

Fluid-bed dryers: Static versus vibrating

Ed Randel, Jim Schak, and Ananta Islam GEA Process Engineering

Fluid-bed dryers are popular for drying wet powders, granules, pellets, and other bulk solids because of the dryers' versatility and heat transfer efficiency, as well as the low cost of natural gas, their typical heat source. This article describes the operation, benefits, and limitations of two types of rectangular fluid-bed dryers — static and vibrating — and explains what feeders and air-material separation equipment are typically used with them.

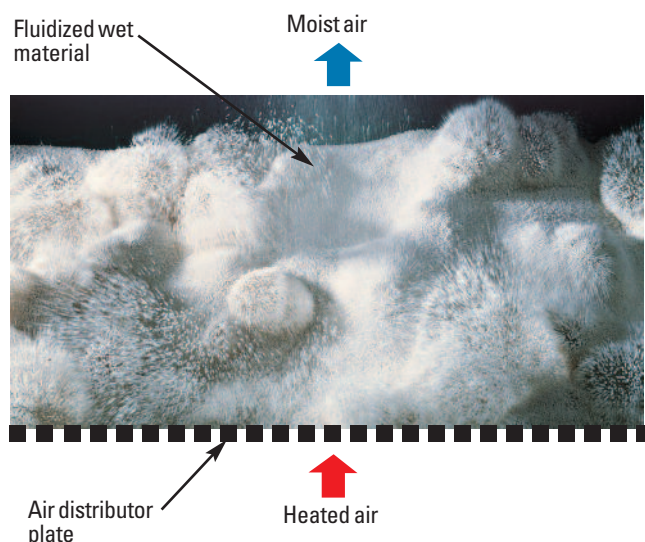
A fluid-bed dryer uses *convection* — heated air in direct contact with the wet feed — to dry material suspended in a fluidized bed. In operation, air heated by a natural-gas-fueled air heater passes upward into the dryer through a perforated air distributor plate (or perforated conveyor pan). This fluidizes the wet feed material, as shown in Figure 1. To obtain a final dried product with uniform moisture content, the air distribution plate's design must provide vertical airflow through the material bed without allowing air to bypass the material bed. As the heated air passes through the wet material, the air carries away the moisture, cools, and is exhausted through a downstream cyclone, baghouse, or other air-material separation equipment. The dried final product is conveyed by various means, depending on the dryer type, to the dryer's discharge.

The fluid-bed dryer's advantage over other dryers is that the fluid-bed unit suspends the material in the heated air 100 percent of the time. In a *conduction* dryer (in which

heat is indirectly transferred to the material through a hot surface, such as the dryer wall), only some of the material contacts the hot surface at one time, and in a convection dryer that doesn't suspend material, such as a rotary dryer, the material contacts the heated air only as the particles shower through the drying chamber with the dryer's rotation. Compared with these dryers, the fluid-bed dryer has a very high heat-transfer rate and a smaller footprint, giving it higher heat efficiency. By intimately mixing the heated air and material, the fluid-bed dryer also brings the air and material close to *equilibrium* (that is, the same moisture content and temperature).

Figure 1

Material suspended in fluidized bed in fluid-bed dryer



Unlike most other convection dryers, the fluid-bed dryer can also be divided into multiple drying and cooling zones with different air temperatures to protect the material from heat damage. Most dried particles are heat-sensitive but are protected by the evaporative cooling effect; for such a material, the first zone has a higher air temperature and subsequent zones have progressively lower temperatures to protect the material as it dries. Other particles, such as starch, are more heat-sensitive when wet and will gelatinize if overheated; in this case, the first zone has a lower air temperature and the subsequent zones have increasingly higher temperatures.

Fluid-bed dryer types

A rectangular fluid-bed dryer can be one of two main types: static or vibrating. How material moves through each dryer is fundamentally different. In a *static* (or *stationary*) *fluid-bed dryer*, the fluidized material bed is deep (usually more than a foot) and the material acts like a liquid, flowing from a high level in the dryer to a low level. In a *vibrating fluid-bed dryer*, the material bed is much shall-

lower (usually just a few inches) and the material is conveyed through the dryer not only by the same liquid-like flow from high to low but by a vibrating conveyor's vibratory action. In the vibrating dryer, the heated airflow's primary function is to dry the material by flowing upward through the conveyor's perforated pan.

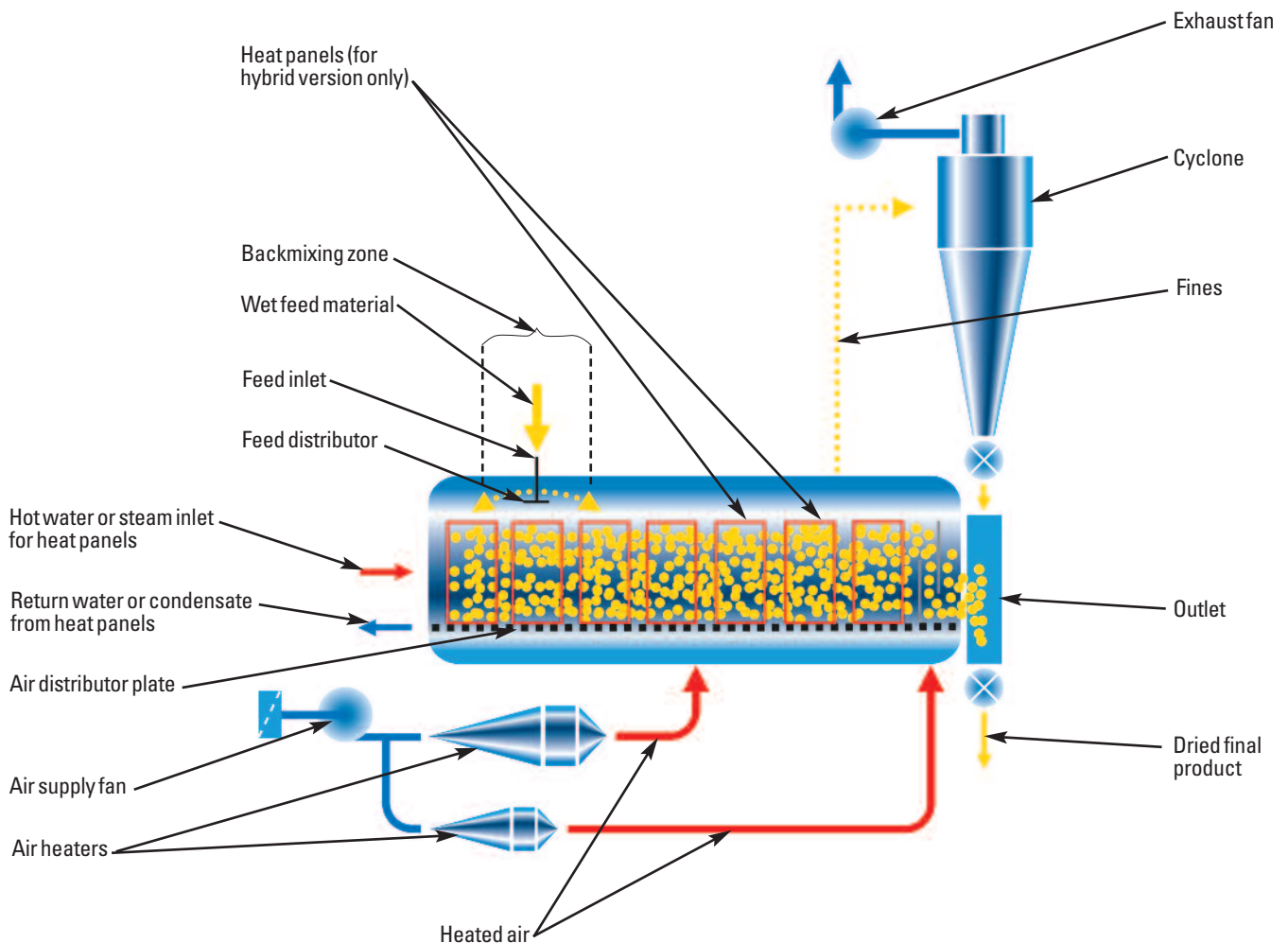
Let's take a closer look at how each dryer operates and is applied.

Static fluid-bed dryer

Operation. A static fluid-bed dryer's operation, as illustrated in Figure 2, differs from that of the vibrating dryer in several ways. (Be aware that the example dryer in Figure 2 has multiple drying zones with air supplied by two air heaters and that the heat panels shown in the drying chamber are for the hybrid version of this dryer, discussed later in this section.) The heated airflow fluidizes the material and promotes its liquid-like flow from the drying chamber's highest point, at the feed inlet, toward the chamber's

Figure 2

Static fluid-bed dryer (hybrid version)



lowest point, at the outlet. The static dryer's deep material bed must be *completely* fluidized to dry and move toward the dryer's outlet. The use of the deep bed reduces the dryer's overall size and, hence, its airflow requirements. The static dryer's design for a given application is usually based on material retention time (determined by developing a drying curve for the material during drying tests). The longer the required material retention time, the greater advantage the static fluid-bed dryer provides over a vibrating unit.

Another major operating difference is that the static fluid-bed dryer has a backmixing zone at the feed inlet, where the wet feed material is distributed by a rotating spreader mechanism called a *feed distributor*. Spraying the wet feed material into the partially dried fluidized material achieves a uniform material moisture content and temperature throughout the drying chamber, allowing the dryer to handle feed materials with a wide range of moisture levels.

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Hybrid version. Another version of this dryer is called a *hybrid static fluid-bed dryer*, in which panels (or tube bundles) located inside the drying chamber and heated by circulating hot water or steam provide conduction heat to the wet material. The heat panels (Figure 2) reduce the amount of heated airflow the dryer requires. Because a fluid-bed dryer's heat efficiency is a function of the amount of warm air exhausted from it, the conduction components in the hybrid static dryer increase the unit's heat efficiency over that of a standard static dryer.

Applications. Typical applications for a standard or hybrid static fluid-bed dryer are polymers, ceramics, and inorganic materials. The dryer is best suited to materials with relatively narrow size distributions and with particle sizes greater than 50 microns but smaller than about $\frac{1}{2}$ inch. The static dryer isn't suited to handling particles that have a large length-to-diameter ratio, such as rice, because the air flowing through the air distribution plate will bypass the material bed and *channel* (form ratholes) between these long particles rather than fluidize them, as shown in Figure 3a.

Vibrating fluid-bed dryer

Operation. In a vibrating fluid-bed dryer, as shown in Figure 4, the heated air flows vertically through the perforated conveying pan, bubbling upward through the shallow bed of wet material on the vibrating conveyor. Because the dryer relies primarily on the conveyor's vibratory action to

transport the material toward the discharge, the airflow velocity can be adjusted to dry materials with a wide particle size range or small particle size without much effect on conveying. Unlike in the static fluid-bed dryer, material in the vibrating dryer doesn't have to be completely airborne to be successfully dried, minimizing fines carryover to the downstream air-material separation equipment. The vi-

Figure 3

Effect of static and vibrating fluid-bed dryer operation on rice particles with large length-to-diameter ratio

a. Static unit's airflow channeling through particles



b. Vibrating unit's vibrating action fluidizing particles



brating conveyor moves material through the dryer in plug flow, achieving first-in first-out flow and reducing the material retention time compared with the static dryer. (Also notice that the example dryer in Figure 4 has both a drying zone and a cooling zone.)

Applications. Some common applications for the vibrating fluid-bed dryer are food products, specialty chemicals, and extrudates. The dryer is ideal for handling materials with a wide particle size range and particle sizes smaller than 50 microns and up to about ½ inch. The dryer is especially suited to handling food and other products with sanitary requirements because the unit can be equipped with a hinged or removable top that allows quick access for cleaning.

Options for feed handling equipment

Both static and vibrating fluid-bed dryers can handle wet solids like powders, granules, pellets, and some filter cakes. The static fluid-bed dryer’s backmixing zone allows it to handle a wider range of higher-moisture materials than the vibrating fluid-bed dryer can, but the vibrating dryer can also be connected to an external backmixing unit to handle moister materials. This external unit (typically a continuous paddle mixer with adjustable paddles) backmixes dried material discharged from the dryer’s outlet with moist feed and discharges the mixture to the dryer’s feeder.

Feeder types. The feeder most commonly used with a fluid-bed dryer is a screw feeder, but a rotary airlock valve, table feeder, belt feeder, or vibrating tray feeder can also be used.

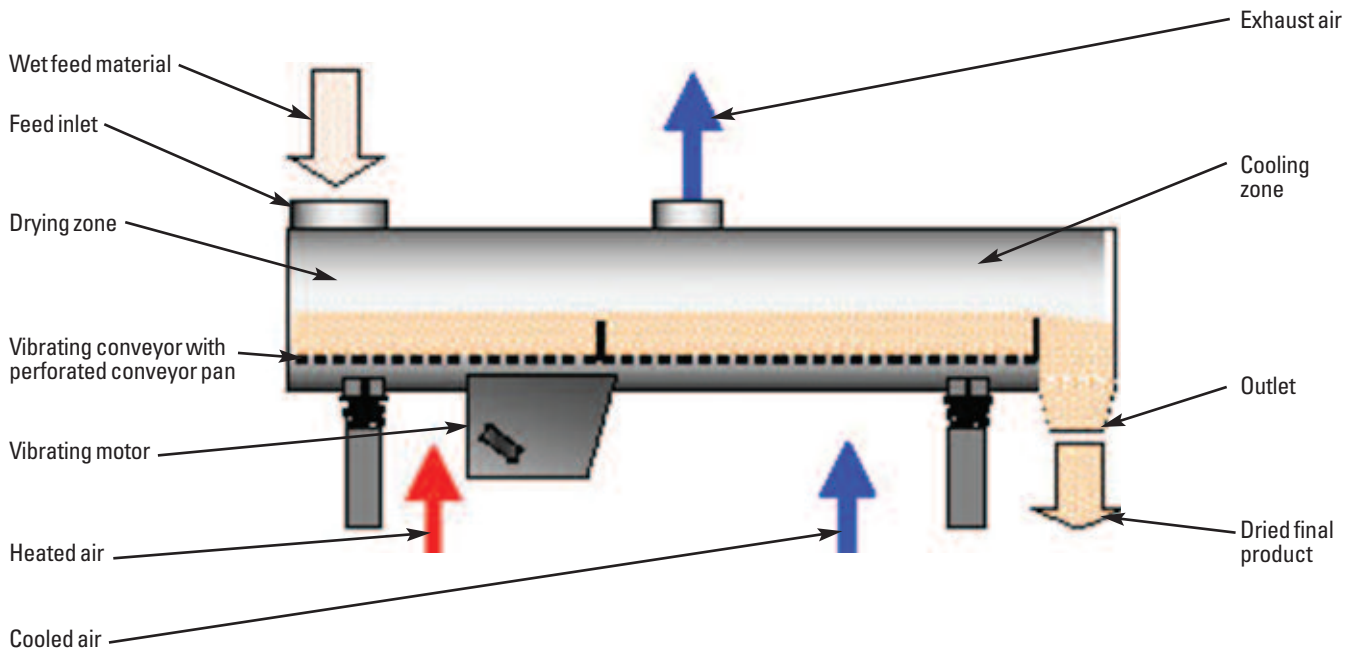
[*Editor’s note:* For more information on this equipment, see the “For further reading” section later in this article.]

With a fluid-bed dryer, the goal is to feed the wet material to the dryer with minute-to-minute accuracy to produce a consistently fluidized bed with uniform moisture content. Consider, for instance, a screw feeder that has one large slowly rotating screw and delivers material to a single discharge point: The material can “plop” off the screw’s end over a period of minutes, producing large moist lumps in the material bed and increasing the bed’s moisture content range. A better screw feeder for a fluid-bed dryer would be a twin-screw feeder with corotating, intermeshing screws operating at a higher speed and delivering material to many discharge points. This feeder will provide more positive conveying action, providing the feeding accuracy required to yield a consistently fluidized bed.

Centrifuges. Mechanical dewatering is always more efficient than thermal drying. For this reason, a dewatering centrifuge can be used upstream from the fluid-bed dryer to dewater wet feeds such as slurries and suspensions and produce filter cake that can be fed to the dryer, reducing the amount of heat energy the drying operation requires. A surge hopper should be used between the centrifuge and the dryer’s feeder to isolate the dryer from the centrifuge for startup, troubleshooting, and maintenance. Be aware that storing the wet filter cake in the surge hopper can make it hard to flow, so the hopper should be equipped with strong agitation and a multiple-screw discharge device to assist flow to the dryer’s feeder.

Figure 4

Vibrating fluid-bed dryer



Options for air-material separation equipment

For separating the dried material from the fluid-bed dryer's moist exhaust air, the three most common equipment options are a cyclone used with a baghouse, a baghouse used alone, and a cyclone used with a wet scrubber. [*Editor's note:* For more information on these equipment types, see "For further reading."] Discussing how to choose one of these options for a fluid-bed drying application is beyond this article's scope; for selection help, it's best to work with a drying or dust collection equipment consultant or supplier. The following information provides general guidance for using each equipment type with a fluid-bed dryer.

Cyclones. In fluid-bed drying applications, the cyclone's relatively low collection efficiency limits it to serving primarily as a precleaner upstream from a baghouse or wet scrubber. The cyclone is easier to clean than a baghouse, which makes it especially useful when the dryer will handle multiple materials. A cyclone is also useful for handling material that can degrade when it remains on filter surfaces over a long period; in such an application, a cyclone installed prior to the baghouse will collect most of the material before it can reach the bag filters.

Baghouses. When a baghouse is used in a fluid-bed drying application, it's important to consider the unit's air-to-cloth ratio and select the right bag filter media. The rule of thumb for determining the air-to-cloth ratio in this application is to use 1 square foot of filter surface area per 4 acfm of air flowing through the baghouse. However, this ratio can vary depending on the material's particle size and other characteristics and the air's dust loading. The baghouse's *can velocity* (the velocity of the air flowing vertically through the baghouse past the bag filters) is also important: When the bag filters are pulse-cleaned, an excessive can velocity will cause the particles to be re-entrained on the filters. While some suppliers equip their baghouses with longer filters to achieve a lower air-to-cloth ratio and reduce the housing's size so it's cheaper to fabricate, this can produce an excessive can velocity and a high pressure drop.

When the bag filters are installed, the centerline distance between them should be large enough to prevent dust from bridging between adjacent filters and to keep the can velocity low.

The static fluid-bed dryer can be equipped with an *integral baghouse*, which is installed partly in the drying chamber and partly at the discharge, to minimize the baghouse's air-to-cloth ratio. With a conventional external baghouse, the dust-laden air must travel through a duct to the baghouse at 3,500 fpm or more, and it's difficult to slow the particles down enough to avoid re-entraining them on the filters during cleaning. In contrast, in the integral baghouse the dust particles never reach 3,500 fpm because they stay in

the drying chamber with an airflow velocity ranging from 100 to 150 fpm, depending on the dryer's design.

Many media are available for bag filters. For most fluid-bed dryer applications, the best media consists of a polytetrafluoroethylene (PTFE; also known as Teflon) laminate over a base material such as polyester or flame-resistant aramid polymer (also known as Nomex). The base material is chosen to handle the operating temperature. Although the PTFE membrane is expensive, it promotes particle release during filter cleaning to maintain the desired pressure drop across the baghouse.

Wet scrubbers. While a few fluid-bed dryers handling water-soluble materials require a wet scrubber to separate the material from air, the wet scrubber has several disadvantages that make cyclones and baghouses much more common choices for fluid-bed drying. The wet scrubber requires water to saturate the exhaust air during scrubbing, but water may not be plentiful at the site and it also adds expense to the drying operation. Because the scrubber removes dust by capturing the particles in water droplets, the water discharged from the scrubber must be treated or put back into the process, making it harder to handle than the dry powder discharged from a cyclone or baghouse. The scrubber also typically has a lower collection efficiency than a baghouse, which can make the EPA clean air permitting process more difficult for a scrubber. The scrubber usually requires a much higher pressure drop (as much as 4 to 8 inches water column more) than a baghouse, adding to the exhaust fan's horsepower requirement.

Summing up each dryer's benefits and limitations

The static fluid-bed dryer is preferred over a vibrating fluid-bed dryer in many applications because it provides greater heat efficiency — at lower cost and with a smaller footprint. In other applications, the vibrating fluid-bed dryer can be a better choice. Here's a brief summary of the benefits and limitations of both dryers.

Static fluid-bed dryer. These major benefits apply to both the standard and hybrid types unless otherwise noted.

- The material bed is usually 5 to 10 (or more) times deeper than in a vibrating fluid-bed dryer, which reduces the static dryer's footprint for the same material retention time. This reduces the dryer's overall airflow and heat energy requirements.
- The backmixing zone allows the dryer to handle feed materials with widely different moisture levels.
- The dryer's lack of vibrating conveyor provides two benefits: The static dryer has fewer moving parts than the vibrating fluid-bed dryer, reducing its maintenance and downtime requirements. The static dryer's lack of vibration also eliminates a need for using flexible connections between the dryer and upstream and downstream equipment; because these connections can be damaged by high

temperatures, the static dryer can be operated at higher temperatures than a vibrating unit.

- When required, the dryer's airflow can be controlled to *blow off* fines — that is, carry them off with the exhaust air to the downstream air-material separation equipment — without exhausting desired-size particles.
- By directing the airflow forward, the unit's air distribution plates help to sweep material out of the dryer for complete cleanout.
- With the hybrid static fluid-bed dryer, the conductive heat panels not only reduce the material bed's size and the amount of heated airflow the dryer requires, but allow the use of smaller air-material separation equipment.
- When the hybrid dryer is used in a closed cycle in which the heated air is recycled back to the dryer rather than exhausted, the dryer's heat panels minimize the amount of air that must be recycled and thermally conditioned. [**Editor's note:** For more information about closed-cycle fluid-bed drying systems, contact the authors.]

The static fluid-bed dryer's limitations are the result of the dryer's reliance on airflow alone for conveying material through the dryer, which makes the unit unsuitable for some materials:

- Air flowing upward through the dryer's air distribution plate will channel through long particles rather than fluidize them (Figure 3a).
- Because material in the static dryer must be completely fluidized to be conveyed through it, the dryer isn't suited to handling a material with a wide particle size distribution. Such a material is difficult to fluidize because the airflow can blow smaller particles off the material bed and out with the exhaust air, or the airflow velocity can be too low to entrain larger particles, causing them to "salt out" (drop out) of the bed.
- It's difficult to maintain a consistently fluidized bed in the dryer with a fine material that has particles under 50 microns. (However, with fine particles larger than 50 microns, using a static fluid-bed dryer with an integral baghouse can help return fines to the dryer.)

Vibrating fluid-bed dryer. The vibrating fluid-bed dryer provides these main benefits:

- The dryer can handle materials with a wide particle size distribution. Because of the vibrating action's role in moving the material through the dryer, the dryer's airflow velocity can be adjusted to prevent blowing off fines or salting out larger particles in these materials without much effect on conveying.
- The dryer can handle fine materials with particles under 50 microns, because the airflow velocity can be adjusted to fluidize these particles with minimal effect on conveying.
- The vibrating dryer can handle any particle shape, including long particles, because its vibrating action minimizes the channeling effect (Figure 3b). As long as the

wet material can be transported by a vibrating conveyor, it can usually be handled in this dryer.

- The dryer's airflow can be controlled to handle process changes or changes in material characteristics more easily than in a static dryer because the conveyor's vibrating action, rather than airflow, plays the primary role in moving material through the dryer.
- The dryer's vibrating action is a more positive conveying force than airflow alone, producing a first-in first-out flow that results in more efficient drying with less airflow and a shorter material residence time than in a static dryer.

The vibrating fluid-bed dryer has these limitations:

- The dryer's material bed is shallow, making the dryer footprint larger than that of a static unit for the same material retention time.
- The dryer's vibrating conveyor adds moving parts to the unit, increasing its maintenance and downtime requirements.
- The need for flexible connections between the dryer and upstream and downstream equipment limits the dryer's operating temperature, because these connections are made of plastic and similar materials that can't handle high temperatures. Even fiberglass connections rated to 500°F won't handle some fluid-bed drying applications.
- Material that's too wet to be handled in the vibrating dryer must be backmixed with dry material in an external backmixing unit, adding cost and complexity to the process.

With the conductive heat panels, the hybrid dryer requires much less airflow and much less energy to heat the air than the standard unit.

Comparing both dryer designs for same application

Understanding how the static and vibrating fluid-bed dryer designs vary for the same application can help you select a dryer by revealing important information about the dryers' comparative sizes, energy costs, and other factors.

In Table I, the data shows how the design factors vary for a standard static fluid-bed dryer and vibrating fluid-bed dryer when drying wet organic salt crystals from 5 percent to 1 percent moisture at the same production rate. While the static dryer has a deeper material bed and longer material residence time than the vibrating unit, it has a much smaller footprint (based mainly on its bed area), requires much less airflow (based on the exhaust air), and uses less energy (including the fan and air heater loads in the table, plus electrical power) for heating the air. In fact, the static

dryer's bed area, airflow, and air heater load are almost half those required by the vibrating dryer. The smaller sizes of the static dryer's upstream filters, fans, and heaters and downstream air-material separation equipment and exhaust fan also reduce the dryer's overall cost compared with the vibrating dryer.

The data in Table II shows how the design of a hybrid static fluid-bed dryer with conductive heat panels offers further

advantages over that of a standard static unit for the same application. The data is based on drying polyvinyl chloride (PVC) powder from about 26 percent to less than 2 percent moisture at the same production rate. With the conductive heat panels, the hybrid dryer requires much less airflow and much less energy to heat the air than the standard unit. In fact, a typical hybrid unit requires 1,500 BTUs per pound of water evaporated, compared with 2,000 or more BTUs for many standard static fluid-bed dryers. **PBE**

Table I

Comparison of static and vibrating fluid-bed dryer designs for drying wet organic crystals at same rate^a

Design factor	Fluid-bed dryer type	
	Static	Vibrating
Production rate (kilograms per hour)	2,300	2,300
Bed area (square meters)	3.5	6.3
Bed height (meters)	1.0	0.2
Exhaust air (kilograms per hour)	7,890	13,500
Dew point (degrees Celsius)	34	30
Air heater load (kilocalories per hour)	87,500	164,400
Fan load (kilowatts)	35	45
Material residence time (minutes)	49	18

^aNote: These values are for illustration purposes only.

Table II

Comparison of hybrid and standard static fluid-bed dryer designs for drying PVC powder at same rate^a

Design factor	Static fluid-bed dryer type	
	Hybrid	Standard
Production rate (kilograms per hour)	1,000	1,000
Bed area (square meters)	3	8
Bed height (meters)	1.2	1.2
Exhaust air (kilograms per hour)	4,000	10,000
Dew point (degrees Celsius)	54	50
Air heater load (kilocalories per hour)	90,000	300,000
Heat panel load (kilocalories per hour)	180,000	0
Total heat load (kilocalories per hour)	270,000	300,000
Fan load (kilowatts)	15	40
Material residence time (minutes)	55	150

^aNote: These values are for illustration purposes only.

For further reading

Find more information on fluid-bed dryers, as well as feeders and air-material separation equipment for the dryers, in articles listed under "Drying," "Feeders," and "Dust collection and dust control" in *Powder and Bulk Engineering's* article index (in the December 2012 issue and at *PBE's* website, www.powderbulk.com) and in books available on the website at the *PBE* Bookstore. You can also purchase copies of past *PBE* articles at www.powderbulk.com.

Ed Randel is a process development manager at GEA Process Engineering, 9165 Rumsey Road, Columbia, MD 21045; 410-997-8700, fax 410-997-5021 (ed.randel@gea.com, www.gea.com). *Jim Schak* (james.schak@gea.com) is national sales manager for the company's Chem Systems Group. *Ananta Islam* (ananta.islam@gea.com) is a sales engineer with the company.

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