With many grinding mills—including roller mills, rotor mills, hammer mills, air-classifier mills, and fluidized-bed opposed-jet mills—successfully achieving the desired production throughput depends on help from a vacuum pneumatic conveying system. The system not only helps draw the material through the mill, but in some cases assists the mill in achieving the final product’s desired particle size.
When a mill’s production throughput is less than its design capacity, a poorly selected pneumatic conveying system is usually at fault, even when the system was supplied as part of the mill package. In some cases, an ineffective conveying system can reduce the mill’s grinding capacity by as much as 50 percent. Yet it’s hard to find published information on how to select an effective pneumatic conveying system for a grinding mill.

In this article, I’ll try to fill this knowledge gap by looking at how to select a pneumatic conveying system for two of the most widely used mills in the pharmaceutical, chemical, and other industries: the hammer mill and the fluidized-bed opposed-jet mill.

**How pneumatic conveying aids mill performance**

A vacuum pneumatic conveying system for a grinding mill has relatively few components: a conveying line that runs from the mill’s outlet to the final product’s destination (such as a cyclone or baghouse), a fan downstream from the destination to create the vacuum, and a few accessory components (such as a diverter valve or damper). You can see a typical pneumatic conveying system for a grinding operation in Figure 1. Despite its apparent simplicity, however, the system must be carefully designed—with properly chosen components—to effectively assist the operation of a hammer mill or fluidized-bed opposed-jet mill.

**Aiding hammer mill performance.** The hammer mill, as shown in Figure 2a, can be used for coarse, medium, or fine grinding. In this mill, particles are reduced mainly by mechanical impact from the unit’s high-speed rotating hammers. When the unit handles low-density materials or grinds materials to fine particle sizes, it must be equipped with a pneumatic conveying system (making it an air-assisted hammer mill) to aid the grinding operation. The conveying system does this in two ways: It quickly removes the right-sized particles from the mill’s grinding chamber through holes in a screen encircling the grinding chamber, and it transports the final product from the mill’s outlet to its destination.

**Aiding fluidized-bed opposed-jet mill performance.** The fluidized-bed opposed-jet mill, as shown in Figure 2b, provides fine to superfine grinding and is especially suited to applications where controlling the final product’s maximum particle size is critical. The mill’s high-velocity air (or other gas) jets force particles to collide with each other in the unit’s grinding chamber, reducing particles only by interparticle collisions rather than by mechanical impact. A rotating classifier wheel above the grinding chamber controls the final product’s particle size distribution by returning coarse particles to the grinding chamber and sending right-size particles to the outlet. The mill’s pneumatic conveying system aids grinding in two ways: Besides helping transport the final product to its destination, the system works with the classifier wheel to achieve the required final particle size distribution.

**Essential design factors**

To select a pneumatic conveying system for your hammer mill or fluidized-bed opposed-jet mill, you must calculate two design factors. One is the mill’s required airflow, which is essential for selecting the conveying system’s line diameter and the sizes of other conveying system components. The other is the system pressure drop, which is a measure of air and material flow resistance across both the mill and the conveying system. The system pressure drop is essential for selecting the conveying system’s fan and motor size.
Figure 2

Mill close-ups

a. Hammer mill

b. Fluidized-bed opposed-jet mill
In the following sections, I’ll explain how to select a conveying system for your hammer mill or fluidized-bed opposed-jet mill based on the required airflow and the pressure drop across the system. The methods for each mill are different, because each mill has unique operating characteristics.

**System selection for a hammer mill**

**Determining required airflow.** To determine the required airflow the pneumatic conveying system for your hammer mill must handle, you need to consider both aspiration air and added conveying air (Figure 2a).

Aspiration air is the air drawn through the hammer mill's inlet and through the screen holes to the outlet by the mill's fan-like rotating hammers. To achieve good mill performance, the pneumatic conveying system has to move this air away from the mill. Added conveying air is the additional air needed to pick up the final product from the product pan (not shown in Figure 2a) at the mill's outlet and convey it to a cyclone, baghouse, or other destination. The aspiration air enters the mill's inlet along with the feed material, while the added conveying air is drawn directly from ambient air into the product pan. Combined, the aspiration air and the added conveying air typically equal your hammer mill's total required airflow, although this can vary depending on the mill's configuration and operating requirements.

There are also some popular rules of thumb for calculating a hammer mill's required airflow, such as from 1 to 3 cfm of air volume per every square inch of hammer mill screen area, or from 800 to 1,200 cfm of air volume per every ton per hour of production. However, use such rules cautiously: Every hammer mill application is unique, with a different feed material density, screen hole size, and other factors. For best results, have your hammer mill supplier run grinding tests using your material to determine the mill's required airflow.

**High airflow caution.** While it may seem like higher airflow should improve hammer mill performance, unnecessarily high airflow will not only increase the mill's operating costs, it can also hinder its performance. Once the feed material enters the mill's grinding chamber, the strong suction created by the higher-than-necessary airflow will force many of the feed particles to strongly “attach” to the screen's internal surface. This reduces the particles' chances of impacting the rotating hammers and blocks many of the screen holes—and these problems are worse if the feed material is light, fluffy, or film-like.

**Determining pressure drop.** Once you've calculated your hammer mill's total required airflow, you can select the conveying system's air-material separator (typically a cyclone or dust collector or both, if required). You can then determine the system pressure drop. Start by using the final product's conveying velocity (also called pickup velocity) to calculate the conveying system's required line diameter. (If you don't know the final product's conveying velocity, you can have this characteristic tested.) Then use the conveying line diameter, the conveying velocity, and your mill's grinding rate to calculate the system pressure drop. When calculating the system pressure drop, don't forget to include the pressure drop across the air-material separator and the pressure drop across the hammer mill itself, which is usually from 6 to 12 inches of water column.

Finally, based on the system pressure drop and the hammer mill's required airflow, you can size the conveying system's fan and motor. [Editor's note: For more details about these steps, contact the author.]

**Inlet size caution.** An undersized hammer mill inlet can prevent aspiration air from entering easily with the feed material, which can greatly reduce the mill's grinding throughput or even cause incoming feed material to jam the mill. Selecting a large-enough inlet will allow the mill's pneumatic conveying system to operate effectively. For an existing hammer mill, this may require modifying the inlet or retrofitting a new one.

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**For best results, have the hammer mill supplier run grinding tests using your material to determine the mill's required airflow.**

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System selection for a fluidized-bed opposed-jet mill

**Determining required airflow.** Determining the required airflow for the fluidized-bed opposed-jet mill (Figure 2b) is simpler than for a hammer mill, because the opposed-jet mill's required airflow is predetermined by the size and number of air nozzles in the mill and the air jet pressure (that is, the pressure of its compressed-air supply). For instance, if your mill has three de Laval (hourglass-shaped) air nozzles, each with a 10-millimeter orifice, and the compressed-air supply is at 85 psig, the airflow from the nozzles totals about 666 scfm. Additional airflow typically includes another 12 scfm for purging the mill's bearings and 70 scfm to purge the classifier wheel's gap (the narrow space between the unit's rotating wheel and stationary mounting plate), yielding a total required airflow of about 748 scfm. You can use the total required airflow to select the system's cyclone and baghouse. Then, you can use your final product's conveying velocity to choose the conveying system's line diameter.

**Determining pressure drop.** Determining the fluidized-bed opposed-jet mill's pressure drop is much more complicated than for a hammer mill, however. The largest pressure drop occurs when the air passes through the classifier wheel. This pressure drop, which ranges from 25 to 30 inches of water column, keeps changing as the gravimetrically controlled feedrate to the mill fluctuates. Despite these pressure-drop fluctuations, the mill's pneumatic conveying system also has to maintain the grinding chamber at a slightly negative pressure (such as 1 inch of water column) or at neutral pressure so it can assist grinding by drawing the required airflow and the final product out of the chamber. For help determining the mill's pressure drop, you may need to run grinding tests in the mill supplier's lab.

The fluctuating pressure drop can make it difficult to design and operate the opposed-jet mill's conveying sys-
tem. Note that to minimize the negative effect of the fluctuating feedrate, it's best to control the material feedrate and airflow into the mill to maintain a solids-to-air mass-flow ratio in the mill of typically no more than 1:2. (This rule also applies to the air-assisted hammer mill.) You can use this rule to double-check whether the conveying system is providing enough airflow for the mill or whether the mill is just too small for your required production rate.

Once you've determined the mill's pressure drop, you can choose the system's fan and motor size.

Moisture caution: The airflow through the mill's de Laval nozzles is isentropic, meaning that the air expands and drops in temperature after it leaves the nozzles. Not only will this lower air temperature affect the calculation for your final product's conveying velocity, it also will condense moisture (introduced to the mill by your feed material) from the air. The moisture can cause fine particles to foul the classifier wheel's surface. This fouling can increase the load on the classifier motor, reduce the mill throughput, change the final product's particle size distribution, or even cause your entire grinding system to shut down. One way to solve this problem is to predry the feed material before it enters the mill. Another solution is to heat the compressed air to keep it from cooling below the dew point. In a less extreme case, periodically cleaning the classifier wheel will work.

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