UNIT: II **(EVAPORATION)**

CLASS:16

TOPIC: PRINCIPAL, CONSTRUCTION, WORKING, USES, MERITS AND DEMERITS OF STEAM JACKETED KETTLE, HORIZONTAL TUBE EVAPORATON, CLIMBING FILM EVAPORATOR

CLASSIFICATION OF EVAPORATORS

I. Evaporators with heating medium in jacket

Example: Steam jacketed kettle (evaporating pan)

11. Vapour heated evaporators with tubular heating surfaces

(A) Evaporators with tubes placed horizontally

Examples: Horizontal tube evaporator

(B) Evaporators with tubes placed vertically

i. Evaporators with short tubes

(a) Single effect evaporators

Examples: Short tube vertical evaporator (Standard vertical tube evaporator)

Short tube vertical evaporator with propeller Basket type evaporator

(b) Multiple effect evaporator

Example: Triple effect evaporator

ii. Evaporators with long tubes

(a) Evaporators with natural circulation

Examples: Climbing film evaporator (Rising film evaporator)

Falling film evaporator

(b) Evaporators with forced circulation

Example: Forced circulation evaporator

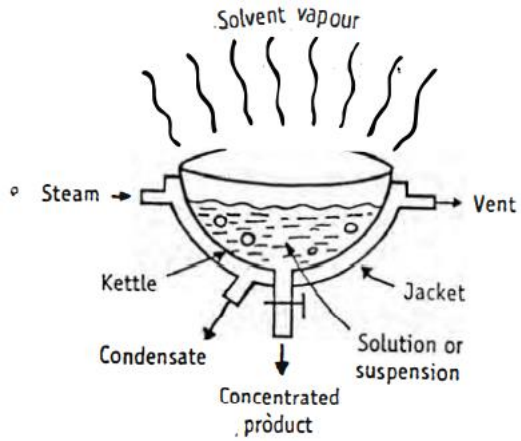
EQUIPMENT

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. Stirring further enhances the vaporisation of solvent molecules.

Construction: The construction of a steam jacketed kettle is shown in Figure. 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.

For smaller quantities, kettle is made up of a single sheet of metal. For larger capacities, several sheets are welded. Though several metals are used as a material of construction, for practical purposes the following are used. Copper is an excellent material for the kettle, because of its good conductivity. If acidic materials are evaporated, some quantity of copper would dissolve. For such preparations, tinned copper is used. 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.



Steam jacketed kettle

An inlet for the steam and an outlet (vent) for non-condensed 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 to be evaporated is placed in the kettle.

Steam is supplied through the inlet. Steam gives out its heat to the contents and the condensate leaves through the outlet. The contents must be stirred manually for smaller volumes and mechanically for larger volumes. Mechanical stirrer is not shown in Figure. The rate of evaporation is fast in the initial stages and decreases gradually as the liquid gets concentrated.

Any room where evaporation is carried by this apparatus must have good ventilation to remove the vapour. Otherwise. the room is quickly filled with a dense fog of condensed vapour and water falls from the roof and runs down the walls. Fans fitted over the pan not only remove the vapour and prevent condensation in the room, but also accelerate the rate of evaporation by quickly removing saturated air from the surface of the liquid.

The kettle may be fixed or made to tilt. A kettle of capacity upto about 90 litres may be made to tilt. But above this capacity, the weight of the pan along with its contents becomes too great to tilt. Hence, the bottom outlet is used to collect the concentrated product.

Uses Evaporating pan is suitable for concentrating aqueous and thermostable liquors, for example, liquorice extract.

Advantages :(1) Evaporating pan is constructed both for small scale and large scale operations.

(2) It is simple in construction and easy to operate, clean and maintain

(3) Its cost of installation and maintenance is low.

(4) Wide variety of materials can be used for construction such as copper, stainless steel and aluminium.

(5) Stirring of the contents and removal of the product is easy.

Disadvantages: (1) In evaporating pans, heat economy is less.

Hence. cost per unit material production is more.

(2) It is not suitable for heat sensitive materials due to long time of exposure.

(3) The heating area decreases as the product gets more concentrated.

(4) As it is open type, vapour passes into the atmosphere, which can lead to saturation of the atmosphere. slowing evaporation as well as causing discomfort.

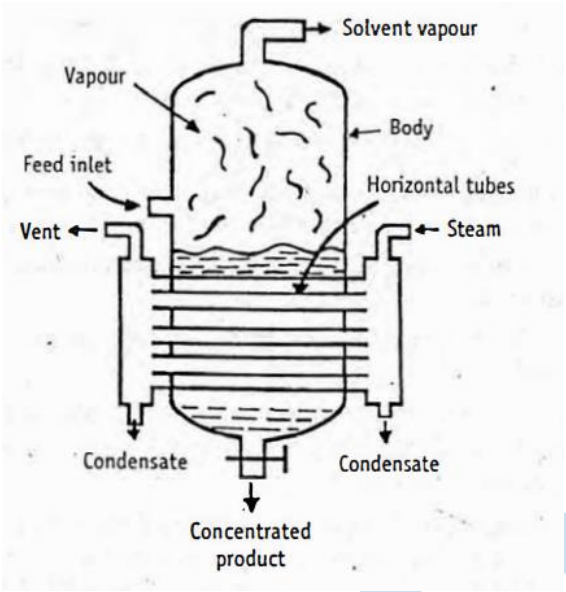
(5) Boiling point of water cannot be reduced, since reduced pressure can not be created in open type evaporator.

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 the 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: The construction of a horizontal tube evaporator is shown in Figure. It consists of a large cylindrical body with conical or dome-shaped top and bottom. It is made up of cast iron or plate steel. An average size of the body ranges from 1.8 to 2.4 metres diameter and from 2.4 to 3.6 metres height.

The lower part of the body consists of a steam compartment with an inlet for steam at one end and a vent for non-condensed gases on the other end. A condensate outlet is provided at the bottom of the steam compartment. In the steam compartment, 6-8 stainless steel horizontal tubes are placed. The tubes are cut long enough so that they project about 25.0 millimetres beyond the tube sheet on both ends. The width of steam compartment is usually half the diameter of the body.

At one convenient point, an inlet for feed is provided (Figure). One outlet for vapour is placed at the top of the dome. Another outlet for thick liquid is placed at the centre of the conical bottom of the body.



Construction of a horizontal tube evaporator.

Working: The feed is introduced into the evaporator until the steam compartment is satisfactorily immersed. Steam is introduced into the steam compartment. The horizontal tubes receive heat from the steam and conduct it to the liquid due to temperature gradient. Steam condensate passes through the corresponding outlet. The feed absorbs heat and solvent gets evaporated. The vapour then 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.

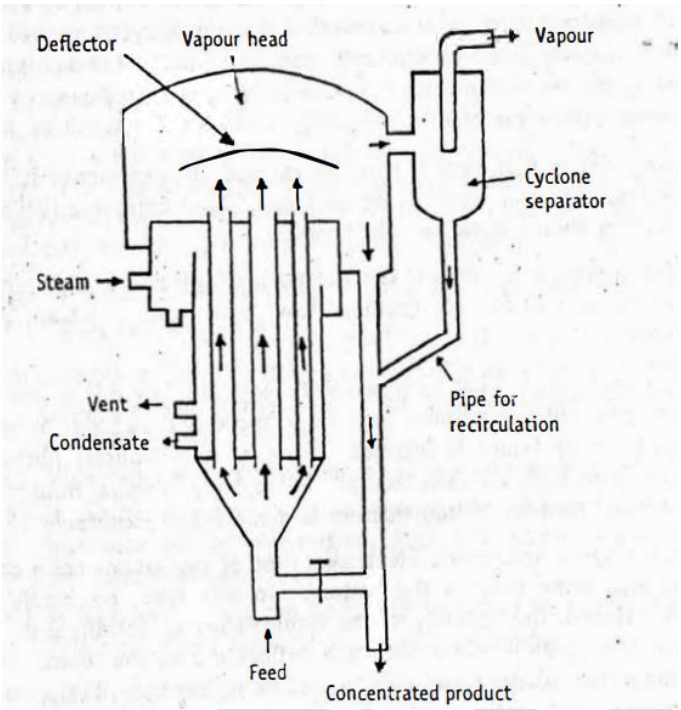
Uses: Horizontal tube evaporator is the best suited for non-viscous solutions that do not deposit scales or crystals on evaporation, for example cascara extract.

Advantage: The cost per square metre of heating surface is usually less in horizontal tube evaporator.

CLIMBING FILM EVAPORATOR (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 construction of a climbing film evaporator is shown in Figure. In this evaporator, the heating unit consists of steam jacketed tubes. Here, the tubes (long and, narrow) are held between two plates. An entrainment separator is placed at the fop to this vapour head. The evaporator carries steam inlet, vent outlet and condensate outlet. The feed inlet is from the bottom of the steam compartment



Construction of a climbing film evaporator

Working: The preheated liquid feed (to be evaporated) is introduced from the bottom of the unit. The height of the liquid column is maintained low, i.e., 0.6 or 1.2 metres 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 and 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 in the tubes. As more vapour is formed, the slug of liquid is blown up in the tubes facilitating the liquid to spread as a film over the walls. This film, of liquid continues to vaporise rapidly. Finally, the mixture of liquid concentrate and vapour eject at a high velocity from the top of the tubes.

The entrainment separator not only prevents entrainment, but also acts as a foam breaker. The vapour leaves from the top, while concentrate is collected from the bottom.

Uses: Using climbing film evaporator, thermolabile substances such as insulin, liver extracts and vitamins can be concentrated. Clear liquids, foaming liquids and corrosive solutions in large quantities can be operated. Deposit of scales can be removed quickly by increasing the feed rate or reducing the steam rate so that, the product is unsaturated for a short time.

Advantages (1) In a climbing film evaporator, large area for heat transfer is provided employing long and narrow tubes.

(2) Since liquid flows at a high velocity, the resistance for heat transfer at the boundary layers is reduced. As a result, the heat transfer is enhanced.

(3) The time of contact between the liquor and the heating sur face is very short. The liquid is in the heater for one second, while its residence time, is 20 seconds in the evaporator. Hence it is suitable for heat sensitive materials.

(4) Unlike short tube evaporator, the tubes are not submerged. So there is no elevation of boiling point due to hydrostatic head.

(5) It is suitable for foam-forming liquids. because foam can be

broken by an entrainment separator.

(6) It requires low hold up and small floor space.

Disadvantages: (1) Climbing film evaporator is expensive, construction is quite complicated.

(2) It is difficult to clean and maintain.

(3) Large head space is required.

(4) It is. not advisable for very viscous liquids, salting liquids and scaling liquids.

(5) If feed rate is high, the liquor may be concentrated insufficiently. If feed rate is low, film cannot be maintained. Dry patches may form on the tube walls.

MCQ Each carry 1 mark

1. In the climbing film evaporator, the problem in the evaporation
    a. Boiling point of liquid
    b. Droplet formation
    c. Entrainment of liquid
    d. Film formation
2. Steam side film coefficients are increased by one of the following methods
    a. Condensing liquid at low-temperature
    b. Decreasing the velocity of liquid
    c. Non-condensed gas in steam should be minimum
    d. Temperature drop should be small
3. The cost per square metre of the heating surface is usually high in one of the evaporators
    a. Horizontal tube evaporator
    b. Falling film evaporator
    c. Steam jacketed kettle
    d. Vertical tube evaporator
4. Which evaporator is used to concentrate insulin, liver extract and vitamins?
    a. Climbing film evaporator
    b. Falling film evaporator
    c. Steam jacketed kettle
    d. Vertical tube evaporator
5. In the climbing film evaporator, what is the purpose of the entrainment separator
    a. Allowing the heat to transfer
    b. Allowing the vapour to escape
    c. Breaking the foam
    d. Pulling the liquid up
6. The following Equipment is best for evaporating concentrated aqueous and thermostable liquors:
        A. Horizontal Tube evaporator
        B. Triple effect evaporator
        C. Climbing Film Evaporator
        D. Evaporating Pan

Each carry 5 marks

1. What are the criteria in selecting the metals for the construction of steam Jacketed kettle?
2. List the merits, and demerits of film evaporator system.

Each carry 10 marks

1. Explain the construction and working of climbing film evaporator.
2. Describe the construction and working of film evaporator of any one type.
3. Explain the construction and working of a horizontal tube evaporator.
4. How does film evaporator function? Elaborate the answer with a neat Sketch of one such evaporator. List the merits, and demerits of film evaporator system.