

## **UNIT-V DRYING**

### **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 and 3) freeze drying, in which frozen materials are placed in a vacuum chamber to draw out the water.

The fundamental nature of all drying process is the removal of volatile substances (mainly moisture) from mixture to yield a solid product. In general drying is accomplished by thermal techniques and thus involves the application of heat, most commonly by convection from current of air. Throughout the convective drying of solid materials, two processes occur simultaneously namely, transfer of energy from the local environment in the dryer and transfer of moisture from within the solid. Therefore this unit operation may be considered as simultaneous heat and mass transfer operation.

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. For example In the sugar industry washed and centrifuged sugar crystals are dried to get finished product for packing.

Drying is an important operation in food processing. Milk is dried in a spray chamber to produce milk powder. All the above examples indicate that wet material loses moisture in direct contact with hot air/gas. The hot air/gas supplies the energy required for drying and also carries away the moisture released by the solid. For heat sensitive materials much of the resistance to drying resides within the material. Unduly high heat and mass transfer rates applied at the surface only result in overheating or over drying of the surface layer resulting in quality problems without

## LECTURE 8

### MASS TRANSFER FOR BIOLOGICAL SYSTEMS

major increase in the drying kinetics. The rate of migration of the moisture from within the solid to the evaporation front often controls the overall drying rate. Therefore, drying may be defined as an operation in which the liquid, generally water, present in a wet solid is removed by vaporization to get a relatively liquid free solid product. Drying of a solid does not demand or ensure complete removal of the moisture. Sometimes it is desirable to retain a little moisture in the solid after drying. Dryer and drying process selection for a specific operation is a complex problem, and many factors have to be taken into account. Though, the overall selection and design of a drying system for a particular material is dictated by the desire to achieve a favorable combination of a product quality and process economics. In general, with respect to the rate and total drying time, dryer performance is dependent on the factors such as air characteristics, product characteristics, equipment characteristics. But despite the many commercially available drying techniques at present most dehydrated products (i.e. fruits and vegetables) are still produced by the method of hot air drying. Because this is regarded as the simplest and most economical.

There are other water/liquid removal processes such as filtration, settling, centrifugation, supercritical extraction of water from gels etc. In all these operations liquid is removed by mechanical means but a considerable amount of liquid is still retained in the solid. This residual liquid can be removed by drying. One such example is the production of condensed milk involves evaporation, but the production of milk powder involves drying.

The phase change and production of a solid phase as end product are essential features of the drying process. Drying is an essential operation in chemical, agricultural, biotechnology, food, polymer, pharmaceutical, pulp and paper, mineral processing, and wood processing industries.

### **PHYSICAL MECHANISM OF DRYING**

Drying does not mean only removal of the moisture but during the process, physical structure as well as the appearance has to be preserved. Drying is basically governed by the principles of transport of heat and mass. When a moist solid is heated to an appropriate temperature, moisture vaporizes at or near the solid surface and the heat required for evaporating moisture from the drying product is supplied by the external drying medium, usually air or a hot gas.

## LECTURE 8

### MASS TRANSFER FOR BIOLOGICAL SYSTEMS

Drying is a diffusional process in which the transfer of moisture to the surrounding medium takes place by the evaporation of surface moisture, as soon as some of the surface moisture vaporizes, more moisture is transported from interior of the solid to its surface. This transport of moisture within a solid takes place by a variety of mechanisms depending upon the nature and type of the solid and its state of aggregation.

Different types of solids may have to be handled for drying crystalline, granular, beads, powders, sheets, slabs, filter-cakes etc. The mechanism of moisture transport in different solids may be broadly classified into (i) transport by liquid or vapour diffusion (ii) capillary action, and (iii) pressure induced transport. The mechanism that dominates depends on the nature of the solid, its pore structure and the rate of drying.

Different mechanisms may come into play and dominate at different stages of drying of the same material. The following terms are commonly used in designing of drying systems.

Moisture content of a substance which exerts an equilibrium vapor pressure less than that of the pure liquid at the same temperature is referred to as *bound moisture*.

Moisture content of the solid which exerts an equilibrium vapor pressure equal to that of pure liquid at the given temperature is the *unbound moisture*.

The moisture content of solid in excess of the equilibrium moisture content is referred to as *free moisture*.

During drying, only free moisture can be evaporated. The free moisture content of a solid depends upon the vapour concentration in the gas.

The moisture content of solid when it is in equilibrium with given partial pressure of vapour in gas phase is called as *equilibrium moisture content*. Similarly, the moisture content at which the constant rate drying period ends and the falling rate drying period starts is called *critical moisture content*. During the *constant rate drying period*, the moisture evaporated per unit time per unit area of drying surface remains constant and in *falling rate drying period* the amount of moisture evaporated per unit time per unit area of drying surface continuously decreases.

## **CLASSIFICATION OF DRYERS**

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

It can be classified based on mode of operation such as batch or continuous, In case of batch dryer the material is loaded in the drying equipment and drying proceeds for a given period of time, whereas, in case of continuous mode the material is continuously added to the dryer and dried material continuously removed. In some cases vacuum may be used to reduce the drying temperature. Some dryers can handle almost any kind of material, whereas others are severely limited in the style of feed they can accept. Drying processes can also be categorized according to the physical state of the feed such as wet solid, liquid, and slurry. Type of heating system i.e. conduction, convection, radiation is another way of categorizing the drying process. Heat may be supplied by direct contact with hot air at atmospheric pressure, and the water vaporized is removed by the air flowing. Heat may also be supplied indirectly through the wall of the dryer from a hot gas flowing outside the wall or by radiation. Dryers exposing the solids to a hot surface with which the solid is in contact are called adiabatic or direct dryers, while when heat is transferred from an external medium it is known as non-adiabatic or indirect dryers. Dryers heated by dielectric, radiant or microwave energy are also non adiabatic. Some units combine adiabatic and non adiabatic drying; they are known as direct-indirect dryers.

To reduce heat losses most of the commercial dryers are insulated and hot air is recirculated to save energy. Now many designs have energy-saving devices, which recover heat from the exhaust air or automatically control the air humidity. Computer control of dryers in sophisticated driers also results in important savings in energy.

## DRYING EQUIPMENT

### *Batch Type Dryers*

#### Tray Dryer

Schematic of a typical batch dryer is shown in figure 2.1. 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.

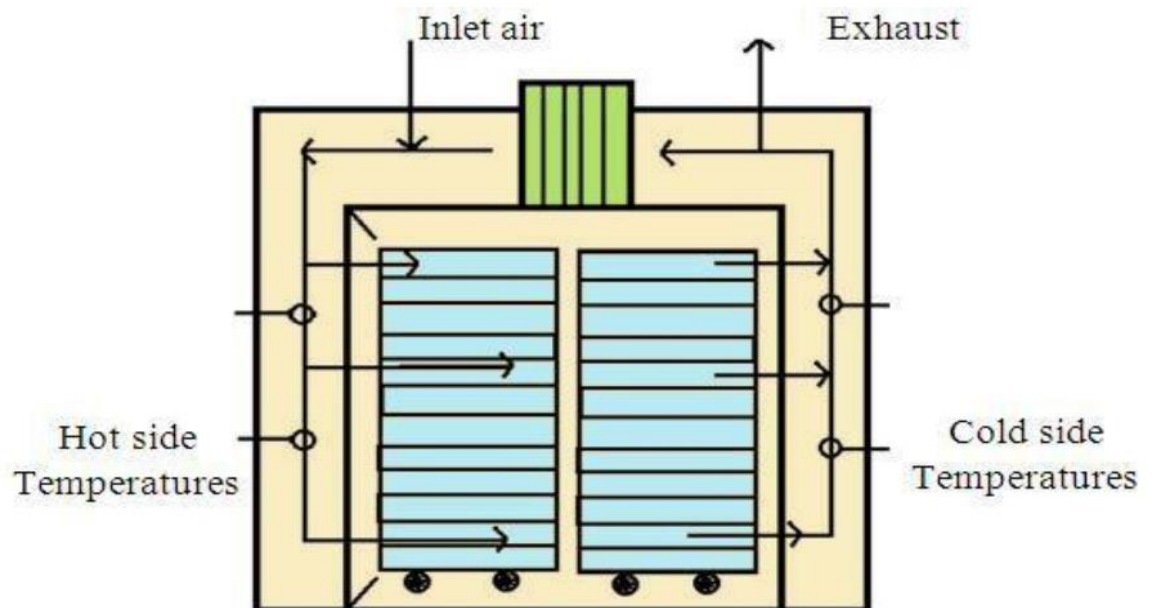


Figure 5.1 Tray drier

## LECTURE 8

### MASS TRANSFER FOR BIOLOGICAL SYSTEMS

These types of dryers are useful when the production rate is small. They are used to dry wide range of materials, but have high labor requirement for loading and unloading the materials, and are expensive to operate. They find most frequent application for drying valuable products. Drying operation in case of such dryers is slow and requires several hours to complete drying of one batch. With indirect heating often the dryers may be operated under vacuum. The trays may rest on hollow plates supplied with steam or hot water or may themselves contain spaces for a heating fluid. Vapour from the solid may be removed by an ejector or vacuum pump. *Freeze-drying* involves the sublimation of water from ice under high vacuum at temperatures well below 0°C. This is done in special vacuum dryers for drying heat-sensitive products.

#### **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.

#### **Agitated Vacuum Dryer**

The agitated vacuum dryer is one of the most versatile in the range and is similar in principle to a pan dryer. The dryer essentially consists of a jacketed cylindrical vessel arranged for hot water, steam or a suitable thermal fluid flow through the jacket for heating. Doors are provided on

**LECTURE 8**  
**MASS TRANSFER FOR BIOLOGICAL SYSTEMS**

the shell, at the top for loading the feed material and at the bottom for discharging. The dryers are available in variety of sizes. The entire drying chamber is well machined to insure small clearance with the agitator blade. Thus ensures proper shuffling of the material and avoids localized overheating. Due to the agitation of the product in the agitated vacuum dryer the drying time is substantially reduced.