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DRYING DESK

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Drying with particle size control: A review

One factor that can greatly influence your dryer selection is the need to maintain or reduce your material's particle size or shape, or both, during drying. In past columns, we've discussed different types of dryers and their ability to do this. In this column, we'll review some of that information.

Dryers that minimize particle attrition

To maintain the size and shape of very fragile particles, you must avoid or at least minimize particle attrition during drying. This requires a dryer that can gently handle the material. The following are typical batch and continuous dryers that meet this requirement.

Tray dryer (batch). A tray dryer consists of a housing enclosing shelves or hollow plates that support multiple drying trays. The dryer operates in batch mode. For each batch, workers spread wet feed material as a shallow layer across each tray, load the trays into the shelves or plates in the dryer, and, after drying, unload the trays. For drying under atmospheric conditions, the dryer uses *convection* — circulating heated air over the top surface of the material on the trays — and this air sweep removes evaporated moisture. For drying under vacuum, the dryer uses *conduction* — circulating an indirect heat-transfer fluid, such as steam, hot water, or hot oil, through the hollow plates under the trays — and a vacuum pump removes evaporated moisture. In either operation, the material remains stationary during drying, eliminating particle attrition. However, the dryer's manual loading and unloading steps are labor intensive. Another limitation is that a moisture gradient can develop across the material's depth on the trays, resulting in nonuniform drying of the final product.

Tray dryer (continuous). The typical continuous tray dryer incorporates a vertical cylindrical housing containing a stack of several circular trays and a vertical shaft mounted with arms and plows that rotate at the center of the trays. Wet feed material is continuously fed onto the top tray, where it forms a shallow layer, and, as the shaft rotates, the arms and plows slowly move the material across each tray in a spiral flow path. The material cascades from the top tray to the tray below, where the spiral flow path reverses, and the final dried product exits the dryer from the bottom tray. The dryer operates by convection under atmospheric conditions, with heated air flowing across the material surface on each tray. The material is continuously turned over by the plows, exposing new material surfaces to the heated airstream for moisture evaporation. This material turnover improves air-to-material contact, which minimizes moisture gradients in the final dried product. The plowing action is slow enough to gently handle fragile particles with very little attrition. The continuous operation also eliminates manual loading and unloading.

Plate dryer. Similar to the continuous tray dryer, the plate dryer uses circular hollow plates instead of circular trays and also operates continuously. The plate dryer is a conduction dryer with steam, hot water, or hot oil flowing through the hollow plates. The dryer can operate under atmospheric conditions, removing evaporated moisture with an air sweep, or the unit can operate under vacuum, removing evaporated moisture with a vacuum pump. The rotating shaft's plows move the material as a thin layer across the plates in a spiral flow path, and the material cascades from the top tray down to the next until exiting from the bottom tray. The dryer's gentle plowing action handles fragile particles with very little attrition.

Belt conveyor dryer. The belt conveyor dryer operates continuously and consists of a long tunnel-like housing containing a moving belt conveyor equipped with a porous belt. Wet feed material is contin-

uously metered onto the porous belt in a thin layer at the housing's inlet end and exits from the housing's opposite end. The convection dryer circulates heated air down through the material layer and through the belt to heat the material and remove the evaporated moisture. Because the heated air passes through the material rather than passing over its surface, as in the batch tray dryer, the material's moisture content is uniform throughout the entire layer. The material remains stationary on the moving belt, eliminating particle attrition and allowing the dryer to handle shaped or formed products such as cereals and snack foods without damage, preserving their geometry or structural integrity.

Dryers that reduce particle size

Several continuous dryers can reduce your material's particle size during drying. Which one is right for your application depends on the particle size you need to achieve. The following dryers are typical choices for drying applications that require particle size reduction.

High-speed paddle dryer. The high-speed paddle dryer consists of a horizontal, cylindrical vessel with a longitudinal rotor-and-paddle assembly. The paddles' tip-to-wall clearance is typically between 0.25 and 0.75 inches, and the paddles' pitch can be adjusted to set the material's residence time in the dryer. Wet feed material is continuously fed into the vessel's inlet end as the rotor-and-paddle assembly rotates, producing a paddle tip speed typically between 1,500 and 2,500 fpm. The dryer uses conduction heating: Steam, hot water, or hot oil circulates through external jacket sections on the vessel to transfer heat through the vessel wall. The rotating paddle's centrifugal action throws the material toward the heated vessel wall, where a thin layer forms and travels along the wall in a spiral flow path. Heat transfers through the wall into the material while moisture is evaporated into the dryer's vapor space (called *annular space,* which is between the inner vessel wall and the rotor assembly's outer surface). An air sweep flowing countercurrent to the material flow path removes the evaporated moisture from the dryer's inlet end as the final dried product exits from the dryer's opposite end. This dryer is suitable for delumping material and, when the paddles' tip speed and pitch are properly adjusted, can coarse-grind material to the granular particle size range.

Flash dryer with cage mill. The flash dryer consists of a round or rectangular duct that pneumatically conveys wet feed material in heated air at 4,000 to 6,000 fpm from the dryer's feedpoint to a material receiver, such as a cyclone or baghouse. Heat transfers by convection from the air to the material to evaporate moisture, and the residence time in the dryer is typically from 1 to 2 seconds. When the dryer is used with a *cage mill* — similar to a rotating squirrel cage, with two facing circular plates connected at their circumference with spacer bars — the mill is located at the dryer's feed inlet after the air heater. The wet feed material enters through the rotating cage mill's flat side, and the heated air passes through the mill's cylindrical periphery and into the dryer duct. As particles are reduced in size in the cage mill, they're entrained in the airstream and are swept out of the cage mill into the dryer duct. Oversize particles that can't be initially swept out into the dryer duct by the heated air continue to roll about the mill, undergoing further drying, which makes them more friable and susceptible to further attrition. The particles eventually become small enough to be swept out of the mill by the heated conveying air, through the dryer duct, and into the material receiver. The flash dryer with cage mill is suitable for delumping material and grinding material to the granular particle size range, but this method can't achieve fine grinding.

Flash dryer with pin mill. The flash dryer can also be used with a pin mill in place of a cage mill. The pin mill consists of a rotating plate with concentric rows of extended pins intermeshing with concentric rows of stationary pins on a mating stator plate. The mill's location and operation when used with the flash dryer are similar to those of the cage mill. However, the pin mill's action provides much finer grinding than a cage mill, producing particles in the micron size range.

Jet mill flash dryer. The jet mill flash dryer consists of a toroidal (donut-shaped) loop of round or rectangular duct and, like a standard flash dryer, also conveys wet feed material in heated air from a feedpoint to a material receiver. Rather than entering at one end of the dryer, the heated air enters through a series of tangential jets at the duct's outer periphery, while exhaust air entrains fines and removes them as the air exits from the loop's inner periphery. As the heated conveying air circulates the particles around the loop, it evaporates moisture. The larger particles are continuously conveyed outward, against the loop's outer wall, where they're finely milled to the micron size range. The jet mill flash dryer is able to produce this fine-milling action without any moving parts, reducing maintenance requirements. **PBE**

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