This month, I’ll follow up on my January 2006 column “Drying with particle size control” to discuss how to increase particle size in a drying system. See Figure 1 for a simple flow diagram of the process.

Many dryer types can be used to increase particle size. They can be classified by the feed type they typically accept: pumpable liquid (a solution or slurry) or nonpumpable feed (a dewatered cake or free-flowing solids). This month, we’ll consider drying systems that use pumpable liquid feed to increase particle size. Four of these drying systems include a spray dryer, the most common dryer for solutions and slurries, while the fifth uses a fluid-bed granulator.

Spray dryer systems

In a spray dryer, the liquid feed is atomized into small droplets and dispersed into a hot drying gas stream (which can be air or inert gas) in the dryer’s spray chamber. The liquid feed can be atomized by a high-speed centrifugal rotary atomizer or stationary spray nozzles. For each type of atomizer, the spray chamber is designed to minimize the chance that wet droplets will strike the chamber wall, which can foul the chamber by building up on the wall and degrade the product. With the centrifugal rotary atomizer, the dryer’s spray chamber is conical and the cylindrical section is relatively short; with spray nozzles, the chamber is a vertical tower. The spray dryer systems operate in continuous mode.

Spray dryer with centrifugal rotary atomizer and conical spray chamber.

The high-speed centrifugal rotary atomizer, located at the spray chamber top, forms droplets that are ejected radially into the drying gas stream entering at the chamber top. To prevent the droplets from reaching the chamber wall and to extend the droplets’ drying path (and thus the drying time), the drying gas stream flows cocurrently (that is, with the droplets) in a helical pattern, spiraling downward through the drying chamber. The larger the droplet size, the larger the dried particle will be. In this dryer, the rotary atomizer’s tip (rotational) speed controls the droplet size: The slower the atomizer’s rotational speed, the larger the droplet. However, the larger droplet’s greater momentum may allow the droplet to penetrate the gas stream’s helical flow path and hit the chamber wall while the droplet is still wet. To minimize this possibility, the chamber diameter can be increased. For a conventional spray dryer using a centrifugal rotary atomizer, enlarging the chamber diameter typically isn’t practical for achieving a dried particle size larger than about 150 microns. Pigments and dyestuffs are typical applications for this spray dryer system.

The author can answer your drying questions in a future “Drying Desk” column. Direct questions to him at American Drying Consultants, 5174 Lexington Avenue, St. Paul, MN 55126-1358 (651-263-3697, fax 651-481-0980, jjwalshpe@netscape.net) or to Editor, Powder and Bulk Engineering, 1155 Northland Drive, St. Paul, MN 55120 (fax 651-287-5650, toneill@cscpub.com).
Spray dryer with stationary spray nozzles and vertical spray tower. The stationary spray nozzles in this dryer can be high-pressure single-fluid nozzles (for the liquid feed alone) or low-pressure two-fluid nozzles (for the liquid feed and compressed air). The drying chamber is called a vertical spray tower because its cylindrical section is taller than that of a spray dryer with a rotary atomizer. The spray dryer with stationary spray nozzles can achieve particle sizes from about 300 to 500 microns. The drying gas can flow in a cocurrent mode (with the atomized droplets), countercurrent mode (against the droplets), or mixed-flow mode (in both directions).

In cocurrent mode, the atomized droplets are dispersed into the drying gas at the tower top and flow downward. The dried particles can discharge in two ways: They can discharge with the drying gas from the dryer’s bottom conical section and pass to a cyclone or baghouse for separation. Or an exhaust gas conduit located at the transition between the dryer’s cylindrical and conical sections can be used for the exhaust gas pass, with the larger dried particles disengaging from the gas flow and exiting by gravity from the bottom conical section. Extending the drying time for large droplets requires increasing the tower height. Typical applications include organic chemicals and other temperature-sensitive materials.

In countercurrent mode, the atomized droplets are dispersed downward into an upward-flowing gas stream. The gas stream exits at the tower top and conveys the fine particles to product separation and collection equipment. The on-size dried particles are separated from the drying gas in the drying chamber and exit from the bottom conical section. With countercurrent mode, larger droplets can be handled without using an extremely tall spray tower. Dried particles are commonly dried in this system.

In mixed-flow mode, the spray nozzles are located at the tower’s lower end and spray upward, resulting in a fountain-like effect as the drying gas flows downward from the tower top and exits at the bottom. This mode dramatically extends the droplets’ drying path, and thus the drying time, without requiring a large increase in the tower height. However, in mixed-flow mode, semidried particles are exposed to the drying gas stream at the fountain’s top — where the drying temperature is highest and where the particles are already partially dried and thus aren’t protected by any evaporative cooling effect. This can overdry and degrade a temperature-sensitive material, which makes the mixed-flow mode most suitable for nontemperature-sensitive inorganic materials, such as ceramics.

Spray dryer with steam condensation agglomeration. Rather than increasing the particle size within the drying chamber, this system uses steam condensation to agglomerate particles after they’ve been dried in a spray dryer. The spray-dried particles are dispersed through a steam curtain, which creates steam condensation on the particles and causes them to form loose agglomerates that are then post-conditioned in a second-stage dryer. The steam curtain can be located inside a chute leading from the spray dryer’s discharge or inside a flanged transition section between the spray dryer’s conical hopper section and the second-stage dryer’s inlet. The second-stage dryer forms stronger agglomerates by removing the condensed liquid, thereby “cementing” the agglomerates.

A typical second-stage dryer is a vibrating fluid-bed dryer that circulates low-velocity drying gas through a gently vibrated bed of material. The material is fed onto the dryer’s mechanically vibrated trough to form a shallow bed (about 3 inches deep), and the vibration gently expands the bed as it moves forward, allowing agglomerates to contact the drying gas flowing around them from the gas distributor screen in the trough bottom. This dryer minimizes agglomerate breakage by providing gentle plug flow of the material bed, in contrast to
the high fluidizing gas velocity and violent bed mixing associated with typical stationary fluid-bed dryers. The steam condensation system produces agglomerates up to about 300 microns and is often used to make instantized food powders.

**Spray dryer with integral fluid-bed dryer.** This drying system for producing agglomerated spray-dried product uses an integral fluid-bed dryer at the spray dryer chamber’s bottom rather than a separate postconditioner. The spray dryer is operated so that the particles discharged into the fluid-bed dryer’s material bed are moderately wet. The material bed is about 12 to 24 inches deep. High-velocity drying gas flows through the gas distributor screen under the bed to violently fluidize the particles while providing thorough backmixing: mixing the partially dried particles with the wet particles to ensure that the wet particles won’t foul the fluid-bed dryer’s gas distributor screen. The final dried agglomerates exiting the fluid-bed dryer can be up to 500 microns. Organic and inorganic chemicals are commonly agglomerated in this system.

**Fluid-bed granulator system**

This system, which can operate in continuous or batch mode, eliminates the spray dryer and uses a stationary fluid-bed granulator. Liquid feed is sprayed directly into the unit’s deep material bed (typically from 12 to 36 inches). High-velocity fluidizing drying gas flows upward through a gas distributor screen into the bed, providing thorough backmixing of recycled dry material with the liquid feed. The resulting granules can have a very wide particle size distribution, ranging from 300 to 10,000 microns or more. The granules typically discharge from a point near the gas distributor screen for easy removal of very large formations. Then the granules are separated by size; the on-size fraction passes to further processing or shipping, and the oversize fraction is conveyed to a milling step. After milling, the material is recycled along with the undersize fraction and fines to the fluid-bed granulator for further processing. The fluid-bed granulator produces a strong granule that’s less likely to break or degrade in solids handling equipment than those produced by other methods. Fertilizers, herbicides, insecticides, and inorganic materials are candidates for fluid-bed granulator systems.

Look for information on drying methods for increasing the particle size of nonpumpable feeds in the January 2007 column — same drying columnist, same technical journal! PBE

**For further reading**

Find more information on dryers and size enlargement equipment in articles listed under “Drying” and “Agglomeration” in Powder and Bulk Engineering’s comprehensive article index at www.powderbulk.com and in the December 2005 issue.

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