

Industrial Process Control (ISC 701)

Dryer

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Introduction

- ❑ The term drying refers generally to the removal of moisture from a substance.
- ❑ It is one of the oldest, most commonly used and most energy consuming unit operation in the process industries.
- ❑ Drying is often necessary in various industrial operations particularly in chemical process industries to remove moisture from a wet solid, a solution or a gas to make it dry and choice of drying medium is depends on the chemical nature of the materials.

Three basic methods of drying are used today

- 1) sun drying, a traditional method in which materials dry naturally in the sun,
- 2) hot air drying in which materials are exposed to a blast of hot air
- 3) freeze drying, in which frozen materials are placed in a vacuum chamber to draw out the water

Classification of dryers

Drying processes and equipment may be categorized according to several criteria, including the nature of material and the method of heat supply and the method of operation.

Drying equipment is classified in different ways, according to their design and operating features.

It can be classified based on mode of operation such as batch And continuous,

Batch Type Dryers

- Tray Dryer
- Pan Dryer
- Vacuum Dryer

Continuous Dryer

- Rotary Dryer
- Drum Dryer
- Spray Dryer
- Flash Dryer
- Fluidized Bed Dryer
- Screen Conveyor Dryers

Batch Type Dryers

□1. Tray Dryer

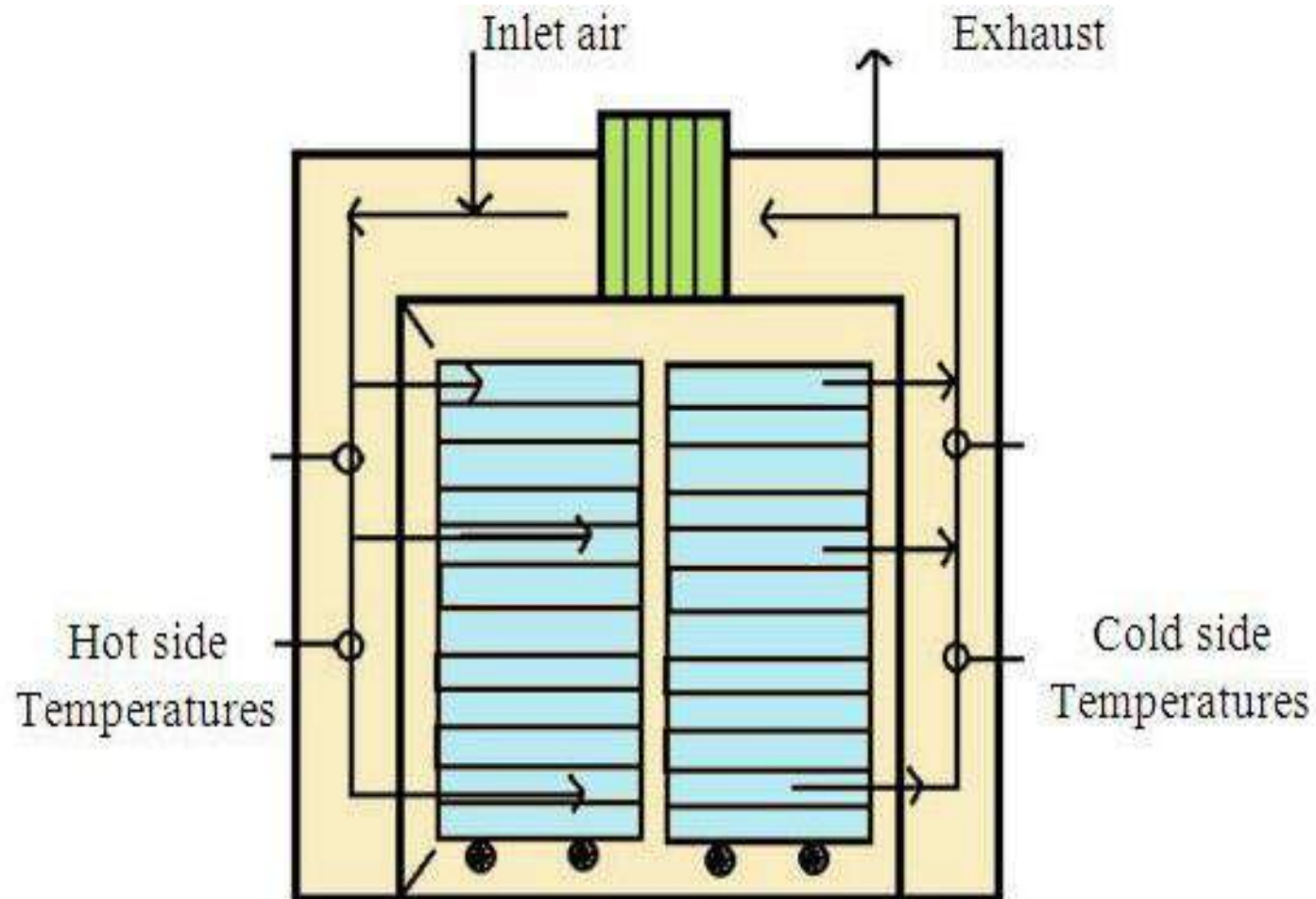


Fig 1. Tray Dryer

Tray Dryer

- ❑ Tray dryers usually operate in batch mode, use racks to hold product and circulate air over the material.

- ❑ It consists of a rectangular chamber of sheet metal containing trucks that support racks. Each rack carries a number of trays that are loaded with the material to be dried.

- ❑ Hot air flows through the tunnel over the racks. Sometimes fans are used to on the tunnel wall to blow hot air across the trays.

- ❑ Even baffles are used to distribute the air uniformly over the stack of trays.

- ❑ Some moist air is continuously vented through exhaust duct; makeup fresh air enters through the inlet.
- ❑ The racks with the dried product are taken to a tray-dumping station

Tray Dryer

Advantages:

- No loss of substances during handling.
- It is a batch dryer. Thus small amount of wet-solid mixtures can also be dried separately.
- The machine is easier to operate and repair.
- Good control to heat and humidity.
- It may be operated under vacuum.
- Through circulation drying can be provided by modifying it

Tray Dryer

Disadvantages:

1. Only a fraction of the solid particles is directly exposed. Heat transfer and mass transfer are comparatively inefficient.
2. It is not suitable for large scale production.
3. It requires high labor usually associated with loading and unloading the compartments.
4. The method is time consuming (24 hours).

Uses:

Sticky materials, granular mass or crystalline materials, precipitates and paste can be dried in a tray dryer.

□ 2.Pan Dryer

- The atmospheric pan drier has a jacketed round pan in which a stirrer or mill revolves slowly, driven from below.
- The slow moving stirrer exposes fresh surfaces and thereby raises the rate of evaporation and, hence, of drying.
- The pan drier is a batch machine and is limited to small batches. Pan driers may be used first to evaporate a solution to its crystallizing concentration and then can function as a crystallizer by sending cold water instead of steam into the jacket.
- The effect of the stirrer during crystallization prevents the growth of large crystals and promotes formation of small, uniform crystals.
- The mother liquor is then drained off and the crystals dried in the same apparatus

3. Vacuum Dryer

Principle:

In vacuum dryer, material is dried by the application of vacuum.

When vacuum is created the pressure is lowered so that water boils at a lower temperature. Hence water evaporates faster.

The heat transfer becomes efficient, i.e., rate of drying enhances substantially.

3. Vacuum Dryer

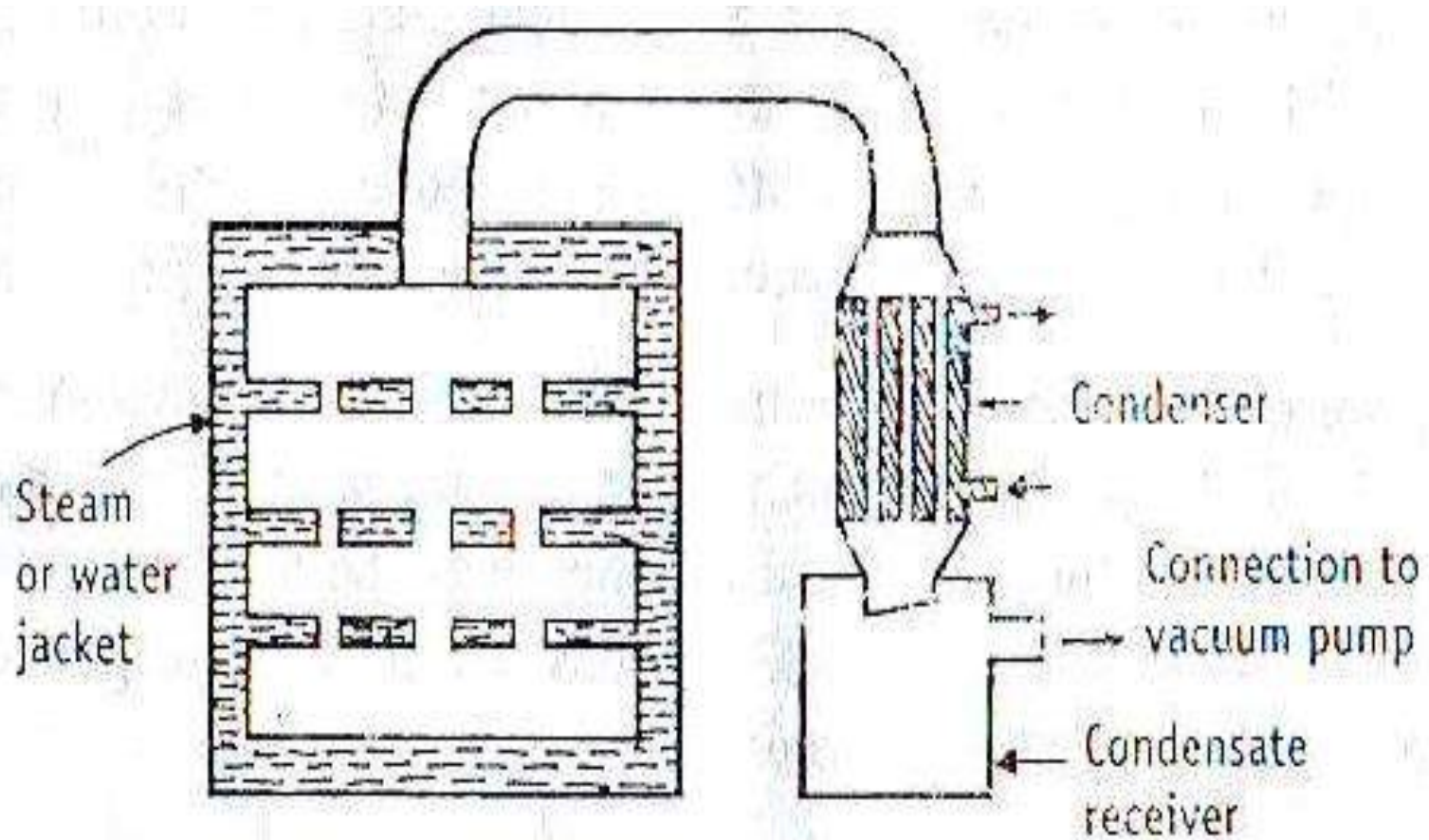


Figure 14-7. Vacuum dryer.

Fig 2 Vacuum Dryer

3.Vacuum Dryer.....

It consists of a cast iron heavy jacketed vessel.

It is so strong that it can withstand the vacuum within the oven and steam pressure in the jacket.

The inner space is divided into a number of portions (shelves), which are part of the jacket.

These shelves provide larger surface area for conduction of heat.

Over the shelves, metal trays are kept for keeping the material

The oven is connected to a vacuum pump by placing condenser in between. Pressure is usually decreased to 30 – 60 kPa.

Steam or hot air is passed through the hollow space of jacket and shelves

3. Vacuum Dryer.....

Advantages:

1. Vacuum dryer provides large surface area for heat transfer.
2. Handling of the material, trays and equipment is easy.
3. It is easy for switching over to the next materials.
4. Hot water of desired temperatures can be supplied.
5. Electrically heated hollow shelves can be used.

3. Vacuum Dryer.....

Disadvantages:

1. In vacuum dryer, heat transfer coefficients are low.
2. It has a limited capacity and used for batch process.
3. It is more expensive than dryer. Labour and running costs are also high.
4. Sometimes, there is a danger of over heating as the material as the material is in contact with steam heated surface for longer period.

Continuous Dryer....

Drum Dryer

- ❑ It is a moving bed dryer. It consists of a horizontally mounted hollow steel drum of 0.6 to 3.0 meter diameter and 0.6 to 4.0 meter length, whose external surface is smoothly polished.
- ❑ Steam or heating coils can be used inside the drum for heat generation. Heat is transferred by conduction to the material that can be controlled with a thermostat.
- ❑ Drum is rotated with a motor device at 1-10 rpm.
- ❑ The liquid or paste material present in the feed pan adheres as a thin layer to the external surface of the drum during its rotation.

Drum Dryer

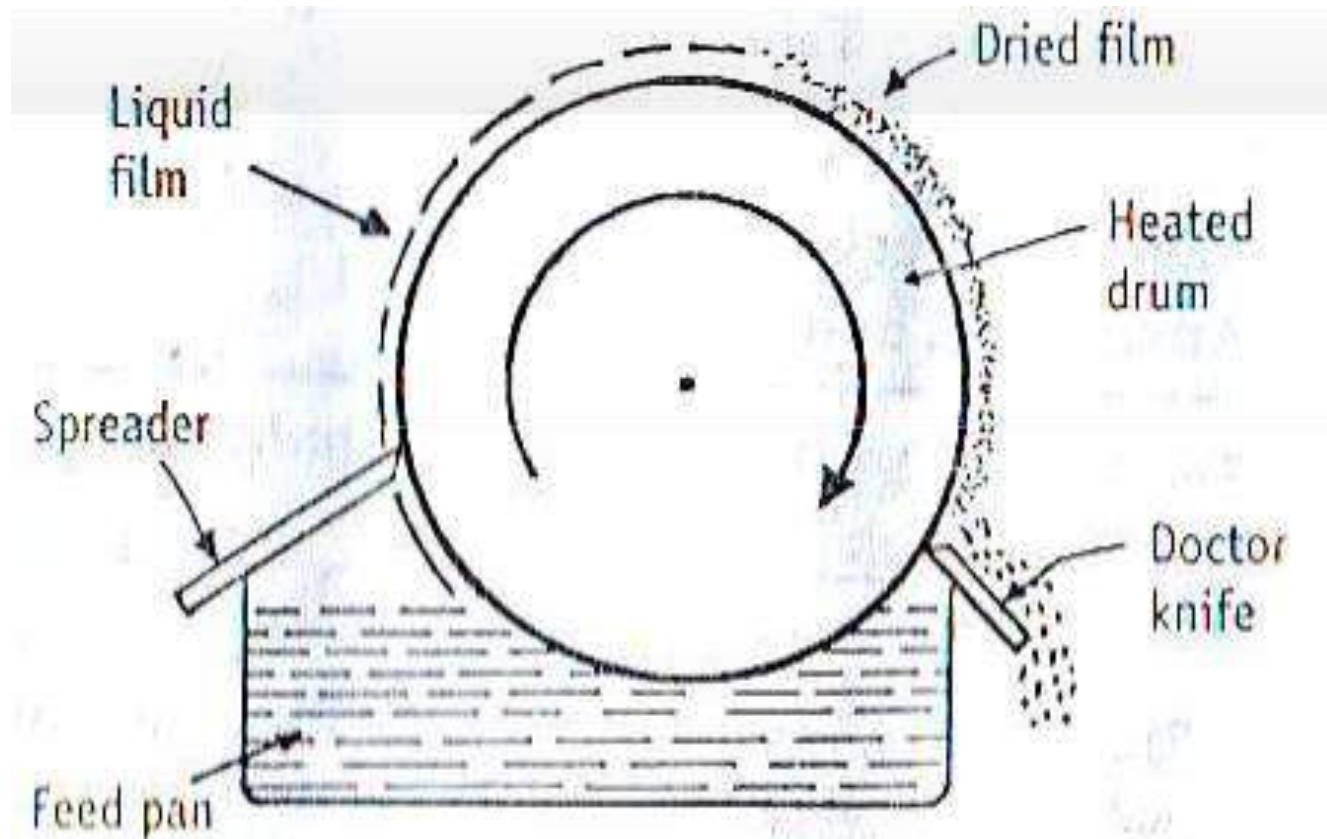


Figure 14-4. Drum dryer.

Drum Dryer

- Wet materials are completely dried during its journey in slightly less than one rotation (from one side to another side of the drum).
- Dried materials are scrapped by a knife, which than falls into a storage bin.
- Contact time of the material with hot metal is 6 to 15 seconds only.
- Therefore, processing conditions such as film thickness and drum temperature are closely controlled.

Drum Dryer

Advantages:

1. This dryer gives a rapid (few seconds) drying and its mass transfer rate is higher.
2. The entire material is continuously exposed to uniform heat.
3. The equipment is compact.
4. Attrition is not possible.

Disadvantages:

1. Operating conditions are critical. Skilled operators are needed to control feed rate, film thickness, speed of rotation and temperature.
2. It is not suitable for solutions or suspensions of low viscosity. of salts with less solubility (**solutes will be precipitated at the bottom**)

Drum Dryer

Uses:

- 1) Drum dryer is used for drying solutions, slurries, suspensions etc.
- 2) The products dried are starch products, ferrous salts, suspensions of zinc oxide, suspension of kaolin, yeasts, pigments, malt extracts, antibiotics, calcium, insecticides, barium carbonates etc.

Pneumatic Dryers

Principle: Systems in which the drying particles are entrained and conveyed in a high velocity gas stream.

This systems further improved on fluidized bed. Ex : Spray dryer

Spray dryer

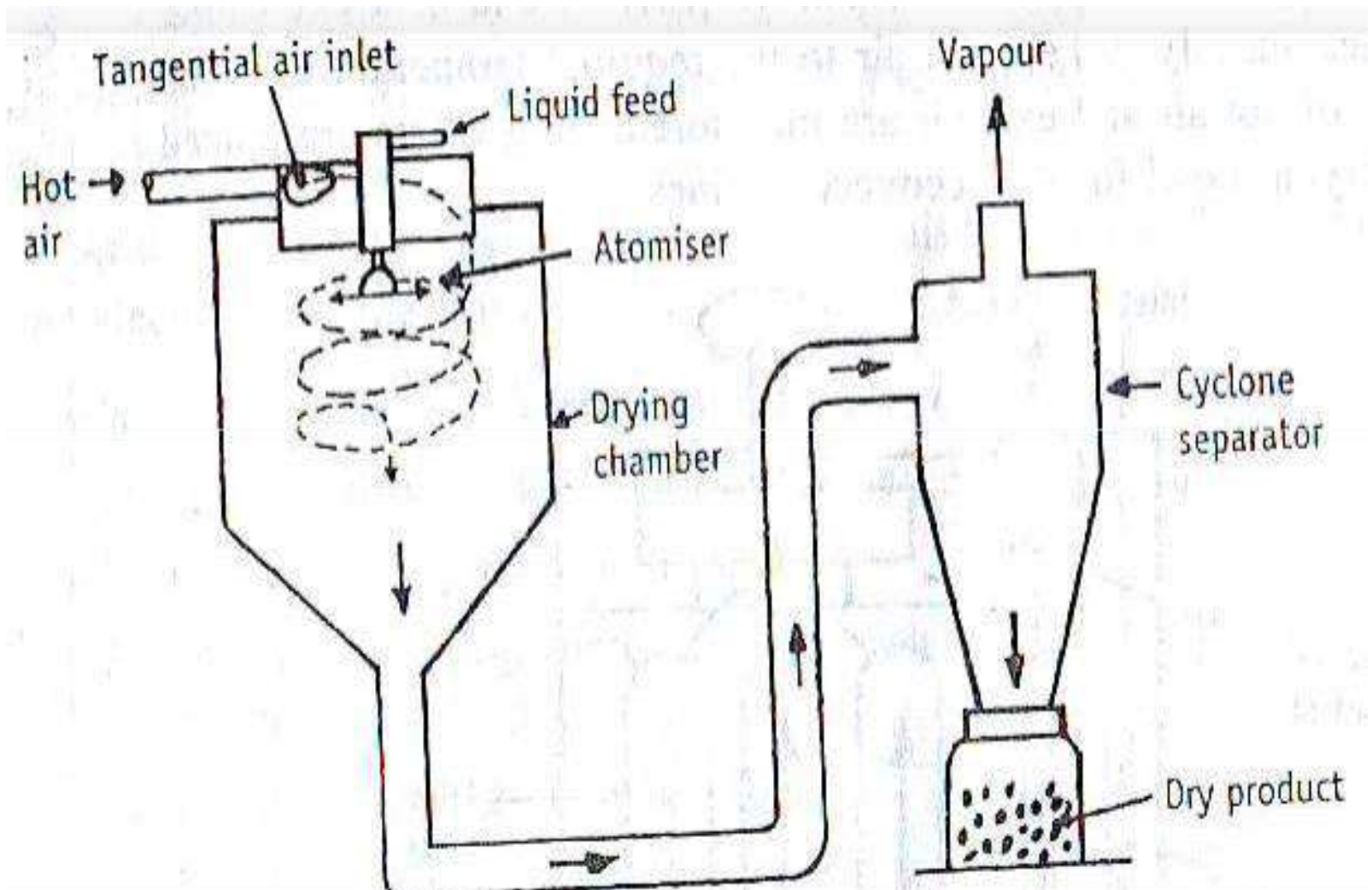


Figure 14-5. Spray dryer.

Operation: Drying of the materials in spray dryer involves 3 stages-

1. Atomization of the liquid from liquid droplets.
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.

Spinning Disc Atomizer.

- ❑ 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, heat inside mounts up which allows the liquid to evaporate at a faster rate.

This tendency of a liquid leads to rise in the internal pressure, which causes the droplets to swell. The shell's thickness decreases where as permeability for vapor 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. Particles size of the final product ranges from 2 to 500 μm . Particles size depends on solid content in the feed, liquid viscosity, feed rate and disc speed.
- ❑ Spray dryer of maximum size have got evaporating capacity up to 2000 kg per hour.

Advantages:

1. The method is a continuous process and drying is rapid and efficient. Drying completes within 3 to 30 seconds.
2. No problem with heat sensitive materials.
3. Fine droplets provide large surface area resulting in efficient heat and mass transfer.
4. Using a suitable atomizer, the product of uniform and controllable particle size can be obtained.
5. Labour costs are low.
6. It is suitable for the drying of sterile products.
7. Either the solution or suspension or thin paste can be dried in one step to get the final product ready for package.
8. Globules of an emulsion can be dried with the dispersed phase inside and continuous phase outside. On reconstitution, the same emulsion will be formed

Disadvantages:

1. Solids can't be dried.
2. Only low viscous liquid can be dried.
3. The method is very bulky and expensive.
4. The thermal efficiency is low, as much heat is lost in the discharged gases.
5. Such a huge equipment is not always easy to operate.
6. Suitable for encapsulation (coating) of solid and liquid particles.

Uses:

Spray dryers are caused 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 thermo labile, hygroscopic or undergoes chemical decomposition.

Example of few products are dried using spray dryer : Acacia, blood, borax, plasma, serum, adrenalin, fruit juice.

Fluidized Bed Dryer

Consists of a compressed air system, pre-filter, heating device, a perforated platform, a harmonizer, a swollen canvas chamber, a thermostat and a timer.

Here wet solid particles are partially suspended in an upward moving forceful hot air stream. In this dryer, **wet granules are contained on the perforated platform**, compressed hot air is passed through the harmonizer.

Compressed **hot air stream** of varying speed **lifts the granules from the bottom**. This condition creates a wavelike surface and is called fluidized state.

The hot gas surrounds every granule to completely dry them. Thus materials or granules are rapidly and uniformly dried.

Fluidized Bed Dryer

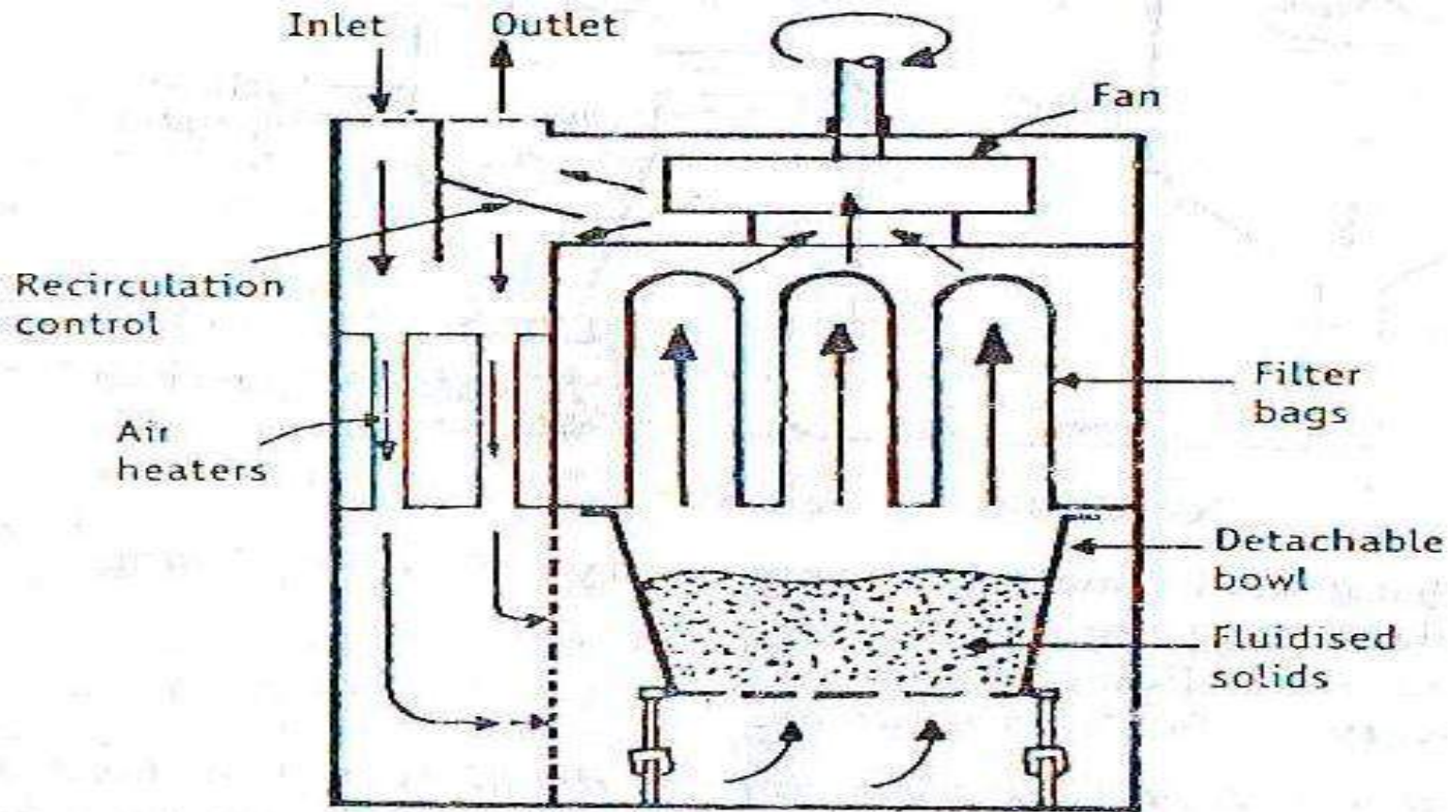


Figure 14-6. Fluidised bed dryer.

Fluidized Bed Dryer

- The air velocity is gradually increased inside the chamber that makes the canvas to swell producing a bigger space for the particles to suspend.
- When air velocity is greater (1.5 - 7.5 meter per second) than the settling velocity of granules due to gravitational attraction, the wet granules remain partially suspended in the hot air stream.
- This makes the wet granules to dry quickly and fall back in a random boiling motion.
- The bags are shaken to remove the entrained particles.
- The **residence time** for drying in this dryer is **about 40 minutes**. The end product is free flowing.

Fluidized Bed Dryer

Advantages:

1. Efficient heat and mass transfer giving high drying rates, thus drying times are shorter than the static bed dryers (15 times faster than tray dryer).
2. The temperature of a fluidized bed is uniform throughout the system and can be controlled precisely.
3. The unit has a high output from a small floor space.
4. Its thermal efficiency is 2 to 6 times than a Tray Dryer.
5. Can be used as either batch type or continuous type.
6. Can also be used **as a mixer**.
7. Also improves uniformity of mixing the ingredients.
8. Very quick and economic dryer.
9. No hotspots are seen like tray dryer.
10. Higher drying temp. can be used compared to tray dryer.

Fluidized Bed Dryer

Disadvantages:

1. Turbulence of the fluidized state may cause excessive attrition of some particles, with damage to some granules and the production of too much dust. So, product loss may occur.
2. Liquid, too wet, sticky and adhesive materials can't be dried.
3. The cleaning of screen and bag filter is troublesome to avoid contamination.
4. Vigorous movement of particles in hot dry air can lead to the generation of static electricity charges and suitable precautions must be taken.

Uses:

1. This dryer is very suitable for drying of granules in the production of tablets.
2. It can be modified for mixing, granulation and drying operations at a time. (Known as **Fluid Bed Processor**)