PES's Modern College of Pharmacy (For Ladies), Moshi, Pune-412105

Class-First Year B. Pharm *Subject: Pharmaceutical Engineering*

Subject in-charge: Ms. Kandekar U.Y. *Lecture Synopsis*

HEAT TRANSFER:

Heat transfer occurs when thermal energy moves from an object with a higher temperature to an object with a lower temperature. Heat will continue to move until both objects reach thermal equilibrium.

Modes of heat transfer

CONUCTION: Heat is transferred from one particle of matter to another in an object without the movement of the object. Heat flows from the warmer object into the cooler object until they reach the same temperature.

CONVECTION:

It is the transfer of thermal energy through currents.Convection occurs in liquids and gases. As liquids and gases gain thermal energy, they expand and decrease in density.

Warmer areas of liquids and gases rise to the cooler areas. The cooler areas then take the place of the warmer areas. This movement of particles creates a current of thermal energy throughout a substance.

RADIATION:

Radiation is the transfer of energy by electromagnetic waves. Radiation does **NOT** require matter to transfer thermal energy.

References:

1. C.V.S. Subramanyam, J. Thima Shetty, Mrs Sarasija Suresh, Mrs V. Kusum Devi. Pharmaceutical Engineering, 1st edition, Publication: Vallabh Prakashan, Page No-104-105.
2. K. Sambamurthy. Pharmaceutical Engineering, Publication: New age International Publication, New Delhi, Page No-63-64.
3. Paradkar A. Introduction to Pharmaceutical Engineering, Publication: Nirali Publication, Page No-38-39.

FOURIERS LAW:

Statement:

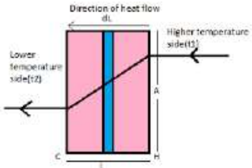
Rate of heat flow through uniform material is proportional to area and temperature drop and inversely proportional to the length of the path flow. Fouriers law can be expressed as:

$$\text{Rate of Heat Flow} \ \alpha \ \frac{\text{area (m}^2\text{)X temperature difference }(\Delta t)}{\text{Thickness (m)}}$$

$q \ \alpha \ A \ \Delta t \ /L$ or $q = K_m A \ \Delta t/L$, where

Km = mean proportionality constant

Derivation: fouriers law can be applied to the metal wall through which conduction of heat is taking place



Area of the wall = A, m^2Thickness ofthe wall = L, m

Face of the wall HH is maintained at higher temperature t1

Face of the wall CC is maintained at higher temperature t2

The heat flow is right angle to the plane A and assumed to be in steady state. Consider thin section of thickness dL at intermediate point in the wall. For this fouriers law can be applied as:

$$\frac{dQ}{d\o} = -\frac{KAdt}{dL} \qquad (1)$$

Q= heat transferred, ø= time, K= Proportionality constant, t=temperature

$$\frac{dQ}{d\o} = \text{constant} = q = -\frac{KAdt}{dL} \qquad (2)$$

References:

1. C.V.S. Subramanyam, J. Thima Shetty, Mrs Sarasija Suresh, Mrs V. Kusum Devi. Pharmaceutical Engineering, 1st edition, Publication: Vallabh Prakashan, Page No-106-107.
2. K. Sambamurthy. Pharmaceutical Engineering, Publication: New age International Publication, New Delhi, Page No-64-65.
3. Paradkar A. Introduction to Pharmaceutical Engineering, Publication: Nirali Publication, Page No-39-42.

STEFAN–BOLTZMANN LAW:

Statement:

The total energy radiated per unit surface area of a black body across all wavelengths per unit time is directly proportional to the fourth power of the black body's thermodynamic temperature

$$j^{\star} = \sigma T^4.$$

The constant of proportionality σ, called the Stefan–Boltzmann constant or Stefan's constant, derives from other known constants of nature. The value of the constant is

$$\sigma = \frac{2\pi^5 k^4}{15c^2h^3} = 5.670400 \times 10^{-8}\,\mathrm{J\,s^{-1}m^{-2}K^{-4}},$$

Where,

k is the Boltzmann constant,

h is Planck's constant,

c is the speed of light in a vacuum.

A body that does not absorb all incident radiation (sometimes known as a grey body) emits less total energy than a black body and is characterized by an emissivity, $\varepsilon < 1$:

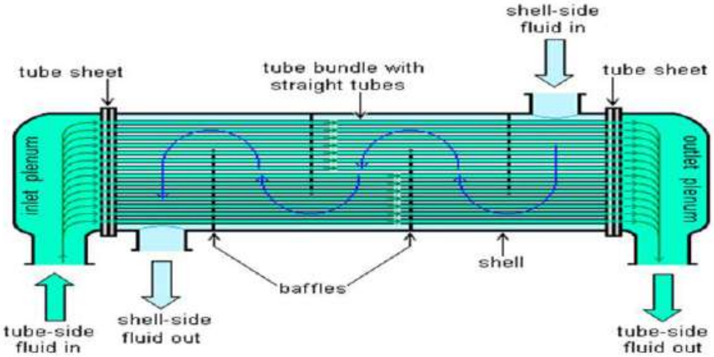
$$j^{\star} = \varepsilon\sigma T^4.$$

- ε is the emissivity of the grey body; if it is a perfect blackbody, $\varepsilon = 1$. In the still more general (and realistic) case, the emissivity depends on the wavelength, $\varepsilon = \varepsilon(\lambda)$

References:

4. C.V.S. Subramanyam, J. Thima Shetty, Mrs Sarasija Suresh, Mrs V. Kusum Devi. Pharmaceutical Engineering, 1st edition, Publication: VallabhPrakashan, Page No-128-130.
5. K. Sambamurthy. Pharmaceutical Engineering, Publication: New age International Publication, New Delhi, Page No-75-76.
6. Paradkar A. Introduction to Pharmaceutical Engineering, Publication: Nirali Publucation, Page No-45-47.

SHELL AND TUBE HEAT EXCHANGER:



- In order to transfer heat efficiently, a large heat transfer area should be used, so there are many tubes. One set of these tubes contains the fluid that must be either heated or cooled.
- The second fluid runs over the tubes that are being heated or cooled so that it can either provide the heat or absorb the heat required.

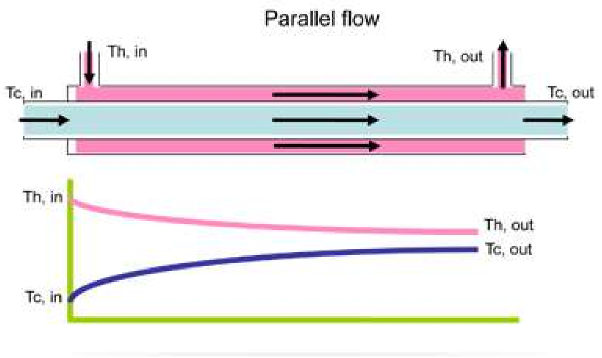
Baffles serve two purposes:

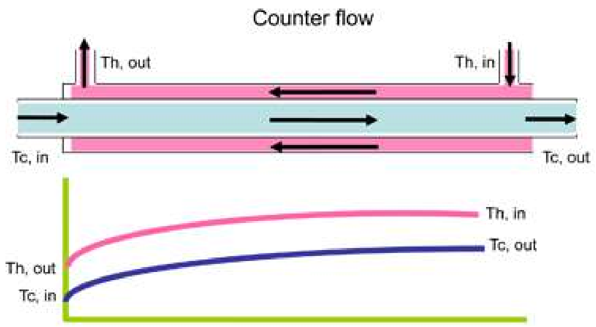
- Divert (direct) the flow across the bundle to Wet the maximum tube surface area.
- Support the tubes for structural rigidity, preventing tube vibration and sagging.
- When the tube bundle employs baffles,
- The heat transfer coefficient is higher than the coefficient for undisturbed flow around tubes without baffles.
- For a baffled heat exchanger the higher heat transfer coefficients result from the increased turbulence.

Reference:

1. Saunders, E. A. (1988). Heat Exchanges: Selection, Design and Construction. New York: Longman Scientific and Technical.
2. C.V.S. Subramanyam, J. Thima Shetty, Mrs Sarasija Suresh, Mrs V. Kusum Devi. Pharmaceutical Engineering, 1st edition, Publication: Vallabh Prakashan, Page No-132-141.
3. K. Sambamurthy. Pharmaceutical Engineering, Publication: New age International Publication, New Delhi, Page No-
4. Paradkar A. Introduction to Pharmaceutical Engineering, Publication: Nirali Publucation, Page No-58-59.

HEAT TRANSFER IN PARALLEL AND COUNTER FLOW:





PARALLEL FLOW:

In parallel flow heat exchangers, the two mediums enter the exchanger at the same end, and travel in parallel to one another to the other side.

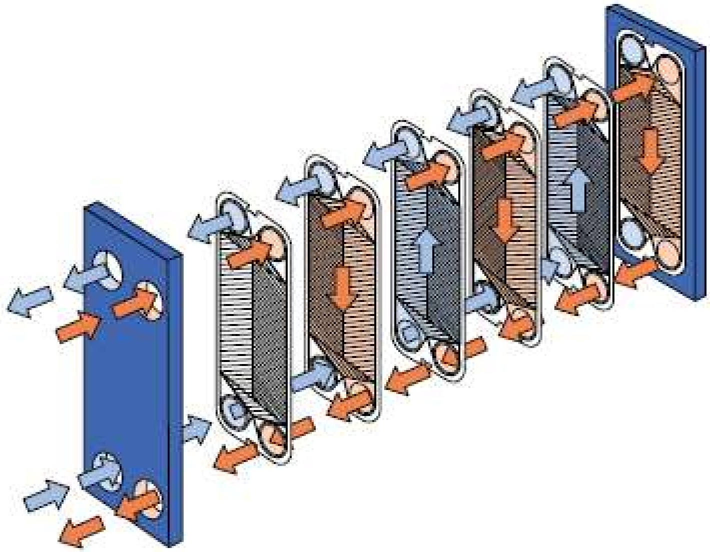
COUNTER FLOW HEAT EXCHANGER

In counter flow heat exchangers the fluids enter the exchanger from opposite ends. The counter flow design is most efficient, in that it can transfer the most heat from the heat transfer medium. The counter-current exchange system can maintain a nearly constant gradient between the two flows over their entire length of contact. With a sufficiently long length and a sufficiently low flow rate this can result in almost all of the property transferred. So, for example, in the case of heat exchange, the exiting liquid will be almost as hot as the original incoming liquid's heat.

References:

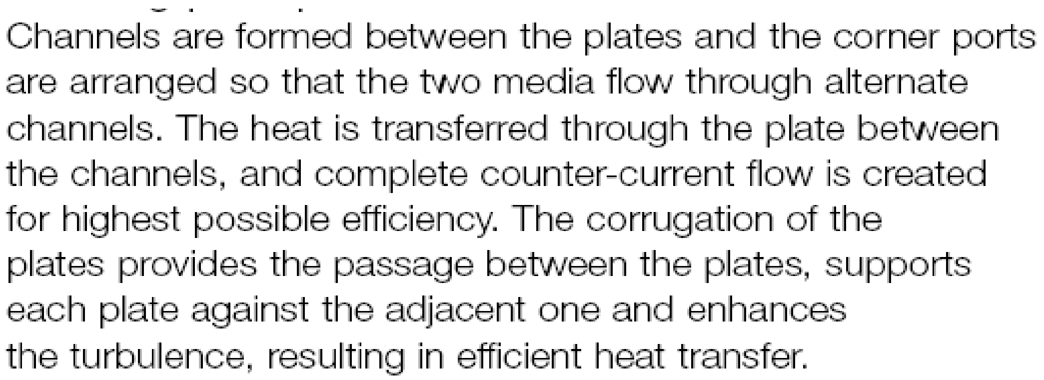
1. C.V.S. Subramanyam, J. Thima Shetty, Mrs Sarasija Suresh, Mrs V. Kusum Devi. Pharmaceutical Engineering, 1st edition, Publication: Vallabh Prakashan, Page No-126-127.
2. K. Sambamurthy. Pharmaceutical Engineering, Publication: New age International Publication, New Delhi, Page No-74-75.
3. Paradkar A. Introduction to Pharmaceutical Engineering, Publication: Nirali Publication, Page No-56-57.

PLATE HEAT EXCHANGER:



Composed of multiple, thin, slightly separated plates that have very large surface areas and fluid flow passages for heat transfer.

This stacked-plate arrangement can be more effective, in a given space, than the shell and tube heat exchanger.

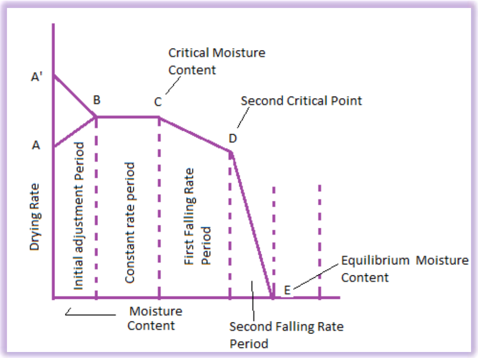


Channels are formed between the plates and the corner ports are arranged so that the two media flow through alternate channels. The heat is transferred through the plate between the channels, and complete counter-current flow is created for highest possible efficiency. The corrugation of the plates provides the passage between the plates, supports each plate against the adjacent one and enhances the turbulence, resulting in efficient heat transfer.

References:

1. A.R. Paradkar, Introduction to pharmaceutical engineering, Nirali Prakashan,10th edition, Page No-

THEORY OF DRYING: (Lecture-28)



Drying rate can be plotted on y-axis and moisture content plotted on x-axis to plot drying rate curve.

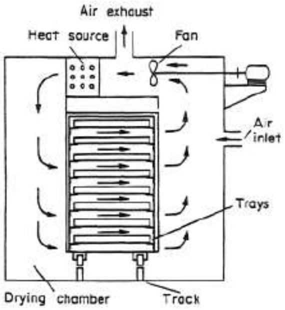
1. Curve AB represents initial adjustment period, solid absorb the heat and temperature increases. At the same time moisture begin to evaporate and thus tends to cool the drying solid. After some time the temperature stabilizes
2. Time corresponds to BC represents the constant rate period. The temperature remains constant and rate o drying is constant. The moisture evaporating from the surface is replaced by the water diffusing from the interior of solid. The rate of diffusion is equal to the rate of evaporation.
3. the time corresponds to CD represents the first falling rate period during this period the surface of water is no longer replaced at a rate fast enough to maintain a continuous film on the surface. Dry spot begin to appear and rate of drying is begin to fall off. The point D is referred as second critical point. Time corresponding to DE represents the second falling rate period. During this period the rate of drying is dependent on the rate of diffusion of vapour of moisture to the surface of the solid. Point E referred as equilibrium moisture content.Beyond E drying rate is zero.

References:

1. C.V.S. Subramanyam, J. Thima Shetty, Mrs Sarasija Suresh, Mrs V. Kusum Devi. Pharmaceutical Engineering, 1st edition, Publication: Vallabh Prakashan, Page No-387-390.

- K. Sambamurthy. Pharmaceutical Engineering, Publication: New age International Publication, New Delhi, Page No-319-322.
- Paradkar A. Introduction to Pharmaceutical Engineering, Publication: Nirali Publucation, Page No-242-246.

TRAY DRYING:



PRINCIPAL:

The hot air is continuously recirculated. Forced convection heating takes place to remove moisture from the solid placed in the trays.

WORKING:

- Wet solid is loaded into trays. Trays are placed in the chamber. Fresh air is introduced through inlet, which passes through heaters and gets heated up. The hot air is circulated by means of fans at 2-5 m/s.
- Turbulent flow lowers the partial vapour pressure in the atmosphere and also reduces the thickness of the air boundary layer.
- Water is picked up by the air.As water evaporates from the surface, the water diffuses from the interior of the solid by capillary action.

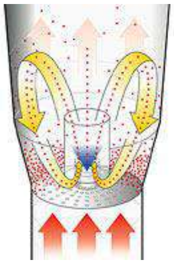
The time of contact is short and amount of water picked up in a single pass is small.

- Discharged air to the tune of 80-90 % is circulated back through fans.
- Only 10-20 % of fresh air is introduced

References:

1. C.V.S. Subramanyam, J. Thima Shetty, Mrs Sarasija Suresh, Mrs V. Kusum Devi. Pharmaceutical Engineering, 1st edition, Publication: Vallabh Prakashan, Page No-390-392.
2. K. Sambamurthy. Pharmaceutical Engineering, Publication: New age International Publication, New Delhi, Page No-297-302.
3. Paradkar A. Introduction to Pharmaceutical Engineering, Publication: Nirali Publucation, Page No-246-248.

FLUIDISED BED DRYER:



PRINCIPAL:

Hot air is passed at high pressure through a perforated bottom of the container containing granules to be dried. The granules are lifted from the bottom and suspended in the stream of air, hot gases is surrounding every granule to completely drying them.

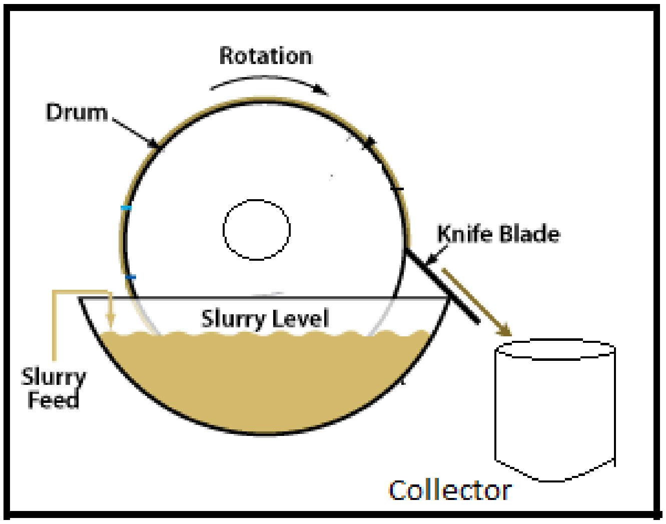
WORKING:

- Moist material is fed onto a shaking perforated steel bed through which the drying air flows. The air is of sufficient volume that it lifts, or 'fluidises', the bed of material allowing intimate contact with each particle. The shaking action of the bed assists in the transportation of the material over the length of the dryer. Moisture is carried away by the air into a dust recovery system, whereby the hot air can be recycled in a closed loop back to the process.
- The flow of air is controlled along the length of the dryer to maximise fluidisation, enabling very wet and sticky materials to be handled. As the material passes along the dryer it gradually loses moisture until the target dryness is achieved, at which point it passes into a cooling zone. Here the hot air is replaced by cool ambient air, which reduces the product temperature to the desired figure.

References:

1. C.V.S. Subramanyam, J. Thima Shetty, Mrs Sarasija Suresh, Mrs V. Kusum Devi. Pharmaceutical Engineering, 1st edition, Publication: Vallabh Prakashan, Page No-397-400.
2. K. Sambamurthy. Pharmaceutical Engineering, Publication: New age International Publication, New Delhi, Page No-309-312.
3. Paradkar A. Introduction to Pharmaceutical Engineering, Publication: Nirali Publucation, Page No-248-251.

DRUM DRYER:



Principle:

The drum dryer is heated on the inside and turns continuously. In a full-continuous process, the product is applied in a thin film on the outside of the drum and begins to dry immediately. After one rotation, a knife scrapes the dried product off the drum surface as a film or as flakes.

WORKING:

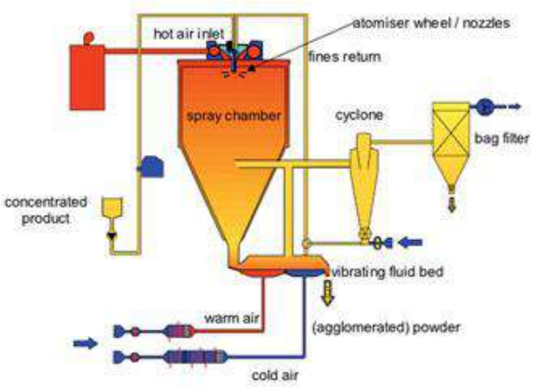
Steam is passed inside the drum. Heat is transferred by the conduction to the material. Drum is rotated at 1-10 revolutions /min.

The liquid material present in the feed pan adheres as a thin film to the external surface of the drum. Dried material is scraped by doctors knife.

References:

1. C.V.S. Subramanyam, J. Thima Shetty, Mrs Sarasija Suresh, Mrs V. Kusum Devi. Pharmaceutical Engineering, 1st edition, Publication: Vallabh Prakashan, Page No-393-394.
2. K. Sambamurthy. Pharmaceutical Engineering, Publication: New age International Publication, New Delhi, Page No-305.
3. Paradkar A. Introduction to Pharmaceutical Engineering, Publication: Nirali Publucation, Page No-262-263.

SPRAY DRYING: (Lecture-31)



PRINCIPLE:

It is a method of producing a dry powder from a liquid or slurry by rapidly drying with a hot gas. This is the preferred method of drying of many thermally-sensitive materials.The fluid to be dried is atomised into fine droplets, which are thrown radially into moving stream of hot gas. The temperature of the droplet is immediately increased and fine droplets get dried instantaneously.

WORKING:

Liquid or fine solid material in a slurry is sprayed in the form of a fine droplet dispersion into a current of heated air. Air and solids may move in parallel or counterflow.

Particles are dried during their journey and finally fall at the bottom.

References:

1. C.V.S. Subramanyam, J. Thima Shetty, Mrs Sarasija Suresh, Mrs V. Kusum Devi. Pharmaceutical Engineering, 1st edition, Publication: Vallabh Prakashan, Page No-394-397.
2. K. Sambamurthy. Pharmaceutical Engineering, Publication: New age International Publication, New Delhi, Page No-306-309.
3. Paradkar A. Introduction to Pharmaceutical Engineering, Publication: Nirali Publication, Page No-252-256.

CORROSION:

Definition:

Reaction of metallic material with its environment

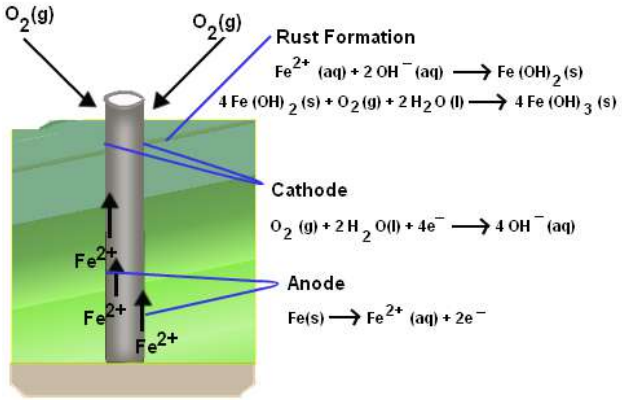
According to electrochemistry, the corrosion reaction can be considered astaking place by two simultaneous reactions: the oxidation of ametal atananode(acorroded endreleasing electrons) and the reduction of a substance at a cathode (a protected end receiving electrons). In orderfor the reaction tooccur, the following conditions must exist:

(1) A chemicalpotential difference must exist between adjacent siteson ametal surface (or between alloysofadifferent compositions).

2) Anelectrolyte mustbe present toprovidesolution conductivity and asasource of material tobereduced atthe cathode.

(3) An electrical path through the metal or between metals mustbeavailabletopermit electron flow.

Corrosion reaction on single metal:



Reaction at anode:

The reactions occuring are:

Fe -------> Fe^{+2} + 2 e- (oxidation)

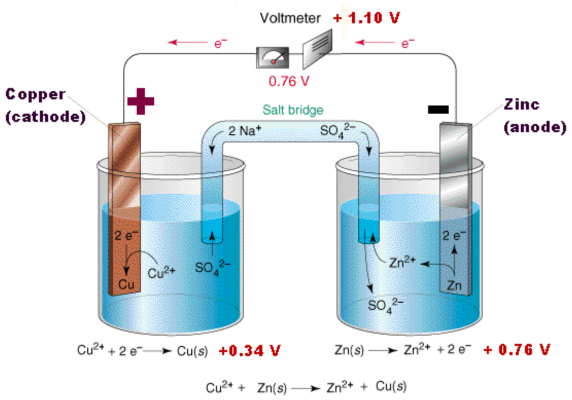
Reaction at cathode:

$2H^+ + 2e^-$--------→ H_2↑ (reduction-bubble formation)

Overall reaction

$Fe^{+2} + 2H_2O$- --------→Fe (OH) $_{2}$ + $H_2\uparrow$(red brown rust)

Reaction between metals:



Results from flow of more active metal to less active metal e.g. zinc (anode) and copper(cathode).

These two metal forms two electrodes and their presence in electrolyte solution forms galvanic cell.

Reaction at anode: (oxidation)

$Zn \longrightarrow Zn^{++} + 2e^-$ (Rough Surface)

Reaction at cathode: (reduction)

$2H^+ + 2e^- \longrightarrow H_2\uparrow$ (Bubble formation)

Corrosion current flows at the expense of anode where cathode gets protected.

In some cases evolution of hydrogen gas is slow .

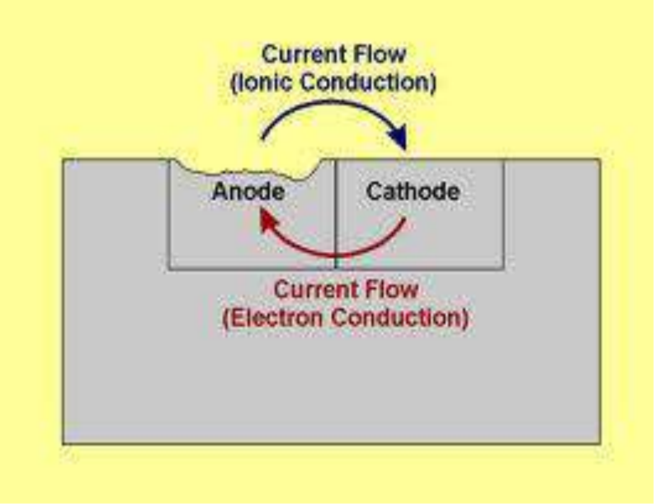
References:

1. C.V.S. Subramanyam, J. Thima Shetty,Mrs Sarasija Suresh, Mrs V. Kusum Devi. Pharmaceutical Engineering, 1st edition, Publication: Vallabh Prakashan, Page No-432-435.
2. K. Sambamurthy. Pharmaceutical Engineering, Publication: New age International Publication, New Delhi, Page No-407-408
3. Paradkar A. Introduction to Pharmaceutical Engineering, Publication: Nirali Publication, Page No-315-317.

TYPES OF CORROSION:

A. Galvanic Corrosion:

Galvanic corrosion takes place when the metallic surface isexposed to anaqueous solution which contains someaggressiveionicsubstances suchasNaCI, HCI, H2S, etc. According to electrochemistry, the galvanic corrosion reaction iscausedbyananodic portionandacathodic portion occurring simultaneously at discrete points on the metallic surface. Flow of electricity from the anodic to the cathodic areas maybegenerated bylocalsiteseither onasinglemetallic surface because of local point-to-point chemical potential differences on the surface or between dissimilar metals. The driving force to cause galvanic corrosion resulted from a difference in theelectromotive force (e.m.f.).



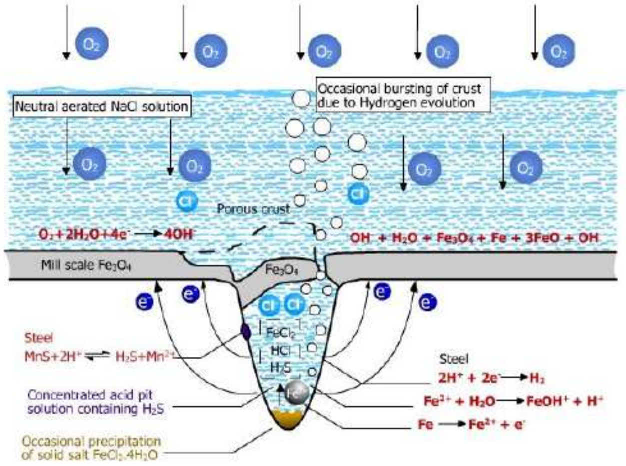
CREVICE CORROSION

This is also known as **Contact corrosion**. It occurs at the place of contact between metals and metals or non metals. This type of corrosion occurs at crevices between the metallic objects e.g. bolts, nuts, washers etc

This type of localized corrosion is caused by variation in' the concentration of environment at various locations on the metal surface such as a deficiency of oxygen, acidity change, build up of ions, or depletion of an inhibitor. The oxygen concentration cell is an electrolytic cell in which the driving force causing corrosion results from a difference in the amount of oxygen in solution at one point as compared with other locations. Attack is accelerated where the oxygen concentration is least. Metal at the area of low oxygen availability becomes anodic to other areas. Because the cathodic area is large compared to the anodic area, the intensity of attack is usually more severe than on surrounding areas of the same surface.

PITTING CORROSION

Pitting is generally associated with stagnant pools of liquid. Most pits develop on horizontal steel surfaces and grow downward. Pitting occurs as small areas of localized corrosion which vary in size, frequency of occurrence, and depth. Rapid penetration of the metal may occur, leading to metal perforation. Pitting is generally not a distinctly identifiable problem for steel because the environment that induces pitting also tends to cause a rapid overall corrosion.



Pits are often initiated because of in homogeneity of the metal surface, deposits or scale on the surface, or breaks in a protective film. These result in the development of cavities orpits. Once a pit is initiated, a concentration-cell is developed since the base of the pit isless accessible to oxygen than is the metal surface.

Halide ions such as chlorides often stimulate pitting corrosion. The mechanism is similar to that described for crevice corrosion. The depletion of oxygen in the pit slows down the generation of hydroxyl ions. The accumulation of positive charges in the form of Fe++then attracts negatively charged chloride ions. The resulting ferrous chloride hydrolyzes to produce insoluble ferrous hydroxide plus excess hydrogen and chloride ions; both of these ions then accelerate the corrosion at the bottom of the pit.

References:

4. C.V.S. Subramanyam, J. Thima Shetty,Mrs Sarasija Suresh, Mrs V. Kusum Devi. Pharmaceutical Engineering, 1st edition, Publication: Vallabh Prakashan, Page No-439-444.
5. K. Sambamurthy. Pharmaceutical Engineering, Publication: New age International Publication, New Delhi, Page No-408-412.
6. Paradkar A. Introduction to Pharmaceutical Engineering, Publication: Nirali Publication, Page No-318-320

INTERGRANULAR CORROSION:

Localized corrosion at grain boundaries of the metal or alloy without appreciable attack on the grains or crystals themselves is called intergranular corrosion. It is the result of a difference in potential between anodic grain boundaries and the grains. When severe, this attack causes a loss of strength and ductility to the extent that the metal is actually destroyed by corrosion.

EROSION-IMPINGEMENT-CAVITATION:

Erosion is the destruction of a metal by the combined action of corrosion and abrasion or attrition resulting from the flow of liquid or gas. When the fluid contains solid particles that are harder than the metal surface affected, erosion will occur by the combined action of corrosion and abrasion. Visual evidence of such attack usually takes the form of directional grooves, gullies, waves, rounded holes, orvall eys. Impingement attack is corrosion associated with turbulent flow of a liquid such as at the entrance of a condenser tube or around bends in a pipeline. The high velocity impingement of a liquid can strip away the metal surface's protective film. Solids and gas bubbles can aggravate impingement attack Air bubbles in a liquid stream are especially harmful.

References:

1. C.V.S. Subramanyam, J. Thima Shetty,Mrs Sarasija Suresh, Mrs V. Kusum Devi. Pharmaceutical Engineering, 1st edition, Publication: Vallabh Prakashan, Page No-439-444.
2. K. Sambamurthy. Pharmaceutical Engineering, Publication: New age International Publication, New Delhi, Page No-408-412.
3. Paradkar A. Introduction to Pharmaceutical Engineering, Publication: Nirali Publication, Page No-318-320.

STRESS CORROSION;

This formofcorrosion canbeaccelerated byeither residual internal stressinthemetal orexternally applied stress.Internal stress maybe produced by non-uniform deformation during cold working (bending, shearing, punching, etc.), byunequal cooling from high temperature, and by internal structure rearrangements involving volume change. Stress inducedby rivets and bolts, and by pressandshrink fitscanalsobeclassifiedasinternal stresses. Stressmaysimplyaffect thecorrosion behaviorofthe metal and, ifcombined with anelectrochemicalreaction, willproduce cracksatanaccelerated rate.

Cyclic or repeated stress results in afatigue failure which is accelerated by corrosion attack. The timerequired to produce stress-corrosion cracking varies from minutes to years. The severity of stress corrosion for agivenmaterial depends, in part, on the degree of stress concentration and the nature of environment and temperature. E.g. cracking ofaustenitic stainless steel in the presence of chlorides,

The stress-corrosion cracking can best beavoided by using appropriate heat treatment, selecting the proper alloy for a givenenvironment, putting theequipment inserviceinastress freecondition, or using suitableprotective coatings.Stresses developedduringfabrication, particularlyduring welding,are frequently the main sources of trouble; stress-relieving or annealing should alwaysbeconsidered

DEZINCIFICATION

Dezincification is recognized by the formation of apronounced copper color, rather than the yellow colorofbrass, of copper-zinc alloys. The corrosionmay occur asplug filling pits or ascontinuous layerssurrounding anunattacked coreof brass. The plug-type dezincification occurs morefrequently onlow-zinc brasses and theuniform type onhigh-zinc brasses. The mechanism may involve selective removal ofzinc,leaving the copper behind, or dissolution of the alloy followed by re-deposition ofthe copper from thecorrosion products.

The tendency to dezincification can be reduced by the addition of small amounts of arsenic, antimony, orphosphorous to the alloy.

References:

1. C.V.S. Subramanyam, J. Thima Shetty,Mrs Sarasija Suresh, Mrs V. Kusum Devi. Pharmaceutical Engineering, 1st edition, Publication: Vallabh Prakashan, Page No-439-444.
2. K. Sambamurthy. Pharmaceutical Engineering, Publication: New age International Publication, New Delhi, Page No-408-412.
3. Paradkar A. Introduction to Pharmaceutical Engineering, Publication: Nirali Publication, Page No-318-320

METHODS OF PREVENTING THE CORROSION:

Modifying the Environmental Conditions.

The corrosion rate can be reduced by modifying the environment. The environment can be modified by the following:

(a)Deaeration: The presence of increased amounts of oxygen is harmful since it increases the corrosion rate. Deaeration aims at the removal of dissolved oxygen. Disolved oxygen can be removed by deaeration or by adding some chemical substance like Na_2CO_3.

(b)Dehumidification: In this method, moisture from air is removed by loweringtherelativehumidityofsurroundingair. Thiscanbe achieved by adding silica gel which can absorb moisture preferentiallyonitssurface.

(c)Inhibitors: In this method, some chemical substance known as inhibitorsareaddedtothecorrosiveenvironmentinsmallquantities. Theseinhibitorssubstantiallyreducetherateofcorrosion.

SurfaceCoating:

Corrosionofmetalsurfacesisacommonphenomenon.Toprotecta metal surface from corrosion, the contact between the metal and the corrosiveenvironmentistobecutoff.Thisisdonebycoatingthesurface ofthemetalwithacontinues,non-porousmaterial,inserttothecorrosive atmosphere.Suchacoatingisreferredtoassurfacecoatingorprotective coating. In addition to protective action, such coatings also give a decorativeeffectandreducewearandtear

ObjectivesofCoatingSurfaces

1.Topreventcorrosion.

2.Toenhancewearandscratchresistance.

4.Toinsulateelectrically

5.Toinsulatethermally

6.Toimpartdecorativecolour.

Phosphating:

Phosphatecoatingsareproducedby the reactionbetweenbase metalandaqueoussolutionofphosphoricacidwithaccelerators(copper salt).Acceleratorsareusedtoenhancetherateofthereaction.

Phosphate coatings do not prevent corrosion completely, they are principallyusedasanadherentbaseprimer-coatforpaint,lacquers,oils etc.

MetallicCoating:

Surfacing coatings made up of metals are known as metallic coatings. Thesecoatingsseparatethebasemetalfromthecorrosive environmentandalsofunctionasaneffectivebarrierfortheprotectionof basemetals.

Themetalwhichiscoateduponisknownasthebasemetal.
Themetalappliedascoatingisreferredtoascoatmetal.
Thedifferentmethodsusedformetalcoatingare.

1.Hot dipping

   (a)Galvanization

   (b)Tinning

2.Metalspraying.

3.Cladding.

4.Cementation

   (a)Sherardizing –Cementation with Zinc powder is called Sherardizing.

   (b)Chromizing-Cementationwith55%Chromiumpowder&45% Aluminaiscalledchromizing (c)Calorizing–CementaionwithAluminiumandAluminapowderis calledCalorizing

5.Electroplatingorelectrodeposition.

ALLOYING:

Both corrosion resistance and strength of many metals can be improvedbyalloying,e-g.Stainlesssteelscontainingchromiumproduce acoherentoxidefilmwhichprotectsthesteelfromfurtherattack. The othernon-corrosivealloysareGermansilver,Aluminiumbronze,Nickel bronze,Duraluminetc.

References:

1. C.V.S. Subramanyam, J. Thima Shetty,Mrs Sarasija Suresh, Mrs V. Kusum Devi. Pharmaceutical Engineering, 1st edition, Publication: VallabhPrakashan, Page No-444-448.
2. K. Sambamurthy. Pharmaceutical Engineering, Publication: New age International Publication, New Delhi, Page No-415-418
3. Paradkar A. Introduction to Pharmaceutical Engineering, Publication: Nirali Publication, Page No-321-323.

DEFINATION AND PRINCIPLE OF EVAPORATION

Evaporation is nothing but a thermal separation process. Theoretically, evaporation means simply vaporization from the surface of a liquid. Vaporization of a liquid below its boiling point is called evaporation.

MECHANISM: When heat applied in solution the motion of molecules increase and molecules present in the surface overcome the surface tension of the liquid and it evaporates because surface molecules have less cohesive force than others.

Factors Affecting Evaporation:

1) Temperature: The rate of evaporation is directly proportional to the temperature.

2) Surface area: The rate of evaporation is directly proportional to the surface area of the vessel exposed to evaporation.

3) Agitation: Agitation is necessary for evaporation.

4) Atmospheric aqueous vapour pressure

The rate of evaporation is inversely proportional to the atmospheric aqueous vapour pressure.

5) Atmospheric pressure on the liquid under evaporation

The rate of evaporation is inversely proportional to the atmospheric pressure on the liquid under evaporation.

6) Type of product required

The selection of the method and apparatus to be used for evaporation depends upon type of product required.

7) Economic factors: When selecting the method and apparatus the economic factors are important

References:

7. C.V.S. Subramanyam, J. Thima Shetty, Mrs Sarasija Suresh, Mrs V. Kusum Devi. Pharmaceutical Engineering, 1st edition, Publication: Vallabh Prakashan, Page No-338-340.
8. K. Sambamurthy. Pharmaceutical Engineering, Publication: New age International Publication, New Delhi, Page No-88.
9. Paradkar A. Introduction to Pharmaceutical Engineering, Publication: Nirali Publication, Page No-224-225.

EVAPORATING PANS:

On a manufacturing scale, liquid extracts containing water are evaporated in open pans called evaporating pans.

- The evaporating pan consists of a hemispherical shallow made of- Copper, Stainless steel, Aluminium, Enameled iron, Steam jacket
- The hemispherical shape gives the best surface\volume ratio for heating and the largest area for the disengagement of vapour.

ADVANTAGES:

1. They are simple, easy and cheap to construct.
2. They are easy to use and clean
3. Stirring of the evaporating liquids can be done easily.

HORIZONTAL TUBE EVAPORATORS:

- The tubes are arranged so as to maximize the heat transfer area between the steam and the liquor.
- The major use is for making distilled water for boiler feed. Horizontal tube evaporators are used in the pharmaceutical industry, pulp and paper industry.
- They are relatively low cost. They have very low headroom.Horizontal tube evaporators are not suitable for salting or scaling liquids.

References:

1. C.V.S. Subramanyam, J. Thima Shetty, Mrs Sarasija Suresh, Mrs V. Kusum Devi. Pharmaceutical Engineering, 1st edition, Publication: Vallabh Prakashan, Page No-341-345.
2. K. Sambamurthy. Pharmaceutical Engineering, Publication: New age International Publication, New Delhi, Page No-90-91.
3. Paradkar A. Introduction to Pharmaceutical Engineering, Publication: Nirali Publication, Page No-226-227.

SHORT-TUBE (CALANDRIA) VERTICAL EVAPORATORS (STV):

The short tube evaporators were the first developed commercially and still represent probably the largest number of unit in operation.

Used in sugar factory.

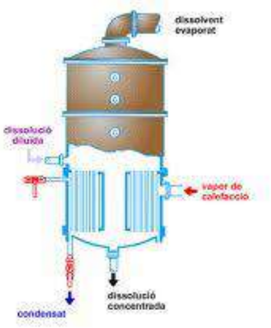
Used for noncorrosive materials.

Advantages

- ✓ Inexpensive
- ✓ Efficient heat transfer at high temperature
- ✓ Easy to descale

Disadvantages

- × Poor heat transfer at low temperature differences or with viscous liquids
- × Require a great deal of floor space



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1. C.V.S. Subramanyam, J. Thima Shetty, Mrs Sarasija Suresh, Mrs V. Kusum Devi. Pharmaceutical Engineering, 1st edition, Publication: Vallabh Prakashan, Page No-345-347
2. K. Sambamurthy. Pharmaceutical Engineering, Publication: New age International Publication, New Delhi, Page No-91-93.
3. Paradkar A. Introduction to Pharmaceutical Engineering, Publication: Nirali Publication, Page No-227-228.

Forced circulation evaporators:

Forced circulation evaporators are one type of natural circulation evaporators with some added form of mechanical agitation.

Construction

Actually it is nothing but an evaporating pan in which the contents are agitated by a stirring rod or pole. Alternatively, a mechanically operated propeller or paddle agitator can be introduced in to an evaporating pan or still, or in to the downtake of a short-tube evaporator.

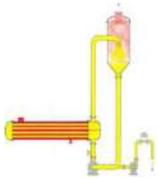
Working principle:

Here the liquor is circulated by means of a pump and as it is under pressure in the tubes, the boiling point is elevated and no boiling takes place. As the liquor leaves the tubes and enters the body of the evaporator, there is a drop in pressure and vapour flashes off from the superheated liquor.

Advantages:

1)These have a great advantage over natural circulation evaporators in that the rapid liquid movement improves heat transfer, especially with viscous liquids or materials that deposit solids or foam readily.

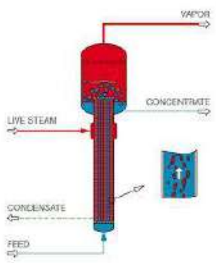
2)The equipment is suitable for operation under reduced pressure due to the capacity of the process to overcome the effect of greater viscosity of liquids.



References:

1. C.V.S. Subramanyam, J. Thima Shetty, Mrs Sarasija Suresh, Mrs V. Kusum Devi. Pharmaceutical Engineering, 1st edition, Publication: Vallabh Prakashan, Page No-351-352.
2. K. Sambamurthy. Pharmaceutical Engineering, Publication: New age International Publication, New Delhi, Page No-97-100.
3. Paradkar A. Introduction to Pharmaceutical Engineering, Publication: Nirali Publication, Page No-236-237.

Climbing (Rising) Film Evaporators:



A rising film or vertical long tube evaporator is a type of evaporator that is essentially a vertical shell and tube heat exchanger. The liquid being evaporated is fed from the bottom into long tubes and heated with steam condensing on the outside of the tube from the shell side. This is to produces steam and vapour within the tube bringing the liquid inside to a boil. The vapour produced then presses the liquid against the walls of the tubes and causes the ascending force of this liquid. As more vapour is formed, the centre of the tube will have a higher velocity which forces the remaining liquid against the tube wall forming a thin film which moves upwards.

Advantages and limitations:

Low residence time

The main advantage of the rising film evaporator is the low residence time of the liquid feed in the evaporator compared to other evaporator designs like plate-type evaporators. This is crucial because it allows the usage of the evaporator in higher operating temperatures and gives assurance of high product quality despite the product being heat sensitive.

High heat transfer coefficients:

This is essential as it reduces the overall heat transfer area requirement which in turn will lower the initial capital cost of the evaporator.

Low efficiency:

While the rising film evaporators are relatively efficient and have a several advantages, some literature suggests that they are not as efficient as the vertical or the horizontal tube falling film evaporator.

References:

C.V.S. Subramanyam, J. Thima Shetty, Mrs Sarasija Suresh, Mrs V. Kusum Devi. Pharmaceutical Engineering, 1st edition, Publication: Vallabh Prakashan, Page No-347-349.

K. Sambamurthy. Pharmaceutical Engineering, Publication: New age International Publication, New Delhi, Page No-94.

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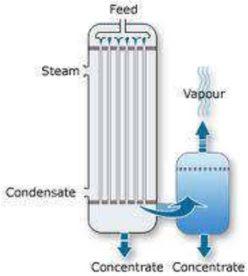
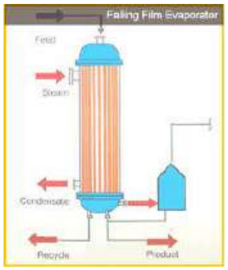
Falling film evaporator:





In case of Falling film evaporator the liquid feed enters at top, gets distributed uniformly in tube bundle by a distributor. The feed flows downwards along the tube walls as a film. It receives the heat from the heating media on the shell side. Vapour is formed and the concentrate flows downward along with the vapour. The entrained liquid in the vapour is separated in the separator and flows upward to vapour nozzle.

Falling film evaporators can be operated with very low temperature differences between the heating media and the boiling liquid, and they also have very short product contact times, typically just a few seconds per pass. These characteristics make the falling film evaporator particularly suitable for heat-sensitive products, and it is today the most frequently used type of evaporator.

However, falling film evaporators must be designed very carefully for each operating condition; sufficient wetting of the heating surface by liquid is extremely important for trouble- free operation of the plant. If the heating surfaces are not wetted sufficiently, dry patches and incrustations will occur; at worst, the heating tubes will be completely clogged. In critical cases extending or dividing the evaporator effects, keeping the advantages of single pass operation, can increase the wetting rate.

References:

1. C.V.S. Subramanyam, J. Thima Shetty, Mrs Sarasija Suresh, Mrs V. Kusum Devi. Pharmaceutical Engineering, 1st edition, Publication: Vallabh Prakashan, Page No-349-351.
2. K. Sambamurthy. Pharmaceutical Engineering, Publication: New age International Publication, New Delhi, Page No-.96-97.
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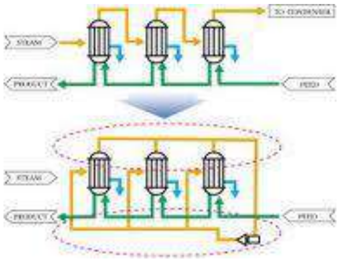
MULTIPLE EFFECT EVAPORATION:



In a two effect evaporator, the temperature in the steam chest is higher in the first than in the second effect. In order that the steam provided by the evaporation in the first effect will boil off liquid in the second effect, the boiling temperature in the second effect must be lower and so that effect must be under lower pressure.

Consequently, the pressure in the second effect must be reduced below that in the first. In some cases, the first effect may be at a pressure above atmospheric; or the first effect may be at atmospheric pressure and the second and subsequent effects have therefore to be under increasingly lower pressures. Often many of the later effects are under vacuum. Under these conditions, the liquid feed progress is simplest if it passes from effect one to effect two, to effect three, and so on, as in these circumstances the feed will flow without pumping. This is called **forward feed**. It means that the most concentrated liquids will occur in the last effect. Alternatively, feed may pass in the reverse direction, starting in the last effect and proceeding to the first, but in this case the liquid has to be pumped from one effect to the next against the pressure drops. This is called **backward feed** and because the concentrated viscous liquids can be handled at the highest temperatures in the first effects it usually offers larger evaporation capacity than forward feed systems.

References:

1. C.V.S. Subramanyam, J. Thima Shetty, Mrs Sarasija Suresh, Mrs V. Kusum Devi. Pharmaceutical Engineering, 1st edition, Publication: Vallabh Prakashan, Page No-356-359.
2. K. Sambamurthy. Pharmaceutical Engineering, Publication: New age International Publication, New Delhi, Page No-.114-116.
3. Paradkar A. Introduction to Pharmaceutical Engineering, Publication: Nirali Publication, Page No-231-232.

Simple Manometer:

- Most commonly used
- Made up of glass
- U-tube filled with a liq. A (Mercury) having a density ρA.
- Above liq. A the arms are filled with liq.B. (water) having density ρB.
- The liq A and B are immiscible.
- Two diff pressure P1 and P2 are applied on two arms.
- Let at point 1 pressure P1 and at point 5 the pressure is P2. $P1>P2$.
- Pressure at point 1= P1
- At point 2 = $P1+ \rho B (m+R) (g/gc)$
- “ “ 3 = $P1+ \rho B (m+R) (g/gc)$
- “ “ 3 = $P2 + \rho Bm (g/gc) + \rho AR(g/gc)$
- “ “ 4 = $P1+ \rho B (m+R) (g/gc)- R\rho A (g/gc)$
- “ “ 4 = $P2 + \rho Bm (g/gc)$
- “ “ 5 = $P1+ CB (m+R) (g/gc) – R\rho A (g/gc)- m\rho B (g/gc)$.
- “ “ 5 = P2
- $P1-P2 = \Delta P = R (\rho A – \rho B) (g/gc)$.

Inclined Manometer:

- It is used to measure a small diff in pressure.
- One arm of manometer is inclined in such a manner that for a small value of reading R the meniscus must move a considerable distance (Ri) along the inclined tube.
- $Ri = R/ \sin \alpha$
- By making α small we can increase the reading Ri
- As $(\rho C – \rho A)$ smaller the larger will be the reading R. for a given value of pressure diff.

- It is used to measure minute gas pressure diff and for calibration of low range of gauges.
- They are free from errors due to capillarity and require no calibration.

Differential Manometer:

- It is also known as two fluid U tube manometer.
- It contains two immiscible liquid A and C having nearly same density.
- The u tube consist of enlarged chamber on both side.
- The meniscus of the liq in the enlarged chambers does not change with change in reading R.
- The changes in pressure in Passing through the series of points 1 to 7 are as follows
- $1= P_1$
- $2= P_1 + a\,.\rho_B\,.g/g_c.$
- $3= P_1 + a\,.\rho_B\,.g/g_c + b.\ \rho_A.g/g_c.$
- $4= P_1 + a\,.\rho_B\,.g/g_c + b.\ \rho_A.g/g_c.$
- $5= P_1 + a\,.\rho_B\,.g/g_c + b.\ \rho_A.g/g_c. - R\,.\rho_C.\ g/g_c.$
- $6= P_1 + a\,.\rho_B\,.g/g_c + b.\ \rho_A.g/g_c. - R\,.\rho_C.\ g/g_c.- d\ \rho_A.g/g_c.$
- $7= P_1 + a\,.\rho_B\,.g/g_c + b.\ \rho_A.g/g_c. - R\,.\rho_C.\ g/g_c.- d\ \rho_A.g/g_c.- a\,.\rho_B\ .\ g/g_c\ .$
- $\Delta P = P_1 - P_2 = R\,(\rho_C - \rho_A)\ .g/g_c.$

References:

10. C.V.S. Subramanyam, J. Thima Shetty, Mrs Sarasija Suresh, Mrs V. Kusum Devi. Pharmaceutical Engineering, 1st edition, Publication: VallabhPrakashan, Page No-28-30.
11. K. Sambamurthy. Pharmaceutical Engineering, Publication: New age International Publication, New Delhi, Page No-14-16.
12. Paradkar A. Introduction to Pharmaceutical Engineering, Publication: Nirali Publication, Page No-9-12.

Reynold's Experiment:

- The existence of streamline flow and transition to turbulent flow may be demonstrated by Reynold's experiment.
- A glass tube is connected to constant over head water tank.
- The rate of flow of water controlled by the coke.
- Dye solution is fed from a hypodermic needle forming a fine jet on the pipe axis.
- At low flow rates a continuous, straight and steady line of dye may be caused to flow down the whole length of the centre of the pipe.
- The color stream are seen as parallel lines.
- The flow of water is considered to be streamline.
- When the velocity of water increased, the colored line begins to waver and the entire mass of water gets uniformly colored.
- Such type of flow is known as a turbulent flow.
- On reducing the flow of water again this turbulence is damped out and the continuous dye line reestablished itself.

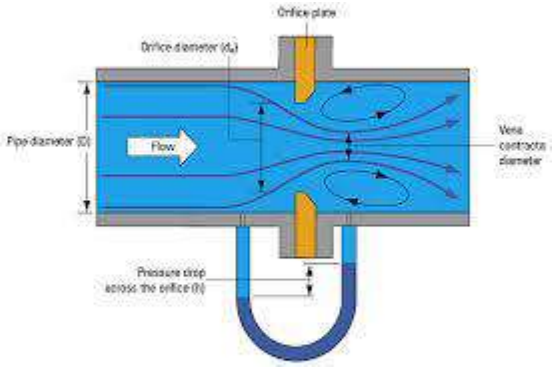
THE SIGNIFICANCE OF REYNOLDS' No, RE

- if the Reynolds number is less than 2100, the flow is laminar. If it is greater than 4000, the flow is turbulent. Flows with Reynolds numbers between 2100 and 4000 are sometimes referred to as transitional flows.
- The fluid in the middle of the pipe will be moving faster than the fluid next to the walls.

References:

1. C.V.S. Subramanyam, J. Thima Shetty, Mrs Sarasija Suresh, Mrs V. Kusum Devi. Pharmaceutical Engineering, 1st edition, Publication: VallabhPrakashan, Page No-31-33.
2. K. Sambamurthy. Pharmaceutical Engineering, Publication: New age International Publication, New Delhi, Page No-16-18.
3. Paradkar A. Introduction to Pharmaceutical Engineering, Publication: Nirali Publication, Page No-14-15.

ORIFICE METER:

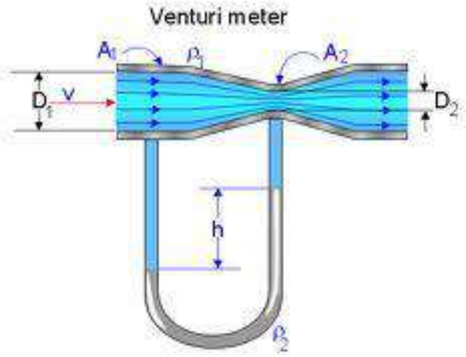


As the fluid approaches the orifice the pressure increases slightly and then drops suddenly as the orifice is passed. It continues to drop until the "vena contracta" is reached and then gradually increases until at approximately 5 to 8 diameters down stream a maximum pressure point is reached that will be lower than the pressure upstream of the orifice. The decrease in pressure as the fluid passes through the orifice is a result of the increased velocity of the gas passing through the reduced area of the orifice. When the velocity decreases as the fluid leaves the orifice the pressure increases and tends to return to its original level. All of the pressure loss is not recovered because of friction and turbulence losses in the stream. The pressure drop across the orifice increases when the rate of flow increases. When there is no flow there is no differential. The differential pressure is proportional to the square of the velocity, it therefore follows that if all other factors remain constant, then the differential is proportional to the square of the rate of flow.

References:

1. C.V.S. Subramanyam, J. Thima Shetty, Mrs Sarasija Suresh, Mrs V. Kusum Devi. Pharmaceutical Engineering, 1st edition, Publication: VallabhPrakashan, Page No-43-47.
2. K. Sambamurthy. Pharmaceutical Engineering, Publication: New age International Publication, New Delhi, Page No-22-23.
3. Paradkar A. Introduction to Pharmaceutical Engineering, Publication: Nirali Publication, Page No-21-22.

VENTURI METER:



- In the upstream cone of the Venturi meter, velocity is increased, pressure is decreased
- Pressure drop in the upstream cone is utilized to measure the rate of flow through the instrument
- Velocity is then decreased and pressure is largely recovered in the down stream cone
- Mostly used for liquids, water.

Volumetric flow rate through a Venturi meter:

$$q=\frac{C_v S_b}{\sqrt{1-\beta^4}}\sqrt{\frac{2g_c(P_a-P_b)}{\rho}}$$

Cv - Venturi coefficient

Sb - Cross sectional area of down stream

β - Ratio of cs areas of upstream to that of down stream.

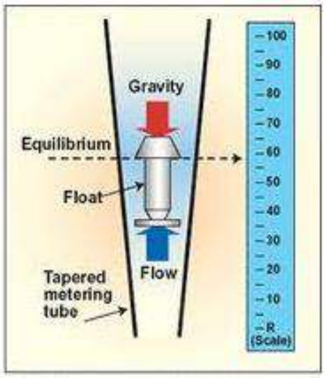
Pa-Pb - Pressure gradient across the Venturi meter

ρ - Density of fluid

References:

1. C.V.S. Subramanyam, J. Thima Shetty, Mrs Sarasija Suresh, Mrs V. Kusum Devi. Pharmaceutical Engineering, 1st edition, Publication: VallabhPrakashan, Page No-47-49.
2. K. Sambamurthy. Pharmaceutical Engineering, Publication: New age International Publication, New Delhi, Page No-23-24.
3. Paradkar A. Introduction to Pharmaceutical Engineering, Publication: Nirali Publication, Page No-22-23.

ROTAMETER:



Rotameter is a typical area meter

•Consists of gradually tapered glass mounted vertically in a frame with the large end up.

•Fluid flows upward through the tapered tube and suspends freely a float (which is submerged in the fluid)

• Float is the indicating element, and the greater the flow rate, the higher the float rides in the tube.

•The tube is marked in divisions, and the reading of the meter is obtained from the scale reading at the reading edge of the float, which is taken at the largest cross section of the float.

•A calibration curve must be available to convert the observed scale reading to flow rate.

Advantages:

•Can be modified to cater to the needs of individual operation
Eg: In case of a rotameter with a metal case, the float can have an extension.

• The float of the rotameter does not rotate in modern designs as it used to in the early ones.

•Float shapes and proportions can be varied for different applications.

References:

1. C.V.S. Subramanyam, J. Thima Shetty, Mrs Sarasija Suresh, Mrs V. Kusum Devi. Pharmaceutical Engineering, 1st edition, Publication: VallabhPrakashan, Page No-51-53.
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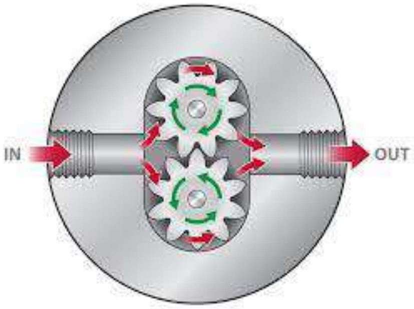
3. Paradkar A. Introduction to Pharmaceutical Engineering, Publication: Nirali Publication, Page No-24-25.

Quantity Flow Meter:



Fluid is flowing from one direction.Two lobes are interconnected, Flowing stream of fluid forces the lobes apart.Fixed quantity of fluid passed through the lobes.Again lobes are joined
Cycle is repeated several times, the amount of fluid flowing per unit time is determined.

PITOTTUBE

Advantageous of pitot tube :

(a) It is easy to remove pitot tube from pipe line.

(b) There are no pressure loss in the pitot tube.

(c) It is easy to install.

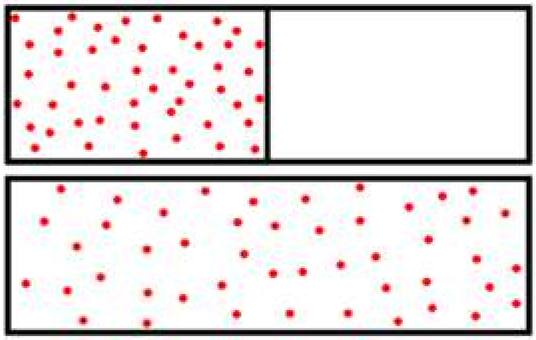
Disadvantageous of pitot tube :

Accuracy is very less in the pitot tube

References:

1. C.V.S. Subramanyam, J. Thima Shetty, Mrs Sarasija Suresh, Mrs V. Kusum Devi. Pharmaceutical Engineering, 1st edition, Publication: VallabhPrakashan, Page No-50, 51, 53.
2. K. Sambamurthy. Pharmaceutical Engineering, Publication: New age International Publication, New Delhi, Page No-25,26,27, 28.
3. Paradkar A. Introduction to Pharmaceutical Engineering, Publication: Nirali Publication, Page No-23, 26.

MOLECULAR DIFFUSION OF GASES



Two adjacent compartments, separated by partition containing pure gases A or B may be envisaged. Random movement of all molecules occurs so that after a period molecules are found remote from their original positions. If the partition is removed, some molecules of A move towards the region occupied by B, their number depends on the number of molecules at the point considered. Concurrently, molecules of B diffuse toward regimens formerly occupied by pure A. Finally, complete mixing occurs. Before this point in time, a gradual variation in the concentration of A occurs along an axis, designated x, which joins the original compartments. This variation, expressed mathematically

$-dC_A/dx$

Where, C_A is the concentration of A. The negative sign arises because the concentration of A decreases as the distance x increases.

Similarly, the variation in the concentration of gas B is

$-dC_B/dx$.

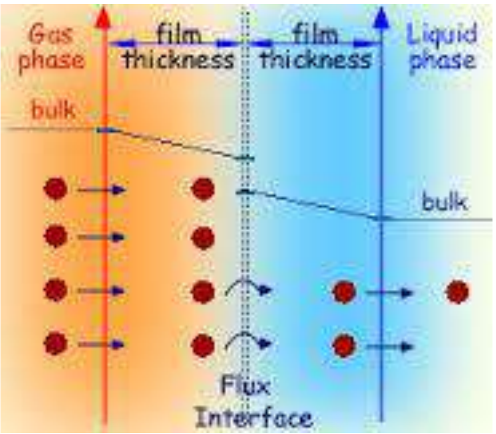
The rate of diffusion of A, N_A, depend on concentration gradient and the average velocity with which the molecules of A moves in the x direction. This relationship is expressed by Fick's Law

$$N_A = -D_{AB}\frac{dC_A}{dx}$$

where D is the Diffusivity of A through B, proportional to the average molecular velocity and, therefore depend on the temperature and pressure of gases.

The rate of Diffusion N_A, is usually expressed as the number of moles diffusing across unit area in unit time.

TWO-FILM THEORY OF MASS TRANSFER



This interface can represent any point in the gas absorption equipment where the gas contacts the liquid.

Assumptions of two-film theory:

· Steady-state: concentrations at any position in the tower do not change with time.

· Interface between the gas phase and the liquid phase is a sharp boundary.

· Laminar film exist at the interface on both sides of the interface

· Equilibrium exists at the interface, thus there is negligible resistance to mass transfer across the interface: (x_i, y_i) is the equilibrium concentration.

· No chemical reaction: rate of diffusion across the gas-phase film must equal the rate of diffusion across the liquid-phase film.

EQUIMOLECULAR COUNTER DIFFUSION

If no bulk flow occurs in an element of length dx, the rates of diffusion of two gases A and B must be equal and opposite, that is $N_A = -N_B$.

The partial pressure of A changes by dP_A over the distance dx. Similarly, the partial pressure of B changes dP_B. As there is no difference in total pressure across the element (no bulk flow), we have

$$\frac{dP_A}{dx} = -\frac{dP_B}{dx}.$$

For an ideal gas the partial pressure is related to the molar concentration by the relation

$$P_A V = n_A RT$$

Where,n_A is the number of moles of gas *A* in a volume *V*. As the molar concentration C_A is equal to n_A/V therefore

$$P_A = C_A RT$$

Consequently, for gas A,

$$N_A = -D_{AB}\frac{1}{RT}\frac{dP_A}{dx}$$

Where, D_{AB} is the diffusivity of A in B. Similarly,

$$N_B = -D_{BA}\frac{1}{RT}\frac{dP_B}{dx} = D_{AB}\frac{1}{RT}\frac{dP_A}{dx}$$

Considering that $dP_A/dx=-dP_B/dx$, it therefore proves that $D_{AB}=D_{BA}=D$. If the partial pressure of A at x_1 is P_{A1} and x_2 is P_{A2}, integration of above equation,

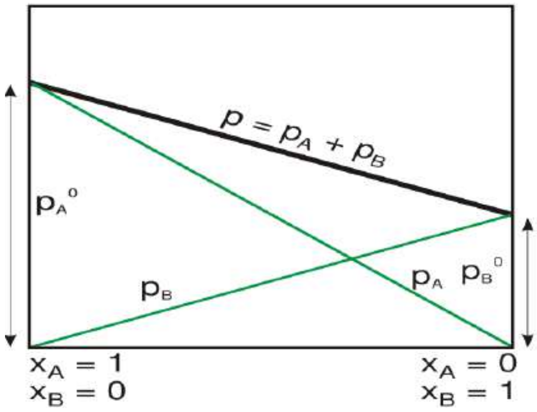
$$N_A = -\frac{D}{RT}\frac{(P_{A2} - P_{A1})}{x_2 - x_1}$$

A similar equation may be derived for the counterdiffusion of gas B.

RAOULT'S LAW

Statement:

The partial vapuor pressure of each component of an ideal mixture of liquids is equal to the vapuor pressure of the pure component multiplied by its mole fraction in the mixture.



Consider a mixture of miscible liquids A and B in this mixture:

Let the partial vapour pressure exerted by A= p_AkPa

Let the partial vapour pressure exerted by B= p_BkPa

Let the vapour pressure exerted by the pure component, A= p^o_AkPa.

Let the vapour pressure exerted by the pure component, B=p^o_BkPa.

Let the mole fraction concentration of liquid, A=X_A

Let the mole fraction concentration of liquid, B=X_B

Raoult's law may be mathematically expressed as:

Partial vapour pressure of liquid = Vapour pressure of pure liquid mole fraction of the liquid

PA= $p^o_A X_A$

PB= $p^o_B X_B$

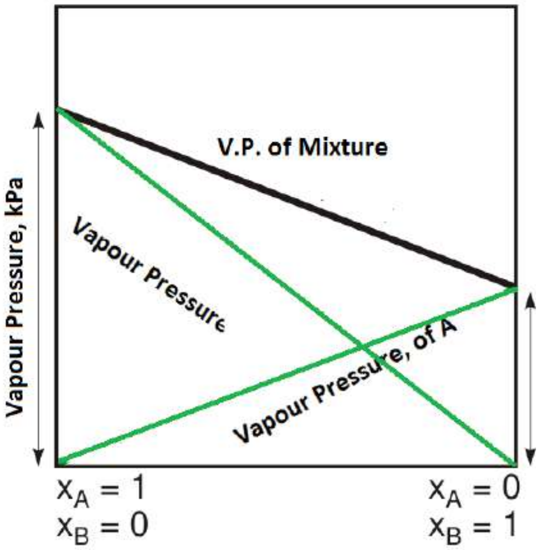
Ideal solution obeys raoults law. These solutions are known as perfect solutions.

E.g.benzene and toluene.

DALTON's LAW

Statement:

Total pressure exerted by a mixture of ideal gases may be considered as sum of the partial vapoyr pressure exerted by each gas, if alone present and occupied the total volume.



It is expressed as:

Total pressure=partial pressure of A + Partial pressure of B

$$P = PA + PB$$

By substituting raoults law equation:

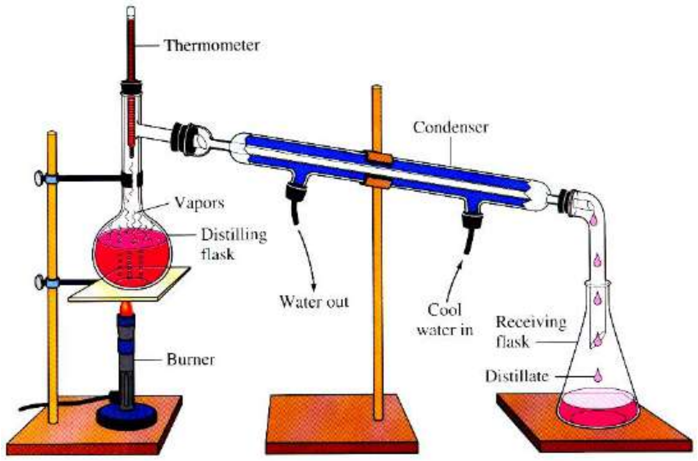
$$P = p^o{}_A X_A + p^o{}_B X_B$$

Their propertiesare additive i.e., the total vapour pressure of the mixture is the weighted average of the vapour pressure of the pure individual constituent.

The partial pressure of the component varies linearly from zero to full vapour pressure as the mole fraction varies from zero two one.

The total pressure exerted by the system at a particular composition is equal to the sum of the partial pressure of its components.

SIMPLE DISTILLATION:



PRINCIPLE:

Liquid boils when its vapour pressure is equal to atmospheric pressure. Simple distillation is conducted at its boiling point. Liquid is heated to form vapour an these vapour are collected in different flask in the form of liquid.

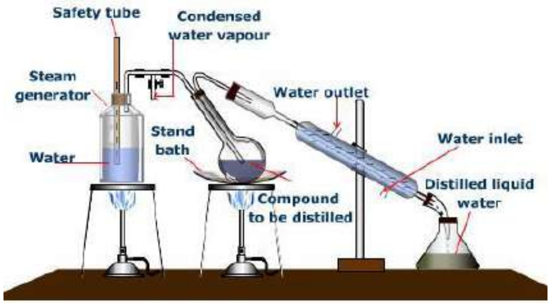
WORKING:

The substance with the lowest boiling point vaporizes first the temperature remaining constant until that substance has completely distilled. The vapor is led into the condenser where, on being cooled, it reverts to the liquid (condenses) and runs off into a receiving vessel. The product so obtained is known as the distillate. Those substances having a higher boiling point remain in the flask and constitute the residue

References:

1. C.V.S. Subramanyam, J. Thima Shetty, Mrs Sarasija Suresh, Mrs V. Kusum Devi. Pharmaceutical Engineering, 1st edition, Publication: Vallabh Prakashan, Page No-304-305.
2. K. Sambamurthy. Pharmaceutical Engineering, Publication: New age International Publication, New Delhi, Page No-134-135.
3. Paradkar A. Introduction to Pharmaceutical Engineering, Publication: Nirali Publication, Page No-273-277.

DIFFERENTIAL DISTILLATION



PRINCIPLE:

Many organic compounds tend to decompose at high sustained temperatures. Separation by normal distillation would then not be an option, so water or steamis introduced into the distillation apparatus. By adding water or steam, the boiling points of the compounds are depressed, allowing them to evaporate at lower temperatures, preferably below the temperatures at which the deterioration of the material becomes appreciable.

WORKING:

The pot is filled with liquid mixture and heated.

Vapour flows upwards though the column and condenses at the top.

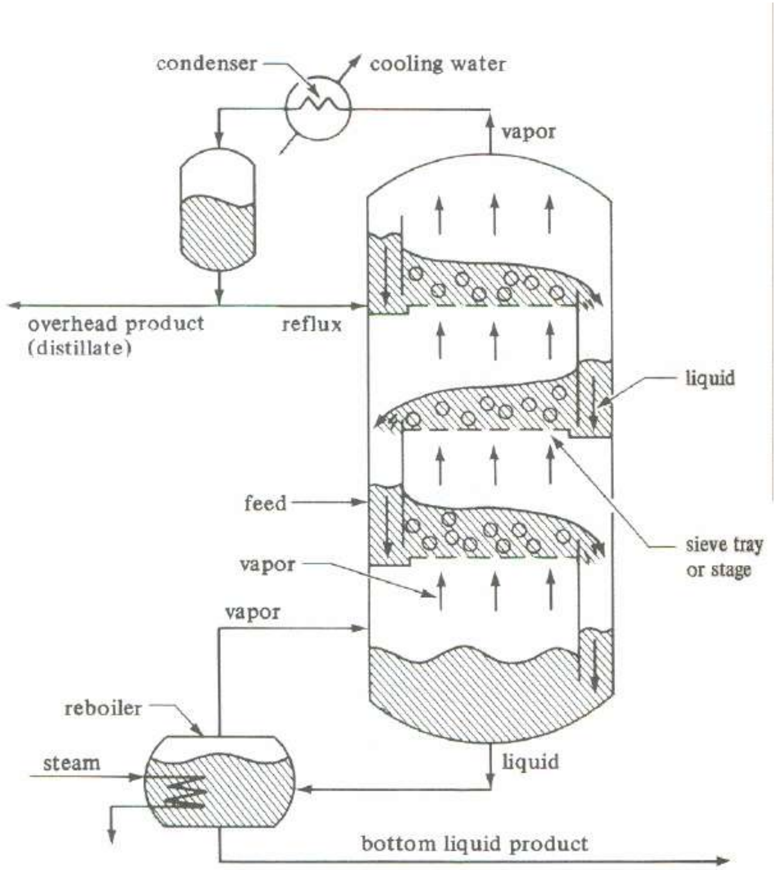
Part of the liquid is returned to the column as reflux, and the remainder withdrawn as distillate.

Nothing is added or withdrawn from the still until the run is completed.

References:

4. C.V.S. Subramanyam, J. Thima Shetty, Mrs Sarasija Suresh, Mrs V. Kusum Devi. Pharmaceutical Engineering, 1st edition, Publication: Vallabh Prakashan, Page No-327-329.
5. K. Sambamurthy. Pharmaceutical Engineering, Publication: New age International Publication, New Delhi, Page No-.153-154.
6. Paradkar A. Introduction to Pharmaceutical Engineering, Publication: Nirali Publication, Page No-296-297.

FRACTIONAL DISTILLATION



1. Feed enters the column somewhere in the middle of the column.
2. Feed is liquid, it flows down to a sieve tray or stage.
3. Vapor enters the tray and bubbles through the liquid on this tray as the entering liquid flows across.
4. The vapor and liquid leaving the tray are essentially in equilibrium.
5. The vapor continues up to the next tray or stage, where it is again contacted with a down flowing liquid.
6. The concentration of the more volatile component is being increased in the vapor form each stage going upward and decreased in the liquid from each stage going downwards.

PES's Modern College of Pharmacy (For Ladies), Moshi, Pune-412105

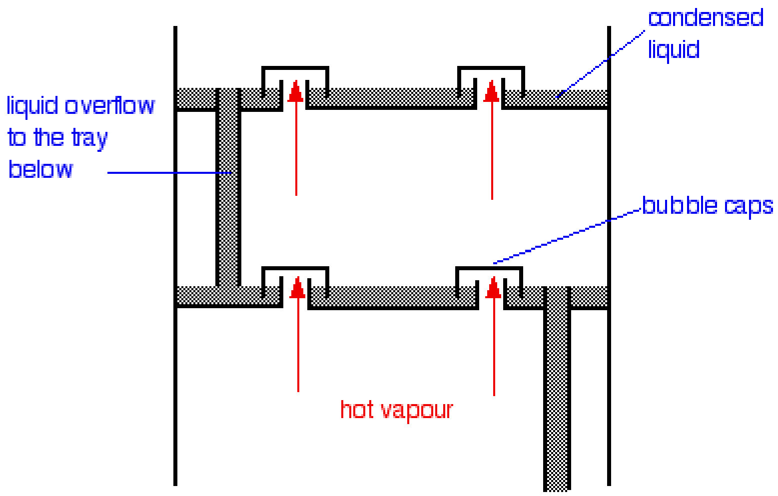
Class-First Year B. Pharm *Subject: Pharmaceutical Engineering*

Subject in-charge: Ms. Kandekar V.Y. *Lecture Synopsis*

FRACTIONATING COLUMNS

The *fractionating column* is a device for increasing the efficiency of re--distillation process. It consists of a vertical column packed with some inert material, such as glass beads or glass helices, or provided with some other device (indentations) for increasing the surface upon which the vapour may condense. As the hot vapours rise through the column, they condense and flow back down the column. The condensate, as it hits the lower, hotter portions of the column, is re-vaporized, and the more volatile components proceed up the column once again. If the column is efficient, this process is repeated many times in the column, and the distillate will consists of the lowest boiling components of the mixture in nearly pure form.

Bubble plate column:

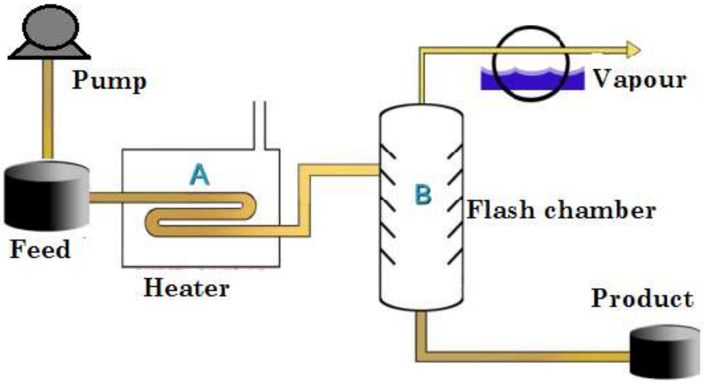


The column contains a number of trays that the liquid collects as the vapour condenses. The up-coming hot vapour is forced through the liquid in the trays by passing through a number of bubble caps.

This produces the maximum possible contact between the vapour and liquid.

The overflow pipes are simply a controlled way of letting liquid trickle down the column.

FLASH DISTILLATION:



PRINCIPLE:

Flash distillation is a single stage separation technique.

When hot liquid mixture is allowed to enter from high pressure zone to low pressure zone, the entire mixture is suddenly vaporized individual vapour phase molecule of high boiling fraction gets condensed, while low boiling fraction remains as vapour.

WORKING:

1. A liquid mixture is pumped through a heater to raise the temperature and enthalpy of the mixture.

2. It then flows through a valve and the pressure is reduced, causing the liquid to partially vaporize.

3. Once the mixture enters a big enough volume (the "flash drum"), the liquid and vapor separate.

References:

1. C.V.S. Subramanyam, J. Thima Shetty, Mrs Sarasija Suresh, Mrs V. Kusum Devi. Pharmaceutical Engineering, 1st edition, Publication: Vallabh Prakashan, Page No-308-310.

MOLECULAR DISTILLATION:

Distillation that is carried out under a high vacuum in an apparatus so designed as to permit molecules escaping from the warm liquid to reach the cooled surface of the condenser before colliding with other molecules.

Theory:

The mean free path of a molecule is defined as average distance through which a molecule can move without collision with another.

The mean free path can be expressed as (λ):

$$\lambda = \eta\sqrt{3/p\rho}$$

P= vapour pressure

ρ = density

η =viscosity

λ=mean path length

The characteristic of the substance influence the method of distillation according to above equation:

a. Liquid having low viscosity and density posseslong , mean path.
b. Substance having high pressure posses low mean free path.

The mean free path can be increased by the viscosity which can be obtained at high temperature and low pressure. Thus nonvolatile liquids become volatile and distillation is possible.

References:

1. C.V.S. Subramanyam, J. Thima Shetty, Mrs Sarasija Suresh, Mrs V. Kusum Devi. Pharmaceutical Engineering, 1st edition, Publication: Vallabh Prakashan, Page No-330-335.
2. K. Sambamurthy. Pharmaceutical Engineering, Publication: New age International Publication, New Delhi, Page No-160-161.
3. Paradkar A. Introduction to Pharmaceutical Engineering, Publication: Nirali Publication, Page No-292-294.