Unit-3

Pharmaceutical Engineering

UNIT-III **10 Hours**

Drying: Objectives, applications & mechanism of drying process, measurements & applications of Equilibrium Moisture content, rate of drying curve. principles, construction, working, uses, merits and demerits of Tray dryer, drum dryer, spray dryer, fluidized bed dryer, vacuum dryer, freeze dryer.

Mixing: Objectives, applications & factors affecting mixing, Difference between solid and liquid mixing, mechanism of solid mixing, liquids mixing and semisolids mixing. Principles, Construction, Working, uses, Merits and Demerits of Double cone blender, twin shell blender, ribbon blender, Sigma blade mixer, planetary mixers, Propellers, Turbines, Paddles & Silverson Emulsifier,

Drying: Objectives, applications & mechanism of drying process, measurements & applications of Equilibrium Moisture content, rate of drying curve. principles, construction, working, uses, merits and demerits of Tray dryer, drum dryer spray dryer, fluidized bed dryer, vacuum dryer, freeze dryer.

Drying:

Introduction:

Drying involves removal of water or another solvent by evaporation from a solid, semi-solid or liquid by application of heat and finally a liquid free solid product is obtained. In general, drying is accomplished by thermal techniques but non-thermal drying processes such as squeezing wetted sponge, adsorption by desiccant (desiccation) and extraction are also used.

Objectives:

- To overcome common challenges in pharmaceutical drying development, including material constraints for scale-up studies and transferring to different equipment types and sizes
- Drying is necessary to make material light weight (weight reduce)
- To encourage further fundamental research and technological advancements for improving the drying process.
- To understand the impact of factors and establish the product specifications, as well as the nature and limits of residual solvents, in agreement with current regulations.

Applications:

- It is used in the production of tablets and granules to improve tablet properties especially, compression of viscous and sticky material.
- Drying is used to remove excess moisture or other volatiles from coatings and various substrates.
- It is used to reduce and control moisture levels in solid materials in the manufacture of many materials.
- Drying is necessary to make material light in weight that help to reduce the cost of transportation of large volume materials (liquids).
- Drying is used as the final step in evaporation, filtration, and crystallization and to preserve materials from environmental factors.

Mechanism of Drying Process:

- Mechanism of drying process involve both mass transfer and heat transfer simultaneously.
- The heat transfer takes place from heating medium to solid material and the mass transfer in value from the solid surface to air.

There are following theories of drying:

- Diffusion Theory (Imp)
- Capillary theory (Imp)
- Pressure gradient theory
- Gravity flow theory
- Vaporization and Condensation theory

Diffusion Theory:

In diffusion theory the rate of flow of water is proportional to moisture gradient.

According to this theory moisture movement may be as follow.

- Water diffuses through the slide to the surface and subsequently evaporates into the surroundings.
- Evaporation of water occurs at an intermediate zone much below the surface then vapours diffuses through the solid into air.

Capillary theory:

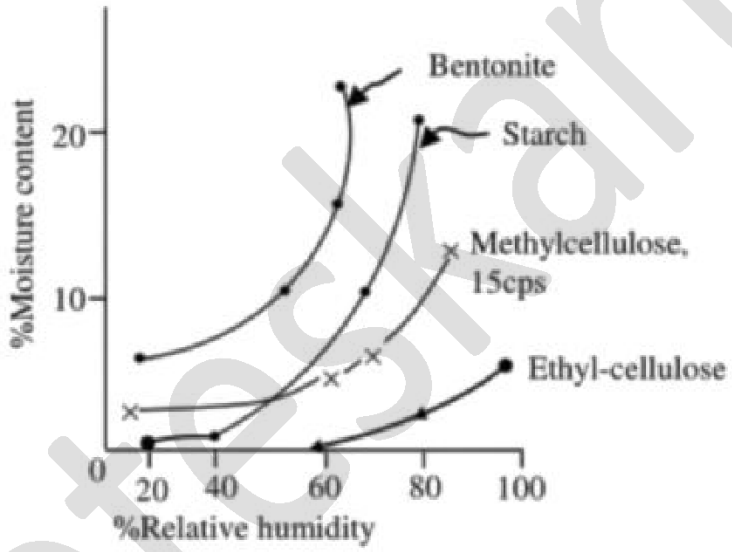
- Capillary theory is applicable to porous granular solids.
- Porous material contains a network of inter connected pores and channels which are not circular or straight.
- As the drying start a meniscus is formed in the capillary and exerts a force.
- This is the driving force for the movement of water through pores towards the surface.
- The curvature of the meniscus depends on the pore diameter and determines the strength of capillary force.
- The capillary force is greater in small pores compared to the large pores.
- Therefore small pores pull more water from the larger pores and thus large pores get emptied first.
- Air enters into the emptied pores and the moisture content is relatively higher near surface.

Pressure gradient theory:

- According to this theory when radiation is applied over the wet material then particles convert into ionize form and after removing radiation it convert into non-ionic form.
- By continues change in ionic and non-ionic form partials shows movement and there vapor pressure is increase and moisture removes into the form of vapors.

Equilibrium Moisture Content:

- The value of EMC can be determined by plotting a graph between % moisture content and % relative humidity.
- The samples are placed in a series of closed chambers (such as desiccators containing a desiccant) for maintaining fixed relative humidity in the enclosed air spaces.
- Thus, the samples are exposed to varying conditions of humidity till the equilibrium is attained (i.e., the sample gains a constant weight).
- Moisture content is the difference in the final and initial weights.
- Now by placing % relative humidity on x-axis and % moisture content on y-axis, an equilibrium moisture curve is plotted to determine the value of EMC



Application:

- Freshness: Fresh products has specified characteristic features. Moisture induces changes in the state of solid. As they age and begin to degrade, some dry out and some pick-up excess moisture and begin to mold.
- Cost: In processed pharmaceutical products, the percentage of water can determine its final price. Generally, a product with more water will cost less.
- Processing: The moisture has effect on the performance of excipients thus manufacturers and physicians need to know the moisture content of product to ensure that it is processed and packaged in a safe, stable way.
- Quality: Moisture content determines the way most product appropriate to administer, taste, feel and look. It is one of the important ways to measure product quality.

Rate of Drying:

- Constant rate period
- Falling rate period

Constant rate period:

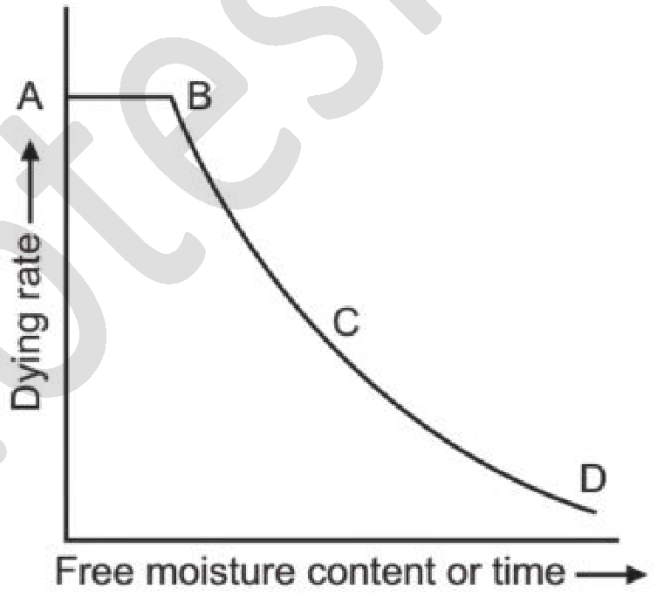
- The moisture vaporized/unit time per unit area of drying surface remains constant.

Falling rate period:

- The amount of moisture vapourised per time per unit area of drying surface decrease continuously.

Critical Moisture content (CMC):

The break point of two zones, where the moisture content at which the constant rate drying period end and the falling rate drying period starts.



- The obtained typical drying rate curve is divided into a constant rate period (AB), a first falling rate period (BC) and a second falling rate period (CD).
- The free moisture content at the end of the constant rate period (B) is known as CMC.
- During drying process, the moisture content is plotted based on the entire material.
- In general, at the start of drying process there is an unsteady state of warming-up period during which wet solid keep changing till the beginning of the constant rate period.

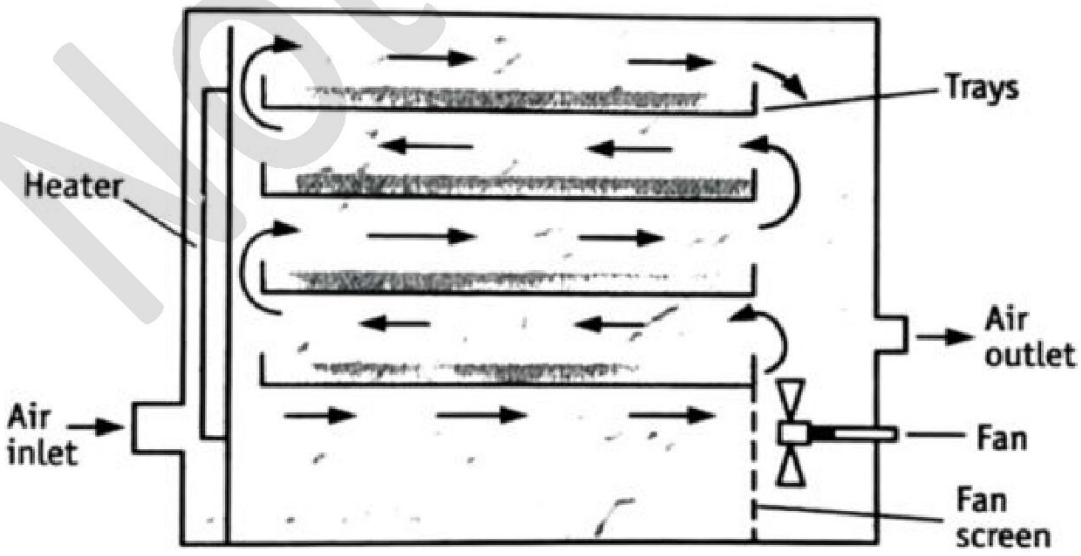
- The drying rate curves are not smooth and continuous which indicates that the drying process involves a single mechanism throughout.
- In drying calculations, the water content in the wet solid is usually expressed on a dry weight basis, i.e. Kg of water/Kg of dry solid.

Tray dryer:

Principles: Tray dryers operate based on the principles of convection and direct heat transfer. Hot air is circulated through a set of trays or shelves containing the material to be dried. As the hot air passes through the trays, it evaporates the moisture from the product, resulting in the drying process.

Construction:

1. **Trays or Shelves**: Tray dryers consist of multiple trays or shelves arranged vertically or horizontally. These trays are made of materials like stainless steel or aluminum to withstand high temperatures and maintain hygiene.
2. **Heating System**: Tray dryers are equipped with electric heaters, steam coils, or other heat sources to generate hot air.
3. **Blowers or Fans**: Fans or blowers are used to circulate the hot air evenly through the trays, ensuring uniform drying.
4. **Control System**: Modern tray dryers come with precise temperature and humidity control systems to optimize the drying process.
5. **Insulation**: Proper insulation is important to conserve heat and energy efficiency.



Working:

1. The material to be dried is spread evenly on the trays in a thin layer.
2. Hot air is generated using the heating system.
3. The blower or fan circulates the hot air through the trays, and as it passes through the material, it evaporates the moisture.
4. The moisture-laden air is vented out, and fresh, dry air is continually supplied.
5. The drying process continues until the desired moisture content is achieved.

Uses:

- Tray Dryers are ideally suitable for drying chilies, spices, papads, potato chips, onions, fish, garlic, grapes, cashew nuts, confectionery, macaroni, wood etc.
- It is also for used for drying pharmaceuticals, chemicals, powders, granules, plastic granules etc.
- Sticky materials, granular mass or crystalline materials, precipitates and paste can be dried in a tray dryer.
- It has been used in agricultural drying because of its simple design and capability to dry products at high volume.

Merits

- It is operated on batch mode so each batch can be handled as a separate entity.
- It is energy efficient dryer as it consumes less energy.
- It's simple to use and clean.
- Tray dryer is available in different sizes thus capital cost can be controlled.
- Chamber walls are heated externally thus prevents condensation.

Demerits

- Tray dryers can be slow to dry materials.
- It provides tendency to over-dry contents in the lower trays.
- The operation is long during cycle (5 to 45 h per batch) and expensive to operate due to high labour requirement for loading and unloading.
- Plastic substances can also be dried using this dryer.
- It is not suitable for large scale production.
- Thermolabile drugs, liquids, slurries, cannot be dried. They can be noisy.

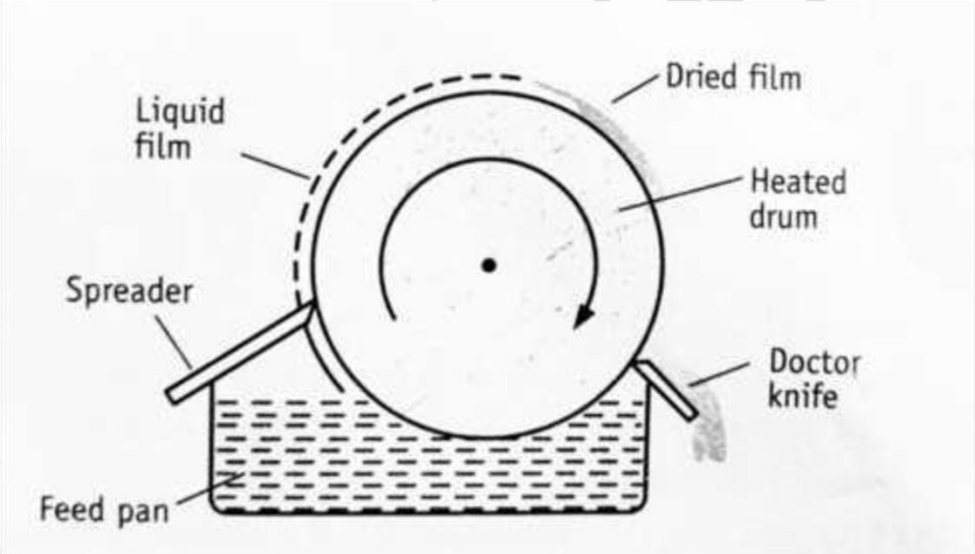
Drum dryer:

Principle:

- Drum dryers operate by applying a thin layer of the product to be dried to the outside of a rotating drum.
- The drum is internally heated by steam which quickly evaporates any liquid from the product. After almost one full revolution the remaining dried material is removed from the drum by a knife as a film or powder.

Construction:

- It consist of a horizontally mounted hollow steel drum of 0.6m to 3.0m diameter and 0.6 to 4.0m length whose externally surface is smoothy polished.
- Below the drum feed pan is placed in such a way that a drum dips partially into the feed.
- On one side of the drum a spreader is placed and on the other side a doctor's knife is placed to scrap the dried material.
- A storage bin (cover) is placed connecting the knife to collect the material.



Working:

- Steam is passed inside the drum heat is transferred by conduction to material also drum is heated.
- Simultaneously drum is rotated at a rate of 1-10 revolutions per minutes.
- The liquid material present in the feed pan adheres as a thin layer to the external surface of the drum during its rotation.
- The material is completely dried during its journey in slightly less than one rotation.
- The dried material is scrapped by the doctor's knife which then falls into storage bin.
- The time of contact of the material with not metal is 06 to 15 second only. Therefore processing condition such as film thickness steam temperature are closely controlled.

Uses:

- Used for drying solution, slurries, suspension, etc.
- Drum dryer is used in drying of liquids and pastes of sticky and highly viscous products.
- It is used under vacuum for drying temperature sensitive products such as vitamins, proteins, yeasts, pigments, malt extracts, hormones and antibiotics.
- It has closed process area that protects the product and/or the environment.
- Drum dryer is used for drying solutions, slurries, suspensions etc.

Advantages:

- Drum dryer gives a rapid (few seconds) drying and its mass transfer rate is higher.
- The entire material is continuously exposed to uniform heat. This process is characterized by short drying time and minimum product heating.
- The equipment is compact 100% closed system and tailored models are available.
- Their simple operation makes them run with the minimum of training and require no specialist maintenance.
- Drum dryers are economical with cheap installation and 24 hour a day continuous production.
- It can have vacuum facilities to prevent dust emission thereby giving a guarantee of optimal hygiene during the complete production process.

Disadvantages:

- The operating conditions are critical and need to be monitored.
- Skilled operators are needed to control feed rate, film thickness, speed of rotation and temperature.
- It is not suitable for low concentration solutions or suspensions of low viscosity.

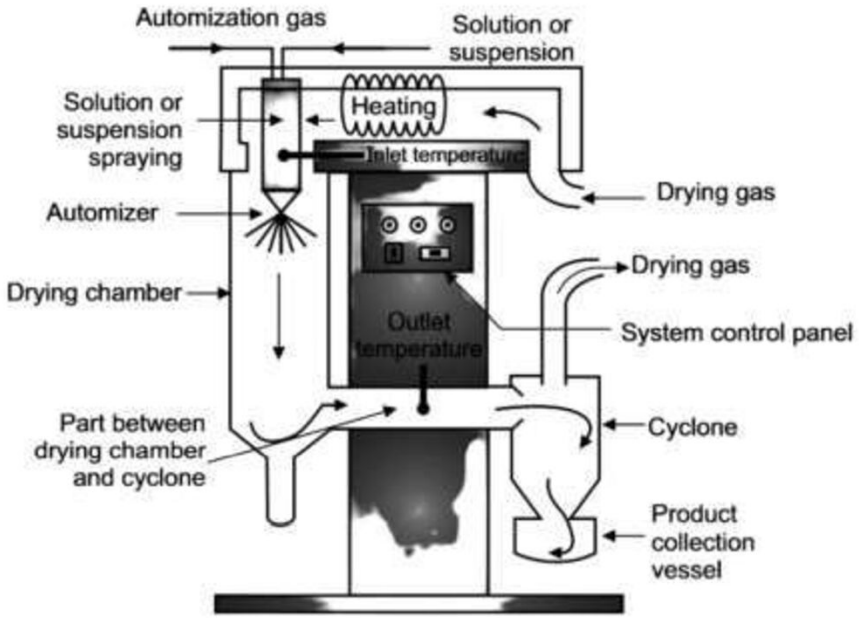
Spray Dryer:

Principle:

- Spray drying is the continuous transformation of feed from a fluid state into dried particulate form by spraying the feed into a hot drying medium.
- The feed is either solution, slurry, emulsion, gel or paste which is provided through pump in atomized form.

Construction:

- Drying chambers with conical bases comprise it.
- All the parts are stainless steel. An inlet for hot air is also provided at the bottom, and a second one is provided at the top for the spray disk atomizer.
- A cyclone separator is connected to the drying chamber for atomization using single-fluid or dual-fluid nozzles. In the bottom of the separator, the dry product is collected.



Working:

- A spray dryer takes a liquid stream and separates the solute or suspension as a solid and the solvent into a vapor. The solid is usually collected in a drum or cyclone.
- The liquid input stream is sprayed through a nozzle into a hot vapor stream and vaporized. Solids form as moisture quickly leaves the droplets.
- A nozzle is usually used to make the droplets as small as possible, maximizing surface area hence heat transfer and the rate of water vaporization.
- Droplet sizes can range from 20 to 180 μm depending on the nozzle.
- There are two main types of nozzles: high pressure single fluid nozzle (50 to 300 bars) and two-fluid nozzles: one fluid is the liquid to dry and the second is compressed gas (generally air at 1 to 7 bars).

Uses:

- Many pharmaceutical and biochemical products are spray dried, including antibiotics, enzymes, vitamins, yeasts, vaccines, and plasma.
- It can be used in preparing micro particles for the preparation of dried liposomes, amorphous drugs, and mucoadhesive microspheres, microcapsules, gastro-resistant microspheres, and controlled-release systems.
- It can also be used to prepare dry elixirs. For example, Flurbiprofen Dry Elixir.

Advantage:

- This technique has ability to operate in aseptic pharmaceutical processing.
- Feed rates in spray drying can range from a few pounds per hour to over 100 tons per hour and thus can be designed to any capacity required.
- The spray drying process is very rapid, with the major portion of evaporation taking place in less than a few seconds.

- It is adaptable to fully automated control system that allows continuous monitoring and recording of very large number of process variables simultaneously.
- Wide ranges of equipment designs are available to meet various product specifications.
- It can be used with both heat-resistant and heat sensitive products.

Disadvantages:

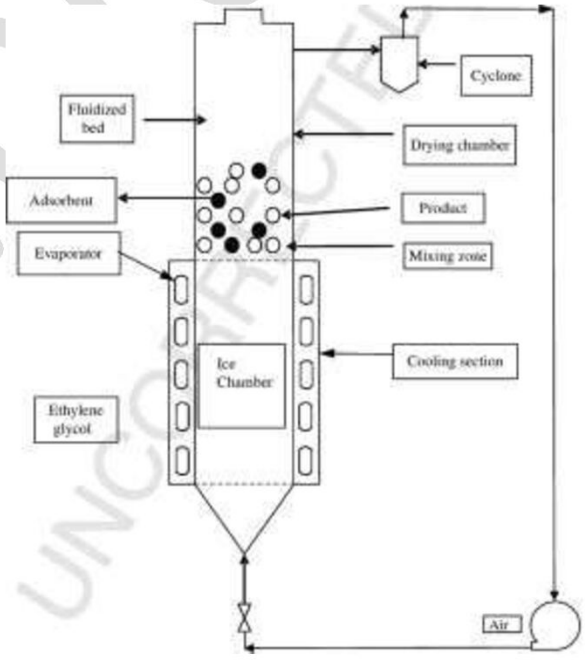
- The equipment is very bulky and the ancillary equipment components are expensive to install.
- The overall thermal efficiency is low, thus large volumes of heated air is wasted as pass through the chamber without contacting a particle.
- It is difficult maintain and clean after use.
- It needs material in liquid form and thus solid materials cannot be dried using spray dryers.
- Product degradation or fire hazard may result from product deposit in the drying chamber.

Fluidized bed dryer:

If air is allowed to flow through a bed of solid powdered material in the upward direction with the velocity greater than the settling rate of the particles, the solid particles will be blown up and become suspended in the air stream.

Constructions:

- There is a removable bowl on the side of the stainless steel fluidized bed dryer, and the pressure chamber is made of stainless steel.
- Air handling units, product vessels, exhaust filters, exhaust blowers, control panels, air distribution plates, spray nozzles, and solution delivery apparatuses are typical fluidized bed dryer components. Fluidization is stable and even when the proper distributor is used during the drying process.
- A suitable pressure drop across the distributor is necessary to ensure proper fluidization.



Working:

- Material to be dried is placed in the bowl type vessel. Air is introduced from the top and heated at required temperature by the heaters.
- The air is filtered through the filter and then passes through the bed of the material at the bottom. The airflow is generated by the fans fitted at the top of the equipment.
- The air flow rate and the operating temperature are adjusted by the control panel. As the flow of air increases, the bed expands and particles of powder start to rise up in a turbulent motion.
- The regular contact with air causes the material to dry. The air leaving the FBD passes through the filter to collect the fine particles of the material.
- Fluidized bed dryer has a high drying rate and the material is dried in a very short time. Material remains free-flowing and uniform.
- FBD bags have finger-like shape to increase the volume of the drying bed that helps to increase the drying rate and decrease the drying time.

Applications:

- This process being fast is used in granulation of pharmaceutical powders.
- It is used for drying moist dibasic calcium phosphate anhydrous (DCPA).
- It is suitable for the formulation, development and production of clinical materials.
- The modified versions of FBD are used as precision granulators, top spray granulators, spray drying granulator and granulator coater.
- Fluidized bed coaters are used widely used for coating of powders, granules, tablets, pellets, beads that are held in suspension by column of air

Advantages:

- It has low capital and maintenance cost.
- Minimum contact time for drying is best suited for heat sensitive products.
- FBD is highly efficient in material drying to desired level.
- Handling FBD is easy due to simple system control panel and thus requires less labour.
- FBD designs come in a wide range of capacities and sizes.
- It shows no hot spots on the final products.
- It is suitable for both continuous and batch material processing.

Disadvantages:

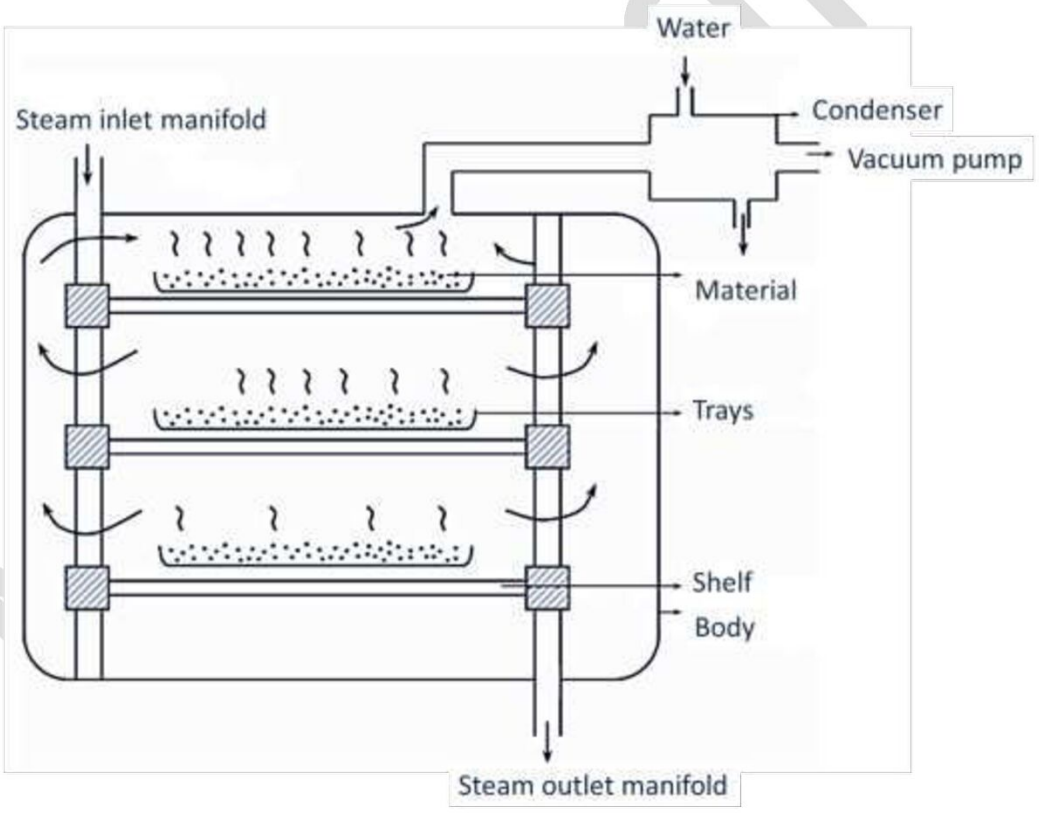
- It has a possibility of product loss.
- There are high chances of electrostatic force build-up.
- Using FBD drying of sticky material is quite difficult.
- The high pressure drop requires more energy to suspend particles.
- Non-uniform product quality for certain types of materials.
- There may be entertainment of fine particles.

Vacuum Dryer:

- Vacuum drying is a method that removes moisture from a solid sample or air.
- The principle is to use a vacuum to lower the boiling point of moisture or solvent. Simultaneously, molecules diffuse to the surface and evaporate due to the low pressure.

Constructions:

- A vacuum dryer consists of a chamber divided into hollow trays or shelves, which increase the surface area for heat conduction.
- The oven door is designed to be airtight and connected to a vacuum pump to reduce the pressure inside.
- The material to be dried is placed on the trays inside the dryer, and the pressure is lowered using the vacuum pump.
- The oven is also connected to a condenser to collect the evaporated moisture.



Working:

- The material to be dried is placed on the trays or shelves inside the vacuum dryer and then reduced the pressure to a range of 30 to 60 KPa using the vacuum pump.
- Then close the oven door tightly and steam is passed through the jacket space and shelves, allowing for heat transfer through conduction.

- Under vacuum, the water in the material evaporates at temperatures of around 25-30°C.
- The vapor is then directed to the condenser.
- After drying, the vacuum line is disconnected, and the dried material is collected from the trays.

Uses:

- Drying heat-sensitive materials that undergo decomposition.
- It is able for Drying dusty and hygroscopic materials.
- It is easy for Separating drugs containing toxic solvents into closed containers.
- Effective in Recovering valuable solvents from feeds through condensation.
- Producing porous end products for certain drugs.

Advantages:

- Easy material handling.
- The hollow shelves can be electrically heated, providing a large surface area for efficient heat transfer.
- Hot water can be supplied through the dryer to allow drying at the set temperature.
- It is suitable for drying heat-sensitive materials without degradation.

Disadvantages:

- Batch process, limiting continuous production.
- Lower efficiency compared to some other drying methods.
- Higher cost and maintenance requirements.
- Risk of overheating due to the vacuum.

Freeze Dryer:

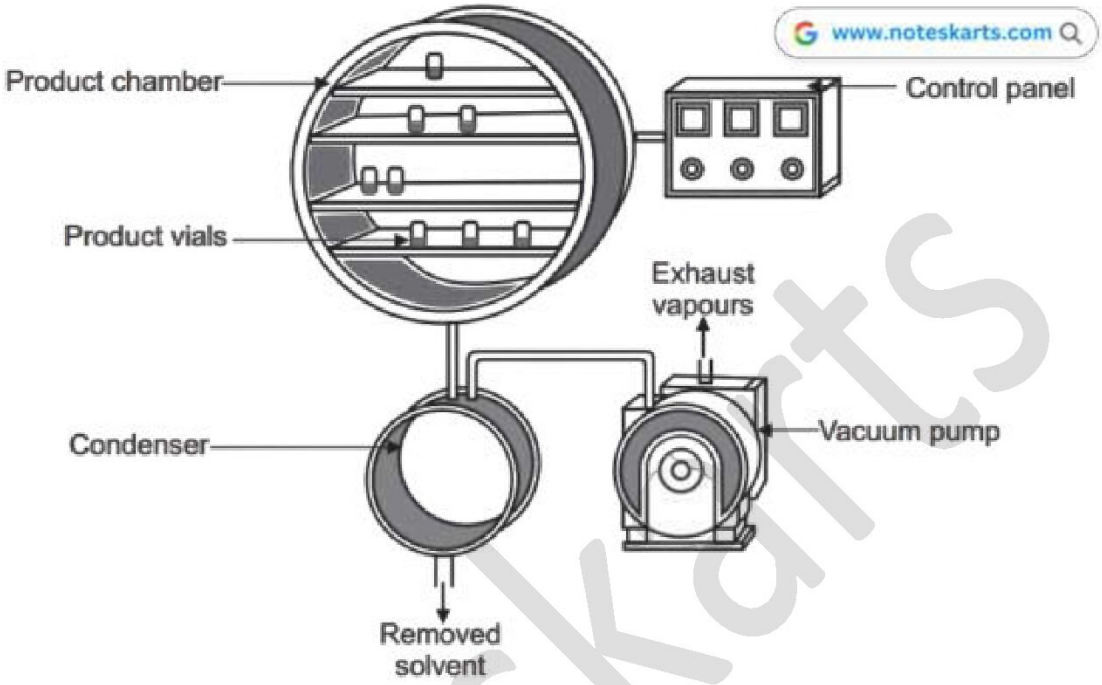
Construction of Freeze Dryer:

Freeze dryers are of three types: manifold freeze dryers, rotary freeze dryers, and tray-style freeze dryers. Their components are as follows:

- A vacuum pump to reduce the ambient gas pressure
- A condenser that removes moisture through condensation on a surface cooled to -20 to -80 °C.
- A freeze dryer includes a vacuum chamber where products to be dried are placed on shelves.
- A vacuum pump, refrigeration unit, and associated controls are connected to the vacuum chamber to allow the drying process.

The distance between the subliming surface and condenser must be less than the mean path of the molecules.

The temperature of the condenser must be much lower than the evaporated surface of the frozen substance (To maintain this condition condenser surface must be cleaned repeatedly)



Working of Freeze Dryer:

- The process begins by freezing the sample and placing it under a vacuum, allowing the frozen water to change directly from solid to vapor without passing through the liquid phase.
- This sublimation of frozen material occurs at low temperature and pressure conditions below the triple point of the liquid.
- The freeze-drying process takes place in multiple stages: sample preparation, freezing, primary drying, secondary drying, and packing. Read all the stages process below:

Freezing:

In this stage samples should be packed in vials, ampoules, or bottles. It is kept on cold shelves (About -50°C). During this stage, the cabinet is maintained at a low temperature and pressure.

Primary Drying:

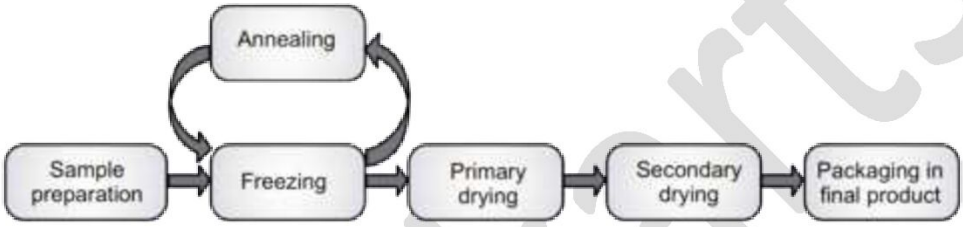
Primary drying involves the removal of ice formed during the freezing stage through sublimation under a vacuum and at low temperatures. Primary drying occurs at pressures of 104 to 109 atmospheres and a product temperature of -45 to -20 °C.

Secondary Drying:

Secondary drying is the final step in freeze drying. It involves desorbing most of the remaining water from the dried product by raising the temperature. At this stage, pressure is also lowered to remove water.

Packing:

During this stage vacuum is replaced by an inert gas, and the bottle and vials are closed.



Advantages of Freeze Dryer

- Freeze-drying preserves the original characteristics, flavors, and aromas of the product.
- Thermolabile materials can be dried.
- Freez drying help in extends the shelf life of the product by removing water and inhibiting microbial growth.
- Loss of volatile materials is less.
- Freeze-dried products can be easily rehydrated by getting the same properties as before.
- Freeze drying can be applied to various materials, including food products, pharmaceuticals, biological samples, and chemicals.

Disadvantages:

- Freeze-drying is expensive process.
- Freeze drying is a time-consuming process compared to other drying methods.
- The product is prone to oxidation due to high porosity and large surface area.

Applications:

- Freeze drying is commonly used to preserve food products, like; fruits, vegetables, coffee, and dairy.
- Many pharmaceutical products, including vaccines, antibiotics, and biopharmaceuticals, are freeze-dried to enhance stability and extend shelf life.
- Freeze drying is used in biotechnology laboratories to preserve microorganisms, enzymes, cell cultures, and other biological samples.

Mixing: Objectives, applications & factors affecting mixing, Difference between solid and liquid mixing, mechanism of solid mixing, liquids mixing and semisolids mixing. Principles, Construction, Working, uses, Merits and Demerits of Double cone blender, twin shell blender, ribbon blender, Sigma blade mixer, planetarymixers, Propellers, Turbines, Paddles & Silverson Emulsifier,

Mixing:

Mixing is defined as a process that tends to result in a randomization of dissimilar particles within a system. Mixing refers to the random distribution into are through one another of two or more separate phases. Some of the mixing operations in the dispensing practice are speculation, trituration, tumbling, geometric dilution etc.

Objectives:

- Mixing aims to ensure that there is uniformity of composition between the mixed ingredients that represent the overall composition of the mixture.
- The primary objective of mixing is to make a homogeneous product using the minimum amount of energy and time.

Applications:

- Mixing of powders in granulation and tablet section.
- Dry mixing of the materials by using blenders for direct compression in tablets.
- Dry blending of powders for capsule filling and compound powders.
- A blending of powders in cosmetics in the preparation of face powders, and tooth powders.
- It is used in the Dissolution of soluble solids in viscous liquids for filling soft capsules and syrups.
- Mixing of two immiscible liquids for preparation of emulsions.

Factors Affecting Mixing:

- **Nature of product:** Smooth particle surfaces are easy for effective mixing.
- **Particle size:** Mixing powders with similar particle sizes is easier, while a significant difference in particle size can lead to segregation.
- **Particle shape:** Spherical particles are ideal for a uniform mixture.
- **Particle charge:** Electrostatically charged particles may exert attractive forces, leading to separation.
- **Proportion of material:** Equal proportion produces fine mixing
- **Relative density:** If the components have different densities, high-density particles settle down.
- **Viscosity:** Increasing viscosity reduces the extent of mixing.

- **Surface tension of liquids:** Higher surface tension limits the process of mixing.
- **Temperature:** Viscosity changes with temperature, thus affecting the mixing process.
- **Mixture volume:** Mixing efficiency depends on the volume of the mixture.
- **Agitator type:** The shape, size, location, and type of agitator affect the degree of mixing.
- **Speed/rpm of the impeller:** Mixing at lower RPMs tends to be more homogenous than at higher RPMs.
- **Mixing time:** Adequate mixing time is essential for achieving the desired homogeneity.

Difference between solid and liquid mixing

Aspect	Solid Mixing	Liquid Mixing
Definition	The process of blending solid pharmaceutical materials. This process is used for mixing dry powder.	The process of combining liquid pharmaceutical materials. It is used for the preparation of Liquid mixtures, suspensions, or emulsions.
Type of materials	Solid powders, granules, or particles	Liquid mixture, suspensions, or emulsions.
Mixing equipment	Mortar and pestle, blender, mixer, or granulator	Magnetic stirrer, homogenizer, or agitator
Sample Size	Large sample sizes are required.	A small sample size is sufficient
Mixing process	Mechanical agitation and blending	Stirring or agitation to achieve uniform dispersion
Uniformity	Mixing solids aims for uniform particle distribution	Mixing liquids aims for a uniform solution or suspension
Challenges	Risk of segregation, poor flow properties	Homogenization, dissolution, or emulsification issues
Time	Solid mixing may take longer due to particle blending	Liquid mixing is usually faster
Heat generation	Solid mixing may generate heat due to friction	Liquid mixing may generate heat due to agitation
Clean-up	Solid mixing equipment requires thorough cleaning	Liquid mixing equipment needs cleaning but is easier
Scale-up	Scaling up solid mixing can be challenging	Scaling up liquid mixing is generally easier

Mechanism of mixing in Solids—

- **Convective mixing—**It is achieved by the inversion of the powder bed using blades or paddles or screw element. A large mass of material moves from one part to another. Convective mixing is referred to as macro mixing.
- **Shear mixing—**In this type, the forces of attraction are broken down so that each particle moves on its own between regions of different composition and parallel to their surface.
- **Diffusive mixing—**It involves the random motion of particles within the powder bed, there by particles change their position relative to one another. Diffusive mixing is referred to as micro mixing.

In Solid-solid mixing operation four steps are involve—

- Expansion of the bed of solids.
- Application of three dimensional shear forces to the powders.
- Mix long enough to permit true randomization of particles.
- Maintain randomization (no segregation after mixing).

Equipment used for solid Mixing— V cone blender, Double cone blender, Ribbon blender, sigma blade mixer etc.

Mixing Of liquids.

Liquid-liquid mixing is considered as a simple operation compared to that of solid-liquid mixing. It involves the formulation of a homogeneous system.

According to theories of solutions, liquid mixtures are classified as follows—

1. **Miscible liquids—**Miscible in all proportion. Example- Ethyl alcohol and water.
2. **Partially miscible liquids—**Miscible in one another at one particular proportion. Example- P-cresol and water.
3. **Immiscible liquids—** These are not miscible. Example- vegetable oils and water.

Equipment used for liquid mixing— Propellers, turbines, Airjet mixer.

Mixing of Immiscible liquids.

- Mixing of immiscible liquids is carried in pharmacy mainly in the manufacturing of emulsions. The equipment used for preparation of an emulsion is known as emulsifier. Generally a fine emulsion can be obtained and therefore, equipment is also known as homogenizer.
- Sometimes, the above equipment directly gives fine emulsion. Otherwise, coarse emulsion is subjected to homogenization in the second stage to get fine emulsion by using one of the following- Silverson emulsifier, colloid mill, rapisonic homogenizer.

Mixing of semisolids.

- Semisolid dosages forms include ointments, pastes, creams, jellies etc. while mixing such dosages forms, the material must be brought to the agitator or the agitator must move the material throughout the mixer.
- The mixing action includes combination of low speed shear, smearing, wiping, folding, stretching and compressing.
- Mixing equipment are also used for preparing tooth paste, pill mass and wet mass for granulation. Some semisolids exhibit dilatants property that is viscosity increase with increase in shear rates. Therefore, mixing must be done at lower speeds.
- The speed must be changed accordingly to thixotropic, plastic and Pseudo plastic materials.
- **Equipment used for mixing of semisolid**— Sigma mixer and planetary mixer (Solid-solid mixer), triple roller mill, colloidal mill.

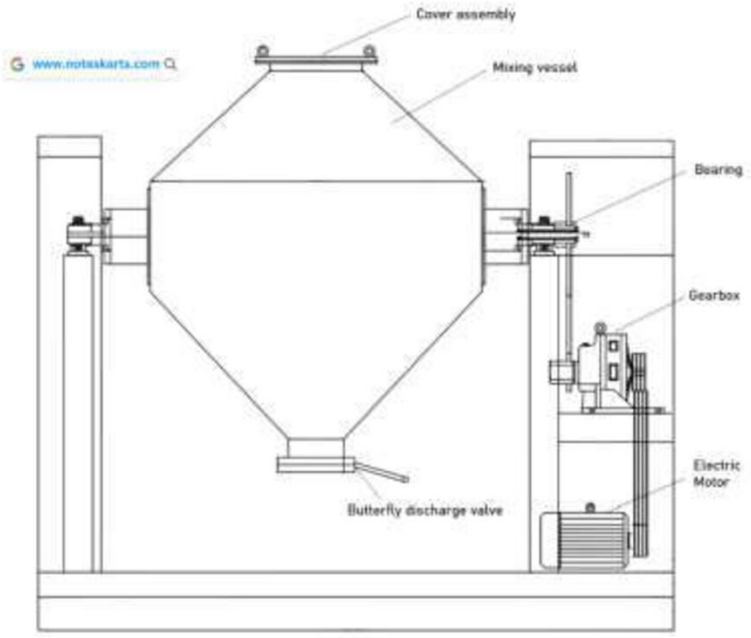
Double cone blender:

Principles:

- It is an efficient design for mixing of powder of different densities. It is usually charged and discharged through the same port. These are used mostly for small amounts of powders.
- The rate of rotation should be optimum depending on the size and shape of the tumbler, nature of materials to be mixed. Commonly the range is 30 to 100 R.P.M.

Construction:

- The conical shape at both the end enable uniform mixing and easy discharge.
- The cone is statically balanced which protects the gear box and motor from any excessive load.
- Powder is loaded into the cone through a wide opening and discharged through a butterfly or a slide valve.
- Depending upon the characteristic of the products, paddle type baffles can be provided.



Working:

- The material is loaded approximately 50% to 60% of its total volume. As the blender rotates, the material undergoes tumbling motion.
- This motion dividing and recombination continuously yields ordered mixing by mechanical means. Blender speed is the key for mixing efficiency.
- At high speed, more dusting or segregation of fines is possible, while at low speeds, not enough shears may be applied.

Uses:

- It is an efficient and versatile machine for mixing of dry powders and granules homogeneously.

Merits:

- It is suitable for fragile granules because of minimum attrition.
- Easy to clean, load and unload.
- They handle large capacities.
- This equipment requires minimum maintenance.

Demerits of Double cone blender

- Need high head space for installation.
- It is not suitable for fine particulate system or ingredients of large differences in the particle size distribution because not enough shears is applied.

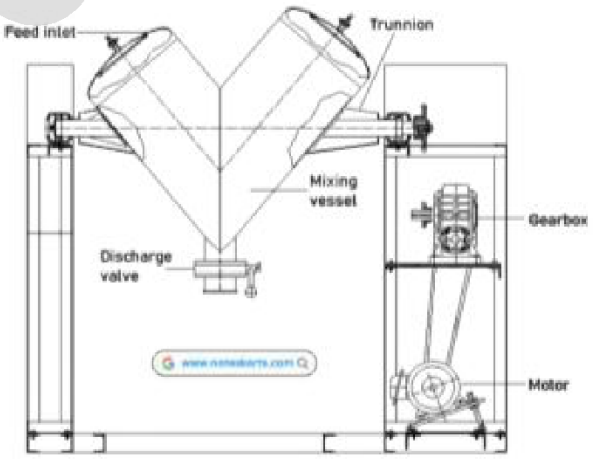
Twin Shell Blender (V Cone Blender):

Principles:

The Twin Shell Blender achieves mixing through a captivating tumbling motion.

Construction:

- Its construction involves two blending shells connected in a V-shaped configuration. Intensifier bars within the blender serve to break up solid clumps, while the product resides at both ends of the V (when the blender is inverted).
- A horizontal shaft, rotating about an axis, induces a tumbling effect, causing particles to intermix on the mixture surface.
- Material charging can occur through either end of the V-Blender, offering flexibility in the process.
- The blending capacity ranges from 20 kg to 1 tonne, depending on equipment size.



Working:

- The Twin Shell Blender, also known as a V-Blender, ranks among the most widely employed tumbling blenders. Material is loaded into the vessel, initiating the blending process.
- As the V-blender tumbles, the material continuously fragments and merges, with the mixing action occurring as the material free-falls unpredictably within the vessel.
- This blending technique harnesses the force of gravity, enabling the powder to cascade within the rotating vessel. It is recommended to fill the V-Blender to approximately 50 to 60% of its total volume.
- The blended product is collected from the bottom of the V-shaped container. Blend times typically range from 5 to 15 minutes, depending on the material properties.

Uses:

- V blenders excel in dry mixing applications, delivering efficient blending in a short span of time.
- They are commonly employed in pharmaceuticals, although they may not be suitable for very soft powders or granules.
- V blenders are widely used in the food industry for products such as milk, dry flavors, spices, and baby foods.
- They also find usefull in pesticide and herbicide manufacturing, animal feed production, and cosmetics.

Merits:

- The double cone-shaped sections at both ends enable reliable powder discharge and homogeneous mix results.
- The statically balanced double cone prevents undue strain on the motor and gearbox.
- The double-cone design makes it simple to load and discharge.
- Material loading and discharge methods are segregated in such a blender to avoid cross-contamination.
- To prevent corrosion and contamination, all contact parts are constructed from stainless steel.
- The blender can process massive amounts of particles.
- Low-maintenance, easy to clean, and simple to use.

Demerits of Twin Shell Blender

- This piece of equipment is not suited for blending fine particles.
- Powders or granules varying in size, including fine and large particles, can't be mixed effectively due to the low shearing force of the blender.
- The blender is not easy to move around due to its weight.
- Considering its 360-degree rotation, the blender cannot be installed in small rooms with low ceilings.
- Most blenders are not equipped with safety guards, so safety precautions must be taken when using the equipment.
- This type of blender is not fully automated, so it requires manual handling, such as loading materials and opening the butterfly valve for discharge.

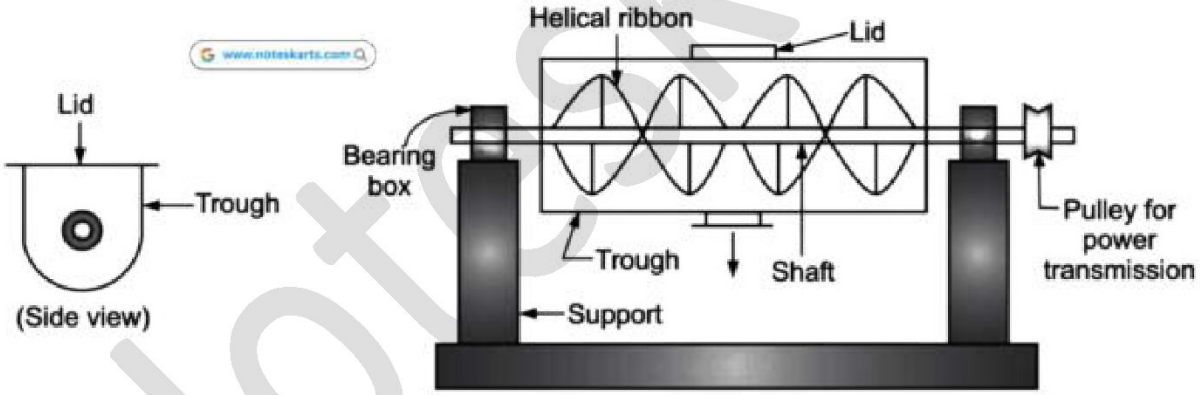
Ribbon Blender

Principles:

- The mechanism of mixing in a ribbon blender relies on shear forces generated by the movement of blade-like ribbons within a stationary shell.
- This mixing process involves convective movements, which allow the redistribution of solids on a macro scale.

Construction:

- It consists of a non-movable horizontal cylindrical shell usually open at the top.
- It is fitted with two helical blades, mounted on same shaft.
- Blades have both right and left hand twist
- Blades are connected to a fixed speed drive.
- Load from top and discharge from bottom



Working:

- To blend the materials, load the material into the blender, filling it between 40 and 70 percent of the total volume of the container.
- The drive system helps the ribbons to rotate. During the blending process, one blade slowly moves the solids in one direction, while the other blade rapidly moves them in the opposite direction.
- This motion ensures that the materials are thoroughly mixed in a short amount of time, resulting in a homogeneous blend. Typically, the blending operation takes around 15 to 20 minutes.

- Once the blending is complete, the material is discharged through a spout located at the bottom of the trough.
- The efficiency of the ribbon mixer's mixing process is influenced primarily by the particle size and bulk density of the ingredients.
- When the ingredients have similar particle sizes and bulk densities, they tend to mix more quickly compared to ingredients that vary in these attributes.

Uses:

- A Ribbon blender is used in the blending process for the large volume solid, semisolid mass.

Merits:

- Ribbon mixers are a cost saving, and also reduce process time.
- It can blend a wide range of materials with minimal flaws.
- It can also be used in food industries to mix food items.
- Required less space to install.

Demerits:

- The movement of particles in the Ribbon Blender is two-dimensional, making it less efficient for mixing compared to a planetary mixer.
- The shearing force is lower than in a planetary mixer.
- Attrition of particles can occur at the wall of the blender due to higher forces.

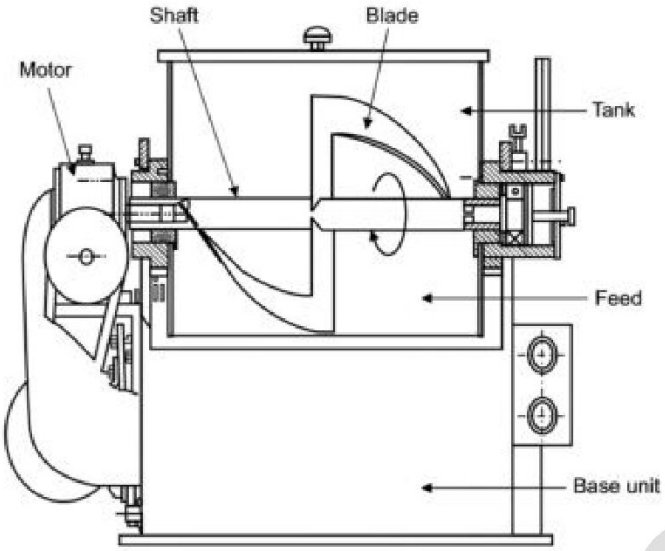
Sigma blade mixer

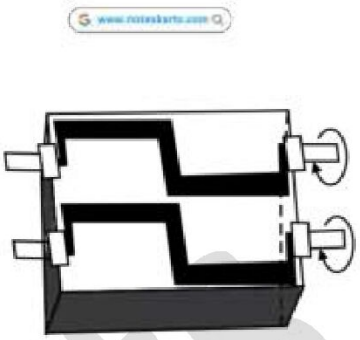
Principles:

The principle involved in these mixers, which handle highly viscous materials, depends on shearing and convecting generated by interlocking sigma-shaped blades. This action induces both lateral and transverse motion of the material.

Construction:

- It consist of double trough shaped stationary bowl.
- Two sigma shaped blades are fitted horizontally in each through of the bowl.
- They are connected to a fixed speed drive.
- The mixer is loaded from top and unloaded by filling the entire bowl.





Working:

- Material are introduced from the top of the through and then covered it.
- Now allowed the sigma blades to rotate through the fixed speed drive.
- The blades move at different speeds, one usually about twice the spud of other, resulting in lateral pulling of the material.
- By moving powders through blades, cascading action (convicting) as well as shear action can be achieved.
- By this mixing take place and final mixing discharge through filling the entire bowl.

Uses:

- It is commonly used fo mixing of dough ingredient in the baking industry.
- It is used for solid-liquid mixing as well as for solid-solid mixing.
- The sigma blade mixer is a commonly used mixer for high viscosity materials in preparing emulsions, syrups and ointments.

Merits:

- The sigma blade mixer leaves less dead spot during mixing operations.
- It is ideal for mixing and kneading of highly viscous mass and sticky products.
- The provision of perforated blades makes it suitable for breaking lumps and aggregates.

Demerits:

- Requires more space for installation.
- It requires proper blade speed adjustments.
- There may be dead spots in the mixing tank.

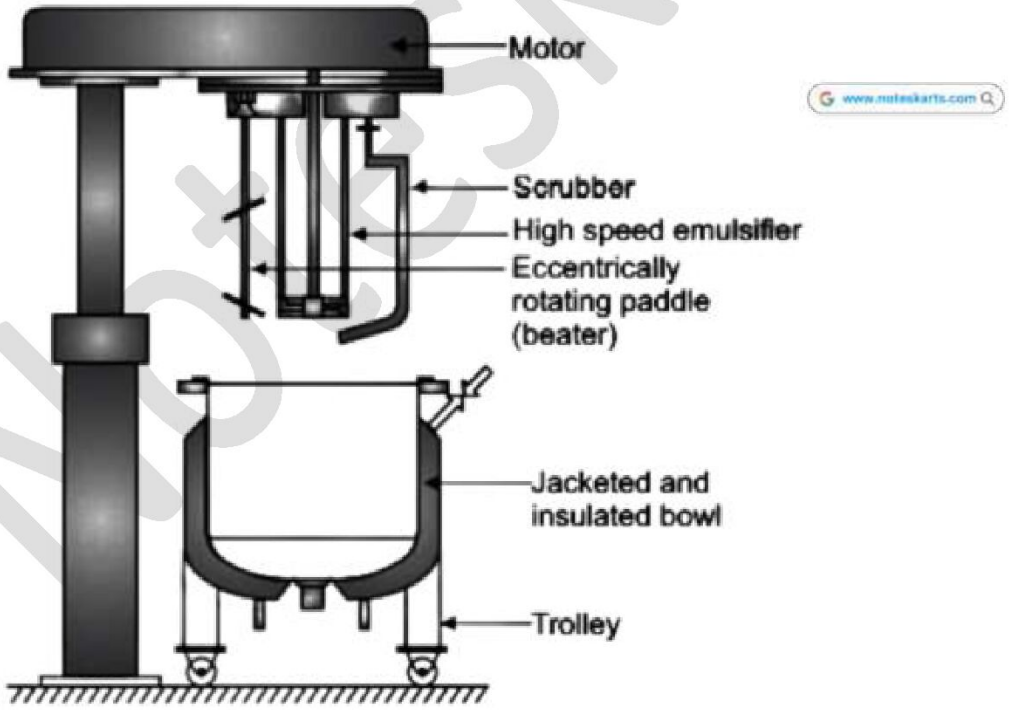
Planetary mixers:

Principles:

The planetary mixer is working on a simple yet highly effective principle. Planetary mixers are equipped with two or three multi-hinged blades that revolve and rotate simultaneously. As a result, the material being mixed flows both up and down and around the inner cylinder, achieving a thorough mixing effect in a short period of time.

Construction:

- The mixer features a vertical cylindrical shell that can be conveniently removed by either lowering it beneath the blade or raising the blade above the bowl.
- The mixing blade is mounted from the top of the bowl, allowing it to efficiently blend the ingredients.
- The mixing shaft is driven by a planetary gear train, which imparts the necessary motion for thorough mixing.
- The shaft rotates around the ring gear, which, in turn, rotates the mixer blade, ensuring the even distribution of the ingredients.
- Planetary mixers are typically equipped with a variable speed drive, offering flexibility in adjusting the rotation speed as per the mixing requirements.



Working:

- The working of a planetary mixer is important for smooth mixing. Here's a step-by-step process of its operation:

- The material to be mixed is loaded into the mixing bowl, ensuring the desired proportions are maintained.
- Once the mixing process commences, the blades start rotating on their own axis while simultaneously orbiting the mixing bowl on a common axis. This dual motion eliminates any dead space within the mixer, ensuring optimal mixing efficiency.
- The combination of rotation and revolution creates a high-shear environment, resulting in the thorough blending of the ingredients.
- After the mixing process is complete, the material is discharged either through a bottom valve or by manual scooping from the bowl, ready for further processing or packaging.

Uses:

- Planetary mixers are designed to ensure ease of operation for operators.
- Planetary mixers are used for wet/dry solid-solid materials mixing.
- It is used for dry powder to wet phase mixing for wet granulation.
- The single planetary mixer is used for mixing of light pastes, gels, and dough.

Merits:

- There are virtually no dead spaces in the mixing bowl.
- The product quality is better and more homogeneous.
- Being a compact equipment, it requires less space

Demerits

- The equipment generates heat which may be unsuitable for proper mixing.
- When handling high viscosity materials the energy required is more.
- As this equipment consists of moving parts maintenance is required.
- As labour requirement is more, the process cost is also high.

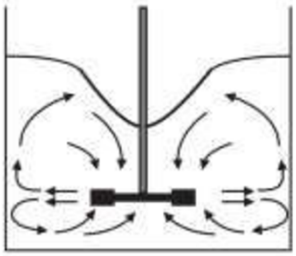
Propellers

Principles:

- It is based on the mechanism of shearing.

Construction:

- A propeller normally contains a number of blades (Three bladed design most common)
- It may be either right or left handed depending on the direction of slant of their blades.
- The size of the propellers is small (sufficient for low viscous liquids)
- General speed upto 8000 RPM.



Working:

- Take a liquids which we have to mix in a container.
- Then dip the propeller in that container with the help of stand etc.
- Now start the motor and allowed to rotate propeller
- The propeller produces axial (longitudinal) movement of liquid which yield to mixing
- After completed mixing remove the propeller from container
- We get mixed liquid in container.

Uses:

- Propellers are used when huge quantities of liquids and dispersions are to be mixed.
- These are useful for mixing liquids having a viscosity of about 2 Pa.s.
- These can handle corrosive materials with glass lining.

Merits

- Effective for high mixing capability.
- Suitable for liquids with a maximum viscosity of 2 Pa.s.
- Effective for mixing gas-liquid dispersions at a laboratory scale.
- Increases material homogeneity.
- Can be used for drying and pressing processes.

Demerits

- Need to be operated at high speed to avoid solid settlings in reactor vessels.
- They need to be operated at low speeds if drying is an additional objective.
- Vortex causes frothing and possible oxidation.

Turbines Mixer

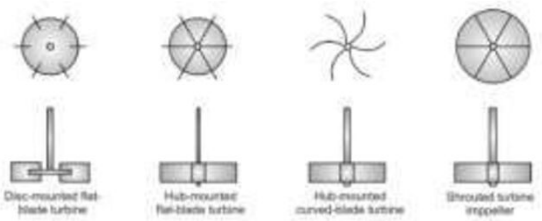
Principles:

- Turbine mixer agitators can create a turbulent movement of the fluids due to the combination of centrifugal and rotational motion.

Construction:

- A turbines consists of a circular disc to which a number of short blades are attached.
- The diameter of the turbine ranges from 30-50% of the diameter of the vessels.

- It rotated at a lower speed than propeller (50-200 RPM)



Working:

- Take a liquid which we have to mixed in a vessels. Then placed the turbine into vessels and start the rotation.
- After certain period when liquid mixed turbine removed from the vessels.

Uses:

- Highly used in chemical reactions and extraction operations. For example, liquid and gas reactions.
- Used in preparing emulsions, suspensions and syrups.

Merits:

- They are highly suitable for making dispersion containing 60% solids.
- As they generate high radial flow efficiency of mixing is high.
- Turbines are used in emulsification as they generate higher shearing forces than propellers even at low pumping rates.

Demerits

- They are not preferred for solvents with high viscosity such as more than 20 cP.
- There is possibility of air entrapment that may cause oxidation of material being mixed.

Paddles

Principles:

- They work on the principle on the principle of Shearing.

Construction:

- A paddle consists of a hub centrally with two long flat blades attached to it vertically.
- Rotates at low speed (100 rpm)
- Paddles with two blades or four blades are common.

Working:

- Take a liquids, which we have to mixed in a tanks, then placed the paddles into tanks and start the rotation.

- A shaft carrying hub-blades at a low speed they push the liquid radially and tangentially.
- After mixing paddles are removed from liquid tanks.

Uses:

- Used in manufacture of antacid suspensions agar and pectin relatives purgatives etc.
- They are used in the mixing of solids, slurries, crystals forming phases during super saturated cooling
- Paddles are used in the manufacture of antacid suspensions and antidiarrheal mixtures such as bismuth-kaolin mixture

Merits:

- As paddle-impellers mixes liquids with low speed the possibility of vortex formation is least.
- These are heavy duty mixers suitable for slow operation.
- They can mix systems effectively with 2 or 4 blades.

Demerits:

- Mixing of the suspensions is poor, thus, baffled tanks are required.
- As they are heavy duty mixers power consumption is very high.
- They are not efficient for mixing variety of materials with different consistencies.

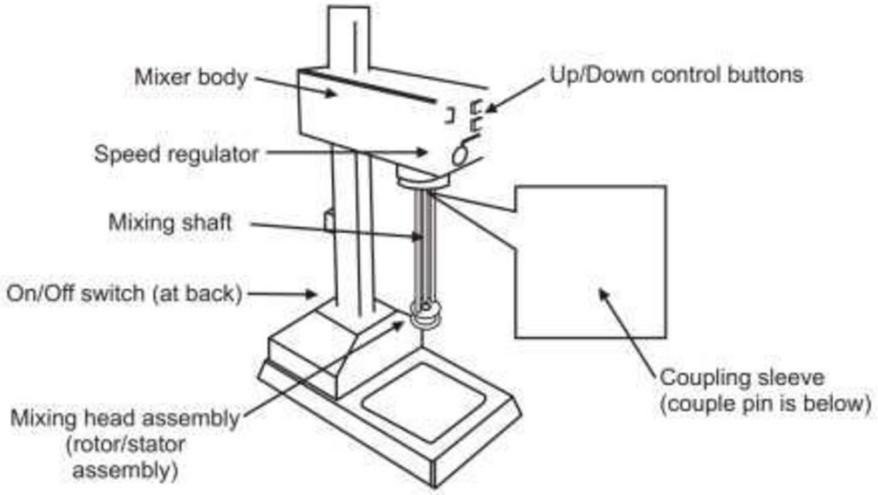
Silverson Emulsifier

Principles:

Silverson mixer produces intense shearing forces and turbulence by the use of high speed rotors. This turbulence causes the liquids to pass through fine interstices formed by closely placed perforated metal sheets. Circulation of material take place through the head by the suction produced in the inlet at the bottom of the head. Circulation of the material ensures rapid breakdown of the dispersed liquid into smaller globules.

Construction:

- It consists of long supporting columns connected to a motor which give support to the head.
- The central portions contain a shaft, one end of which is connected to the motor and the other end is connected to the head.
- The head carries turbine blades.
- The blades are surrounded by a mesh, which is further enclosed by a cover having openings.



Working:

- The emulsifier head is placed in the vessels containing immiscible liquids in such a way that it should get completely dipped in the liquid.
- When the motor is started, the central rotating shaft rotates the head. This in turn rotates turbine blades at a very high speed.
- This creates a pressure difference; as a result liquids are sucked into the head from the center of the base and subjected to intense mixing action.
- The intake and expulsion of the mixture set up a pattern of circulation to ensure rapid breakdown of the bigger globules into smaller globules.

Uses:

- Silverson mixer is used for the preparation of emulsions and creams of fine particle size.

Merits:

- Silverson mixer is available for thousand liter of mixing.

Demerits

- Occasional there is a chance of clogging of pores of the mesh.