EVAPORATION

INTRODUCTION:-

Definition – Evaporation is the process of vaporizing large quantities of volatile liquid to get a concentrated products .

Applications:1. Evaporation has been use for very long time to obtain salt from sea water.

2. Evaporation is regularly use in food processing ,chemical, kraft paper,and pharmaceutical industries to produce liquid concentrates.

3. Pharmaceutical companies use evaporators to remove excess moisture from drugs,thus improving product stability.

CLASSIFICATION: According to type of construction

a) Bare tube type evaporator
b) Finned tube evaporator
c) Plate evaporator
d) Shell and tube evaporator
e) Shell and coil evaporator
f) Tube in tube evaporator

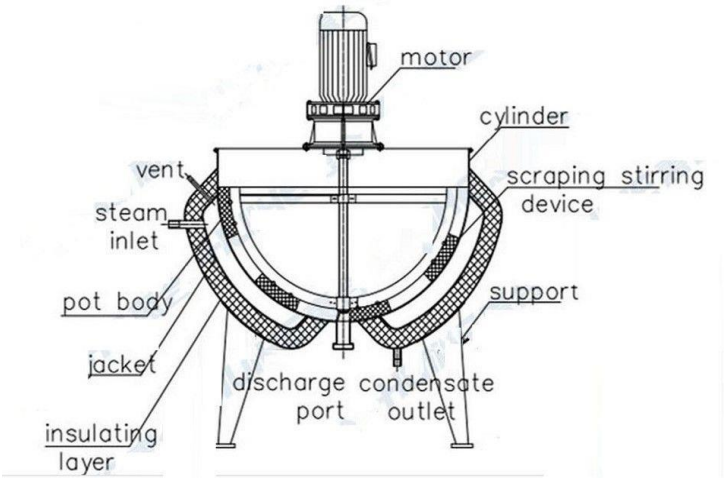
According to the manner in which liquid refrigerant is fed

a) Flooded evaporator
b) Dry expansion evaporator

EQUIPMENT:

1. STEAM JACKETED KETTLE:-

Principle :- the steam jacketed kettle or evaporating pan is an evaporators that can be used for the bulk evaporation of water from aqueous liqids.the hot steam causes heat to pass through the inner pan ,by conduction,to the solution that is to be evaporated .



Working:

1.In first step,liquid to be concentrated is placed in the kettle.

2.In second step,steam is supplied from inlet and condensate comes outsite from the outlet.

For fast evaporation liquid to be concentrated is stirred manually or mechanically. Proper ventilation is needed for removal of vapour of liquid.

3.In third and final step,concentrated liquid is collected from the outlet present at the bottom of the kettle.

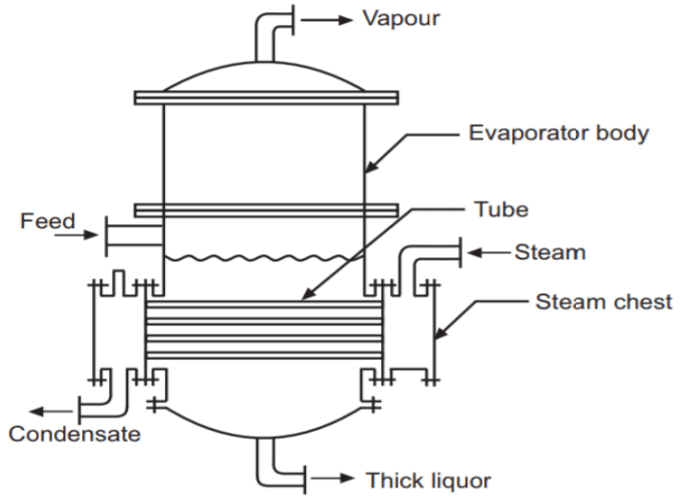
Uses:-

1.steam jacketed kettles are mainly used for the concentration of aqueous extracts.

2.These are also used for the concentration of thermostable.

2. HORIZONTAL TUBE EVAPORATOR(VAPOUR INSIDE TUBES):-

Principle:-The steam enters the tube and condenses to give up its heat of condensation. the evaporator enters the steam inside the tubes,and the heat transfer fluid over the tubes ,the steam condenses.from the evaporators and the concentrated solution leaves the solvent evaporated solvent evaporated.



Working:-1. In the first step, feed ins introduced into the evaporator above the horinzontal tubes .

2. In second step,the steam is passes through the horizontal tubes.the feed absorb heat because of temperature gradient an solvent is evaporated. Vapour escapes through the vent.

3.In third and last step,concentrated liquid is collected from the bottom of the evaporator.

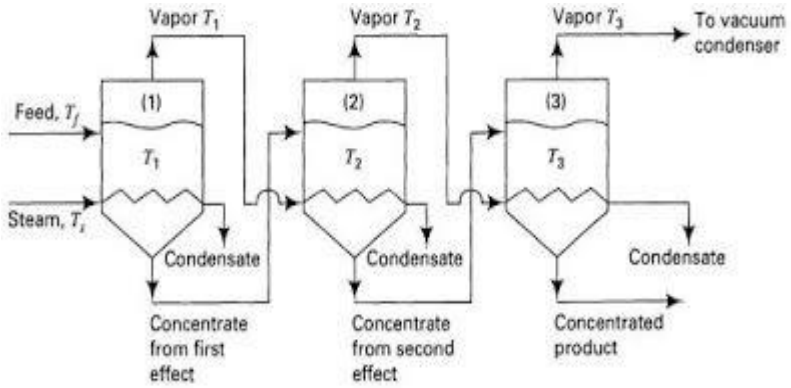
Uses:-These evaporators are mainly use for concentration of non viscous liquids which do not produced crystal as well as do not deposite scales after or during evaporation.

3. VERTICAL TUBES EVAPORATORS(VAPOUR OUTSIDE TUBES):-

- Vertical short-tube evaporator(Vapour outside tubes)
- Vertical Long-tube vertical evaporator
  - Vertical Long –tube(climbing film)evaporator
  - Vertical Long-tube(falling film)evaporator

4. MULTIPLE EFFECT EVAPORATOR AND ECONOMY OF MULTIPLE EFFECT EVAPORATOR

Principle:-The multiple-effect evaporator uses the water vapour for one effect as the heating medium for the next effect ,which operates at a lower boiling point. The latent heat in water vapour can also be reuse by thermally or mechanically compressing the vapour to a higher pressure and temperature.



Working:- Multiple effect evaporator Due to heat transfer, the liquid temperature increases & reaches the B.P. during this process, vapour well be generated from the liquid feed. • So, formed vapour displaces air in the upper part of 1st evaporator. • Moreover, the vapour also displaces the air in the steam space of the 2nd evaporator. • After complete displacement of air by vapour in the steam compartment of 2nd evaporator, the second • valve is closed. • The vapour of 1st evaporator transmits its heat to the liquid of 2nd evaporator & gets condensed. • Condensate is removed through the second condensate valve. These steps continue in the 3rd evaporator also.

Uses:-

1. These are used for the concentration of various products like cascara extract.

2.These are mainly used for the preparation of table salt from sea water nad caustic soda.

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PREPARED BY: Ms.Archana Aare (Roll No-01)

Ms.Urmila Anande(Roll No-02)

GUIDE BY: Miss.Archana Kadam

CLASS: second year B.pharmacy

ACADEMIC YEAR:2021-22

DISTILLATION

DEFINITION

- "Distillation is defined as the separation of the components of a liquid mixture by a process involving vaporization and subsequent condensation at another place."

APPLICATIONS:

- Separation of volatile oils- cloves (Eugenol comprises 72- 90%, Vanilin, acetyl eugenol).
- Separation of drugs obtained from plant and animal sources- Vit. A from fish liver oil.
- Purification of organic solvents-absolute alcohol (100%).

SIMPLE DISTILLATION

Simple distillation is a process of converting a single constituent from a liquid (or mixture) into its vapour, transferring the vapour to another place and recovering the liquid by condensing the vapour, usually by allowing it to come in contact with a cold surface.

Principle

Liquid boils when its vapour pressure is equal to atmospheric pressure. Simple distillation is **conducted at its boiling point**

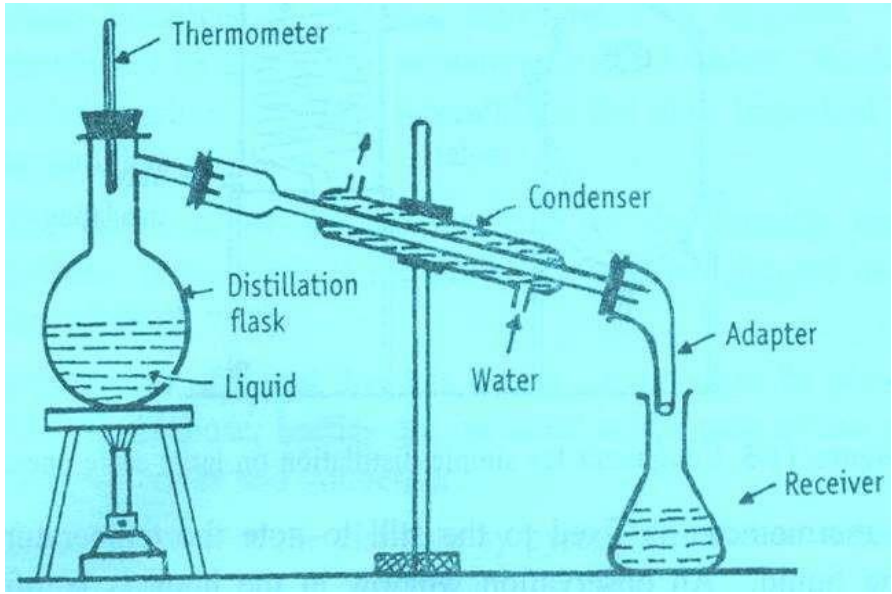
WORKING:

- The liquid to be distilled is filled into the flask to one-half to two-third of its volume. Bumping is avoided by adding small pieces of porcelain before distillation

CONSTRUCTION:

- It consists of a distillation flask with a side arm sloping downwards.

Condenser is fitted into the side arm by means of a cork



FLASH DISTILLATION

Flash distillation is defined as a process in which the entire liquid mixture is suddenly vaporized (flash) by passing the feed from a high pressure zone to a low pressure zone.

Principle:

When a hot liquid mixture is allowed to enter from a high- pressure zone into a low-pressure zone, the entire liquid mixture is suddenly vaporised.

Working:

- The feed is pumped **through a heater at a certain pressure**. The liquid gets heated, which enters the vapour-liquid separator through a pressure-reducing valve. **Due to the drop in pressure**, the **hot liquid flashes**, which further **enhances the vaporisation** process.

Construction

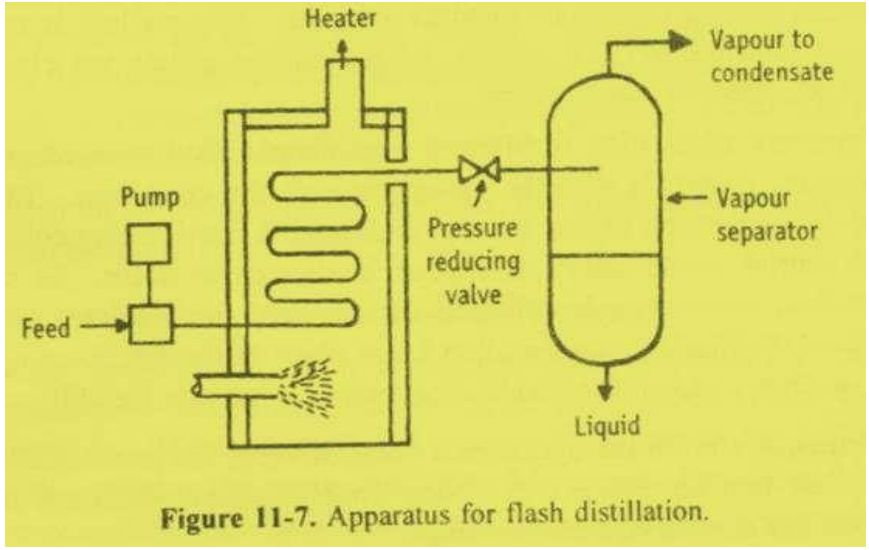


Figure 11-7. Apparatus for flash distillation.

Steam distillation

- Steam distillation is method of distillation carried out with aid of steam.

It is used to separate High boiling substances from non-volatile impurities - Separate immiscible liquids

Principle:

A mixture of immiscible liquids begins to boil when sum of their vapour pressure is equal to atmospheri pressure.

CONSTRUCTION:

Metallic steam can fitted with cork having two holes.

Safety tube inserted up to bottom through one hole to maintain pressure in side stem can, more over when steam comes out from safety tube indicates that can is empty.

- **Working :**

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HEAT TRANSFER

Work is one of the basic modes of energy transfer in machines the action of force on a moving body is identified as work. The work is done by a force as it acts upon a body moving in the direction of the force .Work transfer is considered as occurring between the system and the surroundings work is said to be done by a system is the sole effect on things external to the system can be reduced to the raising of a weight. Unit of the rate of heat transfer is Watt.

APPLICATION:

1.Evaporation :

Heat is supplied in order to convert a liquid into a vapour , which is subsequently removed. This process is used for preparing vegetable extracts. A construction similar to shell and tube heat exchanger is employed in evaporators. The heat flow can be quantified so as to estimate the efficiency of process.

2.Distillation:

In this two liquids are separated by the application of heat. Heat is supplied to a liquid mixture for converting the liquid into vapors so that the individual vapors components are condensed at another place. In case of steam distillation, steam will be in direct contact with the material.

3.Drying:

Removal of small amount of moisture from product is called drying . drying generally involves direct heating.

E. g. In the production of tablets, heat is passed through a carrier gas over a bed of wet solid mass for achieving drying. In case of spray drying, heat is supplied to the solutions and suspensions (as in case of production of milk products).

MECHANISMS OF HEAT FLOW:

1.Conduction :

When heat flow in a body is achieved by the transfer of the momentum of individual atoms or molecules without mixing such a process is known as conduction.

For example, flow of heat through the metal shell of a boiler takes place by conduction as far as solid wall or shell is considered. No mixing is involved. Conduction Is limited to solids and fluids whose movement is restricted

2.Convection:

When heat flow is achieved by actual mixing of warmer portions with cooler portions of the same material, the process is known as convection. For example, heating of water by a hot surface (coil type water heater) is mainly by convection. Convection is restricted to the flow of heat in fluids (i.e. liquid and gases). Convection restricted to the flow of up almost daily in the atmosphere. These are responsible for winds, land an sea breezes, ocean current etc.

3. Radiation :

When heat flows through space by means of electromagnetic waves, such energy transfer is known as radiation.

For example, a black surface absorbs most of the radiation received by it. Simultaneously the absorbed energy is quantitatively transferred into heat . Fused quartz transmits all the radiation that strikes it, while a polished opaque surface or mirror will reflect most of the radiation that strikes it. Solar water heaters, solar cockers, microwave ovens, microwave cockers, sonicator baths etc. are few examples in which radiation is utilized for producing heat.

CONDUCTION:

Heat can flow only when there is a temperature gradient, i.e. heat flows from a hot surface to a cold surface. The rate of conduction through solid can be studied easily, since it is the sole phenomenon. The basic law of heat transfer by conduction can be written in the form of rate equation as follow:

$$\text{Rate} = Driving force / Resistance \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

The driving force is the temperature drop across the solid surface. The greater the temperature drop, the greater will be the rate of heat flow.

The flow of heat will also depend on the conductivity of the materials through which it is flowing. For example, conduction of heat is faster through an iron rod than through a wooden log. This factor is represented by the term resistance, which can be quantitatively expressed by Fourier's law.

$$Resistance = Thickness\ of\ the\ surface(m) / mean\ proportionality\ constant\ (W/_m . K) \times area\ of\ the\ surface(m^2)$$

$$= L / k_m A \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Equation **(2)** for resistance can be obtained from the Fourier's law.

Fourier's law:

Fourier's law states that the rate of heat flow through a uniform material is proportional to the area and the temperature drop and inversely proportional to the length of the path of flow.

The Fourier's law may be mathematically expressed as:

$$Rate\ of\ \text{h}eatflow \propto Area\ (m^2) \times temperature\ difference(\Delta t)$$

$$thickness(m)$$

$$q \propto A.\Delta t\ /L$$

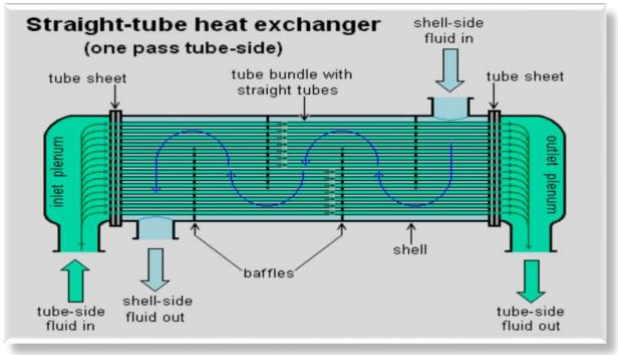
Or **$q = km.A.\Delta t\ /L$** **……(3)**

Where, km is mean proportionality constant.

EQUIPMENT:

TUBULAR HEATER (SHELL-AND-TUBE HEATER):

Shell-and-tube heater is the simplest form of a tubular heater. It is a single-pass tubular heater.



Working:

Steam or other vapour is introduced through a connection F into the space surrounding the tubes. The steam flows down the tubes. In this process, the tubes get heated. The condensed vapour is drained at G. Non- condensable gases, if any, escape through the vent K provided at the top of the casing. The fluid to be heated is pumped through the connection H into distributing chamber D2. The fluid flows through the tubes.

The steam and fluid are physically separated, but are in thermal contact through the thin tube walls. The fluid in the tubes get heated due to heated transfer by conduction through the metal wall, followed by stagnant layer and finally by convection. The total heat transfer is affected by single pass of fluid. Thus, the heated fluid reaches the distributing chamber D1 and leaves through the exit point, I In the sheet-and-tube heater, the cross sectional area of the tubes is larger. Hence, the velocity of the fluid inside the tubes is low.

Advantage:

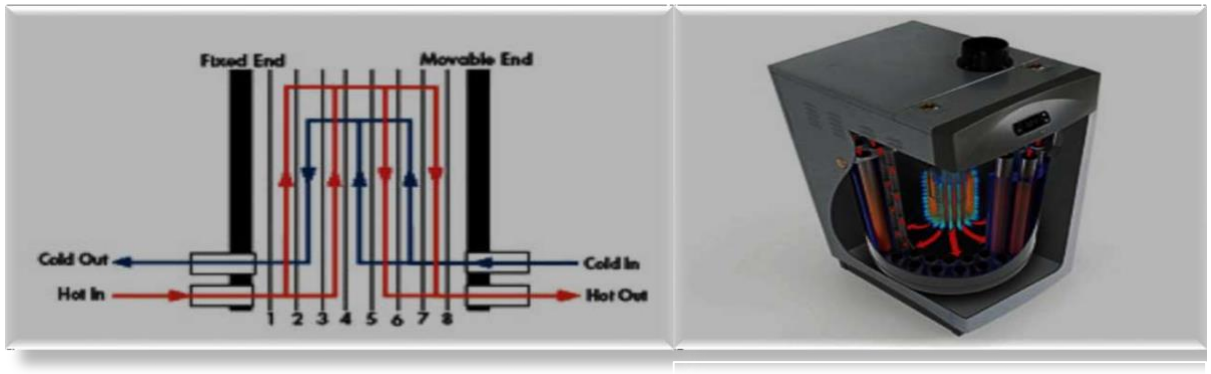
In a single –pass tubular heater, large heating surface can be packed into a small volume .

Disadvantages :

1. The velocity of fluid following in these tubes is low because of large cross –sectional area or larger surface.
2. The expansion of the tube and shell takes place due to differences in temperatures this may lead to the loosening of the tube sheets or buckle the tubes .

MULTI-PASS HEATER:

In a multi-pass heater, the velocity of fluid can be increased. As a result, heat transfer coefficient also increases. As the name indicates, the liquid to be heated is passed through the tubes several times before leaving the equipment. This facilitates the heat transfer. Therefore , multi-pass tubular heaters are superior to the single-pass shell-and-tube heaters.



Working:

Steam is introduced through the connection into the space surrounding the tubes. As the steam flows down, the tubesget heated. The condensed vapour is drained. Non-condensable gases, if any, escape through the vent provided at the top of the casing.

The fluid to be heated is pumped at high velocities into the right distribution chamber through the compartment; A. High velocity facilitates the effective heat transfer. In this construction, fluid is directed to enter only fraction of the tubes by means of baffles placed in the distribution chamber.

The liquid enters compartment A and flows to the left into compartment B, back to the right to compartment, and so on in the same sequence of alphabetical order. During this process , fluid in the tubes get heated, due to heat transfer by conduction through the metal wall, followed by a stagnant layer and finally by convection.

Advantage:

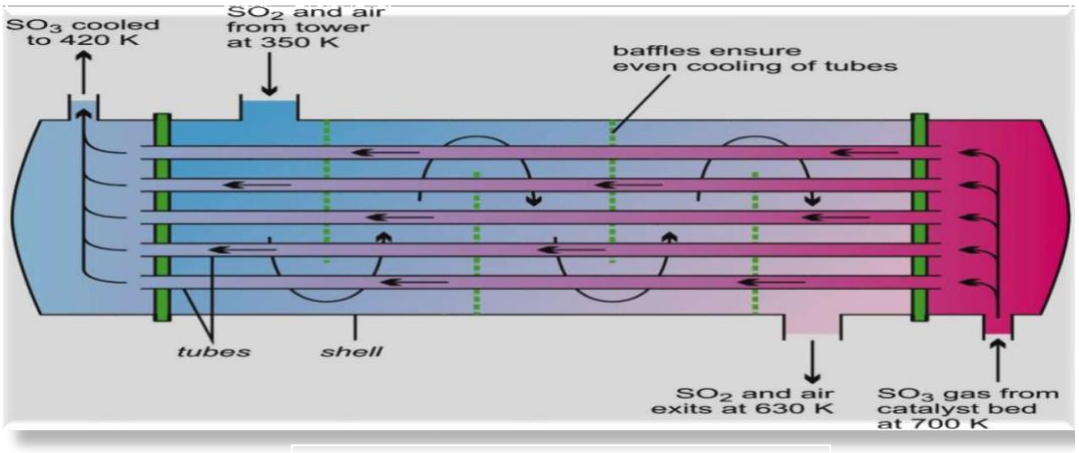
Multi-pass heater is to improve velocity of fluid.

Disadvantage:

The fabrication of a multi-pass heater is more complicated.

LIQUID-TO-LIQUID INTERCHANGER:

The basic construction and working of any heat transfer equipment more or less remains the same. Only a few modifications are included.



Working:

The hot fluid (heating medium) is pumped from the left-side top of the shell. The fluid flows outside the $t_8u_5$bes and moves down directly to the bottom. Then, it changes the direction and rises again. This process is continued till it leaves the heater. Baffles increase the velocity of the liquid outside the tubes. Baffles also allow the fluid to flow more or less right angles to the tube, which creates more turbulence. These help in reducing the resistance to heat transfer outside the tubes. Baffles lengthen the path and decrease the cross-section of path of the cold fluid.

Advantages:

In liquid to liquid interchanger, heat transfer is rapid as the liquid

1. passes at high velocity outside the tubes.

2. flows more or less at right angles to the tubes .

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PREPARED BY : Ms. Janhavi Bhere.
GUIDED BY : Miss. Kadam A. J.

ACADEMIC YEAR : 2021-22.