UNIT-III

DRYING

INTRODUCTION OF DRYING

- Drying is defined as the removal of small amount of water or other liquid from a material by the application of heat.
- In drying the water vapors is removed at the temperature below the boiling point.

THEORY OF DRYING

Moisture Content-The moisture present in a solid may exist is more than one physical condition.

Bound Water-It is minimum moisture held by the material that exerts an equilibrium vapors pressure less than pure water at the same temperature.

Unbound Water-It is the amount of water held by that exert an equilibrium vapors pressure is equal to that of pure water at same temperature.

- Substances containing bound water are called hygroscopic substance.
- Substances containing unbound water are called non hygroscopic substance.

MECHANISM OF DRYING

- Mechanism of drying can be discussed in two heads namely.

  (1) Equilibrium relationship

  (2)Rate relationship

Equilibrium Moisture Content (EMC)-It is amount of water present in the solid which exert a vapors pressure equal to the vapor pressure of the atmosphere surrounding it.

Measurement of EMC

Sample are placed in a series of closed chamber

↓

Maintain the RH by desicant

↓

Exposure is continue with the material other a constant weight

↓

Difference in the final and initial weight gives the moisture content

Factor affecting of EMC-Mainly two factor are affect the EMC

- (1) NATURE OF MATTERIAL
- (2) NATURE OF AIR

NATURE OF MATERIAL

- Non porous materials like talk have EMC practically equal to zero.
- Fibrous colloidal organic substance has high EMC value.
- Porous solid have much higher EMC value

NATURE OF AIR

- For air of zero humidity, EMC of all material is zero.
- As the temperature of air increase the EMC of solid decrease

Other factor for efficient drying

- Large surface area for heat transfer.
- Efficient heat transfer per unit area (to supply sufficient latent heat of vaporization or heat of sublimation in case of freeze-drying)
- Efficient mass transfer of evaporated water through any surrounding boundary layers, i.e. sufficient turbulence to minimize boundary layer thickness.
- Efficient vapour removal, i.e. low relative humidity air at adequate velocity.
- It is convenient to categorize pharmaceutical driers according to the heat transfer method they use, i.e. convective, conductive or radiant.

FREE MOISTURE CONTENT (FMC)

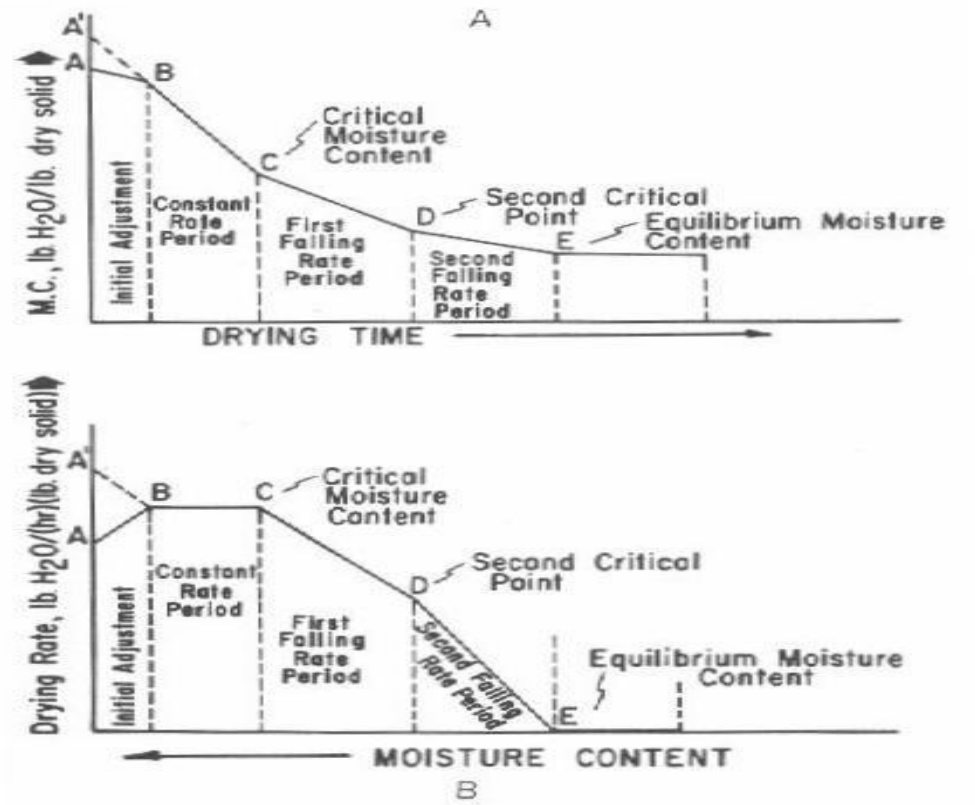
FMC is the amount of water that is free of easy to evaporate from the solid surface.

FMC = TOTAL WATER CONTENT-EMC

DRYING RATE CURVE

The rate at which drying occurs has been found to show certain phases in which the change in moisture content is plotted against time. From A to B the relationship is linear, which is known as the constant-rate period, whereas from B to C the rate of loss of moisture decreases and is known as the falling-rate period. The end of the constant rate period, B,is referred to as the critical moisture content.

- A graph is plotted by taking FMC on x-axis and drying rate on y-axis
- The curve so obtained is called drying rate curve



Explanation of Drying Curve

- In this firstly (AB) represent the initial adjustment period during this period the solid absorbed heat and temperature increase.

In this at equilibrium- Heating=rate of working

- The time corresponding to BC represent the constant rate period the temp. remain constant and the rate of during is constant.
- The moisture evaporating by surface is replaced by the water diffusing from anterior of the solid. In this , **The rate of diffusion=rate of evaporation**
- The time corresponding to CD represent the first falling rate period .Dry spot begins to appear and rate of drying begins to fall of.
- At point D the film of surface water completely evaporated. In this **rate of evaporation>rate of diffusion**
- The time corresponding DE represent the second falling rate period. During this period the rate of drying is represent on the rate of diffusion of vapour of moisture to the surface of the solid .In this the **rate of drying directly promotional to rate of diffusion**
- Beyond E the drying is equal to zero. Therefore moisture content and temp. remain constant. Beyond E continue drying is wastage of time and energy.

Selection of the suitable drying method: The following points should be considered before the selection of the suitable drying method:

- Heat sensitivity the material being dried.
- Physical characteristics of the material.
- Nature of the liquid to be removed.
- The scale of the operation.
- Available sources of heat (steam, electrical)

CLASSIFICATION OF DRYER

A. Static bed dryer
   1.Tray dryer
   2.Freeze dryer

B. Moving bed dryer
   1.Drum dryer
   2.Roller dryer

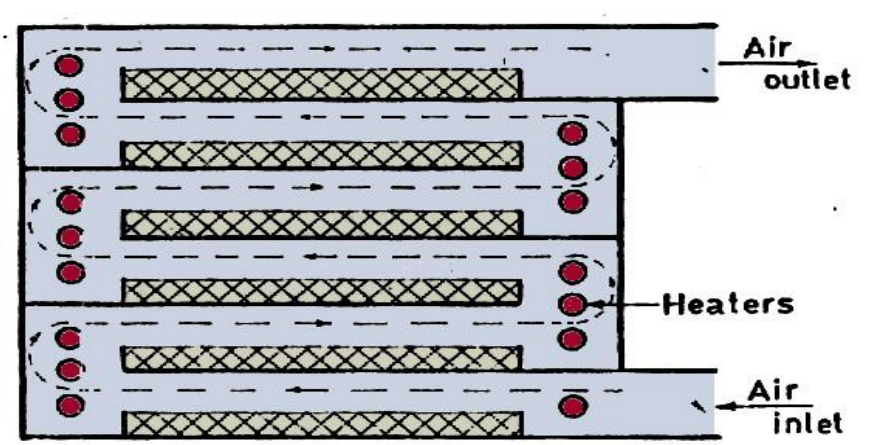
C. Fluidised dryer
   1. F.B.D.
   2. Plug flow dryer

D. Pneumatic dryer
   1. Spray dryer

E. Vacuum dryer
   1. Low pressure dryer
   2. High pressure dryer

TRAY DRYER

Principal-In tray dryer hot air is continuously circulated over the tray Force convection heating takes place to remove moisture from the solid material.Simultaneously the moisture air is removed by circulating fan through outlet damper.



Directed-circulation tray drier

CONSTRUCTION

Working

Wet solid is loaded into tray

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Tray are placed in the chamber

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Fresh air is introduced through inlet

↓

This passes through the heater and get handle up

↓

Hot air is circulate over the tray

↓

Water evaporate from the surface

↓

Constant temp. and uniform air flow over the material can be maintained for achieving uniform drying

Advantage

- In tray dryer handling of material can be done by without loss
- Tray dryer is operate batch wise
- Each batch of material can be handle as a separate entity
- Variable product can be handling efficiently.

Disadvantage

- Tray dryer require more labour to load and unload of the product, hence cost increase.
- The process is time consuming

USES -It is used for-

- Sticky material
- Granular material
- Crystalline solid
- Crude drugs
- Powder
- Tablet granules

FREEZE DRYER

It also known as **lyophilization**. That is system is made solvent loving for removing the same solvent are product.

Principle-In freeze drying water is removed from the frozen state by sublimation. That is direct change of water from solid into vapour without conversion into a liquid phase. Sublimation drying consist of simple reducing the temp. and pressure to value below the triple point. Under these conditions any heat transfer is used as latent heat. The temp. must be below the triple point temp. and it is usual to work range -10 to 30°c **.**Similarly the pressure must be below the triple point and pressure between 10 to 30 N/M^2 .

CONSTRUCTION

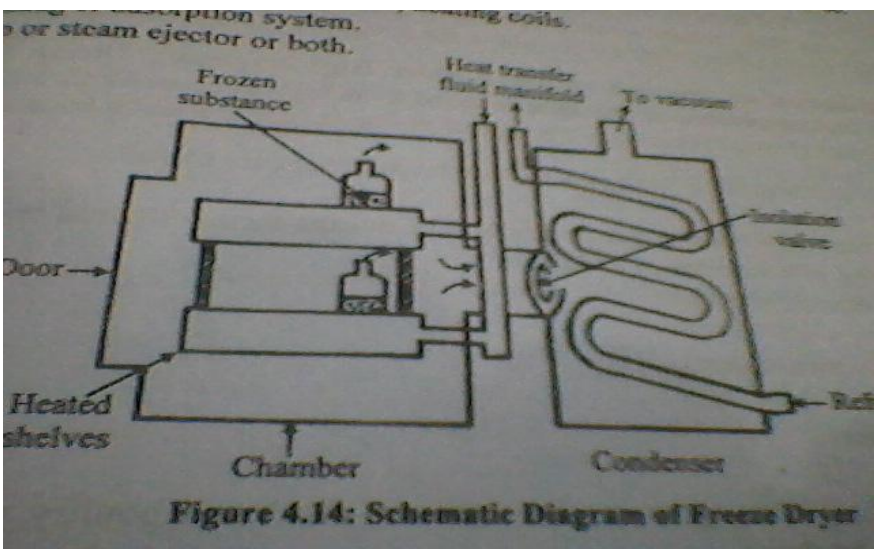

Figure 4.14: Schematic Diagram of Freeze Dryer

- Drying chamber
- Heat supply by heating coil
- Vapour condensing are adsorption system
- Vacuum pump

Working

Preparation and pre treat moist , placed the tray

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Prefreezing for solidifying water

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Primary drying (sublimation of ice water under high vacuum

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Secondary drying (removal of residue moisture under high vacuum)

↓

Remove the tray

↓

Collect the product

Advantage

- Thermo labile material can be dried.
- Denaturation does not occur.
- Migration of salt and other solvent does not takes place
- Loss of volatile material is less.
- Moisture level can be kept very low.
- Stability can be maintained.
- The final product can be stored at low temp.

Disadvantage

- The product is oxidized, some time due to porosity and large surface area.
- Running cost of equipment is high.
- It is not suitable for non-aqueous solvent.
- It is time consuming process

Limitations of the freeze drying

- The depression of the freezing point caused by the presence of dissolved solutes means that the solution must be cooled below the normal freezing temperature for pure water (-10-30).
- Sublimation can only occur at the frozen surface and is slow process (1mm thickness of ice per hour). So, the surface area must therefore be increased and
- The liquid thickness prior to freezing be reduced in order to reduce the thickness of ice to be sublimated.
- At low pressure large volumes of water vapour are produced which must be removed to prevent the pressure rising above the triple point pressure.
- The dry material often needs to be sterile, and it must also be prevented from regaining moisture prior to the final packaging.

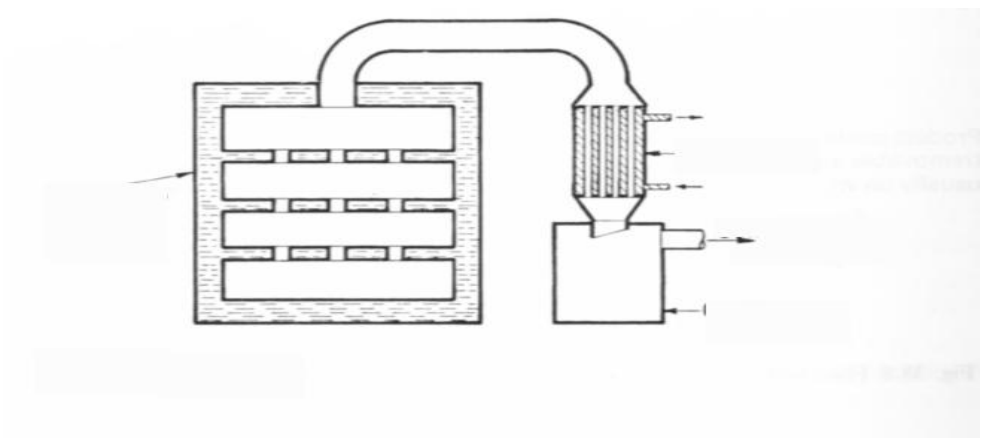
USES

- It is used for following product –
- Blood product and its fractional product
- Bacterial and viral culture
- Human tissue
- Antibiotic and plant extract.
- Steroids , vitamins and enzymes

VACUUM DRYER

Principle-In vacuum dryer the material is dried by the application of vacuum. When vacuum is created the pressure is lowered .So that water boiled at a lower temp.hence water evaporate faster. Operating pressure is usually about 0.03 to 0.06 bar at which pressure water boil at 20 to 30°C

CONSTRUCTION



Working

Material to be dried is spread and trays

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The tray are placed in the drying chamber by vacuum pump

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Increase pressure up to 30-60 kp

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Supply steam heater water heat

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Evaporation of water take place at 25-35°c

↓

End of the drying vacuum line disconnected

↓

Material collected from the tray

Advantage

- Vacuum dryer provides large surface area for heat transfer
- Handling of material ,trays and equipment is easy
- It is easy for switching over to the next materials
- Electrical heated hollow shelves can be used

Disadvantage

- In vacuum dryer ,heat transfer coefficients are low
- It has a limited capacity and used for batch process
- Labour and running costs are high

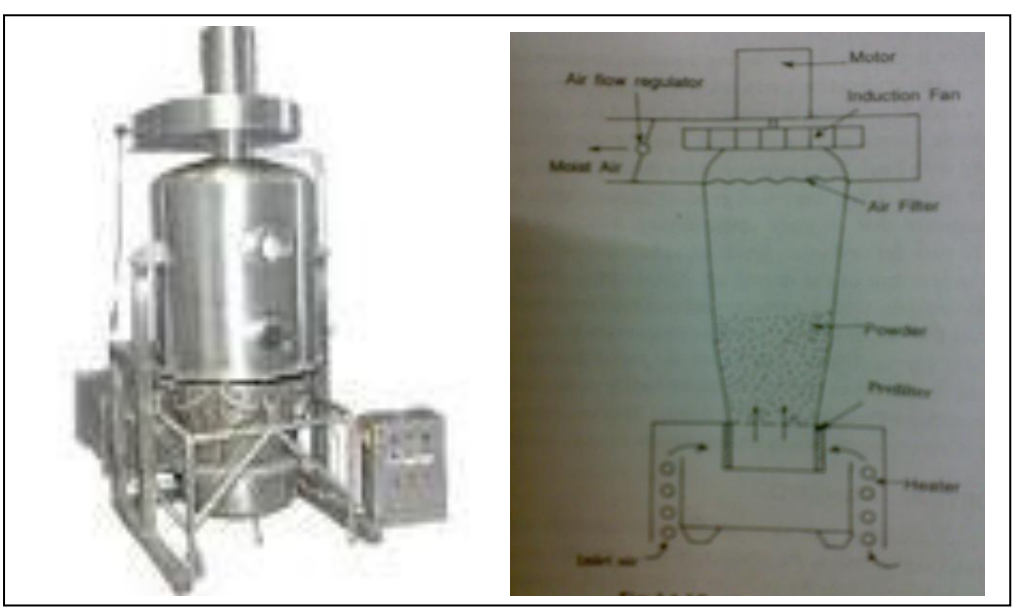
USES

- It is used for following-
- Heat sensitive materials
- Dusty and hygroscopic materials
- Drug containing toxic solvent
- Friable dry extract

FLUIDISED BED DRYER-

Principle:-In fluidized bed dryer hot air is passed at high pressure through a perforated bottom of the container containing granules to bed dried the granules lifted from bottom and suspended it in the steam of air hot gas or air is surrounded every granule to completely dry them. Thus material or granule are uniformly dried.

Construction:-



Working

Drying material in FBD follow following steps-

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Wet granules o be dried are place in detachable bowl.

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Bowl is push into dryer.

↓

Fresh air is allow to enter.

↓

Hot air flow through bottom of the bowl.

↓

Increase velocity of air by rotating the fan.

↓

Material are suspended in air stream.

↓

Gas surrounded every molecule to completely dry them.

↓

Air leaves the dryer by passing through finger filter.

↓

Residence time for drying is about 30-40 minute.

↓

At last detach the bowl and collect the product.

Advantage

- FBD require less time(20-40min)
- Its labor cost is low.
- Its available in different size(5-1300kg/hr)
- Thermal efficiency is 2-6 times greater than tray dryer.
- Higher drying temp can be used
- It is either continuous or batch type process

Disadvantage

- Many powder developed electric charge during drying.
- Some time particle passed out through bag filter.

Uses-

- It is used in drying of granule.
- Also used in mixing of granule and filter.
- Modified form of FBD used in powder coating

SPRAY DRYER

Principle-The spray dryer provides a large surface area for heat and mass transfer by atomizing the liquid to small droplets. These are sprayed into a stream of hot air, so that each droplet dries to a solid particle. The drying chamber resembles the cyclone ensuring good circulation of air, to facilitate heat and mass transfer, and that dried particles are separated by the centrifugal action

CONSTRUCTION

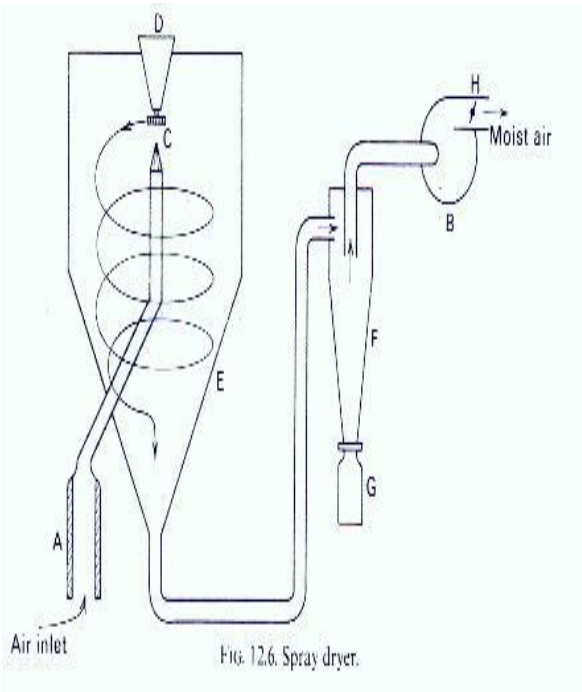


FIG. 12.6. Spray dryer.

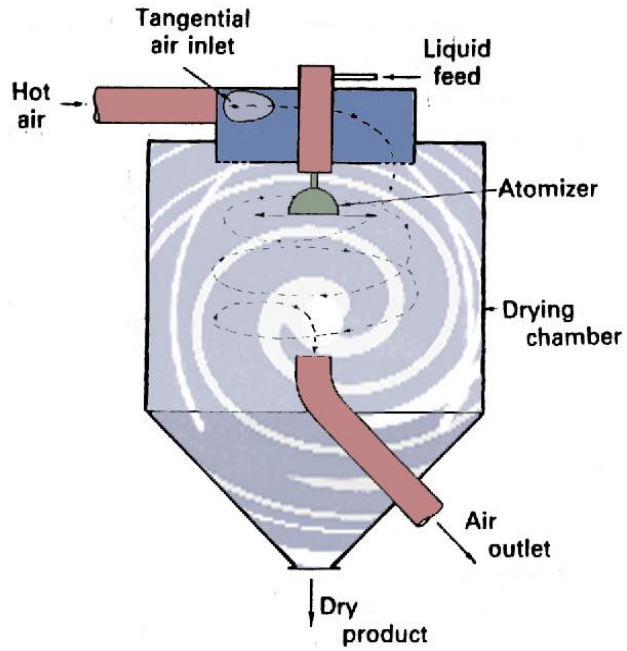
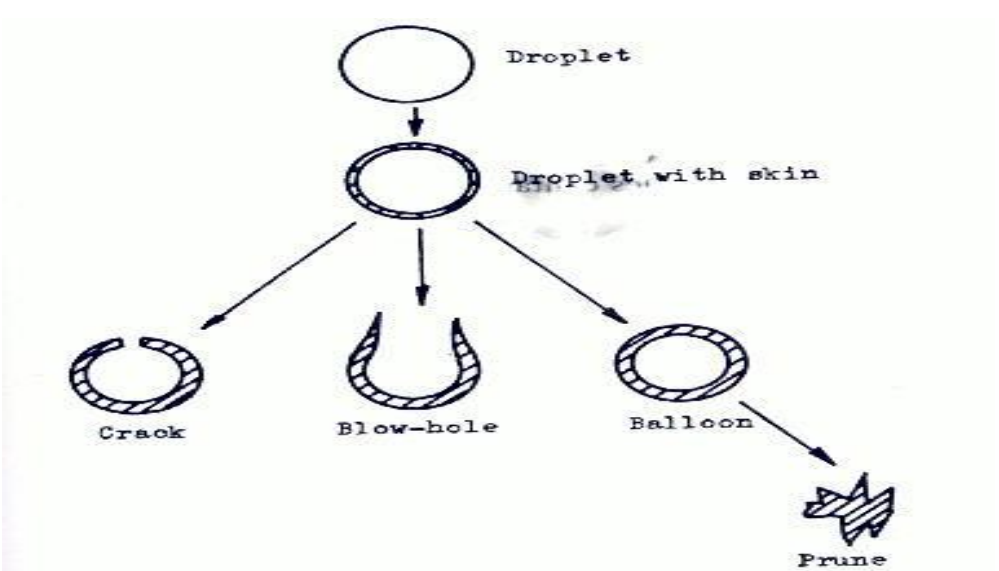


Fig. 38.13 Spray drier

WORKING-The products are uniform in appearance and have characteristic shape, in the form of hollow spheres with a small hole. This arises from the drying process, since the droplet enters the hot air stream, and dries on the outside to form an outer crust with liquid still in the center. This liquid then vaporizes, the vapour escaping by blowing a hole in the sphere. This method of drying allows a dry product to retain some properties of feed , e.g., a drop from an emulsion dries with continuous phase on the outside. When reconstituted, the emulsion is easily re- formed.



Advantages

- The product is free-flowing, with almost spherical particles, and is especially convenient for tablet manufacture.
- Labour costs are low, the process yielding a dry, free-flowing powder from a dilute solution, in a single operation with no handling.
- It is possible to operate spray driers aseptically using heated filtered air to dry products such as serum hydrolysate.
- Some spray driers operate in a closed-circuit mode with an inert gas to minimize oxidation of the product. Volatile solvents can be recovered from such systems.

Disadvantages

- The equipment is very bulky, connected to accessories, fans, heaters,) That is make it expensive

Uses:

- Drying of any substance in solution or in suspension form.
- It is most useful for drying of thermo labile materials e.g. antibiotics.
- Suitable for large quantities solution.
- Suitable for soluble and insoluble substances e.g. citric acid, gelatin, starch.
- It can produce spherical particles in the respiratory range e.g. dry powder inhalers.
- Drying of milk, soap and detergents which are pharmaceutically related compounds.