Effective drying is often a crucial step in many processing operations. In addition to its obvious importance in developing an attractive and useable product, drying is frequently used to facilitate material handling, reduce shipping costs, increase process equipment capacity, and optimize product preservation during shipment and storage.

Vacuum drying is one of the most efficient forms of material drying known. A typical batch-operated vacuum agitated dryer consists of an enclosed drying chamber connected through a condenser to a vacuum system. Steam or another heat-transfer fluid is piped to a jacket surrounding the chamber. Wet material enters the dryer, and the vacuum system reduces drying chamber pressure as the heat-transfer fluid flows through the jacket and, in some cases, the internal mixing elements. These heated surfaces provide indirect-contact drying.

As evaporation occurs and the wet material dries, the vapor is drawn by vacuum up through the dryer’s vacuum stack or jacketed pulse-back filter to a condenser, where the vapor is exposed to low temperatures, condensing it back into a liquid. This condensate flows into a recovery or holding tank for later reuse or disposal. Once the cycle is complete, the dried material is unloaded.

The three major variables that affect the removal of moisture from solids in a vacuum dryer are vacuum level, the available surface area of the material, and the amount and efficiency of the heat-transfer surface area.

Optimizing each of these variables is the key to efficient drying.

**Vacuum level for drying**

When applying vacuum during drying, the liquid being removed boils at a lower temperature than under atmospheric conditions. Consequently, drying occurs at lower temperatures than in a conventional hot-air dryer or atmospheric agitated dryer. This is especially important for heat-sensitive materials.

A vacuum level of 25 inches of mercury (0.18 atmospheres) can be maintained in a dryer using packing-gland seals for the shafts. To achieve vacuum of 29 inches of mercury (0.03 atmospheres) requires the use of double mechanical seals with a barrier fluid on both the main shaft and the high-speed mills or choppers if present. Access doors, manways, and discharge valve design also greatly affect levels of vacuum achievable inside the dryer. Leakages through these areas can impact drying times.

**Agitation and surface area**

Agitating and individualizing the solid particles to be dried helps improve the drying process and can be accomplished by mixing elements of varying sizes and shapes.

The size, shape, geometric arrangement, and tip speed of the mixing elements rotating within the drying vessel are designed to force the material into multidimensional motion. Particles constantly collide with one another and with the heated interior walls of the jacketed vessel and mixing elements.

The efficiency of heat transfer is a function of how fast material moves within the dryer and is optimized by the selection of the mixing element speed. As seen in Figure 1, once the critical mixing element speed is reached, further speed increases don’t proportionately increase heat transfer. Heat transfer optimization has been achieved.
During the drying cycle of slurries and cake-type materials with high-percentage moisture content, the materials pass through a paste phase and into a lump-forming phase. With continued drying, the particle surface becomes unsaturated and internal drying must occur. High-speed plows or mills help break up these lumps and agglomerates, exposing additional material to the heated indirect-contact drying surface areas.

Figure 2 compares the heat-transfer coefficients attainable for high-shear plow dryers versus paddle or ribbon-type agitated dryers. As shown in the graph, the high-shear plow dryer exhibits a high heat-transfer coefficient, often two to three times higher than that of a ribbon-type or paddle dryer.

**Heat transfer area**

The choice of design for a dryer vessel and its heating jacket also plays a part in an agitated vacuum dryer’s effectiveness. Flat-top, U-shaped paddle mixers and ribbon blenders have less jacketed heat-transfer surface area compared to a fully cylindrical vessel. The design of the jacket is also critical. A fully stayed jacket with labyrinth flow channels can increase the effective indirect-contact surface area by 20 to 40 percent compared to a dimpled or halfpipe jacket design. Selecting a vacuum dryer with maximum heat-transfer surface area for a given process volume minimizes cycle time for efficient, effective material drying. PBE
For further reading
Find more information on drying in articles listed under “Drying” in Powder and Bulk Engineering’s article index in the December 2017 issue or the Article Archive on PBE’s website, www.powderbulk.com. (All articles listed in the archive are available for free download to registered users.)

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