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A Review on Evaporation

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ABSTRACT: Evaporation is the process of vaporizing large quantities of volatile liquid to get a concentrated product. It involves the process of changing the liquid state of a substance to a gaseous state. Evaporation term is derived from the Latin word evaporare, which means "disperse in vapour or steam." It is the most commonly used technique in pharmaceutical industries to eliminate excess moisture from the drug product and make it more stable. Equipments used for evaporation are known as evaporators. Different types of evaporators used are evaporators with heating medium in jacket and vapour heated evaporators with tubular heating surfaces and multiple effect evaporators.
Here, we focus on the different types of evaporators its principle, construction, advantages, disadvantages and applications.
KEYWORDS: Evaporators, steam, multiple effect evaporator

I.INTRODUCTION

[1]. Evaporation is a process of vaporizing large quantities of volatile liquid to get a concentrated product.

Equipment used for evaporation is known as evaporators. Heat is supplied to theevaporator, which transmits it to the evaporating liquid so as to provide latent heat of vaporization. Steam is normally used as a source of heat. Evaporation is a surface phenomenon, that is, mass transfer takes place from the surface. Thus, no boiling occurs.

[2]. In this process liquid state of a substance is changing to a gaseous state due to an increase in temperature or pressure. As the temperature increases the rate of evaporation also increases. The amount of evaporation depends on temperature, and it also depends on the amount of water to evaporate. The aim of evaporation is not to dry but to concentrate the solution. The driving force in evaporation is temperature difference between steam chest temperature and product temperature that result into removal of solvent from the feed that solution is concentrated.

3]. Either solutions or suspensions can be subjected to evaporation. The only condition is that the liquid must be volatile, while the solute must be non-volatile. Since heat is supplied, the constituents should be thermostable. In most of the operations, the liquid is water with a low solid content. The liquid to be evaporated may be less viscous than water or it may be so viscous that it will hardly flow. At the end of the process, the concentrate will be drastically reduced.

II. FACTORS INFLUENCING EVAPORATION

[4]. The rate of evaporation depends on several factors. The relationship may be expressed mathematically as:

$M = KS/p(b-b`)$

Where,
M = mass of vapour formed per unit time (Rate),
S = surface area of the liquid exposed, m^2
p = atmospheric pressure, kPa
b = maximum vapour pressure at the temperature of air, kPa
b` = pressure due to the vapour of the liquid, actually present in the air, kPa
K = constant, m/s
In general mass transfer also depends on the temperature.

1. Temperature

When temperature is increased, the greater will be evaporation.

At a given temperature, some molecules possess higher kinetic energy than the average, while others have lower than average kinetic energy. When temperature of the liquid is raised, more molecules acquire sufficient kinetic energy and escape from the surface to vapour state.

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At boiling point, vapour is formed throughout the body of the liquid as well as from surface. The vapour pressure of the liquid is lowered when a substance is dissolved in it and consequently the boiling point of the liquid increases.

Normally, glycosides and alkaloids decompose at high temperature. Hormones, enzymes and antibiotics are even more heat sensitive. For example, malt extract is prepared by evaporation under reduced pressure to avoid loss of enzymes. Antibiotics are concentrated by freeze drying.

2. Vapour Pressure

[5]. Rate of evaporation depends upon the vapour pressure of the substance. The lower the p value in equation, the greater the evaporation. If the external pressure of the liquid is lower, boiling point of the liquid will also be lower and evaporation becomes faster.

The nature of the liquid is also important for the rate of evaporation. Liquids with low boiling points evaporate quickly because of high vapour pressures at lower temperature.

If the vapour of the liquid is removed as soon as it is formed (under reduced pressure or vacuum), the space above the liquid does not become saturated with the vapour. Hence, evaporation proceeds faster.

3. Surface Area

From the above equation, it is clear that the greater the surface area of the liquid, the greater will be the evaporation. Due to this evaporation is carried out in evaporators that are having large surface area.

4. Moisture content of the feed

In certain components of drug hydrolysis takes place at increased temperature. To prevent decomposition, the material is exposed to lower temperature initially, then exposed to higher temperature for final concentration. For example, belladonna dried extract can be prepared in this way.

4. Type of Product Required

Type of product required sometimes decides the apparatus for evaporation. Open pan produces liquid or dry concentrate. Film evaporator yields liquid concentrate. Spray dryer produces dry products with good solubility. Vacuum evaporator gives porous product suitable for conversion to granules, for example, preparation of granular extract of cascara for tablet making.

5. Time of Evaporation

If exposure timing of a substance is increased the rate at which evaporation is taking place also increases, this can only be done when the substance is thermostable. If the substance is exposed for a short time at higher temperature, it will not destruct the active constituents, due to this reason, film evaporators can be used for evaporation.

6. Economic Factor

The primary considerations in this category are the cost of labour, cost of fuels, and the materials used in making of floor. The type of solvents used are also considered as well as their recovery procedures are also concerned

For evaporation, heat is necessary to provide the latent heat of vaporisation. Therefore, evaporator is designed to give maximum heat transfer to the liquid.

[6]. ADVANTAGES

- Reduces transportation and storage cost.
- Reduce rates of deteriorative chemical reactions.
- Better microbiological stability.
- Recovery of solvent.
- Easy to transport.

DISADVANTAGES

- High capital.
- High energy.
- High maintenance cost.
- Large size of apparatus.
- Corrosion.

III.APPLICATIONS

[7]. Some of the common applications of evaporation has been discussed here

- Used in demineralization of water.
- Evaporation is used in concentration and recovery of dissolved solutes like sodium chloride from aqueoussolution to produce salt.
- Evaporation process is used in manufacture of bulk drugs.
- Used in concentration of chromatographic fractions, glucose and fructose syrups.
- Used in concentrating pharmaceutical herbal extracts in herbal industry.
- Used in manufacture of biological products. For example, Insulin, enzymes, hormones, etc
- Used in preservation of long-term activity or stabilization of enzymes in laboratories.
- Used in ether recovery from fat extraction.

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IV. CLASSIFICATION OF EVAPORATORS

I. Evaporators with heating medium in jacket
Example: Steam jacketed kettle (evaporating pan)
II. Vapour heated evaporators with tubular heating surfaces
A. Evaporators with tubes placed horizontally
Example: 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
Examples: 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

V. EQUIPMENT

STEAM JACKETED KETTLE OR EVAPORATING PAN

Principle: Steam is applied to the pan of the equipment, where the substance to be evaporated is placed. Steam gives out heat to the kettle. By the principle of conduction and convection, the steam is passed to the pan of the equipment.This causes the temperature to increase, and the solvent present in the drug or the substance gets evaporated. While evaporation is taking place, if we use stirring it causes an increase in the evaporation procedure.

Construction: The shape can be described as a hemispherical in shape, which has a pan present in the inner side which is known as kettle. This kettle is enclosed or covered with a outer surface or layer known as jacket. These 2 pans are connected to each other which is having a space through which steam can be supplied to the apparatus.

[8]. Single metals sheets are used in the making of pan or kettle that is used for small quantities. For larger capacities, several sheets are welded. Though several metals are used. Copper is an excellent choice of metal for the evaporating pan due to its good electrical as well as its conducting property. If acidic materials are evaporated, some quantities of copper would dissolve. For such preparations, tinned copper is used. Commonly iron is used in the construction of evaporating pan because of its properties. As iron rusts easily, to prevent this rusting it can be coated with enamel or can also be tinned.

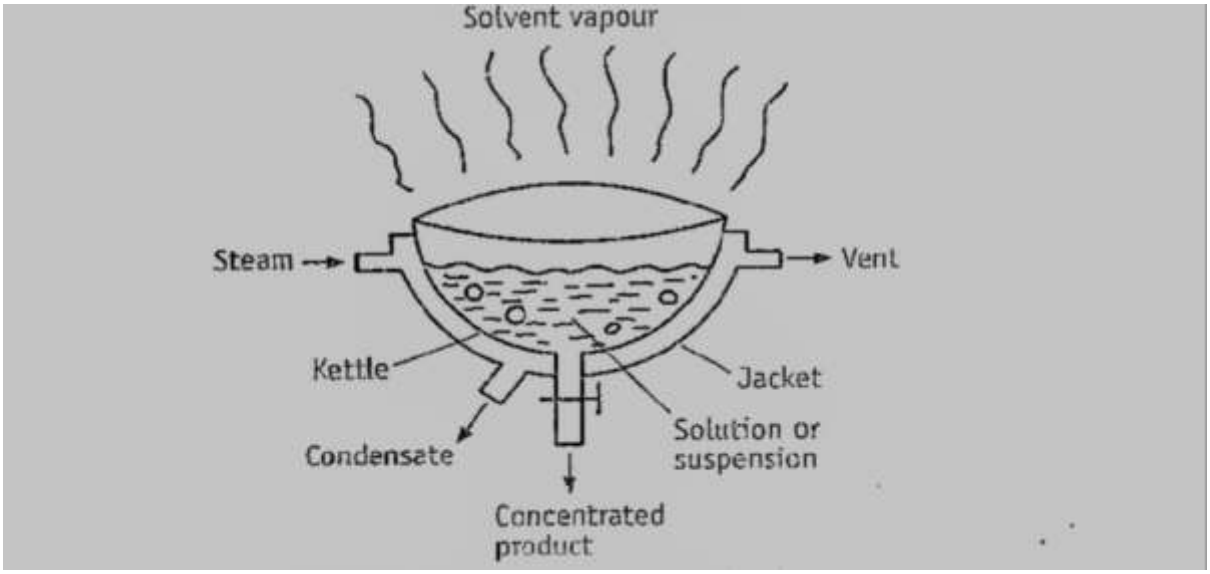

Figure 1: Steam Jacketed Kettle or Evaporating Pan

An inlet for the steam and an outlet (vent) for non-condensed gases are provided near the top of the jacket. Through the bottom portion of the apparatus the condensate is removed. 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. When steam is applied, the heat is

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produced which causes the evaporation and theoutlet provided at bottom removesthe condensate produced. The contents must be stirred manually for smaller volumes and mechanically for larger volumes. At first the rate of evaporation is higher, after some time the evaporation procedure gets slower due to the concentrated product.

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

A kettle of capacity upto about 90L may be made to tilt. When the capacity is increased, weight of the apparatus is also increased, which causes trouble in tilting. Hence, bottom outlet is used to collect the concentrated product.

USES:

- Evaporating pan is suitable for concentrating aqueous and thermostable liquors, Eg: liquorice extract.

ADVANTAGES

- Evaporating pan is constructed both for small scale and large-scale operations.
- It is simple in construction and easy to operate, clean and maintain
- It's cost of installation and maintenance is low
- Wide variety of materials can be used for construction such as copper, stainless steel and aluminium.
- Stirring of the contents and removal of the product is easy.

DISADVANTAGES

- In evaporating pans, heat economy is less.
- It is not suitable for heat sensitive materials due to long time of exposure.
- The heating area decreases as the product gets more concentrated.
- As it is open type, vapour passes into the atmosphere, which can lead to saturation of atmosphere, slowing evaporation as well as causing discomfort.
- Boiling point of water cannot be reduced, since reduced pressure cannot 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. With the help of these tubes, the substance or the product to be evaporated which is present outside the tube gets heated. This causes, the evaporation of the substance or solvent from the preparation and the vapours are eliminated or removed through the upper part of the apparatus, whereas the concentrated product is collected through the bottom part.

Construction: It consist 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 2.4m diameter and from 2.4 to 3.6m height.

[9].The lower part of the body consists of a steam compartment with an inlet for a steam at one end and a vent for non-condensed gases on the other end. At the lower end or bottom portion an outlet. In the steam compartment, 6-8 stainless steel horizontal tubes are placed. The tubes are cut long enough so that they project about 25.0mm beyond the tube sheet on both ends.

At one convenient point, an inlet for feed is provided. For removal of the vapour the outlet is present at the top of the apparatus, whereas, for collecting the concentrated product or liquid the end of the procedure it is placed at the bottom of the apparatus in the centre portion.

USES:

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

ADVANTAGES

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

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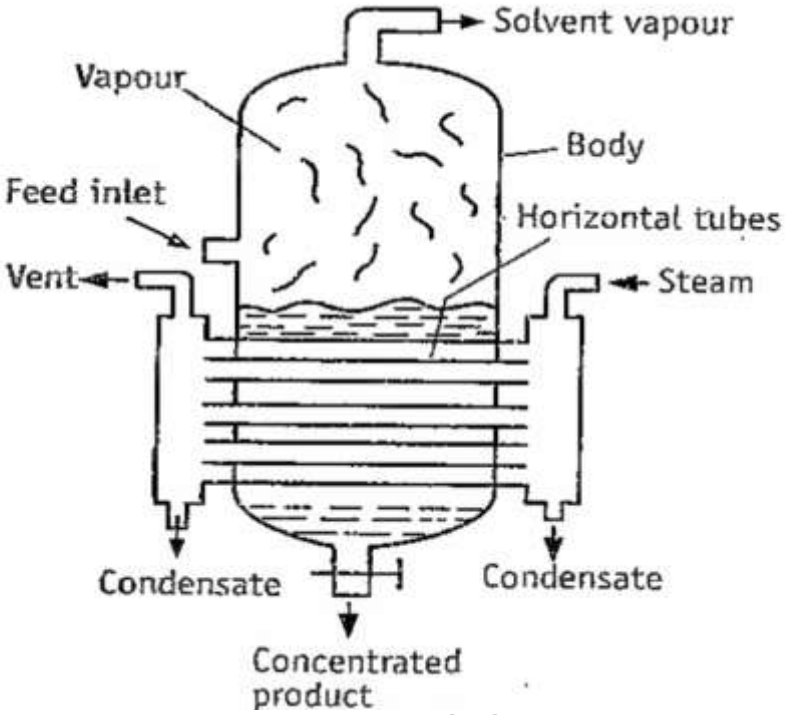

Figure 2: Horizontal Tube Evaporator

Working: The feed is introduced in to the evaporator until the steam compartment is satisfactorily immersed. Steam is introduced into the steam compartment. The tubes that are placed horizontally gets heat and it is then transferred to the liquid to be evaporated. Steam condensate passes through the corresponding outlet. The liquid absorbs the heat, which results in evaporation of the liquid. The vapor then escapes through the outlet placed at the top. This is carried out until a concentrated product is formed and it is collected.

VERTICAL TUBE EVAPORATOR (SHORT TUBE EVAPORATOR)

Principle: In standard tube evaporator, liquid is passed through the vertical tubes and the steam is supplied from outside the tubes. Heat transfer takes place through the tubes and the liquid inside the tubes gets heated. The solvent evaporates and the vapour escapes from the top. The final product is collected from the outlet which is placed at the bottom of the apparatus.

[10]. Construction: It consists of a large cylindrical body made up of cast iron with dome shaped top and bottom. Calandria consists of a number of vertical tubes, whose diameter ranges from 0.05 to 0.075m and length of 1-2m. About 100 such tubes are fitted in a body measuring 2.5m or more diameter. Inlets are provided for steam and feed. Outlets are given for the purpose of collecting the final thick or concentrated product.

USES:

- Vertical tube evaporator is used in the manufacture of Cascara extract, sugar, salt and caustic soda.

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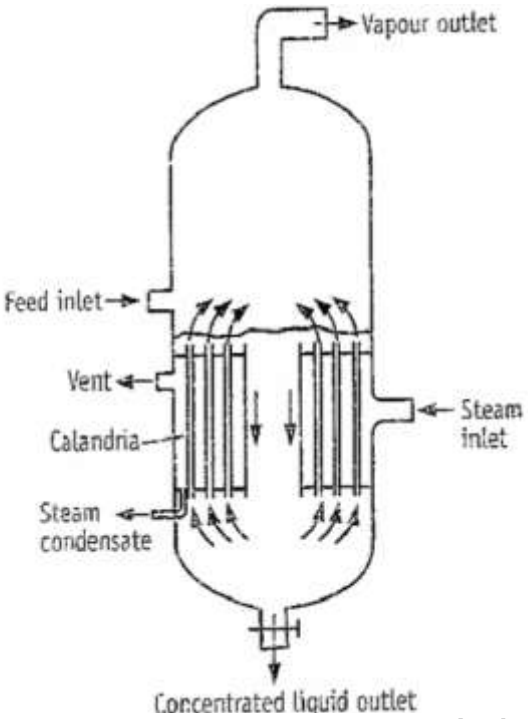

Figure 3: Vertical Tube Evaporator

Working: steam is introduced outside the tubes. The final product is collected through the liquid outlet present at the bottom portion of the apparatus, while the vapours are removed through the vent present on the top portion. The feed is introduced in such a way as to maintain the liquid level slightly above the top of the tubes. The liquid inside the tubes is heated by the steam and begins to boil. It sets up a circulation of hot liquid, which enhances the rate of heat transfer. The vapour escapes through the top outlet. Steam is supplied until required concentration of product is obtained. Finally, the product can be withdrawn from the bottom outlet.

USES:

- Vertical tube evaporator is used in the manufacture of Cascara extract, sugar, salt and caustic soda.

ADVANTAGES

- In vertical tube evaporator, tubes increase the heating surface nearly 10 to 15 times when compared with steam jacketed kettle.
- Vigorous circulation enhances the rate of heat transfer.
- It can be connected to a condenser and receiver, which further increases the rate of evaporation. Such attachment is also suitable for volatile solvents.
- A number of units can be joined to obtain more efficient effect (multiple effect evaporators which work for this effect).

DISADVANTAGES

- The liquid is maintained above the level of the calandria. Hence, the upper layers of the liquid need a long time for getting heated. This problem can be minimised by removing concentrated liquid slowly at the bottom.
- The evaporator is complicated, hence, installation cost increases.
- Cleaning and maintenance are difficult when compared with steam jacketed kettle.
- During operation, the pressure inside the evaporator increases. In large evaporators, where the liquid depth may be of the order of 2.0metres, the pressure increases to 25.0 kilopascals, leading to elevation of the boiling point by 5 or 6 degree Celsius.

Variants:

1) Short Tube Evaporator with Propeller: In short tube vertical evaporator, circulation depends completely on boiling. Steam is supplied into the calandria to induce boiling. When steam supply is stopped, automatically boiling stops. As a result, the particles (if any) settle down. These particles act as nuclei which grow as crystals. Therefore, this evaporator is sometimes used as crystallizing evaporator. If

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such crystallization is undesirable, the problem can be avoided by installing a propeller in the central portion close to the bottom. By increasing the revolutions per minute of the propeller, the capacity of the evaporator can be doubled.

2) Basket Type Evaporator: The basket type of evaporator has a conical bottom and sometimes flat bottom. In this type, boiling is quite violent. Hence, the spouting f the liquid leads to entrainment. This problem can be avoided by placing a deflector over the tubes. In this case, the down-take is annular instead of being central. The advantage of this type is that entire heating element is single unit. The complete unit can be removed for repairs. In addition, the deflector prevents entrainment losses completely.

USES:

- Since mild steel cast iron is used, the evaporator suits well for clear liquids and crystallizing solutions.
- Non-corrosive liquids and mild scaling solutions can also be handled.

ADVANTAGES

- Heat transfer coefficients are high due to high temperature gradient values.
- It requires low-room.
- Cleaning and maintenance is easy.
- It is relatively inexpensive.

DISADVANTAGES

- Heat transfer is poor at low Δt values.
- It requires high floor space and is more in weight.
- Relatively more liquid is retained.
- Rate of heat transfer further decreases due to high viscosity liquids.
- Since body is large, mild steel or cast iron are used for its construction to make it less expensive.

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.

[11]. Construction: 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 top to the vapour head. The evaporator carries steam inlet, vent outlet and condensate outlet. The feed inlet is from the bottom of the steam compartment.

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, that is, 0.6 or 1.2 m 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 concentrated 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.

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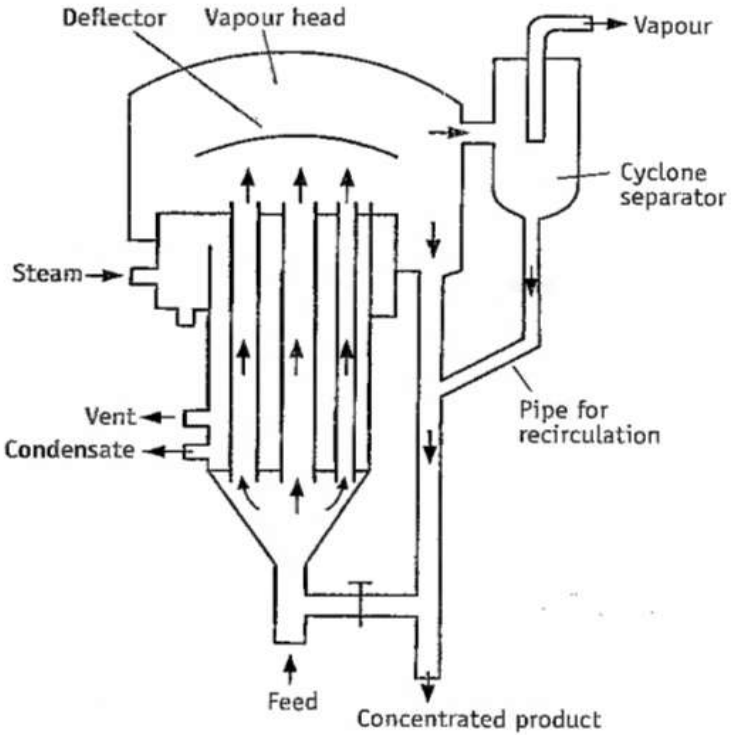

Figure 4: Climbing Film Evaporator

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

- In a climbing film evaporator, large area for heat transfer is provided employing long and narrow tubes.
- Since liquid flows at high velocity, the resistance for heat transfer at the boundary layers is reduced. As a result, the heat transfer is enhanced.
- The time of contact between the liquor and the heating surface 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.
- Unlike short tube evaporator, the tubes are not submerged. So, there is no elevation of boiling point due to hydrostatic head.
- It is suitable for foam-forming liquids, because foam can be broken by an entrainment separator.
- It requires low hold up and small floor space.

DISADVANTAGES

- Climbing film evaporator is expensive, construction is quite complicated.
- It is difficult to clean and maintain.
- Large head space is required.
- It is not advisable for very viscous liquids, salting liquids and scaling liquids.
- 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.

FALLING FILM EVAPORATOR

Principle: In a falling film evaporator, feed enters from the top and flows down the walls of the tubes. The liquid gets heated rapidly due to heat transfer from steam. The liquid boils and becomes vapour, which forms small bubbles. They tend to fuse to form layers of bubbles, which travel down the tubes. Concentration takes place during this downward journey. Vapour and liquid are separated at the bottom.

Construction: The construction of a falling film evaporator is given below. It resembles climbing film evaporator, but it is inverted. In this

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evaporator, the heating unit consists of steam jacketed tubes. The feed inlet is from the top of the steam compartment. The other provisions are stem inlet, vent and condensate outlet remain same. The outlet for the product is provided at the bottom and is connected to a cyclone separator.

[12]. Working: Steam is supplied into the steam compartment. Feed enters from the top of the tubes. The temperature of the boiling liquid is same as that of the vapour head. The feed flows down the walls of the tubes. The liquid gets heated rapidly. The liquid boils and becomes vapour, which forms smaller bubbles. These tend to fuse to form layers of bubbles, which travel down the tubes. Concentration takes place during this downward journey. Vapour and liquid are separated in the cyclone separator.

USES:

- Falling film evaporator is used to separate volatile and non-volatile materials, when the feed is of high viscosity.
- It is used for the concentration of yeast extract, manufacture of gelatin, extracts of tea and coffee.
- It is also useful for concentrating the heat sensitive materials such as fruit juices.

ADVANTAGES

- Falling film evaporator is suitable for high viscous liquids, because the flow of vapour film is assisted by gravity.
- The liquid hold-up is less and hold-up time is very small.
- The liquid is not overheated during the passage and heat transfer coefficients are high even at low boiling temperature.
- Highly acidic and corrosive feeds can be concentrated using impervious graphite tubes and rubber lined vapour heads.

DISADVANTAGES

- It is not suitable for salting or scaling liquids.

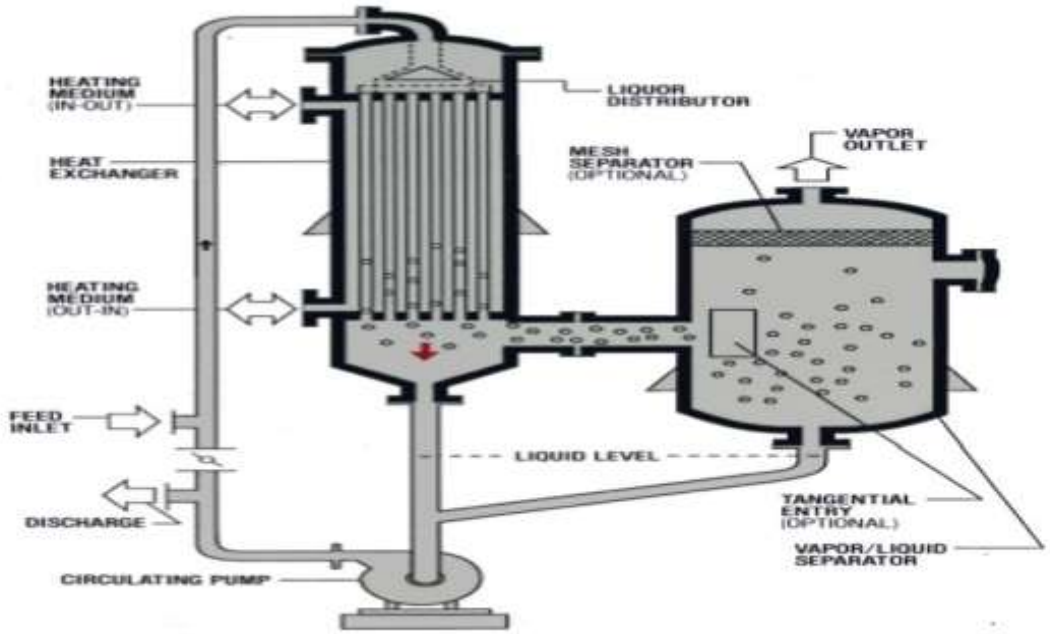

Figure5:Falling Film Evaporator

FORCED CIRCULATION EVAPORATOR

Principle: In forced circulation evaporator, liquid is circulated through the tubes at high pressures 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 affected.

[13]. Construction: The construction of a forced circulation evaporator is described below. The steam jacketed tubes are held between two tube sheets. The tube measures 0.1m inside diameter and 2.5m long. The part of the tube projects into

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the vapour head (flash chamber), which consists of a deflector.

USE:

If evaporation is conducted under reduced pressure, forced circulation evaporator is suitable for thermolabile substances. This method is used for the concentration of insulin and liver extracts.

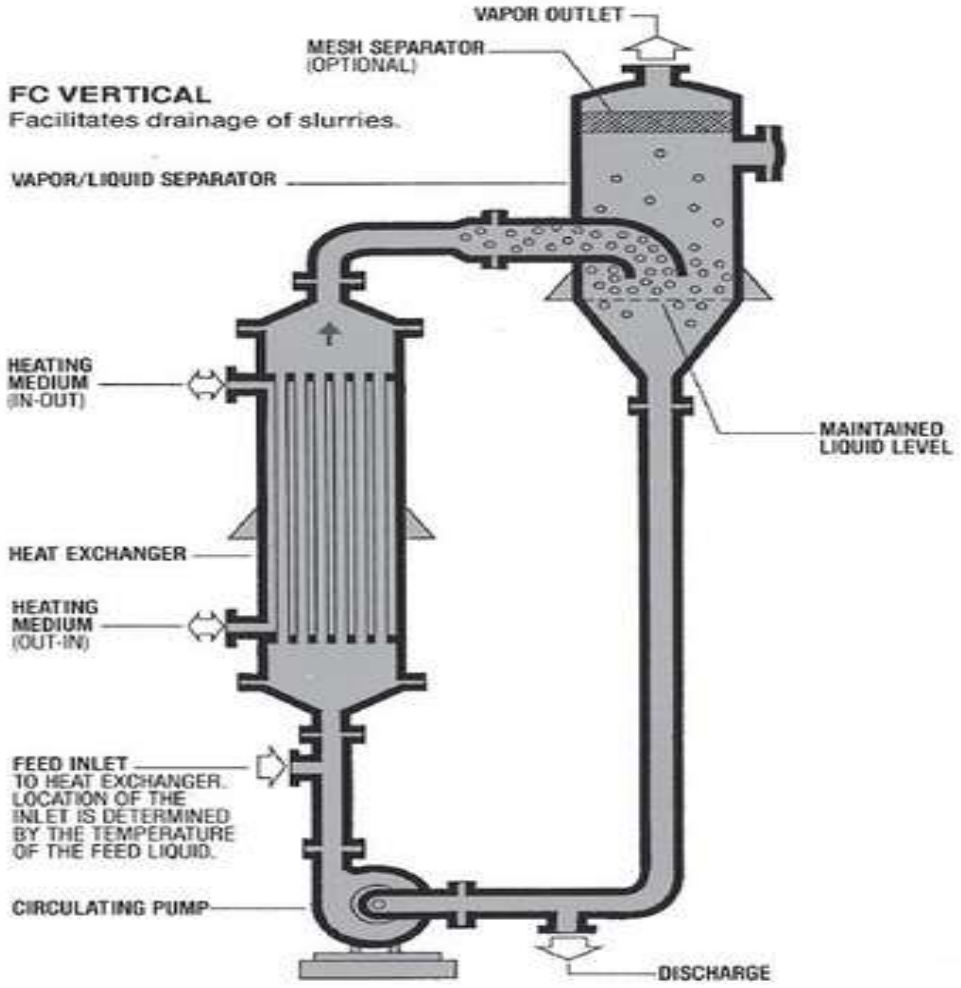

Figure 6: Forced Circulation Evaporator

ADVANTAGES

- In forced circulation evaporator, the heat transfer coefficient is high due to rapid liquid movement.
- Salting, scaling, and fouling are not possible due to forced circulation.
- This evaporator is suitable for thermolabile substance because of rapid evaporation.
- It is suitable for high viscous preparations because pumping mechanism is used.

DISADVANTAGES

- In forced circulation evaporator, the hold-up of liquid is high
- The equipment is expensive, because power (pump) is required for the circulating liquid.

MULTIPLE EFFECT EVAPORATOR

[14]. Multiple tube evaporator is a single effect evaporator, such evaporators are connected in several ways so as to achieve large scale evaporation as well as greater economy. Although multiple effect evaporators are not used in pharmaceutical industry.

ADVANTAGES

- It is suitable for large scale and for continuous operation.

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- It is highly economical when compared with single effect.
- About 5 evaporators can be attached.

Construction: Using 3 evaporators, that is triple effect evaporator. The vapour from first evaporator serves as a heating medium for the 2nd evaporator. Similarly, vapour from the 2nd evaporator serves as a heating medium for the 3rdevaporator. Last evaporator is connected to a vacuum pump.

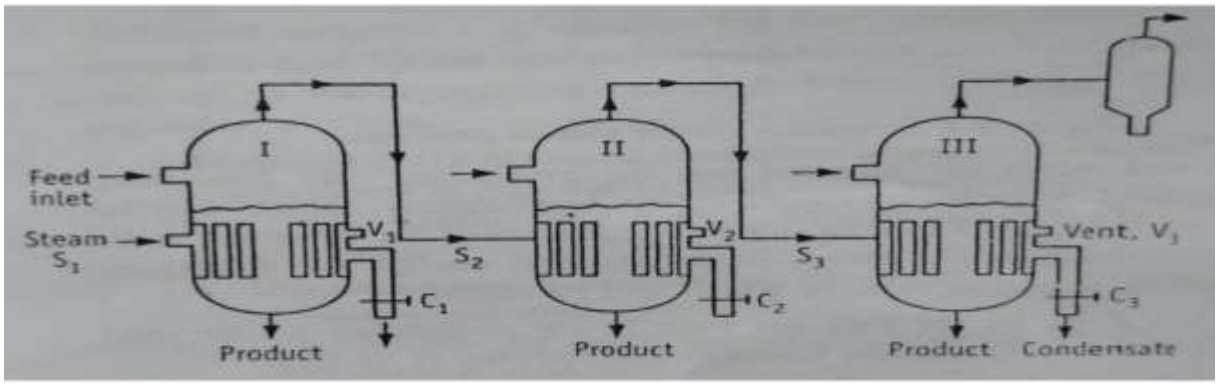

Figure 7: Multiple Effect Evaporator

Working: Parallel feed arrangement is used in this.

Parallel Feed: In this method, a hot saturated solution of the feed is directly fed to each of the three effects (evaporation) in parallel without transferring the material from one effect to the other. The parallel feed arrangement is commonly used in the concentration of salt solutions, where the solute crystallizes on concentration without increasing the viscosity

ECONOMY OF MULTIPLE EFFECT EVAPORATOR

The economy of an evaporator is the quantity of vapour produced per unit steam admitted. It is calculated by considering the following assumptions.

[15]. Feed is admitted at its boiling point. Therefore, it does not require any more heat to raise its temperature. Hence, the applied steam gets condensed to give heat of condensation. This heat will then be transferred completely to the liquid. The heat transferred now serves as latent heat of vaporisation, that is, liquid undergoes vaporisation by receiving heat. Loss of heat by any means is negligible.

The economy of an evaporator may be expressed as:

Economy of an evaporator = Total mass of vapour produced / Total mass of steam supplied

In single effect evaporator, steam produces vapour only once. Hence,

Economy of single effect evaporator = N units of vapour produced / N units of steam supplied = 1

In multiple effect evaporator, one unit of steam produces vapour many times, depending on the number of evaporators connected. Hence,

Economy of multiple effect evaporator = N units of vapour produced / 1 unit of steam supplied = N

Therefore, economy of multiple effect evaporator is N times the economy of the single effect evaporator. However, such a great economy is approximately true as it depends on many factors such as temperature of the feed, temperature range in the evaporator, ratio of weight of feed to the product and pressure difference.

VI.SUMMARY

- Evaporation is the process of vaporizing large quantities of volatile liquids to obtain a concentrated product. It is surface phenomenon.
- The rate of evaporation is controlled by rate of heat transfer.
- Evaporation is influenced by various factors such as: temperature, viscosity, surface area, moisture content of the field, etc.,

- Evaporations are used in various applications such as; manufacture of bulk drugs, manufacturing of biological products and many others.
- Equipments used in evaporation are known as evaporators.
- The primary objective of evaporation is to reduce the volume of the product by some significant amount without loss of the major components.
- Different equipments used for achieving evaporation are: Steam jacketed kettle, horizontal tube evaporator, vertical tube evaporator, falling film evaporator, etc.

VII.CONCLUSION

Evaporation is a process of vaporising large quantities of volatile liquid to get a concentrated product. Evaporation is most widely used in the pharmaceutical industries to concentrate liquids and drugs to make them stable.

Temperature plays a major role in evaporation, that is, increase in temperature cause increase in rate of evaporation. The major role of evaporation is to concentrate the sample. The driving force in evaporation is the temperature difference between steam chest temperature and the temperature of the product which causes the removal of the solvent from the feed.

To make evaporation possible, the main condition is that the liquid must be volatile and the solute used must be non-volatile. And the liquid to be evaporated must be less viscous than water.

Evaporation is affected by various factors such that temperature, surface area, moisture content present in the feed. Evaporation is used in pharmaceutical industries to remove excess of moisture content. For improving the stability of a particular type of product evaporation is carried out. Different types of equipments are used to carry out evaporation efficiently, hence the equipments that are used for evaporation are known as evaporators.

Evaporation is a slow process where; the solvent is often removed by boiling. Rate of the evaporation is controlled by the rate of heat transfer. If the liquid to be vaporized is a organic solvent then it is removed in a closed process to ensure environmental safety.

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