Pneumatic points to ponder...

Building on the information in his first four series of columns, Paul E. Solt, a private consultant with more than 43 years experience installing and troubleshooting pneumatic conveying systems, presents a fifth series, on the general application of pneumatic conveying. In a separate section, Solt also answers your pneumatic conveying questions.

In this sixth column on the general application of pneumatic conveying, we’ll apply information from previous columns to selecting a pneumatic conveying system for a difficult-to-handle material: cohesive powder. As you read this month’s column, it may be helpful to review information in previous columns.

Understanding your material’s characteristics is the first step in selecting a pneumatic conveying system for a difficult-to-handle material: cohesive powder. As you read this month’s column, it may be helpful to review information in previous columns.

Despite the difficult flow characteristics of cohesive powders, you can select a pneumatic conveying system that successfully conveys the material. The following sections give tips on choosing various components and methods to handle a cohesive powder in a dilute-phase pneumatic conveying system. The final section explains how to select a dense-phase conveying system for handling a cohesive powder.

Fluidizing components

Many fine powders can be fluidized, which is a requirement for conveying in dilute phase. Fluidizing powder means passing a small quantity of air upward through the powder bed to separate the particles from each other. This suspends each particle on an air cushion, eliminates interparticle friction, and gives the solids-gas mix all the properties of a liquid.

Some very fine cohesive powders notorious for causing problems in pneumatic conveying systems are titanium dioxide, lead oxide, zinc oxide, and carbon black. In these powders, which are often used as additives in other manufactured materials, up to 100 percent of the particles are smaller than 2 microns. Another group of cohesive powders that are slightly coarser but still cause problems are fine food products that often contain some fat, including cake mixes, doughnut mixes, and ground nuts. Other cohesive powders are any fine powders with surface moisture. The moisture makes the powders sticky, just as water added to wheat flour forms a paste.

On the other hand, if the cohesive powder isn’t allowed to settle in the vessel but is fluidized as it enters it, and if the particles aren’t allowed to stick to each other, you can maintain the powder’s fluidized state. One way to achieve this is by using a screw- or ribbon-type rotating device in the vessel to mechanically agitate the powder, which breaks it up and fluidizes it.

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However, a cohesive powder doesn’t fluidize well. If the powder is allowed to settle in the storage vessel or feed bin, air passing upward through the powder bed fractures the bed, forming a chasm from bottom to top. All the air passes upward through the chasm rather than separating and fluidizing the particles.

In some cases, cycling a stream of fluidizing air intermittently into the vessel—that is, applying the air for 2 to 3 seconds, then stopping it for the same period—will fluidize the powder. Such continuous cycling works to dislodge the settled cohesive powder by forming and then collapsing a chasm in the powder or by creating multiple chasms.

Bin design and flow aids

A cohesive powder tends to bridge or compact when stored in a vessel or feed bin. The powder compresses as it flows downward through a typical bin’s 60-degree cone section and approaches the discharge, then frequently bridges and stops flowing.

Because the powder doesn’t fluidize well, you must carefully design the...
bin or use flow aids to get the powder to flow from the bin into your conveying system. You can enhance powder flow by choosing an effectively designed bin with a steeper (greater than 60 degrees) cone angle, asymmetrical construction, a chisel-shaped bottom, a vibrating bin bottom, or a large discharge opening. You can also choose flow aids, such as air cannons, vibrators, and sonic horns, to enhance powder flow from the bin.

**Rotary feeder**

Using a rotary feeder (or combination rotary airlock feeder) to discharge any dry bulk material from a bin into your conveying system can cause problems. When the material is a cohesive powder, the problems can be more severe.

Usually, the smaller the feeder's inlet and the smaller the rotor pockets the harder it is to pass powder through the feeder. In fact, the powder can be carried back to the powder feedpoint above the rotor rather than discharging into the *pickup pan*, shown in Figure 1, which is the component connecting the rotary feeder and the conveying line. For this reason, some users choose an oversized rotary feeder that has as much as two to three times the necessary capacity. The larger inlet and rotor pockets reduce the powder's compaction and bridging inside the feeder.

But if you select an oversized rotary feeder to help powder flow from the bin into your conveying system, the rotor speed will be very slow. For instance, with an eight-blade rotor turning at 2 rpm, powder will discharge from the rotor pockets into your conveying line only 16 times per minute. This means that the powder would feed in pulses 3.75 seconds apart, which will reduce the conveying system's efficiency.

Instead, you can use a reduced-displacement rotor, as shown in Figure 2, that requires turning the rotor at higher speed. One type of reduced-displacement rotor is fitted with blocks between the rotor blades (Figure 2a). However, a better design is a rotor with half-round, rather than vee-shaped, pockets (Figure 2b). These half-round pockets don't hold powder in the pocket as much as other designs, so the powder can fall more easily into your conveying system.

The problem of powder sticking in the feeder's rotor pockets rather than dropping out can prevent new powder from entering the feeder and reduce or stop feed to your conveying system. At first glance, this can appear to be caused by material bridging in the feed bin above the feeder, even though the problem is actually in your feeder.

To eliminate this problem, you can use a *blow-through feeder*, as shown in Figure 3. Available in several designs, this feeder allows conveying air to enter through the feeder's end head plate. The air passes through the rotor pockets and discharges through the opposite head plate into the conveying line. The airflow through the rotor pockets entrains the powder and cleans it out of the pockets.

Other feeders are variations of this blow-through design. For instance, a feeder with a closed-end rotor, as shown in Figure 4, can't be designed to allow air to blow entirely through
the rotor pockets. But you can use air nozzles or jets to divert conveying air through the feeder’s pickup pan and from there into the rotor pocket to dislodge the powder.

You can use a simple test to tell if powder is sticking in your rotary feeder’s rotor pockets. For the test, insert a copper tube into the feeder to direct high-pressure air into it. If the air dislodges powder from the pockets, you know this is the problem. To correct the problem, you can switch to a blow-through feeder or install air nozzles and jets in your existing feeder.

**Pickup pan**

Your conveying system’s pickup pan — where powder is picked up from the feeder’s discharge and enters the conveying line (Figure 1) — can be any of various designs as long as it satisfies two conditions:

1. The pickup pan’s discharge into the conveying line should be as large as practical to reduce any flow obstruction.

2. The distance from the rotary feeder’s discharge flange to the conveying line’s centerline should be as short as possible.

If the pickup pan is too large, powder can accumulate in it, build up on its walls, and then periodically drop into the conveying line.

A pickup pan that meets these criteria will have minimum volume but provide free powder flow and will be only minimally affected by the counterflowing leakage air passing upward through the feeder. If the pickup pan is too large, powder can accumulate in it, build up on its walls, and then periodically drop into the conveying line, which will cause a pressure surge in your conveying system.

**Conveying line**

Your conveying line’s construction material won’t have a major effect on the conveying system’s operating pressure. However, some construction materials can cause the powder to stick to the line’s inside walls. As the powder builds up on the walls, the inside line diameter reduces, in turn substantially increasing the operating pressure.

Even though it seems that pipe with a rougher surface should have a higher friction factor than smooth pipe and that rubber hose should have a substantially higher friction factor than aluminum tubing, their friction factors aren’t nearly as critical when pneumatically conveying a powder through the line as they are with airflow alone through the line. This is because the conveyed powder coats the line’s inside wall with a fine dust. Once this occurs, the conveying air and powder don’t contact the pipe surface but only the coated wall, which is now smooth regardless of the line’s construction material.

Thus it’s more important to choose your conveying line construction material to discourage excessive buildup inside the line rather than to provide a certain surface roughness or friction factor. Of course, the construction material must be compatible with your powder. For instance, you don’t want to use black hose to convey white powder, because residue from the hose can contaminate your powder.

In some cases, a cohesive powder has been successfully handled in a conveying line whose inside surface is coated with a quick-release material such as Teflon or high-density plastic. However, if the particles are very fine (that is, 100 percent are less than 10 micron), this type of surface coating doesn’t really help.

Instead, you can choose a construction material such as hose that can flex to keep the line clean. Unlike rigid pipe, flexible hose can move, breaking off the powder buildup inside the line and clearing it. Examples of very fine cohesive powders handled in conveying systems with flexible hose include cake mixes, very finely ground almonds with nut oils, oxides, fly ash with gypsum mixture, and very finely ground calcium carbonate.

While the more flexible the hose, the cleaner the line will stay, flexible hose can also be less resistant to wear. If your fine cohesive powder is abrasive, it can wear the hose faster. But wear also depends on particle size. Since most cohesive powders have very fine particles, the particles’ impact energy is small and the hose can have a surprisingly long service life.

[Editor’s note: Find more information on selecting a conveying line in David Mills’ article, “Using rubber hose to enhance your pneumatic conveying process,” page 79.]

**Conveying line bends**

A cohesive powder tends to build up more in conveying line bends than in
A cohesive powder is its ability to penetrate the filter media in the conveying system's air-material separator (or filter receiver). Since some of these particles have diameters of only 1 or 2 microns, a separator with a high air-to-cloth ratio can cause powder to bleed through the filter media and release dirty effluent into the atmosphere.

The air-to-cloth ratio is the cubic feet per minute of airflow per square feet of cloth (filter media surface) area (that is, cubic feet per minute per square feet = feet/minute = air velocity). With a very fine cohesive powder like carbon black, it's common to select an air-material separator with an air-to-cloth ratio as low as 1.

However, this low air-to-cloth ratio may not be enough to keep the cohesive powder from caking on the filter media and can prevent proper filter cleaning as the sticky particles cling to the media's fibers. You can prevent this problem by choosing a quick-release filter media such as Gore-Tex.

**Conveying a coarse material.** You can convey a coarse material through the conveying system to clean buildup from the line's inside walls, as long as you can interrupt conveying for line cleaning and the coarse material doesn't degrade your conveyed material. For instance, if you're conveying pulverized, slightly sticky coal that leaves buildup inside the line, you can convey a small batch of coarse petroleum coke to clean the buildup from the line. The coke can be burned later along with the coal in a blast furnace. In another example, you can clean titanium dioxide from your line by conveying a batch of coarse sand through the line. You can collect and then reuse the sand for later line-cleaning cycles.

**Using a scraper or snake.** Sometimes the cohesive powder buildup inside the line hardens and can't be dislodged by air. In such a case, you can use a mechanical scraper or metal snake, such as for cleaning a sewage pipe, to clean your conveying line.

**Conveying line cleaning methods**
In some cases, powder buildup inside your conveying line is unavoidable. In such a situation, powder collects on the line's inside wall during conveying until the pressure drop builds up to a predetermined level, and then you must clean the line. You need to select a method for cleaning the powder from the line so the pressure drop can reduce to an acceptable limit and conveying can be restarted. Several line-cleaning methods can be used with a cohesive powder.

**Stopping the feed.** If you have an oversized conveying system that can be stopped periodically for cleaning without affecting your conveying capacity, you can clean buildup from the line by stopping the feed and allowing only airflow through the line. This briefly interrupts the conveying cycle. After airflow has cleared the line as much as possible, you can introduce additional air into the line, in a pulsating manner if necessary, to break loose any buildup. When the light line pressure (that is, the line pressure when only air, and no powder, is flowing through the line) reaches a predetermined minimum level, you can restart the conveying system.

**Using a rotating cutter.** You can insert an air-motor-powered rotating cutter at the end of a high-pressure hose into your conveying line to clean out hardened powder buildup, such as cement that has layered inside the line over a long period. As you feed the hose into the line, the rotating cutter advances and the air from the motor blows the cleaned powder out of the conveying line.

**Conveying ice cylinders.** In some cases, users have developed creative line-cleaning solutions. For instance, a foundry had a dense-phase high-pressure conveying system with 4-inch-diameter conveying line for transporting mulled sand, which built up inside the line. So the plant formed cylindrical ice chunks about 6 inches long inside a 4-inch-diameter pipe section and then inserted them one at a time into the conveying system to clean buildup from the line. When the buildup became excessive and stopped an ice cylinder's movement, the cylinder would quickly melt, and another could be inserted.

**Selecting a dense-phase pneumatic conveying system for handling cohesive powder**
A cohesive powder doesn't cause as many problems in a dense-phase system as in a dilute-phase system. The dense-phase system typically doesn't have a pickup pan, and the cohesive powder causes very few problems with the system's conveying line construction material and in the line bends.
Solt answers your questions

Paul E. Solt will answer questions here about previous “Pneumatic points to ponder…” columns or your conveying problems. Send your questions to Solt at the address listed at the end of this column; he’ll select representative questions to answer next time.

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My dilute-phase pneumatic conveying system has 160 feet of horizontal conveying line, 40 feet of vertical line, and six 90-degree bends. If I reroute the line to eliminate two 90-degree bends and 20 feet of horizontal straight line, how much will my system’s conveying capacity increase?

A

To determine this, we can use a linear inverse relationship for line length versus capacity. This will hold very close for small changes to an existing conveying system.

Your system’s present line length — using the equivalent length for each bend as 20 feet of straight line — is:

\[ 160 \text{ feet} + 40 \text{ feet} + (6 \times 20 \text{ feet}) = 320 \text{ feet} \]

The new system will have a line length of:

\[ 140 \text{ feet} + 40 \text{ feet} + (4 \times 20 \text{ feet}) = 260 \text{ feet} \]

After making your suggested changes, we would expect a capacity increase of:

\[ \frac{320}{260} = 33.33 \% \]

—P.E. Solt

But cohesive powder can pack too tightly in the dense-phase system, resulting in high system pressure or low conveying capacity. The powder pistons can also get too large and form a line plug that’s difficult to remove.

The dense-phase system is a temperamental animal that’s more sensitive to changes in the cohesive powder’s characteristics than a dilute-phase system. As a result, the dense-phase system can require frequent, tender loving care to provide the capacity you need when handling a cohesive powder.

Another problem is that cohesive powder often bridges or fails to completely discharge from the blow tank (also called a pressure tank) that feeds the powder to the dense-phase system. In some cases, permanent powder buildup can reduce the tank’s active volume and allow only smaller, more frequent batches of powder to be fed to the system. To keep your powder flowing, you may need to choose a blow tank with very steep cone walls because you can’t use fluidization to help discharge the powder.

Filtering the powder from the conveying system can also be subject to the same problems as filtering the air in a dilute-phase system. But because the dense-phase system uses a smaller volume of air, the particles are less likely to penetrate the filter media in the air-material separator, provided the unit is correctly sized for the application.

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Endnotes


Paul E. Solt is an independent consultant specializing in pneumatic conveying topics for both the American Institute of Chemical Engineers (AIChE), New York, and the Center for Professional Advancement, East Brunswick, N.J. Solt has a BS in mechanical engineering from Lehigh University, Bethlehem, Pa., and holds several patents for pneumatic conveying devices. If you have questions about this column or your conveying system, contact the author at Pneumatic Conveying Consultants, 529 South Berks Street, Allentown, PA 18104; 610/437-3220, fax 610/437-7933 (e-mail: pccsolt@tidalwave.com).