UNIT: III **(DRYING)**

CLASS:23

TOPIC: PRINCIPAL, CONSTRUCTION, WORKING, USES, MERITS AND DEMERITS OF TRAY DRYER, DRUM DRYER, SPRAY DRYER

CLASSIFICATION OF DRYING EQUIPMENT

The classification based on the method of solids handling is more suitable when special attention is given to the nature of material to be dried. Dryers are classified as given in Table.

Classification of Dryers—Mechanism, Examples, Advantages and Disadvantages

Type of dryer and mechanism	*Examples*	*Advantages*	*Disadvantages*
Static Bed Dryer Systems in which there is no relative movement among the solid particles being dried, although there may be bulk motion of the entire drying mass.	Tray dryer and freeze dryer	Attrition is not observed	Only a fraction of the solid particles is directly exposed
Moving Bed Dryer Systems in which the drying particles are partially separated so that they flow over each other	Drum dryer	The entire material is continuously exposed to heat source	Attrition is possible
Fluidised Bed Dryer Systems in which the solid particles are partially suspended in an upward moving heated gas system	Fluidised bed dryer	Solid-gas contact is excellent, uniform drying	Attrition of particles takes place
Pneumatic Dryer Systems in which drying particles are entrained and conveyed at a high velocity gas stream	Spray dryer	Efficient and rapid drying	Attrition of particles takes place

As per the principal mole of operation (regulatory guidance document), dryers are classified as follows.

Direct heating dryers: These allow intimate contact between the material being dried and the heat energy source (heated gas). The same gas is allowed to transport the vapour released from the material. E.g., tray dryer and fluidized bed dryer.

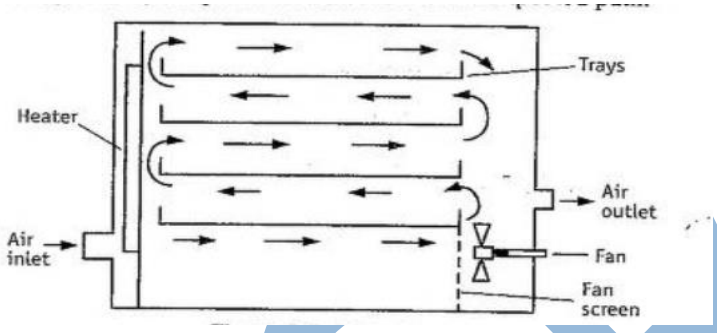
Indirect heating dryers: In this type, energy is transferred from the source (heated liquid) to the material being dried through a conducting wall. E.g., vacuum dryer and drum dryer. Indirect dryer would also be needed when a material requires absolute sterility, for example, sterile solid for injection or reconstitution with sterile water.

EQUIPMENT

Tray Dryer

Principle: In tray dryer, hot air is continuously circulated. Forced convection heating takes place to remove moisture from the solids placed in trays. Simultaneously, the moist air is removed partially.

Construction: The construction of a tray dryer is shown in Figure. It consists of a rectangular chamber whose walls are insulated. Trays are placed inside the heating chamber. The number of trays may vary with the size of the dryer.



Tray dryer.

Dryers of laboratory size may contain a minimum of three trays, whereas dryers of industry size may contain more than 20 trays. Each tray is rectangular or square and about 1.2 to 24 metres square in area. Trays are usually loaded from 10.0 to 100.0 millimetres deep. The distance between the bottom of upper tray and (upper) surface of the substance loaded in the subsequent tray must be 40.0 millimetres.

Alternately the trays can be placed in trucks on wheels, which can be rolled into and out of chamber. Two such trucks can be arranged inside dryer. Dryer is fitted with a fan for circulating air over the trays. Electrically heated elements are provided inside (rather than outside) to heat the air (steam also can be used as it is cheaper). In the corner of the chamber, direction vanes (not shown in Figure) are placed to direct air in the expected path.

Working: Wet solid is loaded into trays. Trays are placed in the chamber. Fresh air is introduced through inlet, which passes through the heaters and gets heated up. The hot air is circulated by means of fans at 2 to 5 metre per second. Turbulent flow lowers the partial vapour pressure in the atmosphere and also reduces the thickness of the air boundary layer. The water is picked up by air. As water evaporates from the surface, the water diffuses from the interior of the solid by capillary action. These events occur in a single pass of air. The time of contact is short and the amount of water picked up in a single pass is small. Therefore, the discharged air to the tune of 80 to 90% is circulated back through fans. Only 10 to 20% of fresh air is introduced. Moist air is discharged through outlet. Thus, constant temperature and uniform airflow over the material can be maintained for achieving uniform drying.

In case of wet granules (as in tablets and capsules) drying is continued until the desired moisture content is obtained. At the end of drying, trays (trucks) are pulled out of the chamber and taken to a tray dumping station.

Uses: Sticky materials, plastic substances, granular mass or crystal- line materials, precipitates and pastes can be dried in a tray dryer. Crude drugs, chemicals, powders, tablet granules or parts of equipment are dried.

Advantages:

1. In tray dryer, handling of materials (loading and unloading) can be done without losses.
2. Tray dryer is operated batch-wise. Batch drying is used extensively in the manufacture of pharmaceuticals for the following reasons.
   a) Each batch of material can be handled as a separate entity.
   b) The batch sizes in the pharmaceutical industry are relatively small (250 kg or less per batch) compared with the chemical industry (1000 kg or more per hour).
   c) The same equipment is readily adjusted for use in drying a wide variety of materials.
   d) Valuable products can be handled efficiently.

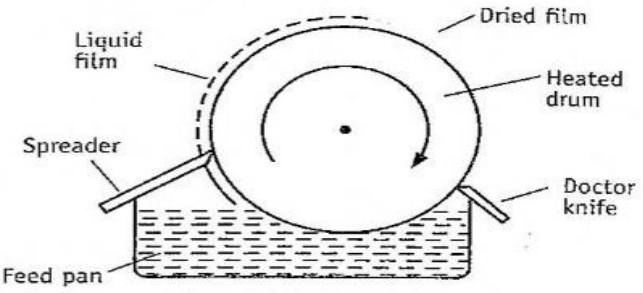
Disadvantages: Tray dryer requires more labour to load and unload. Hence, cost increases. The process is time consuming.

Variants: Tray dryer may be operated under vacuum, often with indirect heating. This is done in special vacuum tray dryers for drying vitamins and other heat-sensitive products.

Tunnel dryer: In this type, trucks are loaded with wet material at one end of the tunnel. The tunnel comprised of a number of units, each of which is electro-statically controlled. The solids get dried and the product is discharged at the other end of the tunnel.

Drum dryer or Roller Dryer (or Film Drum Dryer)

Principle: In drum dryer, a heated hallow metal drum rotates on its longitudinal axis, which is partially dipped in the solution to be dried. The solution is carried as a film on the surface of the dryer and dried to form a layer. A suitable knife scraps the dried material, while the drum is rotating.



Drum dryer

Construction: The construction of a drum dryer is shown in Figure. It consists of a horizontally mounted hollow steel drum of 0.6 to 3.0 metres diameter and 0.6 to 4.0 metres length, whose external surface is smoothly polished. Below the drum, feed pan is placed in such a way that the 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 (or a conveyor) is placed connecting the knife to collect the material.

Working: Steam is passed inside the drum. Heat transfer coefficient of the drum metal is high. Drying capacity is directly proportional to the surface area of the drum. Heat is transferred by conduction to the material. Simultaneously drum is rotated at a rate of 1-10 revolutions per minute. 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 (i.e., from one side to another side of the drum). The dried material is scrapped by the doctor's knife, which then falls into a storage bin. The time of contact of the material with hot metal is 6 to 15 seconds only. Therefore, processing conditions such as film thickness, steam temperature are closely controlled.

Uses: Drum dryer is used for drying solutions, slurries, suspensions etc. The products dried are milk products, starch products, ferrous salts, suspensions of zinc oxide, suspension of kaolin, yeast, pigments, malt extracts, antibiotics, glandular extracts, insecticides, DDT, calcium and Barium carbonates.

Advantages:

1. In drum dryer, drying time is less, only a few seconds. There fore, heat sensitive materials can be dried.
2. Drum dryer occupies less space, as it is compact when compared to spray dryer.
3. As a thin film of liquid is formed on the large heating surface. Rates of heat transfer and mass transfer are high.
4. The product obtained is completely dried and is in the final form.

Disadvantages:

1. Maintenance cost of a drum dryer is higher than spray dryer.
2. Skilled operators are essential to control feed rate, film thickness, speed of rotation and temperature.
3. It is not suitable for solutions of salts with less solubility.

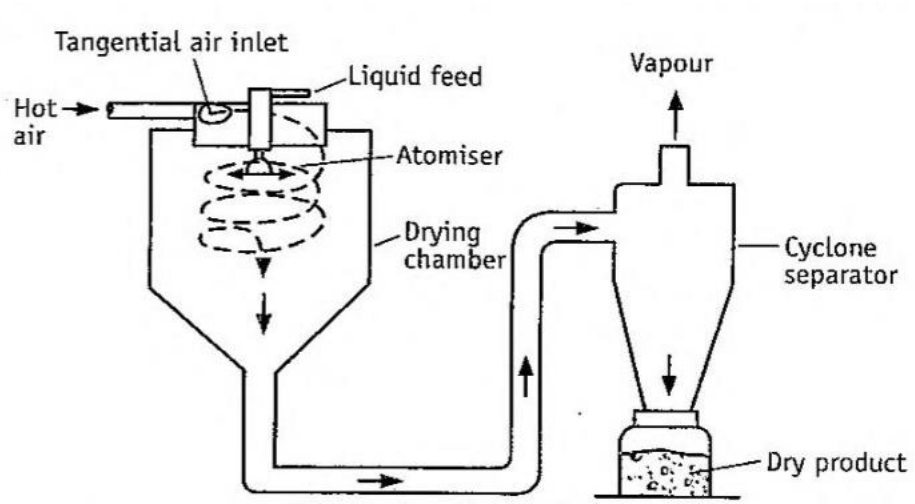
Variants: A vacuum drum dryer encloses both drum and feed line in a vacuum chamber to facilitate of heat sensitive materials. It is suitable for drying of drugs susceptible to oxidation and to recover solvents.

In a large scale, instead of one drum, two drums are set in parallel. Rotating in opposite directions with a common feed inlet. The feed can be introduced on to the drum either by spraying it on the top or by introducing from the bottom.

Spray Dryer

Principle: In spray dryer, the fluid to be dried is atomized into fine droplets, which are thrown radially into a moving stream of hot gas. The temperature of the droplets is immediately increased and fine droplets get dried instantaneously in the form of spherical particles. This process completes in a few seconds before the droplets reach the wall of the dryer.

Construction: The construction of a spray dryer is shown in Figure. It consists of a large cylindrical drying chamber with a short conical bottom. Made up of stainless steel (diameter of the drying chamber ranges between 2.5 to 9.0 metres and height is 25.0 metres or more). An inlet for hot air is placed in the roof of the chamber. Another inlet carrying spray-disk atomizer is set in the roof (shown in Figure 10-6). The spray disk atomizer is about 300 millimetres in diameter and rotates at a speed of 3,000 to 50,000 revolutions per minute. Bottom of the dryer is connected to a cyclone separator.



Spray dryer

Working: Drying of the material in spray dryer involves 3 stages.

1. Atomization of the liquid.
2. Drying of the liquid droplets.
3. Recovery of the dried product

Atomization of the liquid to form liquid droplets: The feed is introduced through the atomizer either by gravity or by using suitable pump to form fine droplets. The properties of the final product depend on the droplet form, hence, the selection of the type of atomizer is important. Atomizer of any type: pneumatic atomizer, pressure nozzle and spinning disc atomizer may be used.

The rate of feed Is adjusted in such a way that the droplets should be completely dried before reaching the walls of the drying chamber. At the same time, the product should not be over heated.

Drying of the liquid droplets: Fine droplets are dried in the drying chamber by supplying hot air through the inlet.

The surface of the liquid drop is dried immediately to form a tough shell. Further, the liquid inside must escape by diffusing through the shell at a particular rate. At the same time, heat transfer from outside to inside takes place at a rate greater than liquid diffusion rate. As a result, beat inside mounts up which allows the liquid to evaporate at a faster which causes the droplets to swell. The shell's thickness decreases This tendency of a liquid leads to rise in the internal pressure, where as permeability for vapour increases. If the shell is neither elastic nor permeable, it ruptures and the internal pressure escapes

The temperature of air is adjusted in such a way that the droplets should be completely dried before reaching the walls of the drying chamber. At the same time, the product should not be over heated

Recovery of the dried product: Centrifugal force of atomizer drives the droplets to follow helical path Particles are dried during their journey and finally fall at the conical bottom.

All these processes are completed in a few seconds. Particle the final product ranges from 2 to 500 mm Particle size depends on solid content in the feed, liquid viscosity, feed rate and disc speed. Spray dryers of maximum size have got evaporating capacity up to 2000 kg per hour. Size of

Uses: Spray dryers are used compulsorily, if

1. The product is a better form than that obtained by any other dryer
2. The quantity of the material to be dried is large
3. The product is thermolabile, hygroscopic or undergoes chemical decomposition.

A few products that are dried using spray dryer are:

acacia	citric acid	hormones	soaps
adrenaline	coffee extract	lactose	sodium phosphate
bacitracin	detergents	methyl cellulose	starch
barium sulphate	dextran	milk	sulphur
blood	extracts	pancreatin	vaccines
borax	ferrous sulphate	penicillin	vitamins
boric acid	fruit juices	pepsin	yeast
calcium sulphate	gelatin	plasma	
chloramphenicol succinate	hexamine	serum	

Advantages:

1. Spray drying is a continuous process and drying is very rapid. Drying completes within 3 to 30 seconds.
2. Labour costs are low as it combines the function of an evaporator, a crystallizer, a dryer, a size reduction unit and a classifier
3. By using suitable atomizer, the product of uniform and controllable size can be obtained. Free flowing product of uniform spheres is formed which is very convenient for tabletting process
4. Fine droplets formed provide large surface area for heat and mass transfer. Product shows excellent solubility.
5. Either the solution or suspension or thin paste can be dried in one step to get the final product ready for package
6. It is suitable for the drying of sterile products
7. Reconstituted product appears more less similar to the fresh material
8. Globules of an emulsion can be dried with the dispersed phase inside and layer of the continuous phase outside. On reconstitution, the emulsion will be formed.

Disadvantages:

1. Spray dryer is very bulky (height of 250 metres and diameter of 9.0 metres) and expensive.
2. Such a huge equipment is not always easy to operate
3. The thermal efficiency is low, as much heat is lost in the discharged gases.

Variants:

(1) Spray dryer can be constructed in such a way as to suit sterile products.
(2) It can be operated under closed conditions to recover solvents.
(3) It can be operated under oxygen free environment
(4) It can be constructed in such a way that the flow of liquid and gas may be co-current, counter current or a combination of both in the same unit.
(5) The same equipment can be used for spray congealing.
(6) It is useful for encapsulation (coating) of solid and liquid particles

MCQ Each carry 1 mark

1. Which equipment is used for drying methylcellulose?
    a. Drum dryer
    b. Spray dryer
    c. Tray dryer
    d. Vacuum dryer
2. Which product is not dried by a spray dryer?
    a. Bacterial & viral cultures
    b. Fruit juice
    c. Lactose
    d. Serum
3. In which of the following dryer, Atomizers are used
    a. Roller dryer
    b. Drum dryer
    c. Tray dryer
    d. Spray dryer
4. Drying process takes long time in one of following equipment
    a. Spray dryer
    b. Fluidized bed dryer
    c. Tray dryer
    d. Drum dryer
5. In a spray dryer, the particle size is closely controlled by one of the following parts of the dryer.
    a. Atomizer
    b. Cyclone separator
    c. Drying chamber
    d. Fluid bed
6. Which one of the following is an example of static bed dryer?
    a. Drum dryer
    b. Fluidised bed dryer
    c. Spray dryer
    d. Tray dryer
7. The product becomes porous, when the following equipment for drying is used.
    a. Drum dryer
    b. Fluidised bed dryer
    c. Spray dryer
    d. Tray dryer
8. Thermolabile substances CANNOT be dried using one the following equipment.
    a. Drum dryer
    b. Lyophilizer
    c. Spray dryer
    d. Tray dryer

Each carry 2 marks

1. Labour costs are low in a spray dryer compared to other dryers. Why?
2. Suggest a dryer that can be used in oxygen free environment and explain the conditions.
3. Why does the product develop electrostatic charges during drying. How can it be prevented?

4. Suggest a suitable modification of batch type tray dryer to a continuous dryer.
5. Suggest a suitable modification in a drum dryer of indirect heating can function for direct heating.
6. Is it necessary to use always air in a spray dryer? Explain.
7. What are the advantages of vacuum dryer over tray dryer? Explain.
8. What is meant by pressure gradient in tray dryer? How is it achieved?

Each carry 5 marks

1. Explain the principle of spray drying with suitable labelled diagram.
2. Explain the principle and working of drum dryer.
3. Describe the function of drum dryer and its uses.
4. Compare the operations of spray dryer and tray dryer.
5. Describe the concept of spray dryer. What are its advantages?
6. Compare the spray drying with other methods of drying.

Each carry 10 marks

1. Describe the concept of spray drying. Describe the specific advantages of spray dried product over drum dried material. Also list the pharmaceutical applications.
2. How do you classify dryers? Describe in detail the constant rate and falling rate periods. Add a note on critical moisture content.
3. For drying of milk, we can use either drum dryers or spray dryers. Which dryer will you prefer and why? Discuss drum dryers in detail.
4. Discuss the construction, working, advantages and disadvantages of spray dryer.