certain industries as practicable for their specific problems. An example of successful application is found in the drying of lacquers.

Conduction Drying

Drying rolls or drums, Fig. 6,[7] flat surfaces, open kettles, and immersion heaters are examples of the direct-contact method. Intimate contact of the material with the heating surface is important, and in some cases agitation is desirable to increase the uniformity of heating or to prevent overheating.

A rather interesting method of conduction drying was put into practical use during the war for the drying of blood

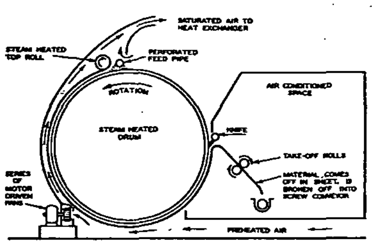

Fig. 6 . . . . Drum Dryer[7]

plasma, and has since been expanded to other fields such as the preservation of bacteria and other micro-organisms. This has come to be known as freeze drying or drying by sublimation. The material to be dried is first frozen and then placed in a high vacuum chamber connected to extremely low temperature condensers. The water is removed by vaporizing from the solid directly to the gas without ever becoming liquid.

Convection Drying (Direct Dryers)

A typical convection dryer is composed of an air-conditioning system, a material handling system, and the dryer housing. In normal practice it is desirable to recirculate as much as 95 percent of the air, from the standpoint of heat economy. There is an optimum point for the percentage of recirculation, depending on the temperature and evaporation rate.

A limited amount of convection drying takes place in almost any dryer such as those described in the preceding paragraphs. However, to be classified as a convection dryer the principal source of heat is the heated air or other gases circulated in the dryer. There are a number of mechanical means of accomplishing this circulation of air or gases, each of which has some particular virtue. Brief descriptions of some important types of convection dryers follow:

Rotary Dryers. These dryers are cylindrical drums which cascade the material being dried through the air stream. (See Fig. 7.) The dryers may be heated directly or indirectly, and the air circulation may be parallel or counterflow. A variation is the rotating-louver type dryer, which introduces the air beneath the flights thus securing very intimate contact.

Cabinet and Compartment Dryers. These are generally considered batch dryers wherein each charge is dried to completion before removal.[7] A wide range includes types from the heated loft with only natural convection, and usually poor and non-uniform drying, to the self-contained units with forced draft and properly designed baffles which give positive results. It is also possible to evacuate some of the systems for low temperature drying of delicate or hygroscopic materials. These dryers are usually loaded with material spread in trays to increase the exposed surface. The trays are loaded directly into the dryer or may be stacked on trucks which are wheeled in. (See Fig. 8.)

Tunnel Dryers. Tunnel dryers are a modification of the compartment dryer, and as a rule are continuous or semi-continuous in operation. Heated air or combustion gas is usually circulated by means of fans, although a few natural draft units are still in use. The material is handled on trays or racks on trucks, and moves through the dryer either intermittently or continuously. The air flow may be parallel, counterflow, or a combination of the two, obtained by center exhaust. Further, the air flow may be across the surface of the trays or up or down through the bed, or in any combination of directions. By reheating the air in this type of dryer or recirculating it, a high degree of saturation is achieved before exhausting the air. This reduces the waste of sensible heat.

A variation of this type dryer is the strictly continuous type having one or more mesh belts which travel through the dryer carrying the product, such as Fig. 9. Innumerable combinations of temperature, humidity, air direction, and velocity are possible. The labor requirement is low on such a dryer, as it can be loaded and unloaded mechanically. There is the disadvantage of hot air leaks at the entrance and exit, although these can be minimized by means of baffles or inclined ends where the material enters and leaves from the bottom.

Spray Dryers. In recent years the spray dryer has become important for the drying of liquids in many fields, especially in the food industry.

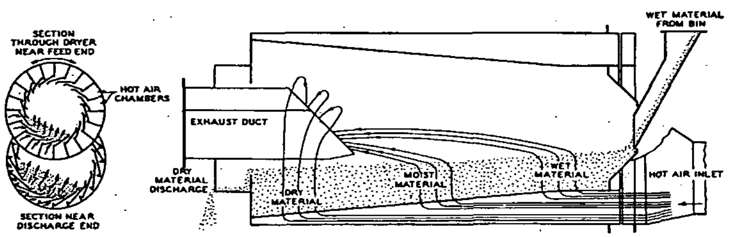

Fig. 7 . . . . Cross Section and Longitudinal Section Through Circulation Dryer[7]

The liquid is atomized by means of pressure nozzles, air jets, or centrifugal bowls into the air stream of a tower or chamber. Inlet air temperatures may run from 250-300 F up as high as 1200 F. Drying times are very short because of the minute particle size. Particles as small as 5 to 10 microns are formed in spray dryers. The dry powder is separated from the air by cyclone separators which are sometimes followed by cloth bags or scrubbing towers.

Because of the high inlet temperatures and the relatively large volume of air required, the efficiency of the spray dryer is relatively low and, consequently, it is seldom used for dilute solutions (less than 30 percent solid). Fig. 10 shows a typical arrangement for a spray drying system.[7]

A common and important feature of all spray processing is the direct conversion of the spray liquid to a granular product

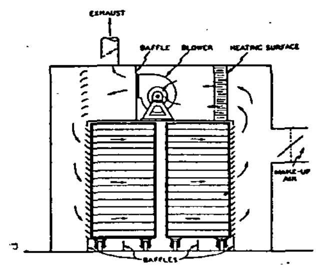

Fig. 8 . . . . Compartment Dryer, Showing Trucks, with Air Circulation[7]

suitable for packaging without grinding or other intermediate handling. Another aspect is the unusually high rate of drying attained. In a well designed system 15 to 30 seconds is a fair time for the passage of the sprayed particle through the drying zone; the particle temperature need not rise materially above the wet-bulb temperature of the drying air. This makes the process particularly adaptable to the drying of heat-sensitive material, some of its most important applications being the drying of milk, eggs, potato flour, soap, and blood.[8]

Tobacco Curing[9]

Considerable progress has been made recently in developing improved tobacco curing systems, through the application of heating equipment for maintaining uniform temperatures. Controlled heat and air circulation shortens the curing period and improves the quality of tobacco.

Suitable barn ventilation effected by bottom and ridge venting reduces the time and cost of curing. Orientation of barn with respect to the prevailing wind is helpful.

Tobacco Re-drying

In modern plants, tobacco is re-dried in continuous, conveyor type machines under controlled temperature and humidity conditions. One type of machine re-dries leaf tobacco in hands. This machine consists of a drying section, cooling section, and ordering section. As the hands are carried through the drying section on sticks, a high velocity of air is directed down through the heads, and a low velocity of

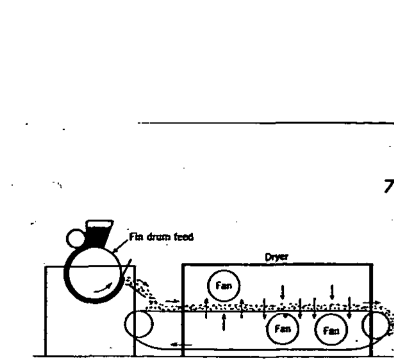

Fig. 9 . . . . Section of Continuous Dryer, Blow-Through Type

air passes over the body of the tobacco resulting in fast and uniform re-drying.

In the cooling section, the tobacco is quickly cooled and conveyed through the ordering section, where a controlled amount of moisture is added in this section which is maintained at almost saturated humidity ratio, so that the leaves can be packed for storage without the danger of breakage.

Agricultural Drying

Information on drying of agricultural products, such as milk, apples, flowers, tung nut, lumber, fruit juices, broom corn, grain, hay, peanuts, tobacco, and other farm crops, may be found in current issues of the *Agricultural Index*.[10]

SOLUTION OF TYPICAL DRYING PROBLEM

Since there are so many types of dryers that may be used, and so many special conditions surrounding each particular problem, it is usually recommended that those having experience with the dryer to be used be consulted. The following example, however, will serve as a guide for typical dryer calculations.

Example 2: Magnesium hydroxide is to be dried from 82 percent moisture on bone-dry basis to 4 percent moisture content on bone-dry basis. The production rate is to be 3000 lb per hr on 4 percent bone-dry basis. Previous experience indicates that a continuous single-conveyor through-circulation dryer with a fin-drum feed as illustrated in Fig. 9 should be used. The dryer is to be heated with steam at 50 psig. The optimum circulating air temperature is 160 F which is not limited by the existing steam pressure.

Step 1: Laboratory tests or previous experience indicate that the material enters the dryer at a temperature of 60 F, with an initial moisture content of 82 percent bone-dry basis. The test drying time is 25 min and the final moisture content is 4 percent bone-dry basis. The temperature of make-up air is 70 F dry-bulb and 60 F wet-bulb. The temperature of circulating air is 160 F dry-bulb and 100 F wet-bulb. The air velocity down through the preformed bed is 250 fpm, and the static pressure drop through the bed is 0.4 in. of water. The dryer

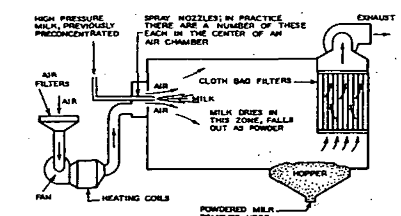

Fig. 10 . . . . Spray Dryer of the Pressure-Spray Rotary Type[7]