

worked either by the pressure of the liquid or by compressed air, or the liquid may be dropped in a fine stream on to a revolving disc rotating at high speed. That portion of the powder that is carried away with the air currents may be recovered in dust collectors and the air or gas may be recirculated in part, after removing surplus moisture.

Loft, compartment, cabinet or room dryers consist of room-like enclosures or boxes in which the material to be dried is placed on trays, trucks, racks, or moving conveyors and is heated by warm air currents which also serve to carry away the evaporated moisture. Drying of this sort is sometimes called *air-processing*. The air is warmed, either by direct mixture with furnace gases, or by contact with surfaces heated by direct flame, flue gases, steam, hot water, or electricity. The source of heat may be *direct*—located within the dryer, usually in the form of wall coils, floor coils, or distributed coils—or *indirect*, the air being heated by radiators outside the dryer and circulated through the dryer by fans and distributing ducts. Baffles are often used to assure the passage of the heated air directly over the surface of the material and to prevent short-circuiting from inlet to outlet. Where the material is placed on trays, shelves or racks, it is advisable to use open-wire screen bottoms for small material or leave spaces between larger articles when possible, to allow the air to travel not only over the material but also upward or downward through it.

Tunnel dryers consist of a comparatively long, narrow box-like enclosure, through which the solid to be dried is moved either continuously or periodically at short intervals, being fed in at one end in a fresh condition and removed from the other end in a dry condition. The material may be carried on some type of mechanical conveyor or on wheeled cars or trucks moving on a track. The drying is done by means of heated air which moves through the dryer from one end to the other, warming the material and removing the evaporated moisture. Some products dry best if the air and material are made to move in the same direction but in most cases it is found best to have the air move in a direction opposite to the travel of the material, that is, counter-currently. Where wheeled cars are used for heavy, bulky products, the rails in the tunnel are often sloped in a ratio of from 60 to 1 to 100 to 1 to obtain the benefit of gravity in moving the material.

One end of the tunnel is usually hotter than the other, both to suit the varying requirements of the different stages of drying and to take advantage of gravity in moving the air end-wise of the dryer. In the natural-draft tunnel, heat is provided at the hotter end by steam coils or other means and the evaporated moisture is removed at the opposite end by means of ventilating chimneys. In the forced-draft or blower type of tunnel, the air is circulated through the tunnel by fans, being heated either by direct radiation within the tunnel or indirect radiation in the fan duct or a combination of both. Evaporated moisture may be removed either by ventilating chimneys or duct openings or by condensers in the duct system.

MECHANISM OF THE DRYING

Stages of Moisture Diffusion.

A thorough knowledge of the mechanism of the diffusion of moisture from the interior of a solid material to the surface and into the air is

necessary to an understanding of the different types of commercial dryers and is essential where the design of the dryer is to be based upon small-scale laboratory tests. Assuming uniform velocity and distribution of air at a constant temperature and humidity, over the surface of the solid, the drying cycle will be divided ordinarily into two distinct stages. The first stage, known as the *constant rate period*, is found in the drying of any very wet solid as long as moisture is brought to the surface so rapidly that the surface remains thoroughly wet and evaporation can proceed at a constant rate, precisely as from a free water surface. The second stage, known as the *falling rate period*, is reached when the moisture in the material has been dried down to a point called the critical moisture content, below which the diffusion of moisture from the interior to the surface is no longer adequate to keep the surface thoroughly wetted. From this point on, the rate of drying will decrease until the operation is completed.

Constant Rate Period

During the constant rate period, the surface is kept saturated with water by diffusion from the interior and the operation is called *saturated surface drying*. The rate of drying is limited by the rate of diffusion of water-vapor, through the surface air film surrounding the solid, out into the main body of the air. When the heat necessary for vaporization is supplied only by thermal conduction through the surface air film, the temperature of the solid is the wet-bulb temperature of the air. Heat gained by radiation or conduction from adjoining dry surfaces raises the temperature of the surface above the wet-bulb temperature. The vapor pressure of the water at the surface, therefore, increases and consequently the driving force causing diffusion through the surface air film becomes greater, causing a corresponding increase in the drying rate.

By placing the wet material in sight of hot surfaces during this constant rate period, the rate of drying may be increased several fold without overheating the material itself. Similarly, material placed on hot shelves, as well as material dried in shallow pans or on heated cylinders, will dry faster because of the heat received by conduction from the surfaces with which it is in contact. A controlling factor during this stage is the velocity of the air, affecting as it does the thickness of the surface air film through which the water-vapor must diffuse. The higher the velocity, the faster will the drying proceed, the rate of drying varying approximately as the 0.6 power of the air velocity.

Falling Rate Period

After the critical moisture content of the material has been reached, two distinctly different forms of diffusion and evaporation are encountered. In both cases, the drying rate falls off rapidly with reduction of the moisture content. In the first type, known as *unsaturated surface drying*, the rate of evaporation per unit surface area is substantially constant and nearly independent of the thickness of the sheet or layer of the material. However, where the solid gains its heat only from the air around it and obtains none by radiation or conduction from adjacent surfaces, the transfer of heat from the air to the solid is, under constant drying conditions, found to be independent of the moisture content and