

FIG. 15. SPRAY DRYER OF THE PRESSURE-SPRAY ROTARY TYPE[8]

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.[9]

SOLUTION OF TYPICAL DRYING PROBLEM

Since there are so many types of dryers which 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.[10]

Example 1. Assume 900 lb per hour of ceramic powder is to be produced. The powder has a specific heat of 0.22 and density of 98 lb per cu ft, wet. Initial moisture content is 19 percent on a wet basis; final moisture content is to be one-half of one percent on a wet basis.

A continuous belt dryer is a logical choice, and previous experience indicates that rubber belts will withstand temperatures up to 200 F, which is also about the highest desirable product temperature. Experience also indicates that a drying time of 45 min is possible at about 160 F dry-bulb and 100 F wet-bulb.

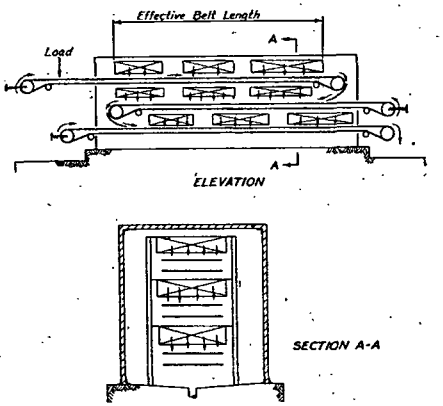

FIG. 16. CONTINUOUS BELT DRYER FOR CERAMIC POWDER[10]

Step 1: Let x = pounds moisture at final condition.

Then, $$\frac{x}{900} = 0.005$$

or, $$x = 4.5 \text{ lb moisture}$$

and therefore the solid will amount to 895.5 lb.

Likewise the weight of the initial moisture x can be found

from $$\frac{x}{895.5 + x} = 0.19$$

or $$x = 210 \text{ lb.}$$

The weight of moisture to be removed is 205.5 lb per hour, and wet material entering dryer is 1105.5 lb per hr.

Step 2: Previous tests indicate that a $\frac{1}{4}$ in. layer of powder gives satisfactory results, and that a desirable air velocity is 50 fpm applied at a right angle to the belt. Based on 45 min ($\frac{3}{4}$ hr) drying time, the dryer holding capacity will have to be $1105.5 \times 0.75 = 830$ lb of wet material or $\frac{830}{98} = 8.45$ cu ft of material.

Assuming a 48 in. wide belt with an effective 42 in. width for the product, each foot of belt length carries 0.146 cu ft or 14.3 lb of wet material. Hence, the linear feet of belt must be $\frac{830}{14.3} = 58$ ft and the total area of exposed product is 232 sq ft. Based on 50 fpm velocity directed at a right angle to the belt the total air circulation will be $232 \times 50 = 11600$ cfm.

For space economy and in order to expose periodically fresh layers of powder to air, a multiple vertical belt arrangement (Fig. 16) with belts traveling in opposite directions, is selected. Three belts each 19.4 ft long will be required. Fig. 16 illustrates the physical arrangement of the dryer.[10] The housing will be about 25 ft long, 8 ft wide and 7 ft high.

Step 3: At the drying conditions of 160 F dry-bulb and 100 F wet-bulb, the air moisture content (from Fig. 6) is 0.028 lb per pound of air. Make-up air will be assumed at 80 F dry-bulb and 72 F dew-point (summer weather), or a humidity of 0.0168 lb per pound of air. The *pick-up* is therefore 0.0280 − 0.0168 or 0.0112 lb per pound of air. Then $\frac{205.5}{0.0112} = 18400$ lb of air per hour or 307 lb per min.

At the elevated temperature, the total air quantity of 11,600 cfm represents 675 lb of air per min. Hence,

Percent make-up air = 46 percent

Percent recirculated = 54 percent

Step 4: Although the drying condition and drying rate should preferably be determined from experience or test results, the drying conditions can sometimes be estimated if the regain characteristics of the product or a similar product are known. In this case the regain characteristics of clay could be used as a guide. Inspection of regain data for typical clays indicates that at about one-half of one percent the vapor pressure of the moisture in the product is about 0.7 in. Hg less than the vapor pressure of free moisture at the product temperature. An assumption is made that the product temperature approximates the air wet-bulb temperature. If an assumption is made regarding the percent recirculated air the desired vapor pressure in the dryer can be estimated. For example assume a use of 46 percent outside air or 307 lb per min. Then the moisture *pick-up* $= \frac{205.5}{60 \times 307} = 0.0112$ lb per pound of air, with a consequent total of 0.0168 + 0.0112 = 0.0280 lb of moisture per pound of air in the leaving outside air, which has about 1.25 in. Hg vapor pressure. This is assumed to be the vapor pressure of the moisture in the product, and thus the vapor pressure of free water at product temperature can be 1.25 + 0.7 = 1.95 in. Hg. The temperature corresponding to 1.95 in. Hg is 100 F, and thus the air wet-bulb can be estimated to be 100 F. At 100 F wet-bulb temperature and 0.028 lb moisture per pound of air, the dry-bulb temperature is 160 F. Obviously, the assumed percentage of recirculated air affects the results, and therefore it is important that it be based on experience. About 50 percent recirculation is reasonable for the type dryer considered in this example.