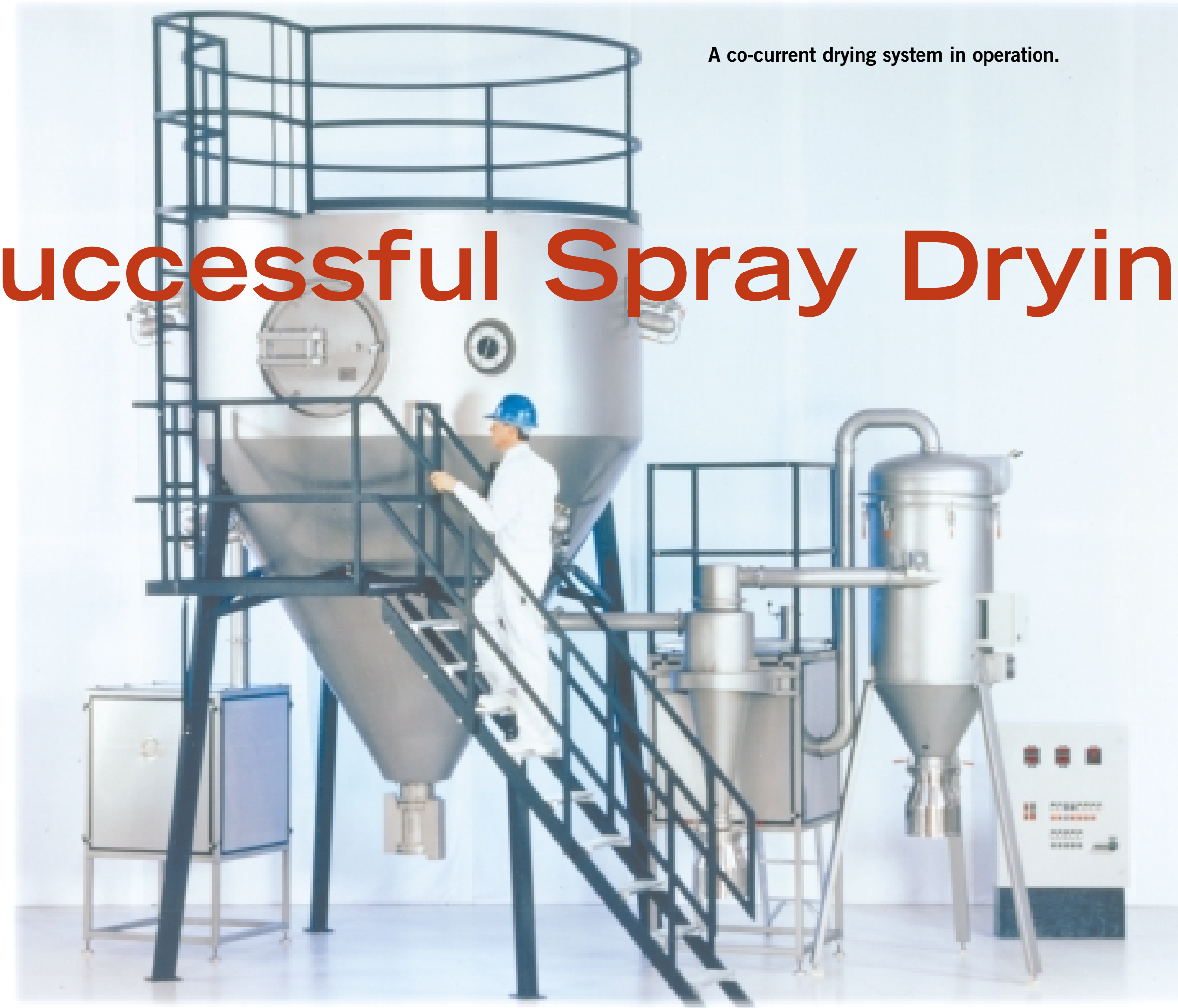
Successful Spray Drying



A co-current drying system in operation.

by **Ove B. Christiansen,** Sales Engineer, Niro Inc., Columbia, Md.

Spray drying is one of the most efficient ways to convert ceramic slurries into a free-flowing powder. It has been used for decades to process clays for whitewares manufacturing, as well as to produce oxide ceramics such as aluminas, ferrites, steatites and titanates.

The most common application of spray drying is in producing powders that will subsequently be pressed and fired, where the unique properties of spray dried products—namely, a narrow particle size distribution and spherical particle shape—result in excellent flow characteristics. For this reason, spray drying has been widely adopted for the manufacture of advanced ceramics, such as carbides, nitrides and borides. Other applications include powders for plasma spray and slip casting, as well as ferrites for toners and magnetic tapes.

To achieve successful spray drying, it is important to understand the process and its capabilities, as well as its limitations.

However, for a spray drying application to be successful, it is important that users understand both the benefits and the limitations of the spray drying process. It is also important that users choose the right system based on the requirements of the application.

The Spray Drying Process

The basic spray drying process consists of three processing steps:

- Atomization of the feed slurry into tiny droplets. This is accomplished using rotary or nozzle atomizers.
- Mixing of the atomized spray with the hot drying gas, typically air, and drying of the individual droplets into solid particles. This is carried out inside the drying chamber, and it is important that the particles are dry (at least on the surface) before they contact the internal surfaces of the drying chamber.
- Recovery of the dried product. This can be done partly from the base of the drying chamber and partly from separation equipment for the spent drying air.

The typical spray drying system for ceramic applications includes a feed system for pumping the feed slurry to the atomizer, an inlet air system with a heater,

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a drying chamber with product discharge, a cyclone collector for fines recovery, a bag filter for air pollution control and an exhaust fan for controlling the air flow through the spray drying system.

This type of equipment allows many different grades to be processed with the least possible cleaning of the equipment between the grades. The press powder is typically discharged from the base of the drying chamber, and the fines recovered in the cyclone can either be mixed in with the chamber faction or recycled back to the preparation equipment for the ceramic slurry. The small amount captured in the bag collector can be discarded if the raw materials are reasonably inexpensive or recycled in the very front of the feed preparation process. Cleaning of the drying chamber is fairly simple and can be accomplished using a tank cleaner nozzle inserted into the drying chamber after the dryer is shut down.

Spray Dryer Configurations

The most common configuration for producing press powders is mixed flow drying with a fountain nozzle (see Figure 1). The air is introduced through the top of the drying chamber, and the ceramic slurry is atomized by a nozzle that sprays upward from the base of the drying chamber.

The maximum average particle size of the product discharged from the drying chamber is 75-150 microns, depending on the size of the drying chamber. Using a pressure nozzle, a very narrow particle size distribution can be obtained with a typical yield of 85-95%, depending on the specific gravity of the spray-dried ceramic. However, if the feed rate to the spray dryer is low (less than 100 lbs/hr), the orifice in the pressure nozzle becomes so small that plugging is inevitable. In such cases, a two-fluid nozzle is used, and the expected yield is reduced to 75-85%. (Yield in this context is defined as the fraction of product discharged from the drying chamber; the rest is conveyed with the spent drying air to the cyclone and bag filter.)

A typical spray dryer installation using this configuration is shown in the photo at right. The cylindrical height required for the spray drying chamber is based on the desired average particle size and specific gravity of the ceramic material.

Where smaller average particle sizes are desired, the typical configuration is co-current drying using a rotary atomizer. This concept is illustrated in the schematic in Figure 2. Finer powders are normally required for pressing very small pieces or for applications such as plasma sprays. For this configuration, the typical average particle size is 25-100 microns, depending on the capacity of the spray drying system. A spray drying system using this configuration is shown in the photo on page 1.

When using the co-current drying configuration, all of the spray-dried powder is often conveyed with the spent drying air to the cyclone collector, eliminating the need to externally mix the two fractions. By using this concept, the yield is normally 95-98%, with the remaining small fraction collected in the bag filter.

Using either of the two configurations described previously, the achievable maximum average particle size depends on the

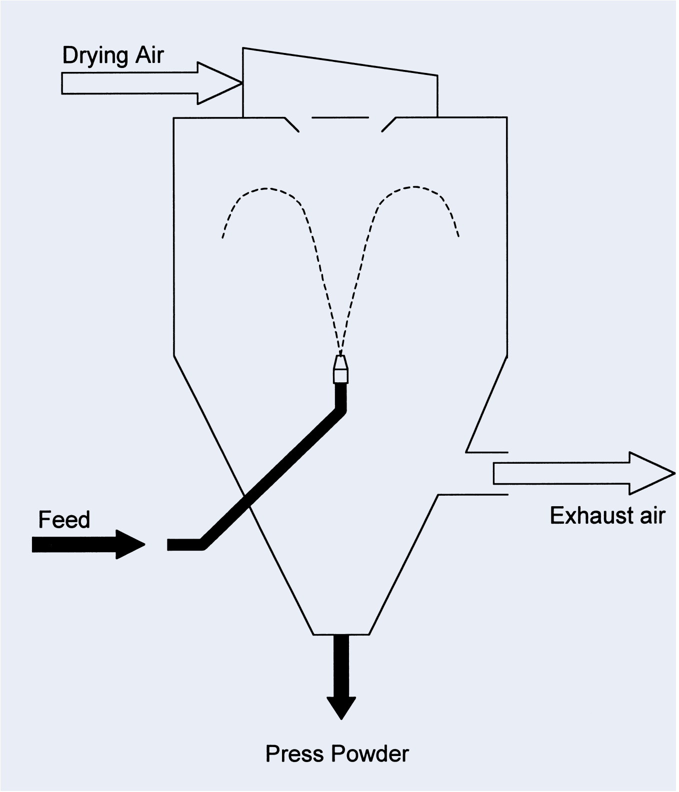

Figure 1. A schematic of a mixed flow drying system using a nozzle atomizer.

A mixed flow drying system in operation.

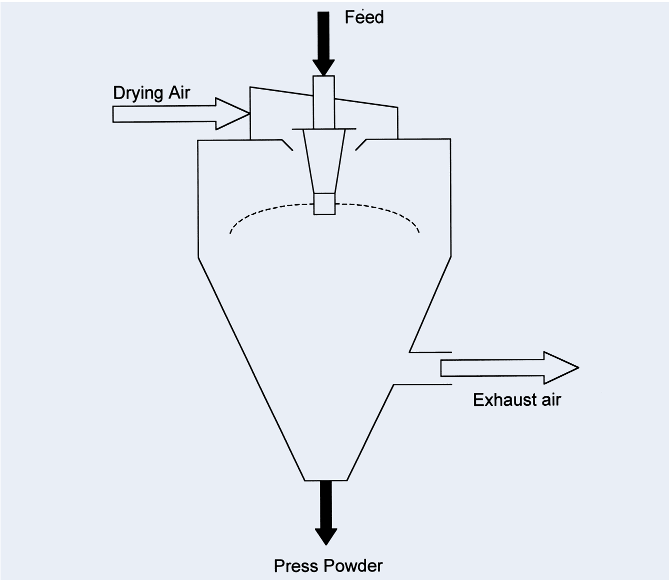

Figure 2. A schematic of a co-current drying system with a rotary atomizer.

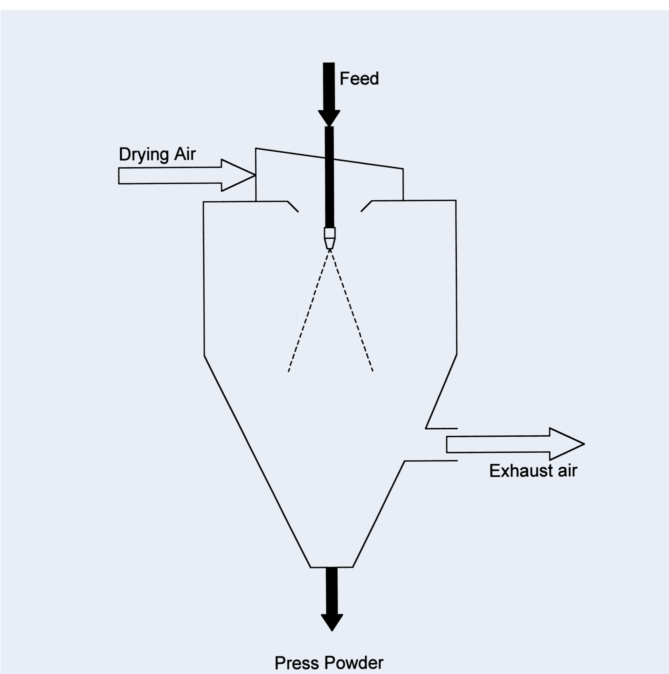

Figure 3. A schematic of a co-current drying system with a nozzle atomizer.

physical dimensions of the drying chamber. In very small plants producing a few pounds per hour of press powder, the products produced will have a maximum average particle size at the lower end of the range indicated. Conversely, for very big spray dryers with capacity in excess of 1000 lbs/hr, the maximum average particle size can easily exceed the upper end of the ranges indicated above. However, such large systems are seldom required in the manufacture of advanced ceramics.

One further application of co-current spray drying is the drying of precursors for very fine grain ceramics. For this application, the feed material to the spray dryer is a metal salt solution, made from nitrates or ammonium salts, for example, which is dried into fairly low bulk density powders. These powders are then subsequently processed by calcination, pyrolysis or any other suitable high temperature treatment. Such applications of co-current spray drying are used either with a rotary atomizer, as described above, or with a nozzle atomizer, as illustrated in Figure 3.

Closed-Cycle Spray Drying

Some ceramic slurries have to be prepared in organic solvents rather than water to prevent oxidation of one or more of the ceramic ingredients. In these applications, a closed-cycle spray drying system using an inert gas, such as nitrogen, is typically used. This concept has successfully been used to process tungsten carbide (hard metals) since the late 1960s. All of the spray dryer configurations described previously can also be used in this type of a spray drying system.

In closed-cycle spray drying plants, the atomized slurry is contacted by hot nitrogen in the spray drying chamber and processed into a free flowing powder like any other ceramic formulation. Dried product is discharged from the drying chamber and the cyclone, and the spent drying gas is introduced into a condenser system. The solvent evaporated in the drying chamber is condensed and recovered. The off-gases from the condenser are then reheated in an indirect heater for reuse in the drying chamber.

Due to the flammability of the solvents, the equipment in the spray drying system has to be explosion-proof, and the drying system itself has to be gas-tight to prevent leakage of solvent vapor into the operating area. This type of spray drying system typically operates under a slight positive pressure to ensure that no explosive mixture of in-leaking ambient air and solvent vapor can be created. Additionally, the instrumentation and control system usually includes oxygen monitors and other safety controls.

Spray Dryer Selection

Spray drying has been used successfully in the ceramic industry for a number of decades. However, to ensure the most efficient operation, it is important to understand the process and its capabilities, as well as its limitations. It is also essential to develop the proper design parameters based in the requirements of the application. Such data can be obtained from existing production facilities, in-house pilot plants or from vendors' test facilities.

For more information about spray drying, contact Niro Inc., 9165 Rumsey Rd., Columbia, MD 21045; (410) 997-6622; fax (410) 997-5021; e-mail obc@niroinc.com; or visit www.niroinc.com.

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