

UNIT - II

Heat Transfer

Heat Transfer - Heat transfer is the process of transfer of Heat from High temperature System to a lower temperature System.

Objectives of Heat transfer Process -

- To Study different mode of heat transfer.
- To determine the rate of heating and cooling.
- To plan change in new heat transfer equipments.
- To determine the efficiency of existing heat exchange equipment.

Application -

Heat is required for drying of wet-masses during production of tablets.

During distillation, heat is required to convert liquids into vapour. there for, individual component get condense at other place.

In case of Steam distillation, steam is required which is in direct contact with material.

To prepare vegetative extract by process of evaporation. Heat is supplied to liquid therefore vapour are formed which are removed.

for recrystallisation of drug supersaturated is achieved by heating saturated solution.

for Sterilization of Pharmaceuticals, dry Heat is required for sterilization of Glasswares and container. while steam is required for autoclaving.

for different process such as boiling, fusion etc. Heat is also required.

Mechanism of Heat transfer-

Heat travel from one place to another in 3 ways -

- 1} Conduction
- 2} Convection
- 3} Radiation

Conduction -

Transfer of Heat between two substance that are in physical contact without mixing

Better the conductor, faster the Heat will be transferred.

example- Metal is a good conductor of Heat.

Conduction occurs when a substance is heated the particle acquire more energy and vibrate more. these molecule then bump into the neighbouring particle and transfer some of their energy to them.

It then continue and transmit the energy from the hot end to the cooler end of the substance.

Convection -

Thermal energy is transferred from Hot places to cool places by mixing of warmer portion with cooler portion of some material.

example- water boiling in a pan.

② If Motion of fluid is due to difference in density which occur by different

in temp., then it is called natural convection.

If motion of fluid is due to mechanical means, then it is called forced convection.

Radiation -

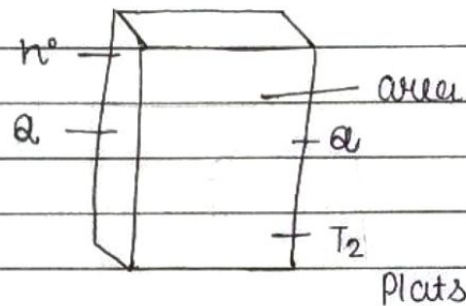
Radiation is a Method of Heat transfer that does not related to any contact b/w the Heat sources & the Heated object, as in the case of conduction and convection.

Heat can be transmitted through the empty space. by electromagnetic radiation. This process of energy transfer is known as radiation.

ex Heat of the Sun or Heat generated by the filament of a Bulb.

fourier's Law -

fourier's law states that the rate of Heat flow through a uniform material is directly proportional to the area and temperature gradient and inversely proportional to the width of the wall from Heat transfer



Temp. gradient - It is the difference at temp. from one place to another (ΔT)

According to this law , $Q \propto A$
 $Q \propto \frac{dT}{dx}$
 $Q \propto A \frac{dT}{dx}$

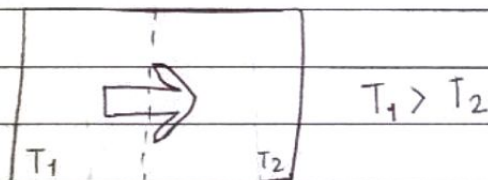
rate of Heat transfer , $\left[Q = -k \frac{A \Delta T}{dx} \right]$

Where Q = rate of Heat transfer
 A = area of wall
 dT = temp. gradient
 dx = width of wall.
 $-k$ = constant

Heat transfer by Conduction -

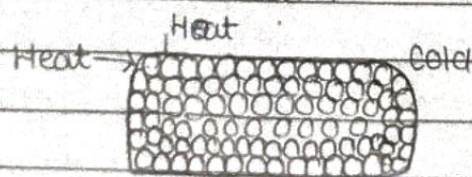
Transfer of Heat through a Solid Material
It may be through fluid, but fluid should be in Stationary.

It also depends upon temperature gradient. - [Difference ^{at time}], because Heat transfer High temperature to low temperature



Now When we provide Heat at one end of substance, then particle of that end vibrate vigorously and then they bump with neighboring particle and transfer their energy.

find this process should be continue untill the last end particle should observe Heat.



Which is responsible for Heat transfer its called Driving force.

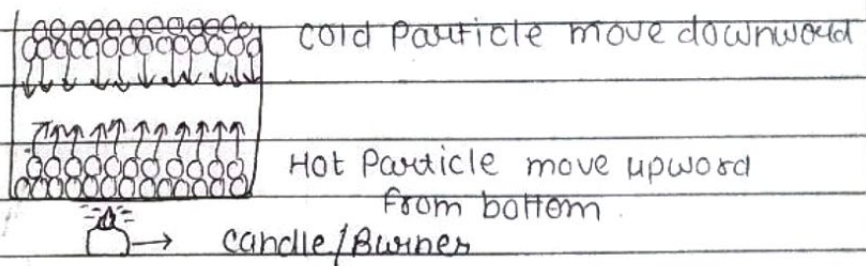
$$\text{Rate of Heat transfer} = \frac{\text{Driving force}}{\text{Resistance}}$$

Heat transfer by Convection -

It is the mode of Heat transfer which occurs mostly in liquid and gases.

In this Method Heat transfer take place with the actual motion of substance from one place with in the Body to the other place.

Example -



When we boil water we have seen bubbles and convert droplets in water on careful observation.

This is example of convection, In which Hot water at bottom become lighter and move upward forcing the cold & denser water at the top to come down and Heated up.

Heat transfer by Radiation:-

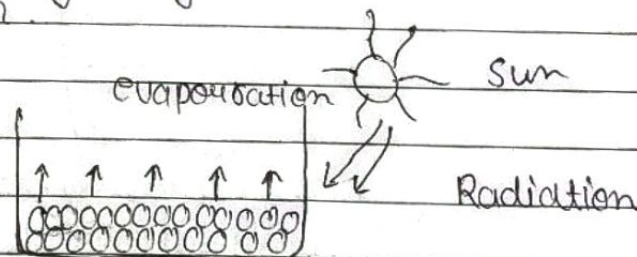
It is another form of Heat transfer.

It does not require any medium and can be used for transfer of Heat in a vacuum.

This Method uses electromagnetic waves which transfer Heat from one place to another.

The Heat & light from the Sun in our Solar System reach our planet using radiation only.

Example - In winter, when we sit near at fire, we feel warm without touching fire. This is possible by radiation.



Heat Exchanger -

Heat Interchanger $\Rightarrow$

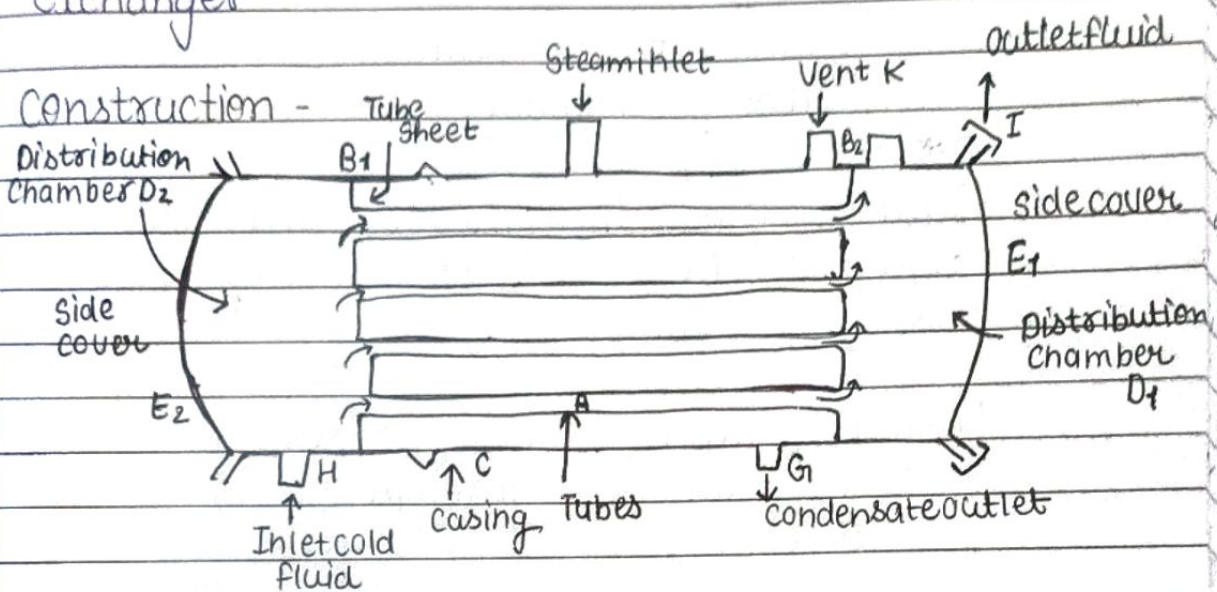
Heat exchanger are the device used for transferring Heat from one fluid (Hot Gas or Steam) to another fluid (liquid) through a Metal wall.

(work on - Conduction or convection Both)

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Tubular Heater or Shell and Tube Heater -

Principle - It is a single pass tubular heater work as a heat exchanger



It consists of a bundle of parallel tubes with thin walls.

The tubes are enclosed in a cylindrical casing.

Two distribution chambers D₁ & D₂ at each end of the casing.

Fluid inlet in D₂ and heated fluid outlet at D₁.

Steam or other vapour is introduced from steam inlet. Non-condensed vapour escapes from vent & condensed vapour drains and outlets.

Working -

Steam is introduced into tube and tubes get Heated.

The fluid to be Heated pump into Distribution Chamber D₂

fluid flow through Heated tube & steam and fluid get Heated by single pass of fluid.

Heated fluid reach Distribution Chamber (D₃) and leaves through Hot fluid outlet.

Advantages -

Large Heating Surface area into small space.

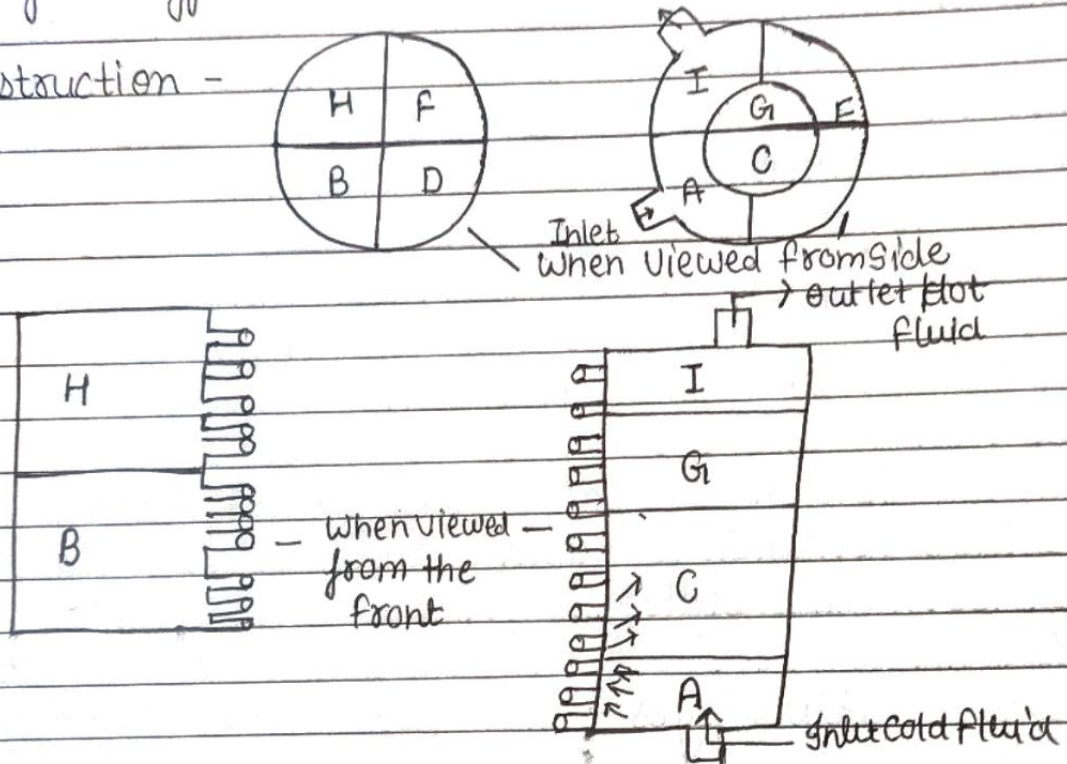
Disadvantage -

Velocity of fluid is low so Heat transfer coefficient is also low.

Multi Pass Heater -

Principle — In this Heater velocity of fluid increase so, Heat transfer coefficient is also increase.

Construction -



It consist of Bundle of Parallel tube wrapped in cylindrical casing.

Two Distribution Chamber are present on each side of the casing.

So liquid flow through several tubes back & fourth.

Working -

Steam introduced into space surrounding the tubes and tubes get heated.

Fluid to be heated pumped at high velocities into eight distribution chamber A. High velocity facilitate effective heat transfer.

Liquid enter into compartment A and flow to compartment B, from compartment B to compartment C.

So fluid pass back and forth in several tubes and leave the equipment from outlet.

Advantages -

Multi pass Heater decrease the cross section of fluid path so increase the fluid velocity.

Disadvantage -

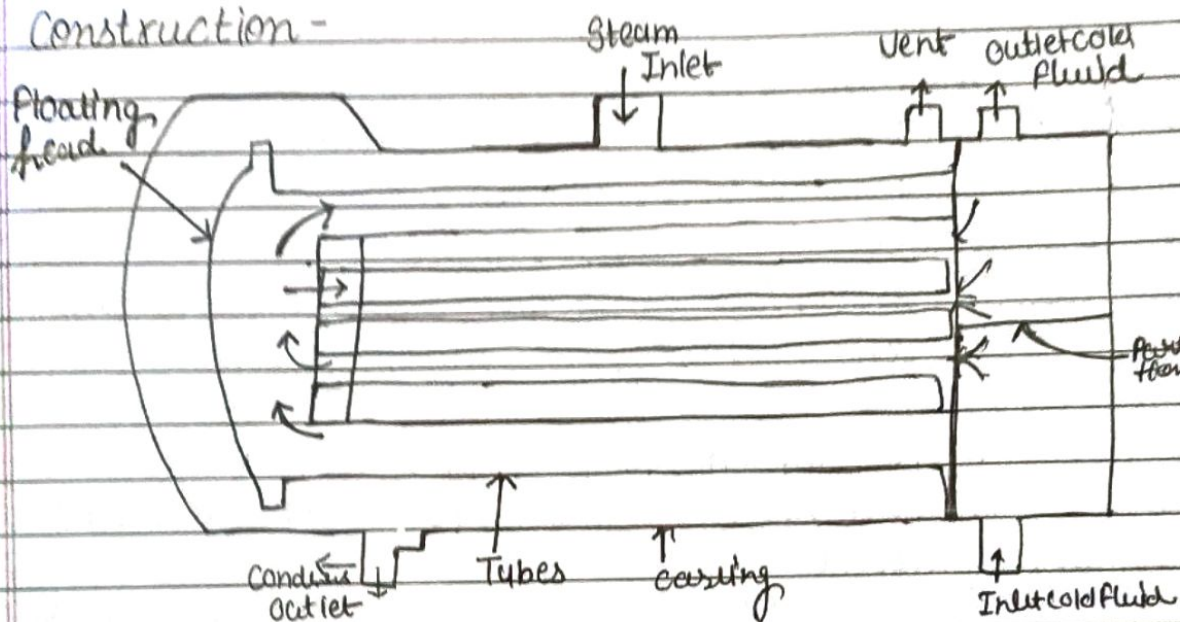
Fabrication is complicated.

Pressure drop through pipe increase due to enhance velocity.

Floating head to pass Heaters -

Principle - In this Heater ends of tube structurally independent of the casing (floating pipe)

Construction -



It consist of Bundle of Parallel tube is enclosed in a casing

Right side of the distribution chamber Partition (Have same no. of tube). fluid inlet & outlet.

Left side of the distribution chamber (tube) not connected to casing. (known as Floating Head)

Steam or vapour introduced through inlet provision or made for escape of (superheated) condense vapour and exist of Non-

Condensed Upward.

Working -

Steam is introduced through inlet & steam flow down the tubes and tubes get heated.

Fluid to be heated introduced into distribution chamber.

Fluid flow through the pipe reach floating head and change direction.

Then reach next part of distribution chamber. During this pass fluid get heated.

(Due to Heat transfer by conduction by metal wall then by convection in fluid)

Then Heated fluid leaves from outlet.

Heat Interchangers -

Heat Interchanger are devices used for transferring heat from one liquid to another or from one gas to another gas through a metal wall (Heating medium is hot liquid)

Baffles -

Consist of circular disk, these are perforated to receive tubes.

Working -

Area placed outside the tubes. These increase velocity of liquid which create more turbulence so increased heat transfer coefficients.

Working -

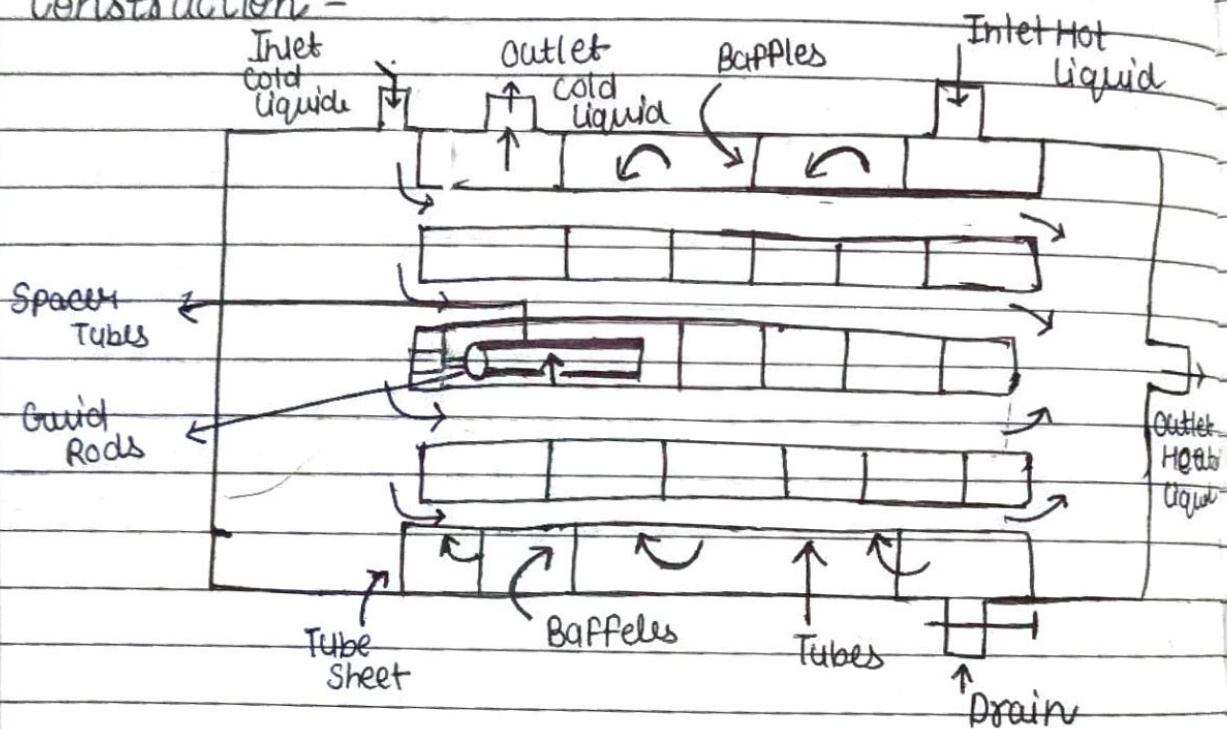
Baffles are placed outside the tube. These increase velocity of liquid.

Which create more turbulence so increase heat transfer coefficient.

Working -
Vessels are placed outside the tube. these increase velocity of liquid which create more turbulence so increase heat transfer coefficient.

Liquid to Liquid Interchanger -

Construction -



Tubes sheets special rod are assembled and tubes are installed are arranged with appropriate.

Baffles are arranged with appropriate spacing.

The casing have provision for introducing heating medium outlet for fluid at High right side Tube.

Each side of tube two distribution chamber is provided.

Left side chamber contains an inlet for fluid to be heated. Right side chamber contain outlet for heated liquid at entire.

Working -

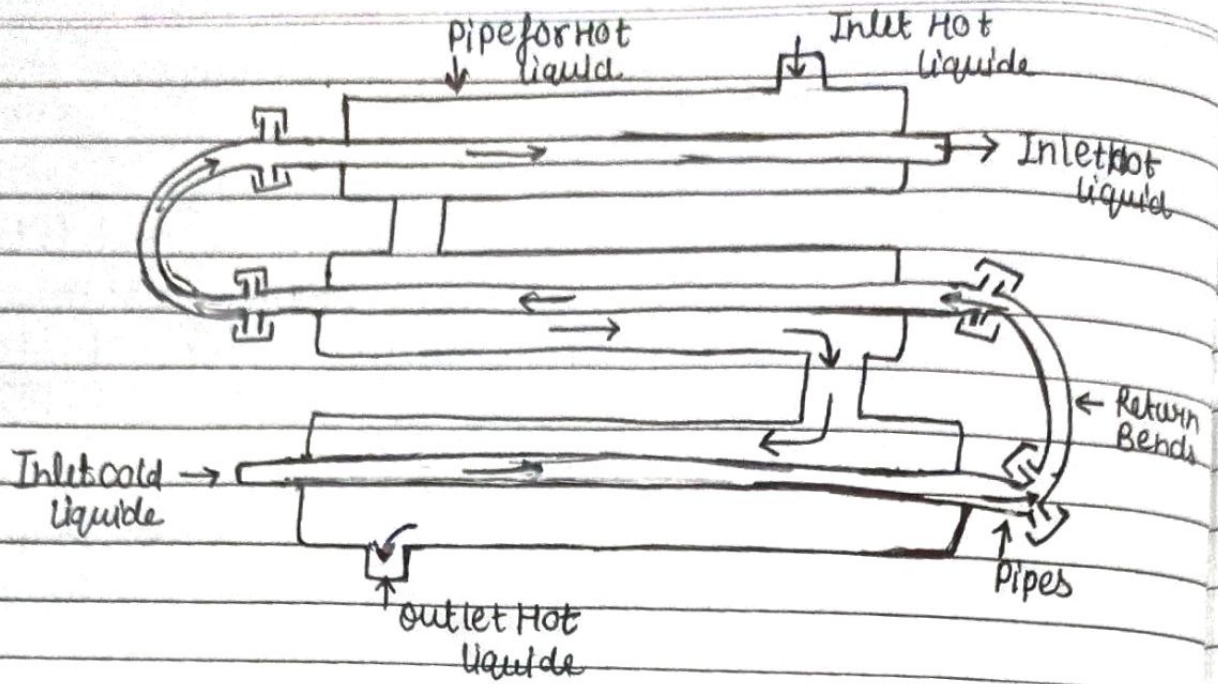
- ⇒ Hot liquid is pumped through inlet fluid move downward.
- ⇒ Thus it change the direction & rise again ^{Backflow} increase the velocity of liquid creates more turbulent.
- ⇒ liquid to be heated is pumped through inlet & pass through the tubes get heated (Single-pass).
- ⇒ Heated liquid collected from outlet.

Double pipe Heat Interchanger -

Heat transfer in this equipment is more efficient than liquid liquid heat interchanger.

Construction -

- The pipe are used one tube inserted in other.
- ⇒ Inside the tube is for cold liquid to be heated. & outside pipe act as jacket for circulating hot liquid.
- ⇒ Glass tube, standard iron pipe, Graphite tube are used.



Double pipe Heat Interchanger

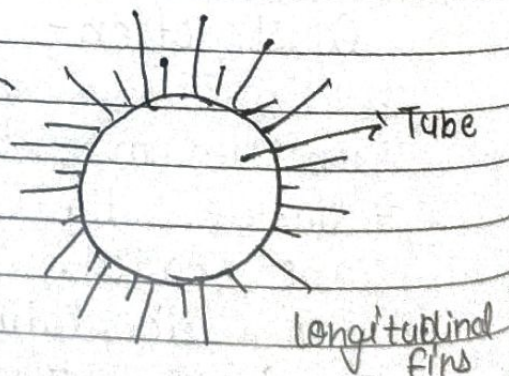
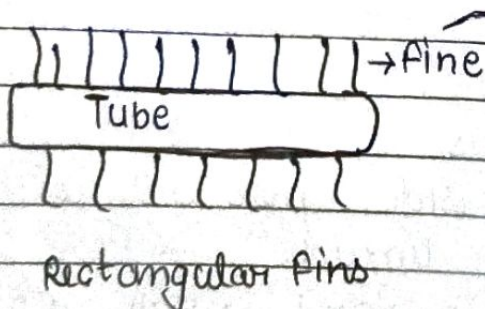
Working -

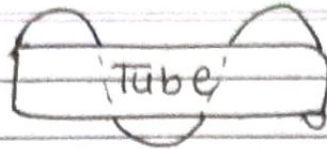
Hot liquid is pumped into jacket section and pipes gets Heated.

liquid to be heated is pumped through inlet & liquid travel through tubes and gets heated.

leave the liquid through inlet.

Finned Tube $\Rightarrow$





Spiral Fins

Heat transfer rate $\Rightarrow$

$$Q = UA\Delta t$$

U = Heat Transfer coefficient

A = Area

So surface area of content is enhanced by fixing fins outside the tube.

Construction-

Uses - Reduce size of operator increase surface area of content use increase rate of heat transfer.

Distillation -

Distillation is the process of separating the substance / components from liquid mixture by selective evaporation & condensation (Vapour to liquid)

Example - R.O.

It separates mixtures based on differences in their volatile in a boiling liquid mixtures.

Distillation is a unit operation or a physical separation process & not a chemical rxn.

Distillation process mainly involve two steps-

Step I - converting liquid into vapour phase.

Step II - Transferring the vapour to another place & recovering the liquid by condensation process.

Application -

Distillation is most widely used in pharmaceutical laboratory. The various application are -

Distillation is used for preparation of distilled water.

Steam distillation is used for separation of volatile oil / from vegetable drugs. Such as Eucalyptus oils.

molecular distillation - method are used to purify different organic compound.

This process is also used for recovery of solvents from crude drugs. Extracts from the preparation of Galenicals.

For Purification of organic solvents, distillation is used.

In Petroleum industry, using flash distillation method the crude oil is separated into different fraction.

Distillation method are used to estimate alcohol content in dosage form such as - elixirs.

Classification of Distillation Method -

These distillation method are used on laboratory scale as well as industrial scale -

Simple Distillation

Flash Distillation

Fractional Distillation

Distillation under reduced pressure

(Vacuum distillation)

Steam distillation

molecular " "

Simple Distillation -

Simple Distillation is a process of converting a single component from a mixture into its vapour.

Transferring the vapour to another place & recovering liquid by condensation.

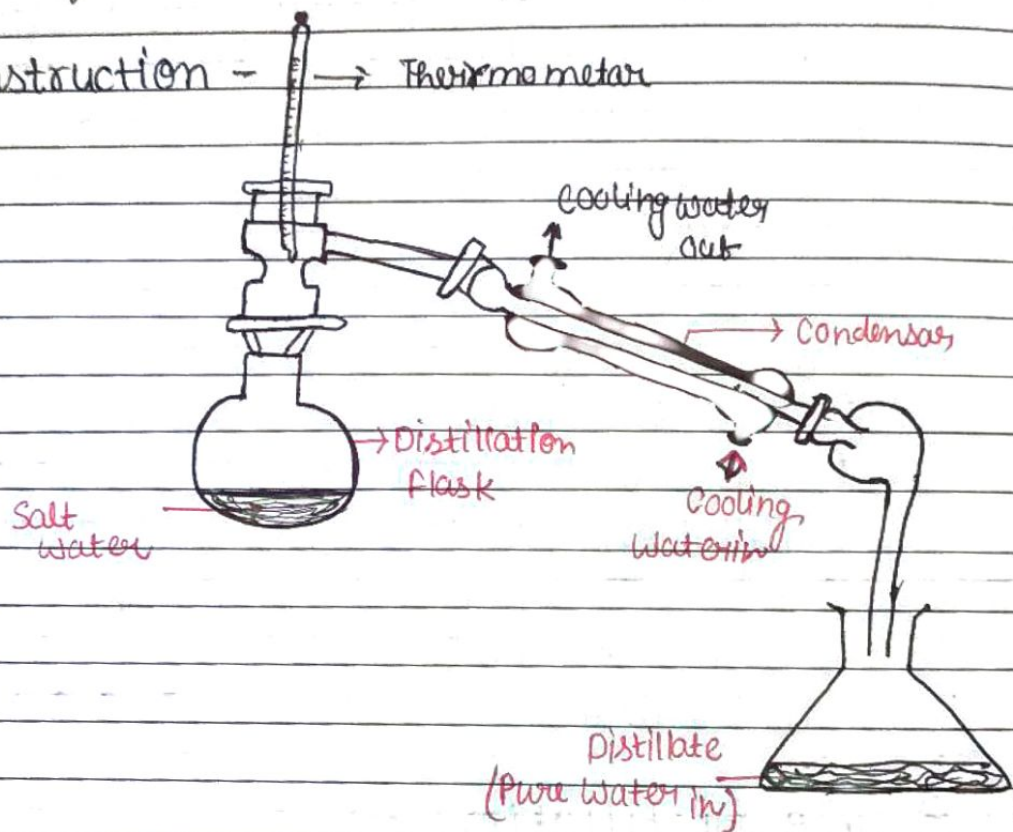
This process is known as differential Distillation.

Principle -

liquid boil when its vapour pressure is equal to atmospheric pressure.

Simple distillation is conducted at its boiling point.
Higher the relative volatility of a liquid better the separation.

Construction -



It consists of distillation flask with side or sloping downward.

Condenser is fitted in side arm by carb.

The condenser is usually water jacketed.

The condenser is connected with receiver using an adapter.

The whole apparatus is made up of glass.

Working -

liquid to be distilled filled into flask and porcelain pieces are used to avoid bumping.

A thermometer is inserted into the flask and water is circulated through jacket of condenser.

The content Heated Gradually (Slowly),

liquid start boiling, vapour rise up & passes downside arm to condenser.

Vapour is condensed and collected in receiver.

The heating is adjusted so that distilled is collected at rate of one two drop per second.

Application -

used for preparation of distilled water & water for injection. Volatile & aromatic water are prepared.

Organic solvent are purified.

Few official compound are prepared.
Isopropyl spirit of nitrous, ether & aromatic
spirit of Ammonia.

Non Volatile solid are separated from
volatile liquid.

(Sudden)

Flash Distillation-

It is defined as a process in which the
entire liquid mixture is suddenly
vaporised (flash) by passing it
from high temp.

Zone to low temperature zone.

It is also known as equilibrium distillation.

Principle-

When a hot liquid mixture is
allowed to enter from high pressure zone
to low pressure zone. (liquid vaporised
suddenly).

The entire liquid mixture suddenly
vaporised (Flash vaporisation).

(liquid equal
to vapour)

During this process chamber get cooled.

In individual vapour phase molecule of
higher boiling friction & low boiling
friction remain as vapour.

Construction -

- It consists of a pump connected to feed.
- Pumping the feed into heating chamber through a pipe.
- Other end of a pipe introduced into vapour separator through pressure reducing valve pipe.
- The vapour is collected from pipe located at above & liquid is collected through pipe (outlet) at bottom of separator.

Working -

Feed is pumped through heater at a certain pressure.

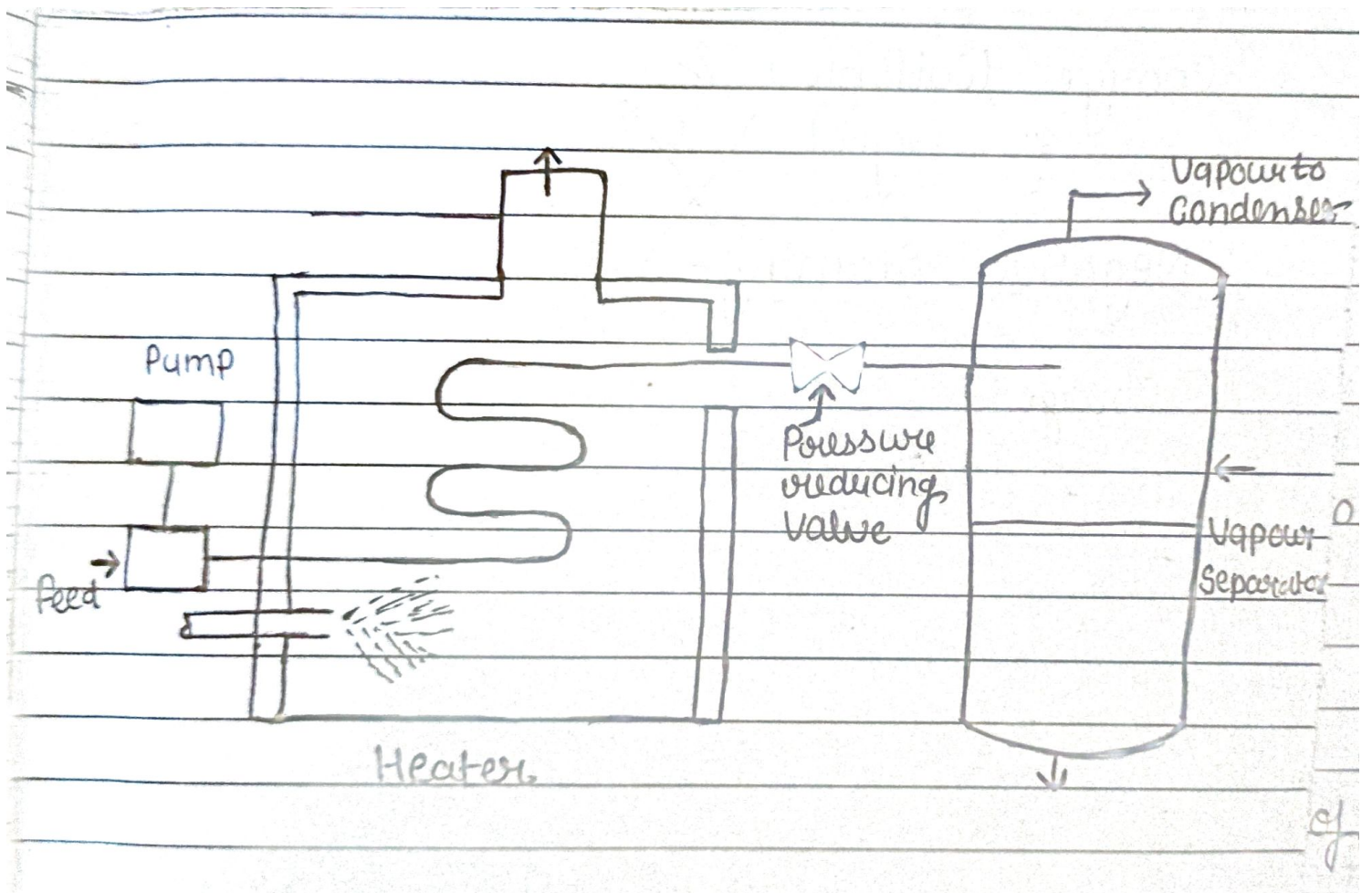
Liquid gets heated at inter vapour separator through pressure reducing valve.

Due to drop in pressure the hot liquid flash sudden vapourisation induces cooling.

High boiling fraction molecules get condensed & low boiling fraction molecules remain as vapour.

Advantage -

Flash distillation process can be used for separating components of different volatilities very easily.



Disadvantage -

⇒ It is not suitable for the separation of components with comparable volatilities.

Uses -

The separation process is widely used in refining crude oil.

Fractional Distillation -

⇒ It is a process in which vapourisation of liquid mixture to a mixture of constituents from which desired one is separated in pure form.

⇒ This Method also called as Rectification

Principle -

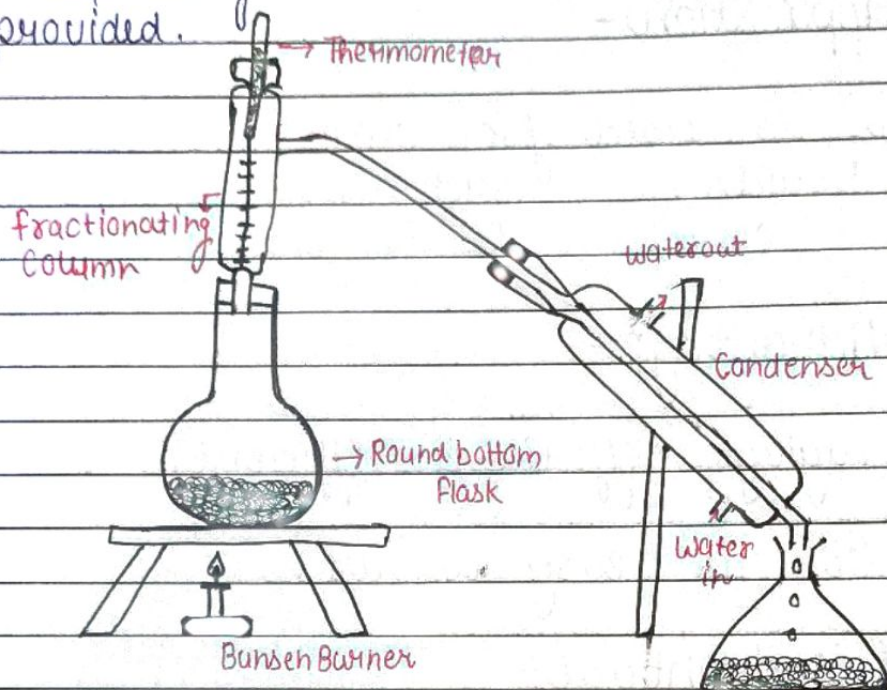
⇒ When a liquid mixture is distilled partial condensation of vapour is allowed in a fractionating column.

⇒ In this column ascending vapour from still allow to come in contact with condensing vapour returning to the distilled.

⇒ The resulting enrichment (large) of vapour to more volatile component.

Construction -

- ⇒ The fractionating column is inserted b/n Still & Condenser.
- ⇒ Supply of heat at Bottom of the Still.
- ⇒ At top of the column Condenser is provided.



Working -

- ⇒ The mixture to be distilled is fed to the boiler & Heated.
- ⇒ The sequence of events occurring in the fractionating column.
- ⇒ When liquid boiling point reached & when the vapour condensed.
- ⇒ In this column ascending vapour from

Still allowed to come in contact with
Condensing Vapour returning to the
Still.

- ⇒ The result enrichment of Vapour to
more volatile component.

Application -

- ⇒ It is used for separation of miscible
liquids. such as - acetone & water
Chloroform & Benzene.

Advantage -

- Highly effective & efficient.
- ⇒ It is easy to use.

Disadvantage -

- It can't be used to separate miscible
liquids which form azeotropic mixture.

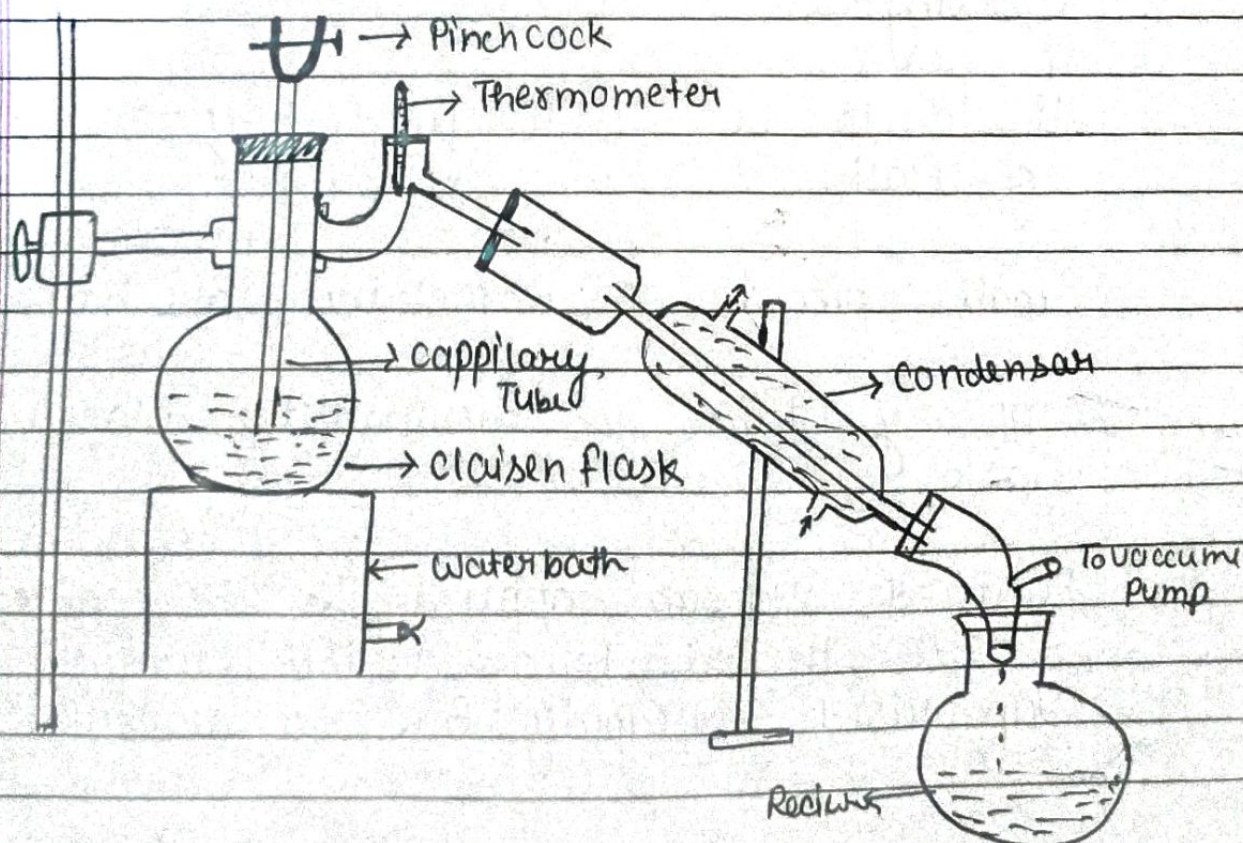
Distillation Under reduced pressure (Vacuum Distillation) -

Distillation under reduced pressure may be state that a distillation at a temp. lower than its boiling point by application of vacuum.

Principle -

Liquid Boil when vapour pressure equal to atmospheric pressure if external pressure is reduced by applying vacuum the boiling point of liquid decrease.
(So liquid boil at lower temp.)

Construction -



It consist of a double neck distillation flask & also called as Claisen Flask.

Thick wall glass apparatus. use for vacume distillation.

Claisen Flask in one neck is introduced thermometer & second neck present porcelain piece.

Water Bath or oil bath is used for Heating.

Claisen Flask is connected with condenser & vacuum pump attached to adapter connected to receiver.

Working-

Liquid to be distill fill half or $\frac{2}{3}$ Volume of flask.

Small pieces of Porcelain are half filled

capillary tube & thermometer placed in flask.

Required vacuum applied & the content are heated. temp. rise liquid get vapourised rapidly. Due to vacume.

Application -

Preventing Degradation of Active
Constituent like enzyme, Vitamin,
Glycosides.

Changing physical form. ex - cascara
Sagrada.

Disadvantage -

Forming is major problem
in case of Biological & Plant extract.

St

Steam Distillation -

Steam Distillation carried with aid of
Steam for Heating

Steam Distillation used for Separation of
High Volume Substance from non-volatile
impurities immiscible liquid.

Principle -

In Mixture of immiscible liquid boil
when sum of there vapour pressure
equal to the atmospheric pressure.

Construction -

Steam Distillation consist of
Metallic steam can fitted with cork
having two whole.

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one whole insert safety tube (to control pressure) & second whole insert bent tube (connected to flask)

The flask is connected with condenser & condenser connected with receiver with the help of adapter.

Working-

Steam can filled with water & non aqueous liquid placed in flask. (small quantity)

Steam can and flask heated at the same time.

Mixture get heated & steam carries volatile oil & passes through condenser

Condensed immisible liquid is collected in receiver separated by separating flask.

Application-

used for separation of immisible liquid.

used for extracting most of volatile oil like. Eucalyptes oil or cloves.

Camphor is distilled by this method.

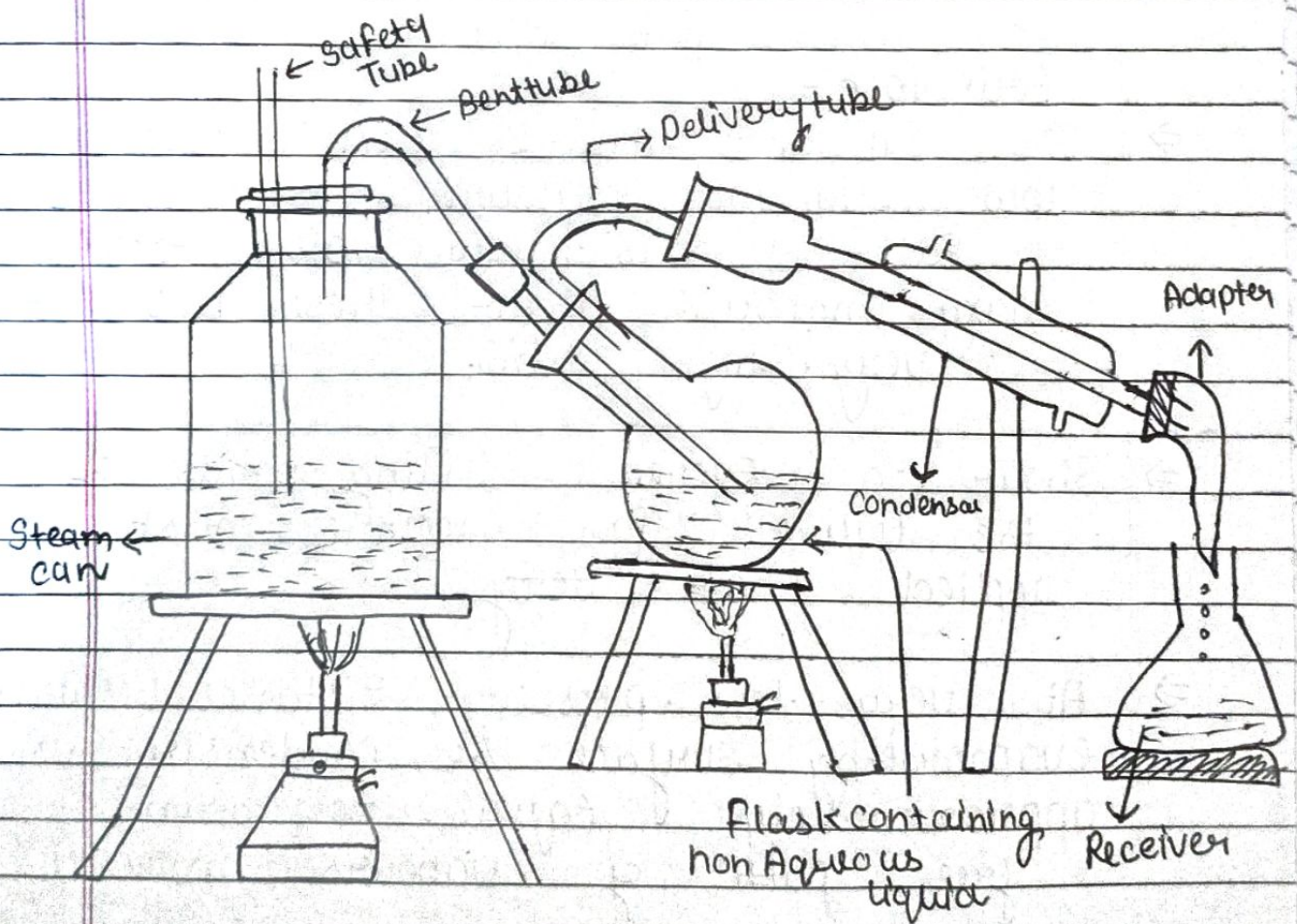
Advantages -

Volatile oil can be separated at low temp. without loss of aroma.

Substance have low volatility can be distill.

Disadvantages -

Non-Suitable when a immisible liquid react with water.



Molecular Distillation -

Molecular Distillation is defined as Distillation process in which each molecule in the vapour phase travel mean free path & get Condense individually (without intermolecular collision)



By use of vacume.

This is called evaporating distillation or short path distillation.

Principle -

⇒ The substance to be distill have very low vapour pressure.

Ex - viscous liquid, oil, Greases, waxy material show these boil at very high temp.

⇒ Show to decrease Boiling point of the liquid High vacume must be applied at very.

⇒ At very low pressure Distance between evaporating surface & condenser is approximately equal to mean free path of vapours molecule.

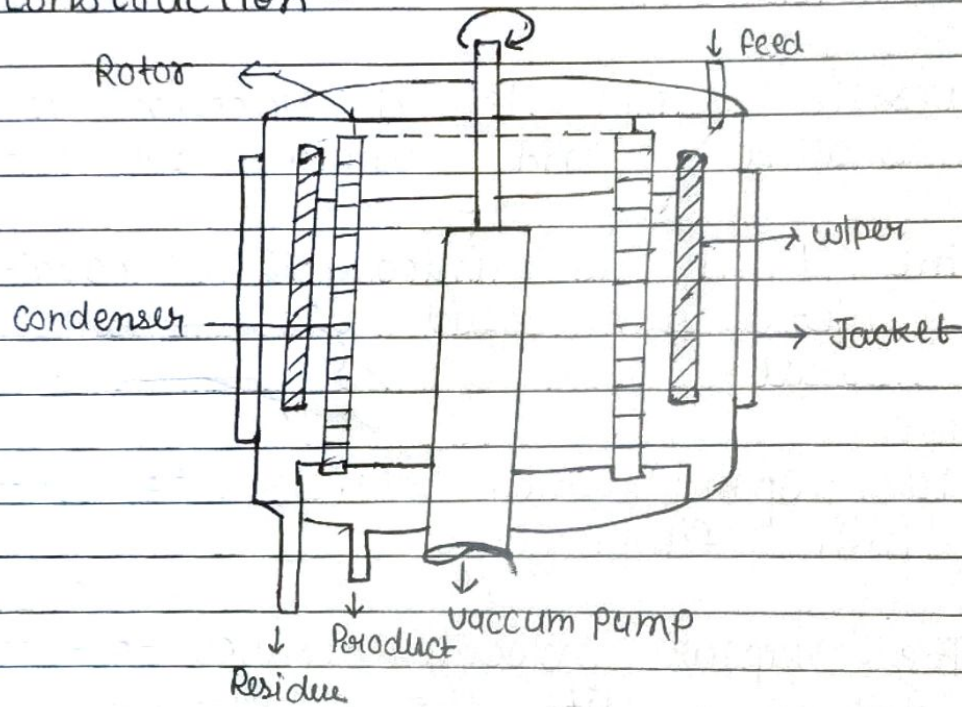
⇒ Molecules living the surface of liquid hit the condenser surface.

Construction-

Molecular Distillation Based on method of formation of liquid film apparatus divided into two types -

- 1) Wiped film molecular still / falling film molecular still -

Construction -



The vessel has a Diameter of 1m.

The wall of vessel are provided jacket for Heating.

Wipers are adjust to vessel wall connected to rotating head through a motor.

A Condensar are arranged very closed to wall.

Vacume pump is connected to centre of vessell

from Bottom Distillate and undistillate residue is collected.

Working -

vessell is Heated, Vacuum is applied and wiper are rotated.

The feed is introduced through inlet. as liquid flow down the wall

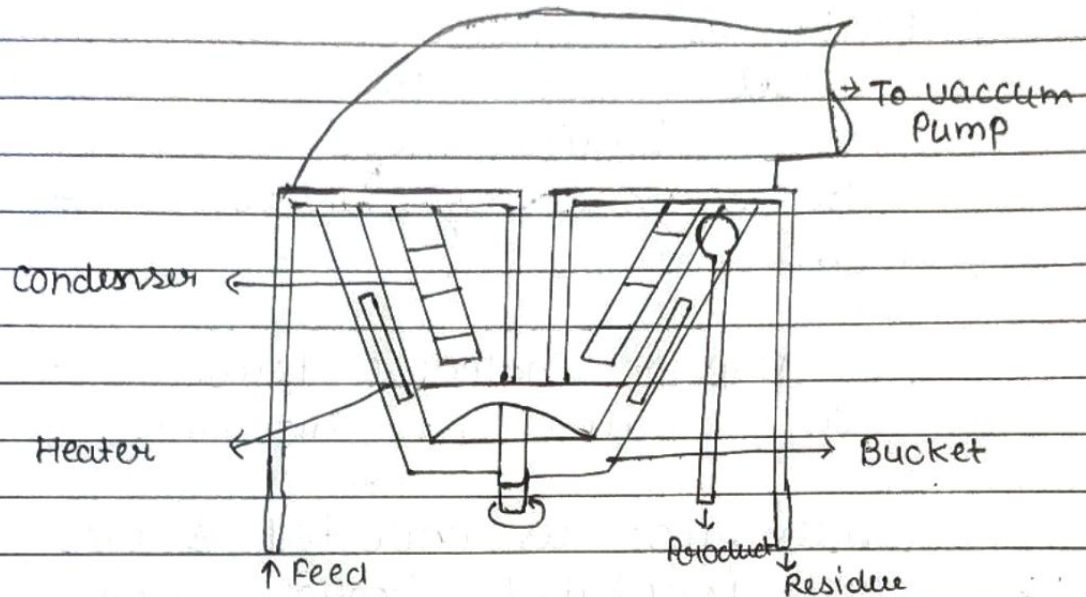
It is spread by wiper. to form a thin film.

The vapour molecule travel to mean free path & hit the condenser.

Condensate collected into a vessell & residue is collected from bottom & recirculate through the feed.

Centrifugal Molecular Still

Construction -



It consists of Basket Shaped Vessel 1-1.5 Diameter, rotated at High Speed.

Heaters are provided externally.

Condensers are arranged very close to evaporating surface.

Vacuum pump connected to entire vessel at top.

Provision are made feed into center product receiver, Product residue

Working -

Vacuum is applied at centre of vessel & Basket rotate at High Speed.

Feed is introduced from centre of vessel. Due to centrifugal force liquids move outward over the surface of vessel and form a film.

The vapour molecule travel its mean free path and hit the condenser.

Condensate is collected & residue is re-circulated through feed.

Application-

Purification of chemical like tri cresyl phosphate, Di Butyl Phthalate & Di methyl Phthalate.

Used in refining of fixed oil

Vitamin A is separated from fish liver oil.

Evaporation -

Introduction -

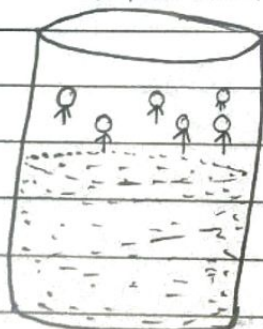
Evaporation is a process of vaporization of large quantities of volatile liquids to get a concentrated product.

Equipment used for the operation are known as evaporators.

Heat is supplied to the evaporator, which transmit it to evaporating liquid so as to provide latent heat of vapourisation.

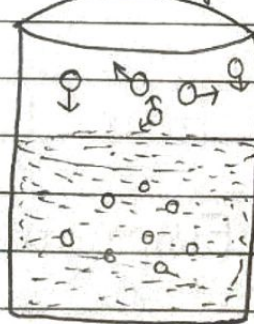
Evaporation is a surface phenomenon that is mass transfer takes place from the surface thus boiling is not occurs.

Evaporation



Vapour pressure
Atmospheric pressure
Bubbles can not form

Boiling



Vapour pressure
Atmospheric pressure
Bubbles can form & rise

for evaporation some conditions are given-

The liquid must be volatile, while Solute must non volatile.

Solute is thermostable.

liquid which used for evaporation must be less viscous than water or it may be so viscous that it will hardly flow.

Application -

It is used in the preparation of liquid, Softy & Dry Extract.

It is used in manufacture of biological product (Enzymes, Hormones....).

To Get demineralized water.

Difference between evaporation & other heat process -

Evaporation

The residue is a conc. liquid

Evaporating liquid is only one component

Other Heat process

Drying - the residue is solid.

Distillation - Evaporating liquid is a

in most of the cases

Combination of two or more components.

No attempt is made to separate the mixture of vapour even if any.

Distillation It is compulsory to separate each component.

The purpose of evaporation is to get a concentrated liquid only, but not to get crystals as it happens in some situations.

Crystallization The purpose of concentrating the solution is to get crystals.

Factor Influencing Evaporation -

Temperature -

Higher the temperature greater the vapour pressure hence greater evaporation.

The temperature should be below the boiling point.

Vapour Pressure -

Rate of evaporation is directly proportional to vapour pressure of liquid.

Lower the atmospheric pressure greater the evaporation.

Nature of liquid is important for evaporation rate.

If outer atmosphere is dry higher the evaporation rate.

Surface Area -

larger the surface - area greater the evaporation.

Moisture Content of feed -

Some drugs undergoes hydrolysis in presence of moisture.

So to prevent decomposition material exposed to low temperature initially than exposed to high temperature.

Ex- Drug extract of belladonna.

Time of Evaporation -

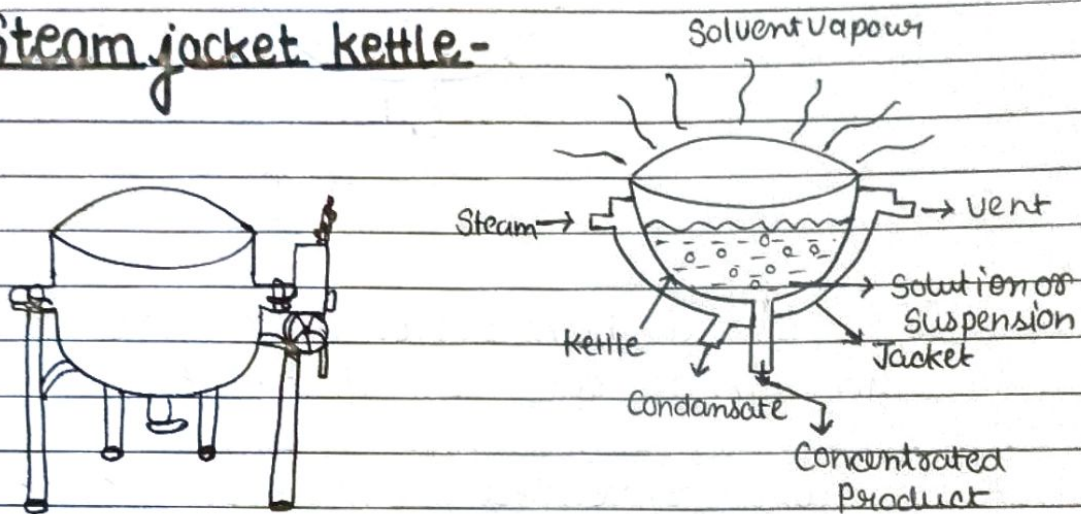
If time of exposure is longer greater evaporation for thermostable substance.

Exposure of drug high temp. to short temperature for thermostable substance.
Ex - film evaporators.

Economic factors- Economics of labour, fuel, floor surface space & material are primary consideration.

Recovery of solvent & utilization of waste heat reduction in costs.

Steam jacket kettle-



Principle

Steam is supplied to the jacketed kettle in which aqueous extract is placed.

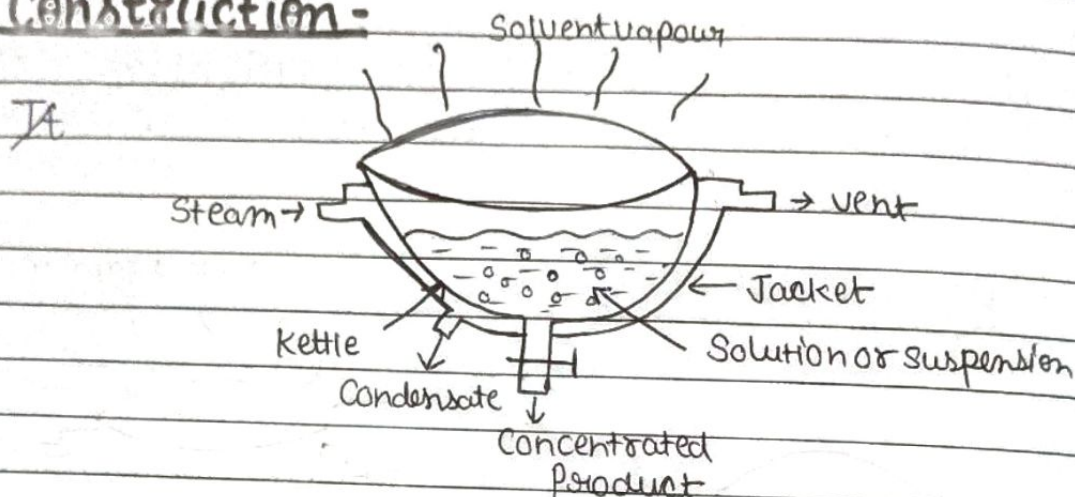
Steam gives out heat to the kettle.

The heat is transferred to the aqueous extract by conduction and convection.

The temperature rise and escaping tendency of the solvent molecules into vapour increases.

Stirring for the vaporization of solvent molecule.

Construction -



It is a hemispherical structure consist of an inner pan called Kettle.

It is enveloped with an outer pan called Jacket.

Two pans are join to enclosed space through which steam is pass

for kettle copper is a good material because of its good conductivity, but for acidic material evaporation instead of copper use tinned copper.

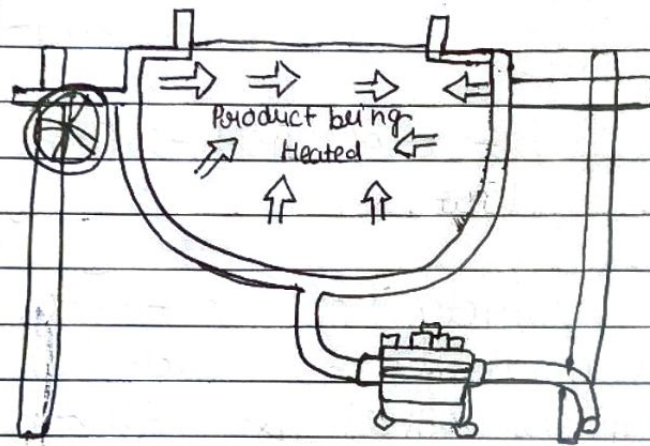
Iron is used for construction of the jacket because it has minimum conductivity.

Inlet for the Steam and outlet for non condensed gas are provided near the top of the jacket.

Condensed Steam leaves the jacket through the outlet provided at the top of the bottom

for the discharge of the product one outlet is provided at the bottom

Working -



Aqueous extract to be incorporated its place in the kettle.

Steam is supplied through the inlet

Content Stirred by mechanical stirrer.

Rate of evaporation is fast in the initial stages and decreases gradually as the liquid gets concentrated.

for such equipment must have a good ventilation to remove the vapour.

To prevent condensation in the room and dense fog of condensed vapour.

Advantage-

Use in both small scale and the large scale.

Simple construction and easy to operate clean and maintain.

Its cost of installation & maintenance is low.

Wide variety of material can be used for construction such as copper, stainless steel & aluminium.

Stirring after contains and removal of the product is easy.

Disadvantages-

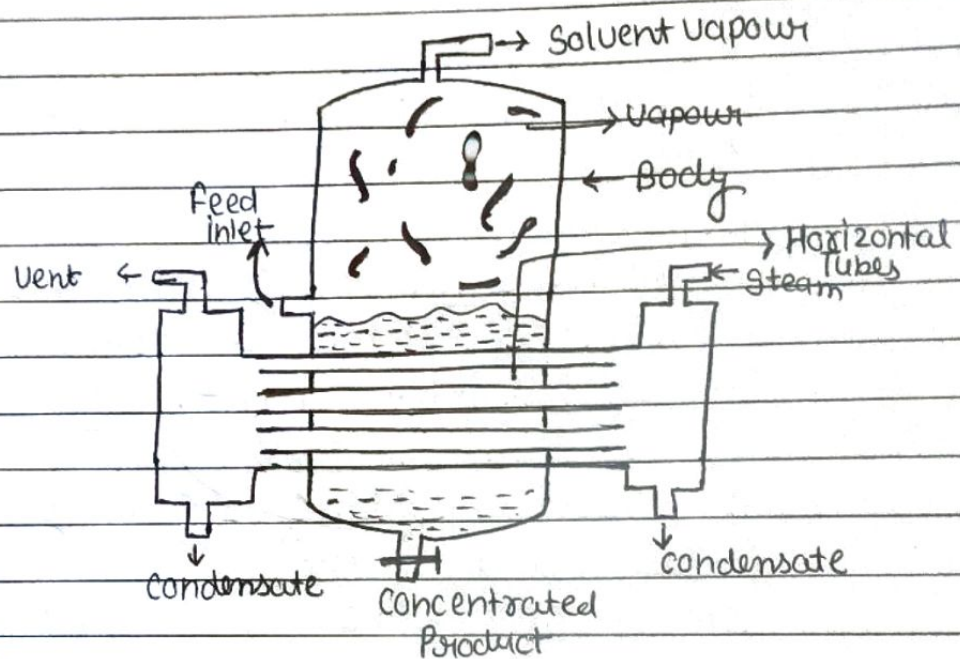
Cost per unit material production is more.

It is not suitable for heat sensitive material due to long time of exposure.

The heating area decreases as the product gets more concentrated.

Saturation of vapours in atmosphere which lead to decrease rate of evaporation.

Horizontal tube evaporator -



Principle -

Steam is passed through horizontal tubes which are immersed in a pool of liquid to be evaporated.

Heat transfer takes place through the tubes and liquid outside the tubes gets heated.

The solvent evaporated and escape from the top.

Concentrated liquid is collected from the bottom.

Construction -

It consist of large cylindrical body with conical or domed shape top & bottom.

It is made up of cast iron & (or) Steel plates.

An Average size of the body range from 1.8 to 2.4 meters diameter & from 2.4 to 3.6 meters height.

The lower part of the body consist of a Steam compartment with inlet for Steam at one end and the vent for non condensed gases on the other end.

Condensed 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 mm. beyond the tube sheet on the both ends.

feed inlet is provided, one outlet for vapour is placed at the top of the dome & for the produce discharge one outlet is provided at the bottom.

Working:-

The feed is introduced into the evaporator until the steam compartment is satisfactorily increased.

Steam is introduced into the steam compartment & tubes receive heat from steam and conduct it to the liquid due to temperature gradient.

Condense passes through the corresponding outlet.

The feed absorbs heat & solvents gets evaporated.

The vapour then escapes through the outlet place at the top.

This process is continued until a thick liquid is formed which is collected from the bottom outlet.

Uses -

A horizontal tube evaporator is the best for non viscous solution that does not deposit scales or crystals on your operation.

Advantages -

Cost effective.

Forced Circulation Evaporator -

Construction -

The steam jacketed tubes are held between two tubes sheet.

Inside diameter is 0.1 m. & 2.5 m. long.

The part of tubes projects into the vapour head (flash chamber) which consist of a deflector.

The vapour head connected to return pipe which runs downwards & enters into the inlet of a pump.

Principle -

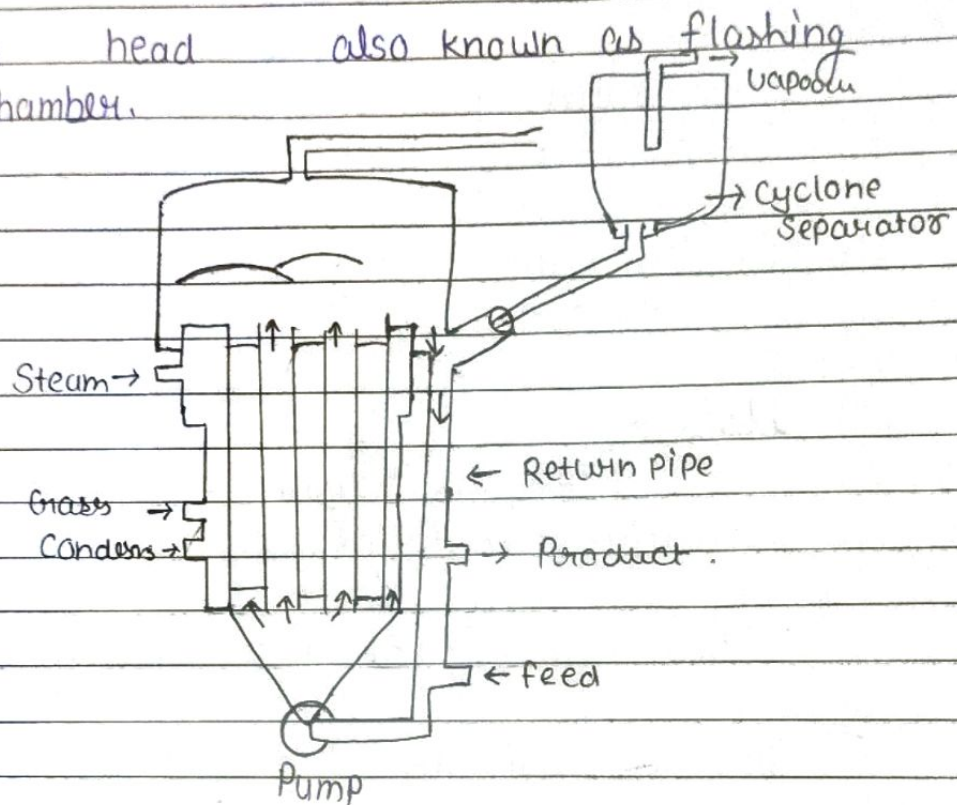
liquid is circulated through tubes at high pressure by means of pump.

Hence boiling does not takes place because boiling point elevated.

forced circulation also create agitation.

When liquid leave the tubes enters in vapour head pressure falls down.

Vapour head also known as flashing chamber.



Working -

Steam introduce into Calendra's.
Pump feed the liquid tube with positive velocity.
As the liquid moves up through the pipe, it gets Heated & begins to boil.

The vapour & liquid mixture rushes out of the tube at a high velocity.

The mix Strikes the deflector, which throws the liquids downward.

The result is an effective separation of liquid & vapour.

Vapour enters in cyclone separator & leaves equipment.

Concentrated product liquid returns to pump for further evaporation.

Finally the product collected from outlet.

Uses -

It is used for concentrating heat sensitive material.

It is used for insulin & liver extract.

It is suitable for corrosive solution.

It is suitable for crystallising operation where the crystals are to be suspended at all the times.

Advantages-

It has a high heat transfer coefficient due to rapid liquid circulation.

Salting & scaling are not possible due to forced liquid circulation.

Due to rapid circulation it suitable for heat sensitive material.

It is also used for high viscous liquid.

Disadvantage-

The equipment is expensive.

Climbing Film Evaporator-

Principle -

Evaporator tubes externally heated by the steam.

Pre Heated feed enters from the bottom and flows a through the heated tubes.

liquid gets heated rapidly.

The liquid near to wall becomes vapour and forms small bubbles.

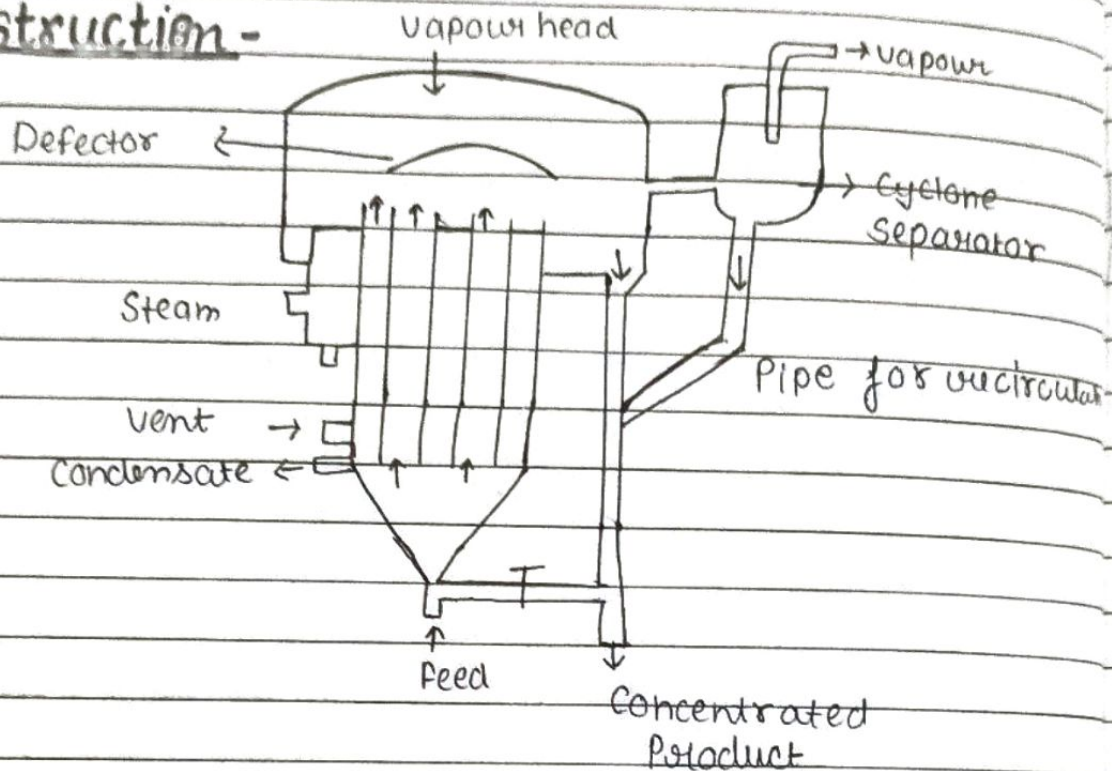
Tend to fuse to larger bubbles, which travels up in the tubes.

The liquid film is blown up from the top of the tubes and strikes deflector kept above.

This throws up the liquid concentrated down into the to lower part from where it

is withdrawn.

Construction -



The Heating unit consist of Steam jacketed tubes.

Tubes are held between two plates.

An entrainment separator is place at the top to the Vapour head.

It carries Steam inlet, Vent outlets & Condensed outlet.

The liquid is feed form the bottom of the Steam compartment.

Working:-

Pre heated liquid feed is introduced from the bottom of the unit.

The height of the liquid column is maintained low.

Steam enters into the spaces outside the tubes through the inlet.

Heat is transfer to the liquor through the walls of the tubes.

The liquid becomes vapour and forms smaller bubble which tends to fuse to larger bubble.

Deflector act as a foam breaker.

The vapour leave from the top and concentrated product form in the tube.

After formation of conc. Product it collected from the outlet.

Advantage:-

Large surface area is provided for heating.

Due to high velocity of feed the resistance for heat transfer at

Boundary layers are reduce.

It is suitable for Heat Sensitive because very short contact time of feed & Heating Surface.

It is suitable for foaming liquid.

Disadvantage-

It is expensive & construction is complicated.

Difficult to clean.

large head space is required.

It is not advisable for highly viscous liquid.

Multiple effect Evaporator-

It is same as verticle evaporator but instead of the one evaporator use multiply evaporators.

Construction -

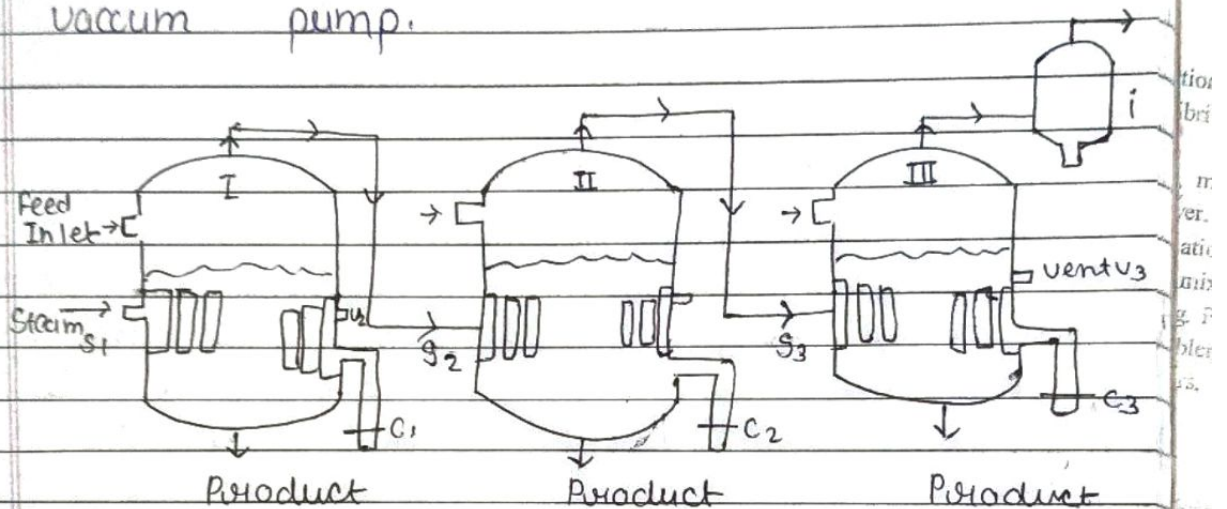
Construction of triple effect evaporator remain same as verticle evaporator.

The Vapour from first evaporator serves

as a heating medium for the 2nd evaporator.

2nd evaporator serve as heating medium for 3rd evaporator.

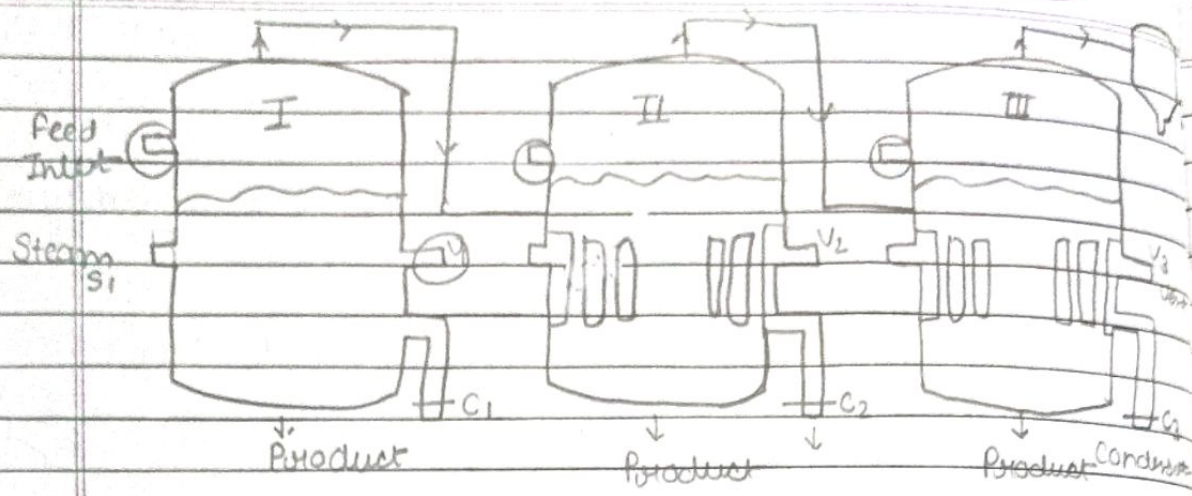
last evaporator is connected to a vacuum pump.



Working -

Parallel feed.

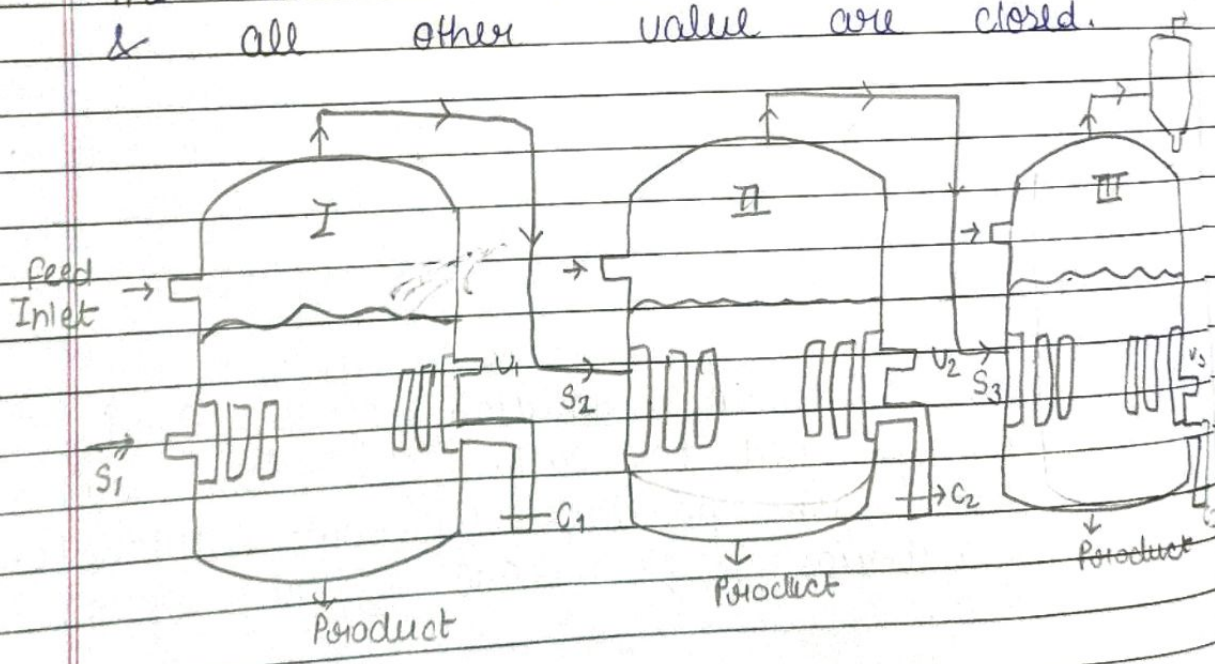
A Hot Saturated Solution of the feed is directly fed to each of the three effect in parallel with out transferring material from one effect to the other.



Operation -

In the beginning the equipment is at room temp. & atmospheric temperature the liquid feed is introduced to all three evaporator upto the level.

The vent VI, V2 & V3 are kept open & all other valve are closed.



Now high vacuum is created in the liquid chambers of evaporators.

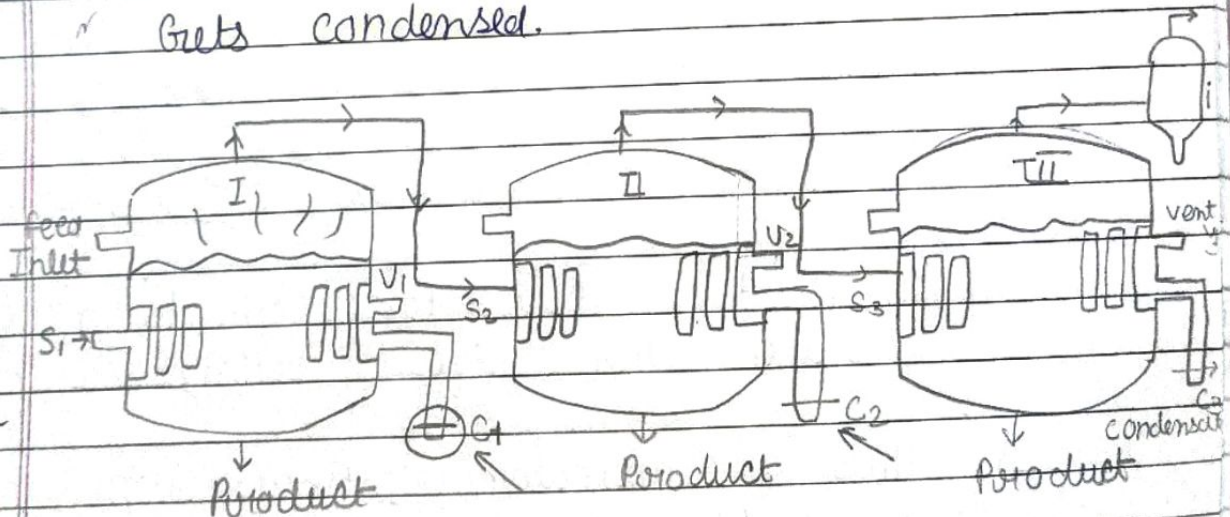
The Steam valve S_1 & condensed Valve C_1 is opened.

Steam first replace cold air in the Steam space of 1st evaporator.

When all the cold air is removed the Valve V_1 is closed.

The Supply of Steam is continue untill pressure is maintain 1st evaporator.

Steam give its temp. to the liquid feed in the 1st evaporator & Gets condensed.



Condensed remove through C_1

Due to heat transfer vapour is generated from liquid.

Some steam is displaced in space of 1st evaporator & moreover the vapour also displaced in 2nd evaporator.

After complete displacement of air by vapour in the steam compartment of 2nd evaporator, the valve V_2 is closed.

The vapour of 1st evaporator transmits its heat to the liquid of 2nd evaporator & gets condensed.

Condensed remove from the C_2

Above steps continue in 3rd evaporator.

Finally three evaporator come to a steady state with liquid boiling all bodies

In this evaporator continues supply of feed and steam.

Economy of Multiple Effect Evaporator -

Consider three thousand liter liquid is given for evaporation.

Single Vertical evaporator have capacity of evaporate one thousand litre liquid after consumption of 50 kg/hour of Steam.

Multiple effect evaporator have capacity of evaporate 3000 litre liquid after consumption of 50 kg/hour of Steam.

$$\text{Economy of an evaporator} = \frac{\text{Total mass of vapour produced}}{\text{Total mass of Steam supplied.}}$$

$$\text{Economy of Single an evaporator} = \frac{\text{NUMETS mass of Vapour produced}}{\text{Nunt of mass of Steam supplied.}}$$

$$\text{Economy of multiple effect evaporator} = \frac{\text{Nunt of Vapour produced}}{\text{1 unit of Steam supplied}}$$

Advantages -

It is suitable for large scale & for continuous operation

It is highly economical when compared with single effect.

About 5 evaporators can be attached.