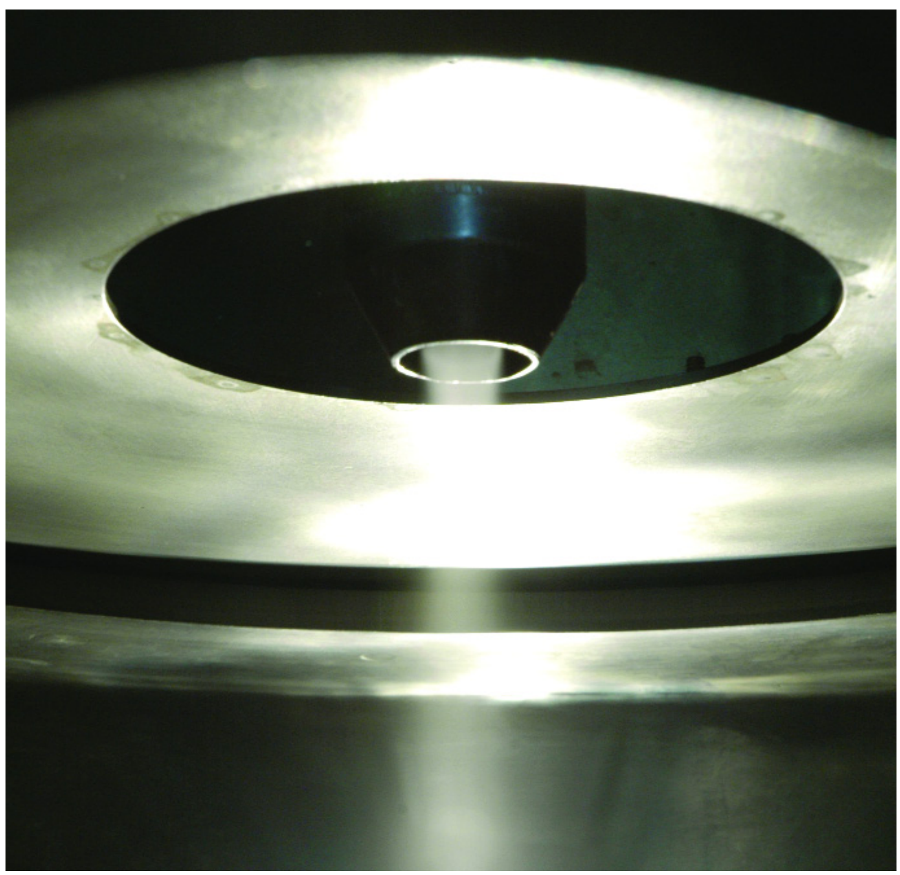
Test center

Xtreme drying

A pulse-combustion drying test center shows a nanotechnology company how it can produce large quantities of ultrafine, uniform particles.

Rechargeable electric cars have been touted by some as a solution to US overconsumption of petroleum. However, the electric cars that currently are available suffer a serious drawback: Their rechargeable batteries are expensive, have a limited life (as little as 2 to 3 years), and have the potential to overheat and spontaneously combust. Altairnano, Reno, Nev., is working to change that. One of the company's primary products is the NanoSafe lithium battery pack, which it sells to an electric vehicle manufacturer. This battery can potentially last the lifetime of the vehicle (or longer), maintain a charge for up to 250 miles, and recharge in less than 10 minutes on an industrial charger. In addition, it won't explode. When Altairnano was producing a limited quantity of this product, the company used an in-plant spray dryer to produce the very fine lithium-compound particles used in the batteries. But last year the company needed to expand its production capabilities and began looking for a dryer that would meet its needs.

Using an Internet search, Altairnano engineers came across Pulse Combustion Systems (PCS), San Rafael, Calif., a supplier of pulse-combustion spray-drying equipment, product development services, and toll drying. Intrigued by the information on the supplier's Web site, Altairnano engineers called PCS president James Rehkopf, and after discussions, decided to send samples of the company's material to the supplier's Payson, Ariz., test center to evaluate how the pulse-combustion dryers would handle it.



The pulse-combustion spray dryer's atomization nozzle (top center) is essentially an open pipe ranging in size from ⅛ to 1 inch wide. The material flowing out of it is instantaneously atomized and dried by the hot, turbulent gas pulses.

Pulse-combustion drying

Pulse-combustion drying has been around since the late 1970s, but it hasn't been widely used in industry, in part because the earlier systems were extremely noisy and somewhat crude in operation, says Rehkopf. His company found ways to solve these problems, including the development of a quieter, industrialized version of the pulse combustor, use of an insulated stainless steel drying chamber to dampen the sound, and more sophisticated instumentation to refine the dryer's operation.

Pulse-combustion drying could be described as an extreme form of spray drying. In fact, a pulse-combustion dryer looks much like a conventional spray dryer, and both dryers atomize the feed (though by different means) in a tall, slim drying chamber. Both processes also collect the finished product similarly — via a baghouse or cyclone-baghouse combination.

But there are significant differences. A conventional spray dryer typically has a nozzle assembly on top of the drying chamber. This assembly contains one or more pressure nozzles that use high pressure to force a fine liquid spray containing a small percentage of solids into the drying chamber. Atomization puts high shear on the material being atomized. Low-velocity heated gas (usually air) in the drying chamber heats and dries the particles passing through it during their fall to the drying chamber's bottom discharge cone.

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The two large pipes feed quench air (left) and combustion air (right) into the pulse-combustion unit.

The inlet and outlet air temperatures aren't widely different, so the heat transfer rate is relatively low, says Rehkopf. In addition, abrasive and corrosive materials can damage the high-pressure nozzles, requiring fairly costly maintenance.

A pulse-combustion dryer, on the other hand, doesn't have pressure nozzles; it has a single open nozzle that uses very low pressure (about 1 psi) to introduce a (typically) much more saturated solution or slurry into the drying chamber. The initially large material droplets divide into progressively smaller particles as they're contacted by high-velocity, high-heat, turbulent gas pulses during atomization. Atomization puts no mechanical shear on the material being atomized; instead, atomization is caused by gas dynamics. Because the gas is so turbulent and hot, evaporation occurs almost instantly, preventing even delicate materials, such as egg whites, from being damaged by excessive exposure to the heat. And, because the atomization nozzle is so large — essentially, it's an open pipe — abrasive and corrosive materials cause little harm.

The equipment. The pulse-combustion unit that sits atop the drying chamber consists of an outer shell, a rotary air valve, an internal combustion chamber, a gas inlet, a gas pilot, a tail pipe, a quench-air inlet, and the atomizer. In operation, air is pumped into the outer shell at low pressure. The rotary air valve feeds the air into the combustion chamber. At the same time, fuel (natural gas or propane) enters the combustion chamber and is ignited by the pilot. The fuel explodes, creating extremely hot (up to 2,000°F) air pressurized to about 3 psi. The hot air rushes down the tail pipe toward the atomization nozzle. Before it reaches the nozzle, quench air blends with the hot air to bring it to the desired material contact temperature. This cycle of air, fuel, ignition, and quench air is repeated at a controlled rate of about 80 to 110 times per second. In the meantime, feed material is continuously pumped into the atomization nozzle, and the pulsing hot air instantly atomizes the material as it exits the nozzle, drying it in less than a second. (Material in a conventional spray dryer may take up to 30 seconds to dry.)

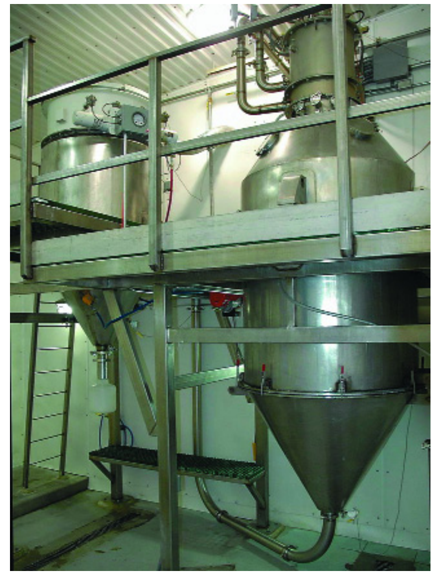
Typically, to achieve very fine particles in a conventional spray dryer, the slurry has a high percentage of liquid. This makes the pressure nozzle's work easier and also minimizes the solids in the drying chamber, which reduces the unintended agglomeration and material accumulation on the drying chamber walls that often occurs. It also limits the amount of dried material that's produced in a given time.

"We've [dried] detergents so thick that we made a dough ball and tossed it into the feed pump hopper and it atomized into a really nice powder."

In pulse-combustion drying, the feed material can have a very high percentage of solids. In fact, Rehkopf says, "We've done detergents so thick that we made a dough ball and tossed it into the feed pump hopper and it atomized into a really nice powder." Being able to use more highly concentrated feed material means that more material can be dried in a shorter time at a lower cost.

The test center

The supplier's test center includes a model P-0.1 pilot dryer and a P-1 production dryer. The pilot dryer is used to test products, optimize powder quality and drying parameters, and toll-dry short runs of high-value material. The P-1 dryer is used for scale-up demonstrations and toll drying. It releases 1 million BTUs of heat and evaporates 400 pounds of water per hour. The company also manufactures dryers in other sizes to meet various customers' needs. Currently, the



Material dried in this pulse-combustion dryer (right) is collected by a baghouse (left).

largest dryer it manufactures is a P-3, which releases 3 million BTUs of heat and evaporates up to 2,000 pounds of water per hour.

The test center also contains dust collection equipment, various types of lab equipment, and extensive instrumentation equipment. The test center conducts bench tests free and charges fees for pilot and scale-up testing and toll drying.

According to Rehkopf, his company's pulse-combustion dryers will dry nearly any material. "If you can pump it, we can probably dry it," he says. Over the past few years, the supplier has tested hundreds of materials and found very few that couldn't be effectively dried in the dryers. "There are a few exceptions," he says. "Rubbery and stringy materials don't work very well. They'll atomize but won't break down properly to smaller and smaller particles. They tend to form a rubbery ball."

"Materials containing high sugar concentrations are also a problem," Rehkopf says. "The dried particles tend to melt onto the stainless steel drying chamber walls and stick there. It's frustrating, because we can't get this beautiful powder out."

The dryer supplier encourages customers to come to the test center and observe the tests as they're conducted. Some customers prefer to simply send material and wait for the test results.

Conducting the tests

One of the materials Altairnano wanted to test in the pulse-combustion dryer was a lithium-titanium oxide. It wanted to discover if it could expect to produce a larger quantity of particles at a cost-effective price by switching to this type of drying.

To start the testing process, in April 2006, the company sent a 10-gallon slurry sample to the test center. The first thing the test center does with materials it hasn't worked with before is perform bench tests, which include a finger test and a pan-drying test. For the finger test, a technician simply rubs the material through his or her fingers. The technician wears gloves if the material presents any minor health hazard; the test center seldom handles materials that present significant hazards. The finger test determines some of the material's basic characteristics. If the material is stringy and sticky as it's rubbed, it's likely to be more challenging to work with.

For the pan-drying test, essentially, lab personnel spread the material in a pan and dry it with heat. If the resulting material is flaky and dry, that's a good sign that it will dry well in the pulse-combustion dryer. If the material is gelatinous and shiny, that means that it will tend to melt rather than dry. Such material isn't a good candidate for pulse-combustion drying, although if handled carefully with sufficient dilution, it may dry adequately, says Rehkopf.

Altairnano's material did well in the bench tests, so the next step was to do pilot-scale tests. These are conducted in a model P-0.1 pulse-combustion dryer, which releases 100,000 BTUs and evaporates 40 pounds of water per hour. Before drying the material, the technician analyzes the material for viscosity, percentage of solids, and pH. This helps establish drying parameters such as atomization energy, inlet and outlet temperatures, viscosity ranges, and feed preparation. The material is then pumped into the dryer, where every detail of the drying process is monitored. "The dryer is completely instrumented," says Rehkopf, "so absolutely everything can be measured."

Some of the measurements include inlet and outlet temperatures, several temperatures taken throughout the process, and combustor pressure. These help determine the most effective nozzle size and suitable atomization pressure.

With Altairnano's material, as with that of other customers, test center personnel performed several variations of the tests using different sets of parameters. The results of these tests enable the test center to recommend slurry viscosity, atomization pressure, and other parameters to achieve the results the customer requires. The test center sent all test data, as well as the dried material, back to Altairnano, which then did its own particle analysis tests to confirm the results and determine which drying parameters produced the most desirable material for its process.

The particles produced in the pulse-combustion dryer were finer and more uniform than the ones the company had been producing in its spray dryer.

Impressive results

Altairnano engineers were impressed with the test results. The particles produced in the pulse-combustion dryer were finer and more uniform than the ones the company had been producing in its spray dryer. In October, the company placed an order for two model P-0.4 dryers to be delivered as soon as possible. These dryers release 400,000 BTUs of heat per hour and have a 160 lb/h evaporation rate.

Pleased with the results of these tests, the company has subsequently tested other materials, including pigments and ceramic materials, at the test center. It has also had PCS do toll drying for them. **PBE**

Note: To find other articles on drying, look under "Drying" in *Powder and Bulk Engineering*'s comprehensive article index at www.powderbulk.com and in the December 2006 issue.

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