Preventing and solving some common pneumatic conveying problems

Amrit Agarwal  The Dow Chemical Company

If your pneumatic conveying system has problems — such as being unable to convey multiple materials at the desired capacity, degrading your material, or creating safety hazards — the cause is probably a flawed system design. This article’s first section details how you can prevent such problems by running conveying tests on your materials during the system design process. The remaining sections explain how you can diagnose and solve problems in a poorly designed existing pneumatic conveying system.

Designing a pneumatic conveying system that effectively conveys your material and operates without problems requires accurately understanding your application and, in particular, knowing your material’s conveying properties. These conveying properties depend primarily on the material’s physical characteristics, including particle size and shape, bulk density, softness or hardness, elasticity, temperature sensitivity, moisture sensitivity, and permeability.

Unfortunately, published theoretical calculation methods for designing pneumatic conveying systems don’t take all of these material conveying properties into account. While the calculation methods can produce an approximate system design, they’re unlikely to produce a correct system design unless you use your past conveying experience and knowledge of your material’s conveying properties to adjust these calculations.

Preventing conveying problems through testing

One common method for obtaining system design data is to run lab tests on a small pilot-plant conveying system and then use the results to design the production-scale conveying system. This requires using scale-up factors to convert the pilot plant’s conveying line diameters, line lengths, and line routing to production size. The problem with this method is that it’s typically impractical to run lab tests under your actual conveying conditions.

For example, if you have a heat-sensitive material, you need to test the material when it’s hot to determine operating pressures and conveying velocities. But even if you heat the material for the test, it will cool off very quickly when it’s conveyed in the pilot plant’s cold conveying lines. Even if you insulate and heat the lines, keeping the material hot will be difficult. As a result, the test may not accurately reflect your real conveying conditions. The problem of accurately reflecting real conditions also affects tests of hygroscopic materials and friable materials, as well as tests of a conveying system’s ability to handle multiple materials. It’s also almost impossible to recreate the production conveying line’s actual length and routing in the pilot plant because the line lengths and diameters that can be installed in a test lab are limited. While scale-up factors can help you adjust your test results, scale-up isn’t a perfect science and will only produce an approximate system design.

Because of these problems, it’s better — whenever possible — to use an existing conveying system in your plant to test your material under real conveying conditions and for sufficiently long conveying periods. The conveying line diameter and length generally will be closer to those in
your final system too, so you can use much smaller scale-up factors in adjusting your test results. However, your existing conveying system probably isn’t designed for running tests. This means that the system may not have blowers and rotary valves that can run at different speeds. It also may not have the instrumentation required for your test. Installing additional instrumentation typically doesn’t cost much, but making changes to your blowers and rotary valves can be expensive. As a result, testing your material on an existing conveying system may give you only limited data. But this data will be far more accurate than that you derive from theories or lab tests.

If you don’t have an existing conveying system in your plant, you can test your material in a supplier’s test lab, but select a test lab whose pilot-plant design comes close to your system design. Also run the tests for a sufficiently long time to get as many data points as possible.

Design the system so that the conveying velocity throughout the conveying line is higher than the hardest-to-convey material’s saltation velocity.

If you won’t be designing a pneumatic conveying system in the near future but, instead, you have an existing system that exhibits problems, you can still use conveying tests. Running such tests can often help you correct the underlying system design errors that created the problems. The following sections describe how to diagnose and solve some common pneumatic conveying problems, including lost capacity when conveying multiple materials, material cross-contamination, material degradation, safety hazards, and limited conveying capacity.

Lost capacity when conveying multiple materials
To convey several materials in the same conveying system without excessive operating complexity, you can always run the system at the same conveying rate that will move all the materials. But this low rate may result in lost production capacity with your easy-to-convey materials.

This problem usually occurs because the conveying system wasn’t originally designed to handle the hardest-to-convey material. Consider, for example, a system designed to convey various grades of polyethylene pellets. Each grade has different properties, such as particle shape, particle size distribution, density, bulk density, melt index, particle temperature, modulus of elasticity, additive content, hardness, and permeability. In general the hardest-to-convey polyethylene grade is the one with the largest particle size distribution, lowest density, highest melt index, highest temperature, and highest modulus of elasticity. As long as the system was designed for conveying some other material, its capacity when moving this hardest-to-convey material will be much lower than its capacity when conveying the material it was designed to handle.

To solve this problem, improve your conveying system’s design to handle the hardest-to-convey material. You can do this by running conveying tests on each material you’ll convey and then modifying the system design based on the test data for the hardest-to-convey material.

You must also allow large enough safety margins in the system’s design to ensure that the system achieves your required conveying capacity. Typical safety margins are:

- 10 percent for the conveying rate.
- 10 percent for data collection or system calculation errors.
- 10 percent between the maximum allowable conveying pressure and system interlocks (which automatically shut down the feeder or blower).
- 10 percent between the blower’s pressure-relief valve setpoint and the system’s maximum conveying pressure. (A good rule of thumb: If the blower’s pressure rating is 15 psig, the conveying system’s pressure drop for the hardest-to-convey material should be about 10 psi.)

Also consider conveying velocity. Design the system so that the conveying velocity throughout the conveying line is higher than the hardest-to-convey material’s saltation velocity. This will prevent the material from salting out (that is, dropping out) of the conveying gas when the conveying velocity is too low. As a safety factor, use a minimum conveying velocity at least 25 percent higher than the material’s saltation velocity.

Material cross-contamination
If some material is contaminated by another material during pneumatic conveying, it can cause problems in your downstream process. For example, even a few particles of a black powder can contaminate a white powder conveyed in the same system. Or if low-density polyethylene is used in a blown-film production line (which produces a bubble of extruded polyethylene to make polyethylene film), even a few particles of high-density polyethylene can cause the blown-film bubble to collapse, which will shut down the entire production line.

If, as in these cases, cross-contamination is completely unacceptable in your process, it’s best to improve the system’s design by providing a dedicated conveying line for each of your conveyed materials. But this is very costly. A less costly option is to design and operate one common
conveying system with sanitary construction. Such a system can handle multiple materials but can be fully cleaned between materials and has mechanical components that are designed to prevent material accumulation. Follow these guidelines when designing the system:

- Install a check valve immediately upstream of the material feedpoint to prevent any material from flowing backward into the system’s gas-only line.
- Install a sanitary-construction rotary valve at the material feedpoint.
- Use conveying line couplings and flanges designed to prevent collecting or trapping particles.
- Install metal detectors in the system’s receiving hoppers to detect any metal contaminants.
- Install the receiving hopper’s vent filter outside the hopper so that any dust discharged by the filter doesn’t contaminate the next material entering the hopper.
- Use mass-flow bins and silos to supply material to or receive material from the system. Such vessels empty completely even during continuous system operation. These vessels should have no internal components that can collect or trap even a few particles.
- Wash the bins and hoppers before introducing another material to the system.

**Material degradation**

Pneumatically conveying a material can cause it to wear, break up, or smear, resulting in dust, fines, or streamers. Streamers are usually formed in plastics conveying as the plastic is heated and softened during conveying, leaving plastic residue inside the conveying line that eventually peels off in strips; streamers generally cause more significant conveying problems than dust or fines. But dust, fines, and streamers can all cause a range of problems, including plugging the outlets of bins and silos, feed hoppers, dust collectors, cyclones, and other vessels; jamming rotary valves; preventing slide gates from fully closing; and causing cross-contamination between conveyed materials.

Dust and fines usually result from these conditions in a pneumatic conveying system:

- The conveying velocity is very high.
- The conveying line’s internal surface is rough.
- The conveying line has too many bends.
- The material-to-gas ratio is too low.
- The conveyed material is brittle.

Streamers usually result from these conditions:

- The conveyed material is soft.
- The conveying line’s internal surface is smooth.
- The conveying velocity is very high.
- The conveying gas temperature is high.
- The conveying line temperature is high.
- The conveying line has too many long radius bends.

The best way to avoid these problems is to design a conveying system — or improve an existing system design — to prevent the formation of dust, fines, and streamers. A properly designed dense-phase conveying system can prevent the formation of all three. A properly designed dilute-phase conveying system can prevent streamers, but won’t prevent dust and fines generation. However, a process called elutriation can remove dust and fines in a dilute-phase system. In this process, the conveying line passes through an elutriator, installed before the filter receiver, in which a properly designed stream of upward-moving gas separates the dust and fines from the conveyed material and carries them to the filter receiver.

To prevent or substantially reduce streamer formation when conveying plastics, use the following techniques:

- Minimize the conveying velocity by using stepped lines, if necessary.
- Minimize the conveying gas temperature by using a gas cooler (for a pressure conveying system).
- Use a conveying line with a rough internal surface.
- Use as few bends as possible and, instead of long radius bends, use special bends and tees that reduce friction between the material and the bend’s outer surface as the material moves through the bend.

**Safety hazards**

Pneumatic conveying system safety hazards can take the form of dust leaks in conveying lines, dust clouds inside enclosed vessels, electrostatic shocks, and hydrocarbon gases. Your conveying system’s design must protect your plant personnel and property from these hazards.
Dust leaks in conveying lines. If your conveyed material is combustible and leaks from the conveying line, it can form a dust cloud. Such a cloud can lead to a dust explosion in an enclosed space if the material’s minimum ignition energy is low (less than 10 millijoules) and a source of high-enough ignition energy (greater than 10 millijoules) is present in the area. Poor housekeeping practices can also result in the buildup of dust layers on flat surfaces inside your plant. When an explosion occurs, these dust layers will form another dust cloud and lead to a more violent secondary dust explosion.

Dust leaks typically occur with a pressure conveying system. To stop such emissions from your pressure conveying system, improve the system’s design by making it gas-tight. Concentrate on using gas-tight conveying line components, such as couplings and flanges that can hold the line’s internal pressure without leaking. Improve your maintenance and housekeeping practices to keep plant surfaces free of dust.

Dust clouds inside enclosed vessels. Enclosed vessels — including dust collectors, bin vent filters, filter receivers, bins, and silos — can be explosion hazards under certain conditions.

Dust collectors, bin vent filters, and filter receivers are intrinsically more susceptible to dust explosions because they collect dust and fines from the conveying gas. If these units are under an air atmosphere and have a sufficiently high source of ignition energy, a dust explosion can occur inside them. This is more likely to happen when the dust and fines have a low minimum ignition energy. For example, in a pulse-jet dust collector that uses bag filters and wire cages, electrostatic charge can accumulate on the filter surfaces because of the friction between each bag filter and wire cage during pulse-jet cleaning. Unless the resulting charge is dissipated to ground, this charge will become concentrated on the filters, where it can become an ignition source.

Enclosed vessels — including dust collectors, bin vent filters, filter receivers, bins, and silos — can be explosion hazards under certain conditions.

The most common way to protect your dust collector, bin vent filter, and filter receiver from explosions is to install an explosion-relief panel on each unit. The panel will release or break open immediately after an explosion initiates in the unit, venting the explosion’s quickly developing pressure into an area outside the plant or safely away from workers and other equipment. For help in determining how to select and install the relief panels, follow the guidelines in the National Fire Protection Association (NFPA) standards 68 and 69. Also make sure that in a unit with bag filters, each filter has an exposed sewn-in grounding strap that makes a firm contact with the metal cage. This grounds the cage assembly through the unit’s tube sheet.

A dust explosion can also occur in a bin or silo handling a combustible dust if the vessel is under air atmosphere and an ignition source with an ignition energy higher than that of the dust is present in the vessel. These conditions are more likely when the material is a granular or powdered plastic, food, chemical, or agricultural product because such materials can contain particles under 200 mesh, which are easily ignited. To prevent an explosion in your bin or silo, follow the guidelines in NFPA standards 68 and 69 for explosion-relief panels, inerting explosion suppression, electrical area classification, and grounding.

Electrostatic shocks. A worker can experience a severe electrostatic shock by contacting a conveying line whose surface has accumulated a high electrostatic charge. Such a charge can develop as the result of friction created by conveying a synthetic material or by conveying virtually any material in a plastic conveying line. Unless the charge is dissipated to ground, it will accumulate on the line’s surface. In most plants, conveying lines are located in pipe racks above ground level; a worker who contacts one of these high lines and receives a severe shock can fall to the ground and be injured.

An electrostatic discharge is also a hazard in an area classified as hazardous for electrical installations. If the area contains a combustible gas, such as hydrocarbon gas, an electrostatic discharge from the conveying line surface can cause the gas to ignite and lead to a potentially serious explosion.

To prevent worker injuries and explosions, make sure your conveying lines are fully grounded and bonded, the grounding is continuous, and the line’s resistance to ground is less than 10 ohms. Also check the grounding’s continuity as part of your regular maintenance program.

Hydrocarbon gases. Materials such as plastics can produce hydrocarbon gases as they react in process vessels. When such materials are pneumatically conveyed just after they’re produced, they usually contain residual hydrocarbon gases. These can evolve in the conveying system and accumulate in downstream bins and silos, where the gases create an explosion hazard in these vessels and the system’s dust collector. When combined with the fine dust particles present in the vessels, the hydrocarbon gases form hybrid mixtures that are more explosive than dust or hydrocarbon gases alone.

To prevent explosion hazards when conveying such a material, use an inert gas such as nitrogen instead of air for conveying. Maintain an inert atmosphere in your bins and...
silos to prevent a dust explosion in them. Provide enough purging countercurrent flow of inert gas into the space above the material in each vessel to reduce the hydrocarbon gas concentration to one-third of the hydrocarbon gases' lower explosivity limit.

Because inert gas is more expensive than air, you can reduce operating expenses by using a closed-loop conveying system to recycle the gas. The system also prevents excessive hydrocarbon gas buildup by removing some of the old inert gas and adding fresh gas; the system also adds more inert gas to make up for rotary valve leakage. Be aware, however, that designing a closed-loop pneumatic conveying system is more complicated than designing a conventional pressure or vacuum conveying system. The need to both recycle and add fresh inert gas to the closed-loop system while it safely handles and vents hazardous gas buildup creates a more complex system, with more components and instrumentation.

**Limited conveying capacity**

Limited conveying capacity in your existing conveying system is generally caused by one of three conditions: the system’s blower has reached its pressure limit; the system’s feeder, typically a rotary valve, has reached its feeding limit; or the conveying velocity is too low, causing the material to salt out of the conveying gas.

The blower can reach its pressure limit for any of these reasons:

- The system was originally designed for a different, easier-to-convey material.
- The conveying rate has been increased from the original design rate.
- The line routing has been changed from the original system layout.
- Additional bends or flexible hoses have been added to the conveying line.
- The original conveying system design was incorrect.

The only way to improve the conveying capacity is to thoroughly study the conveying system to determine which condition is to blame so you can correct it.

If the rotary valve can’t feed material into the conveying line at your desired rate, it has reached its feeding limit. The valve’s feeding capacity depends on the valve’s speed, volumetric displacement per revolution, leakage rate, and fill efficiency. A very high valve speed actually reduces the feedrate because it doesn’t allow enough time for each returning empty pocket to fill with material. As a general guideline, limit the rotary valve’s tip speed to about 100 fpm. Also, for a pressure conveying system, properly vent your rotary valve to release leakage and displacement gases, which otherwise can reduce the valve’s feeding capacity. If your existing rotary valve’s fill efficiency can’t be improved, install a larger rotary valve to restore your desired feeding capacity.

A low material velocity in any conveying line section can limit your system’s conveying capacity. The material velocity is typically about 20 percent less than the conveying gas velocity. For a constant-diameter conveying line the gas velocity continues to increase toward the system’s endpoint, but the material velocity may decrease by 20 percent or more as the material goes through a bend. If the material velocity is too close to the material’s saltation velocity, the material can salt out after going through a bend. A conveying system with a few bends close to each other can make this situation worse, most likely reducing the material velocity and limiting the system’s conveying velocity. To restore conveying capacity, increase the system gas flow by increasing the blower speed, but ensure that the blower pressure doesn’t exceed your system design limits.

**References**

1. For more information on explosivity limits and other explosion safety factors, see articles listed under “Safety” in Powder and Bulk Engineering’s comprehensive “Index to articles” (in the December 2001 issue and at www.powderbulk.com).


**For further reading**

Find more information on designing and troubleshooting pneumatic conveying systems in articles listed under “Pneumatic conveying” in Powder and Bulk Engineering’s comprehensive “Index to articles” (in the December 2001 issue and at www.powderbulk.com).

**Amrit Agarwal** is senior research specialist at The Dow Chemical Company, Technical Center, South Charleston, WV 25303; 304-747-5724, fax 304-747-2561 (agarwal@dow.com). He holds an MS in mechanical engineering from the University of Wisconsin-Madison and an MBA from West Virginia College of Graduate Studies in Charleston. He has more than 38 years experience in pneumatic conveying and bulk solids handling.