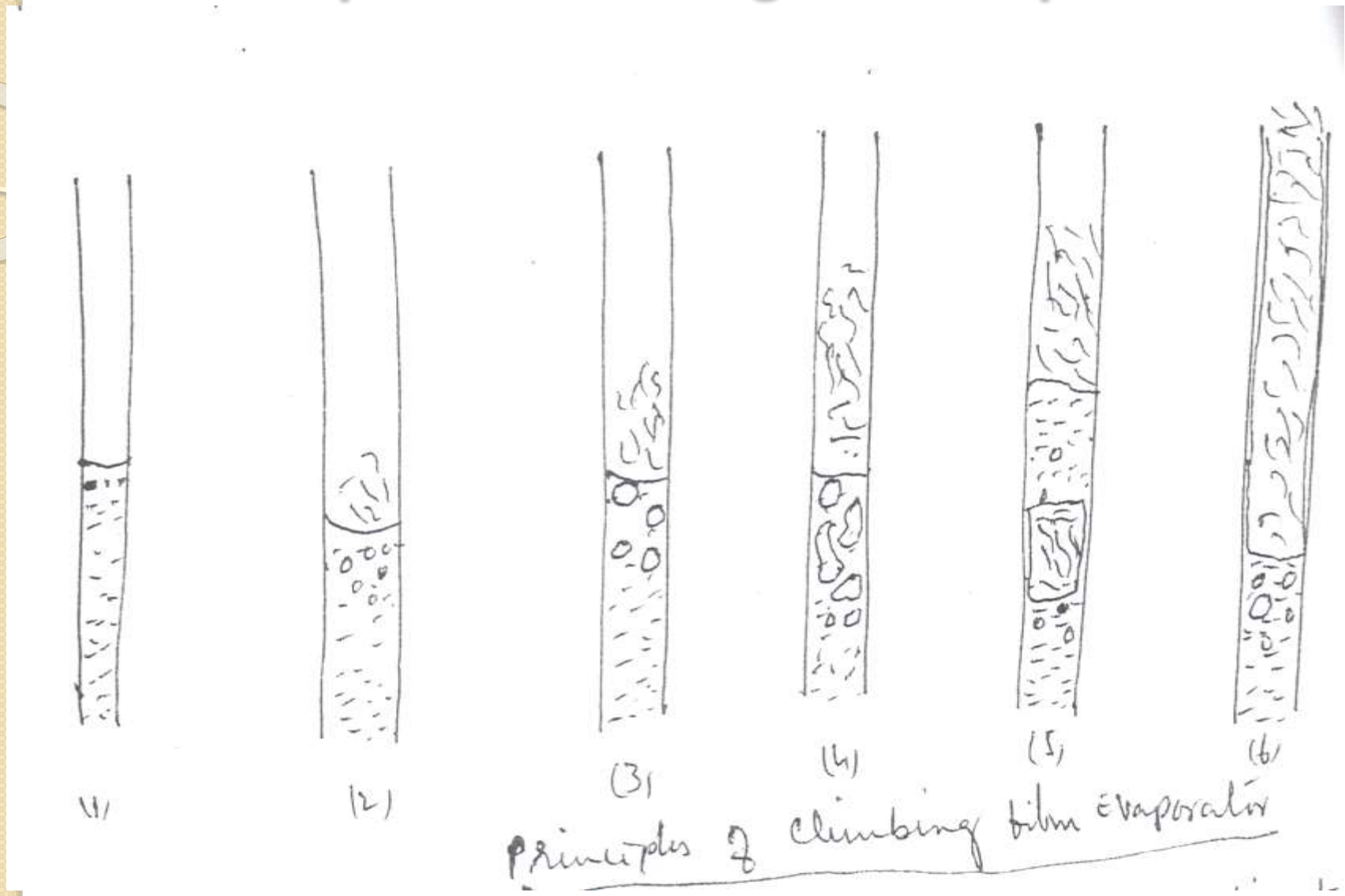
(b) Others – Wiped film evaporator
– Agitated film evaporator

(c) Miscellaneous – Multiple effect evaporator

Climbing Film Evaporator



Principles of Climbing Film Evaporator



- **Advantages:**

1. The very high film velocity reduces boundary layers to a minimum giving improved heat transfer.
2. Use of long narrow tubes provide large areas for heat transfer.
3. Because of increased efficiency of heat transfer, a small temperature difference is sufficient, with loss of damage to thermolabile materials.
4. The time of contact between liqour and heating surface is very short when compared to conventional type (1-20 sec) which is more advantageous for heat sensitive materials.

5. Evaporation rate is very high, since the film formation gives an extremely large surface area in relation to the volume of liquid.

6. The mixture of liquid and vapor enters the separator at high velocity, which improves the separation efficiency and makes the method especially suitable for materials that foam.

7. Although the tubes are very long, they are not submerged as in the short-tube evaporator, so that there is no elevation of boiling point due to hydrostatic head.

- **Disadvantages:**

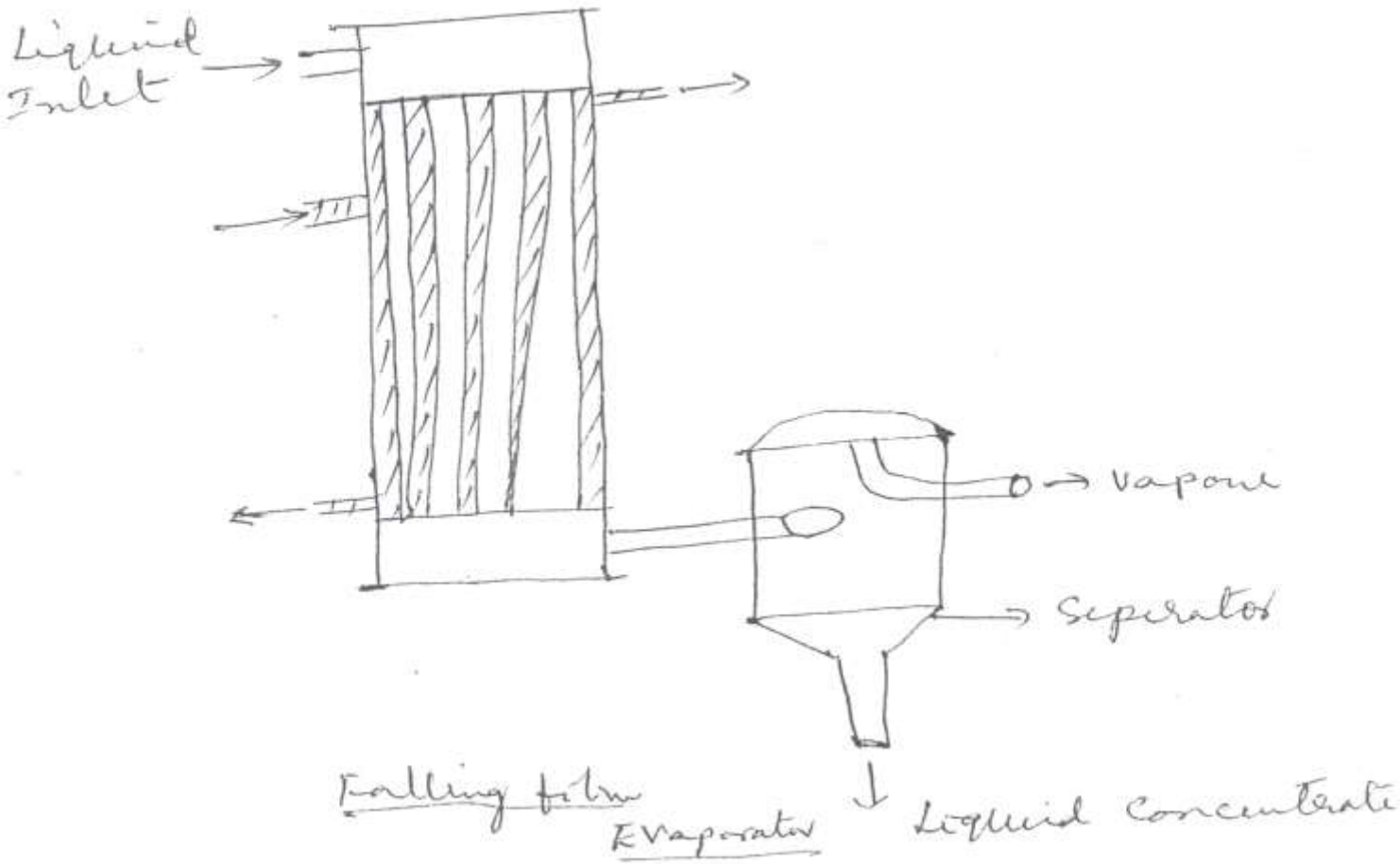
1. It is expensive to manufacture and it is difficult to clean and maintain.
2. The feeding rate is critical.
   (a) If the feed rate is too high, the liquid may be concentrated insufficiently.
   (b) If the feed rate is too low, the film cannot be maintained and dry patches may form on tube wall.

- **Applications:**

1. Due to rapid evaporation, minimum temperature gradient and short heating time, this method approaches the perfect method for pharmaceutical products.
2. Thermolabile materials can be suitably evaporated.

   Eg: Concentration of solutions such as insulin, liver extracts and vitamins.

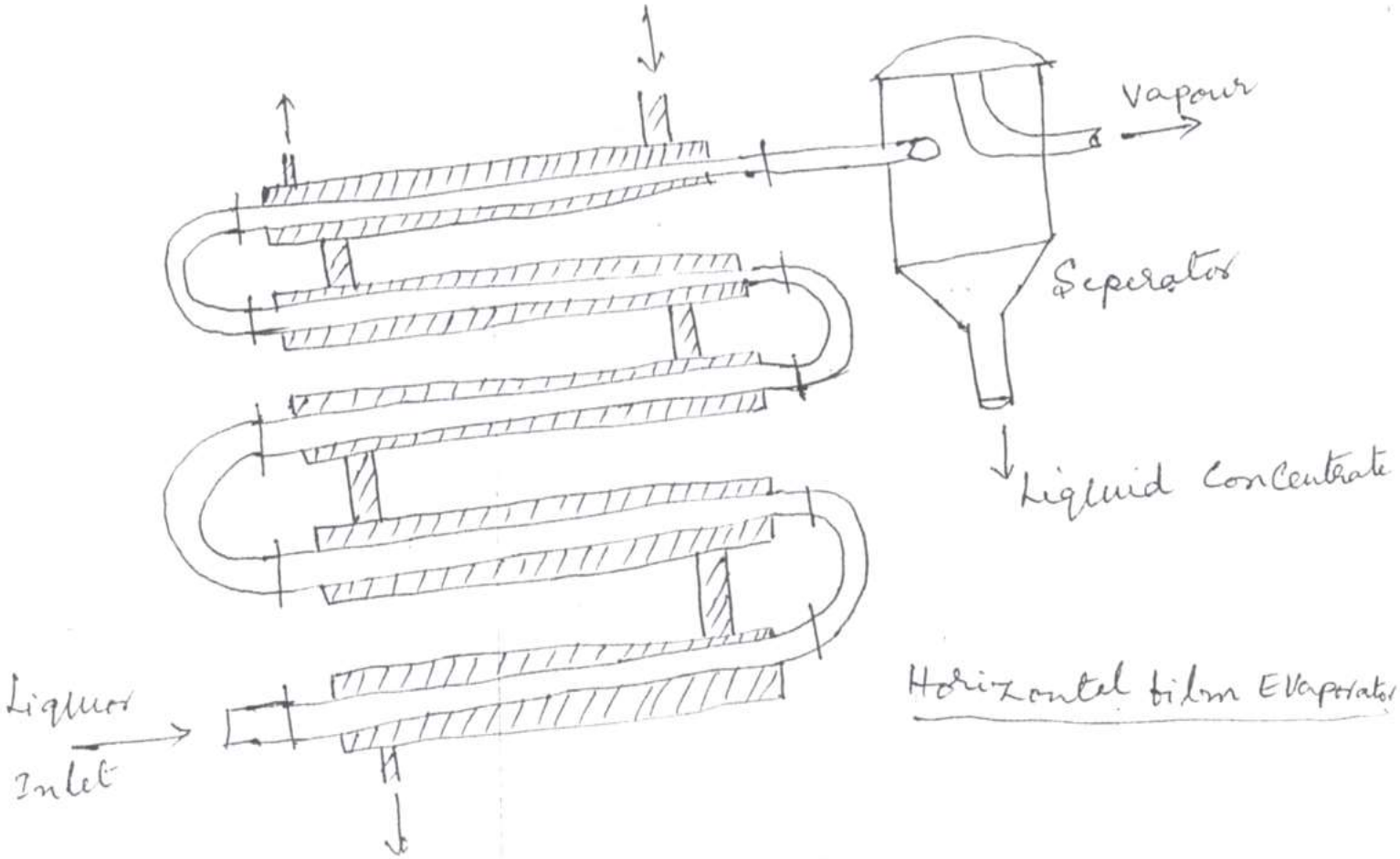
Falling Film Evaporator



- **Advantage:**

1. The movement of the liquid film is assisted by gravity, enabling more viscous liquids to be handled.

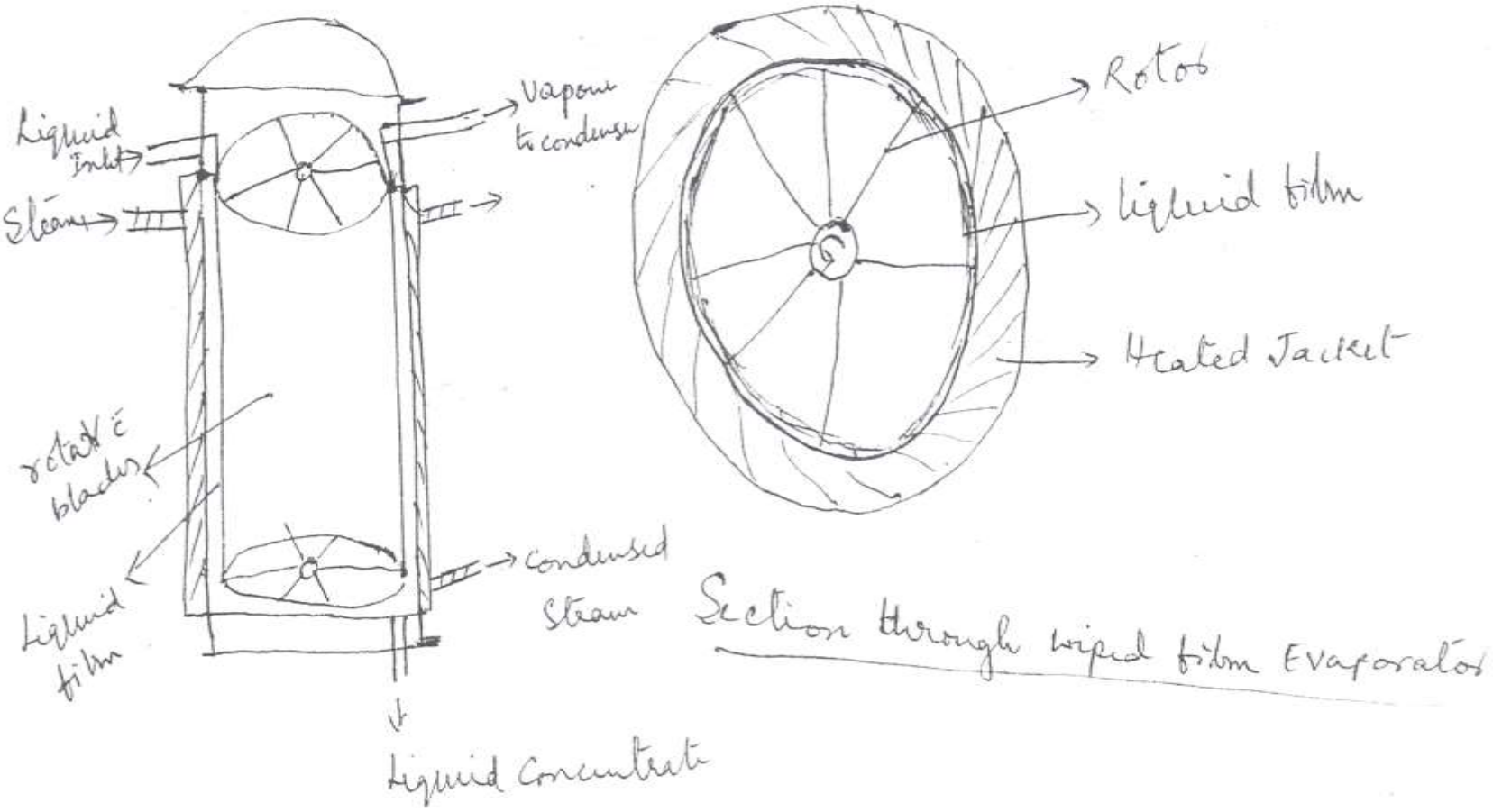
Horizontal Film Evaporator



- **Advantages:**

1. Occupies very small space and U bends can be easily removed.
2. Used safely with small batches of different materials.

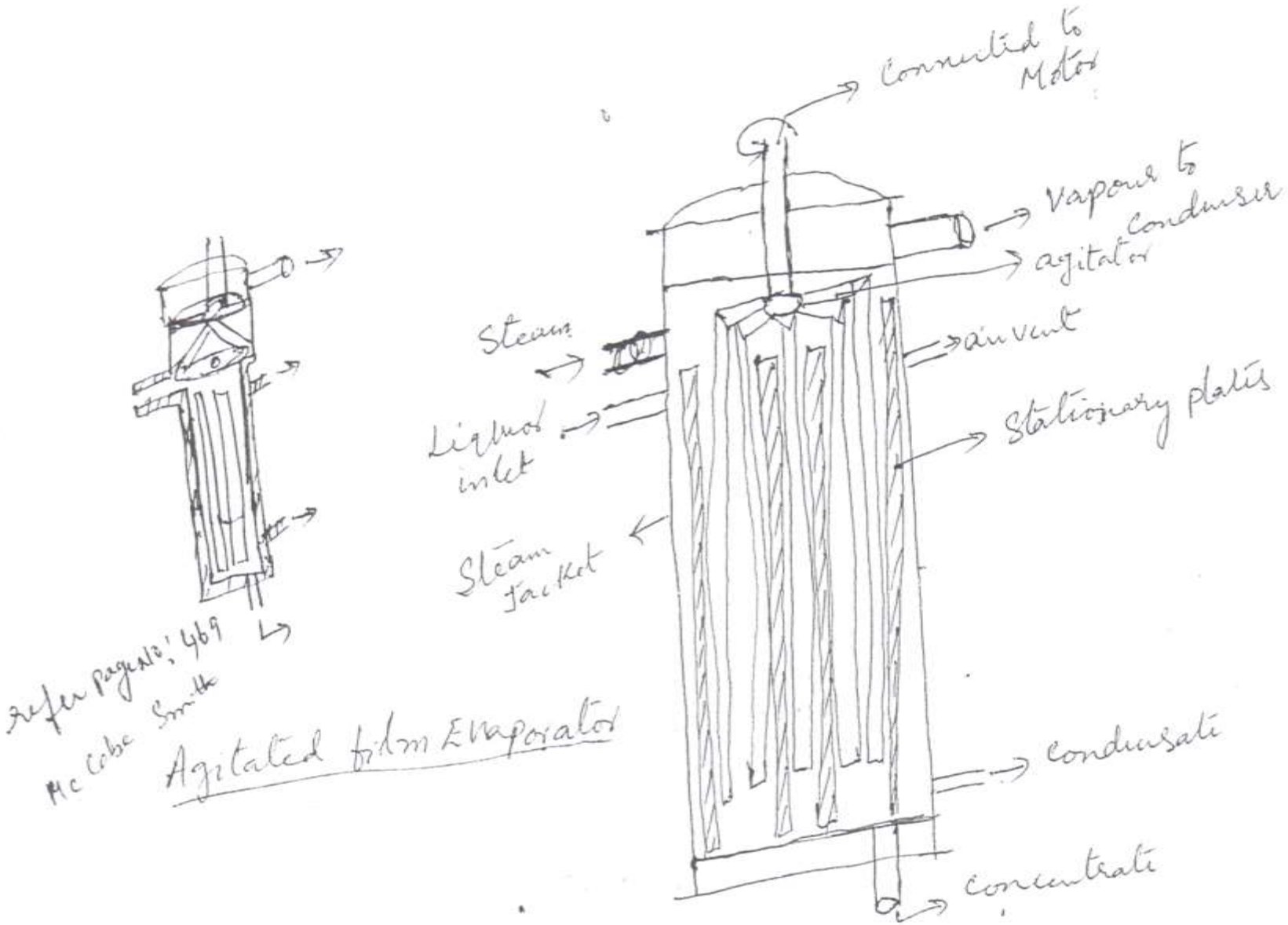
Wiped Film or Rotary Film Evaporator



- **Advantage:**

1. Because of good heat transfer, this method is especially useful with liquids that are too viscous to be processed in units in which the film is formed naturally.

Agitated Film Evaporator



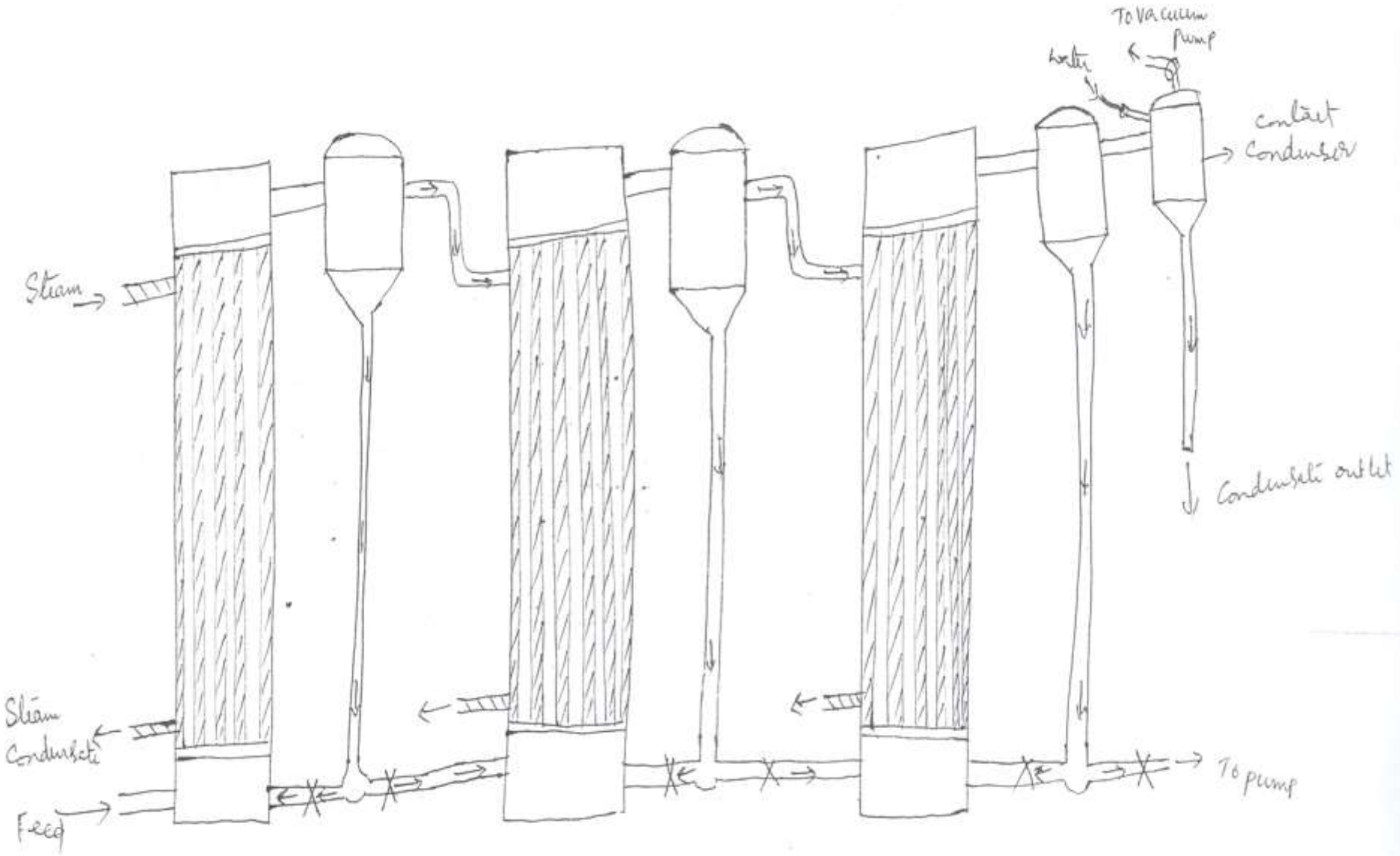
- **Advantages:**

1. This equipment is more suitable to provide high rates of heat transfer with viscous liquids.
2. This is particularly effective with such viscous heat-sensitive products as gelatin, rubber, latex, antibiotics and fruit juices.

Disadvantages:

1. Its cost is very high.
2. It consists of various internal moving parts, which may need considerable maintenance.

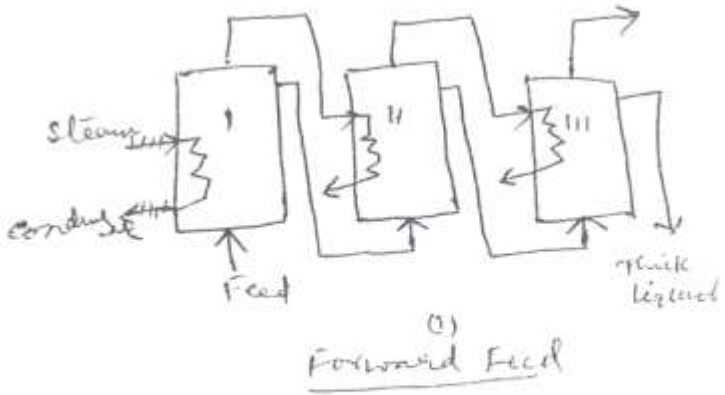
Multiple Effect Evaporator



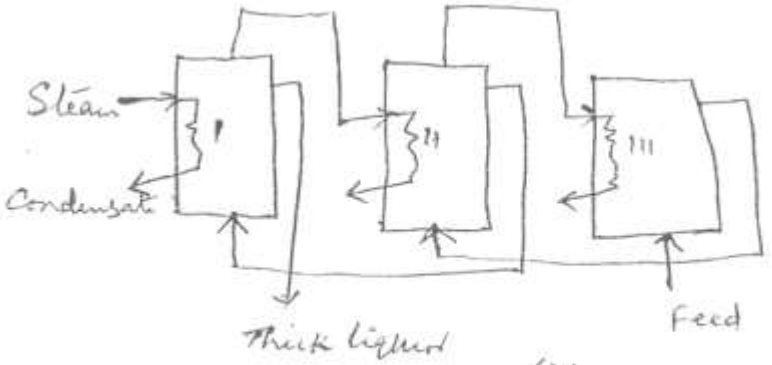
Various Feeding Techniques

- Various liquor feeding techniques are;

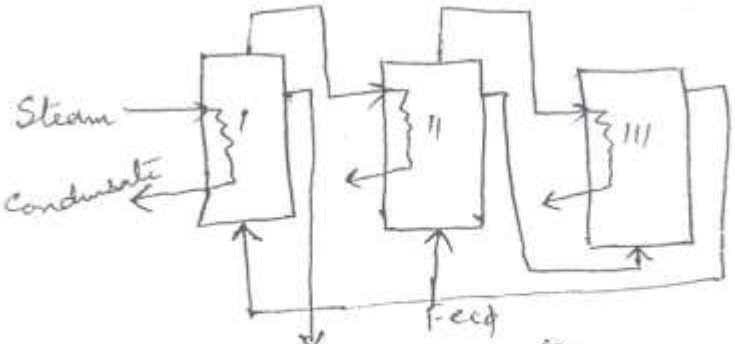
  1. Forward feed 2. Backward feed 3. Mixed feed 4. Parallel feed



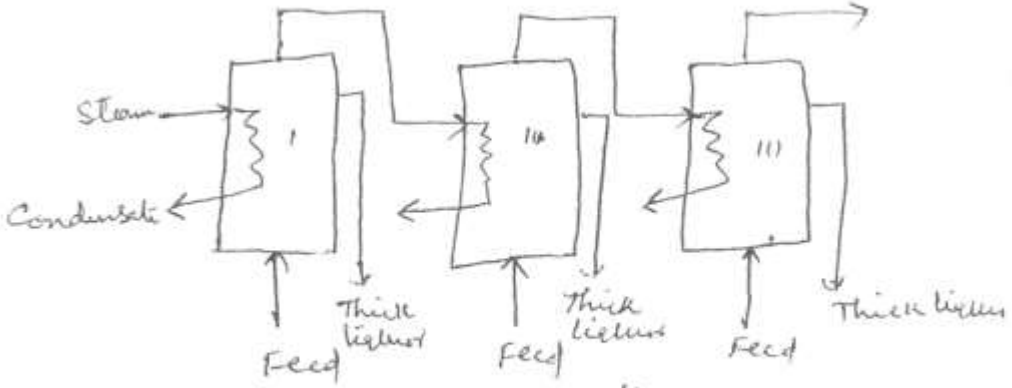
(1) Forward Feed



(2) Backward Feed



(3) Mixed Feed



(4) Parallel Feed

Capacity and Economy of Multiple Effect Evaporator

1. Multiple effect evaporator is more economical than any other conventional evaporator.
2. Capacity of multiple effect evaporator is no way greater than single conventional evaporator. This is due to elevation of boiling point. It remains same in conventional and multiple effect evaporators.

- If heating load and heat of dilution are neglected, the capacity of an evaporator is directly proportional to rate of heat transfer. The heat transferred in 3 effects is given by;

$$q_1 = U_1 A_1 \Delta T_1 \qquad q_2 = U_2 A_2 \Delta T_2 \qquad q_3 = U_3 A_3 \Delta T_3$$

- Assume that the surface area is A sq.mts in each effect and that the overall coefficient U is also same in each effect.

$$qT = U_A (\Delta T_1 + \Delta T_2 + \Delta T_3) = UA\Delta T$$

Where ΔT is the total temperature drop between the steam in the first effect and the vapor in the last effect.

- If the overall coefficient is the same as in each effect of the triple effect evaporator, the rate of heat transfer in the single effect is

$$qT = UA\Delta T$$

THANK YOU