Choosing The Right Pneumatic Conveying Method For Process Material Handling

An engineers’ and executives’ guide to specifying the appropriate specific conveying method for operations in the field of process material handling

AZO®

Table of Contents

Differences Between Mechanical and Pneumatic Conveying

There are two primary ways of conveying material in the process material handling world: mechanical and pneumatic conveying. While many mechanical systems are closed systems (with covers), one benefit to pneumatic conveying is that you can be sure when opting for a pneumatic system that it will be a closed system. This can be safer for the product as there is less chance foreign material will enter the process and contaminate the product.

One of the most compelling advantages of a pneumatic system is its ability to convey vertically, horizontally, around corners and in multiple directions within the facility. Pneumatic systems are also easy to expand should the need to alter a system become apparent sometime following setup.

Expertise from AZO: Pneumatic Conveying

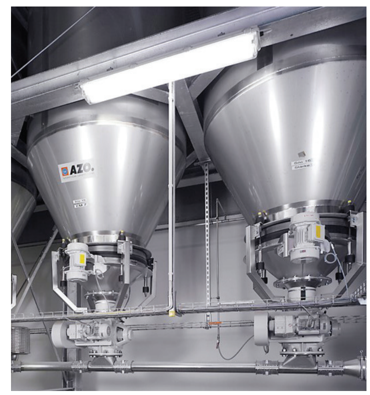
When it comes to pneumatic conveying from your rail cars, silos or super sack unloading equipment, there are many considerations that determine how you should handle materials. For instance, the choice to use vacuum or pressure conveying can be as critical as it is entirely situational. Depending on the materials you and your operation are looking to convey, choosing between dilute phase and dense phase conveying will also better fit different processes. Ultimately, an engineer will have to consider what is possible with the resources available and which methods will best suit the material being conveyed.

Safety, efficiency and cost represent just some of the factors to keep in mind when deciding between vacuum or pressure conveying. Whether or not material should be conveyed gently, ingredients should be protected against segregation (de-mixing) or if the effects of abrasion on your equipment should be minimized will determine whether dilute or dense phase conveying is appropriate in the end. Particle size of your material, its bulk density and other key characteristics also play critical roles when opting for either dilute or dense phase.

Utilizing Inert Gases to Pneumatically Convey

Inert gas conveying systems make up a small percentage of the conveying systems in use for process material handling. It is reserved much of the time for companies that handle materials that are critical and sensitive. Still, there are a few scenarios in which we recommend or facilitate inert gas conveying systems in the process material handling world. If you're conveying materials which are sensitive, hazardous or highly explosive, consider asking about conveying with inert gases for safety purposes. One other reason for utilizing an inert gas for conveying purposes can be when it is required to use a particularly dry gas as a conveying medium for hygroscopic materials.

Benefits of Vacuum Conveying



In most cases vacuum conveying is cleaner, safer, efficient and more flexible. In a pressure conveying system, the air mover (in most cases a P-D pressure blower) is located near the product entry point or prior to the product entry point. This makes it possible for a glowing ember to enter the conveying line where powders are suspended in the air stream.

The presence of oxygen, an ignition source (such as a glowing ember) and fuel have the propensity to lead to an explosion in this specific situation. In addition to operators' safety being jeopardized, reputational damage to a company's credibility could soon follow. Proper first steps in the effort to prevent hazards that lead to an explosion include a proper risk assessment, proper grounding, a spark arrester and preventative measures. There are many standards for fire prevention that are accessible through the National Fire Protection Association (NFPA). These can be found in the 2019 version of NFPA 652 and the 2020 edition of NFPA 61.

Vacuum systems also lend themselves to a more dust-free operation because they operate below atmospheric pressure. This means that there is no tendency for outward leakage. While the NFPA is not an enforcement organization and does not carry out its various standards on its own, Authorities Having Jurisdiction (AHJs) do reference the standards released by the NFPA in various regulations. Keep in mind that it's of critical importance to keep up with NFPA standards by performing a dust hazard analysis. No matter which vacuum or pressure conveying systems you utilize, you should also identify the combustible dust hazard characteristics of your material.

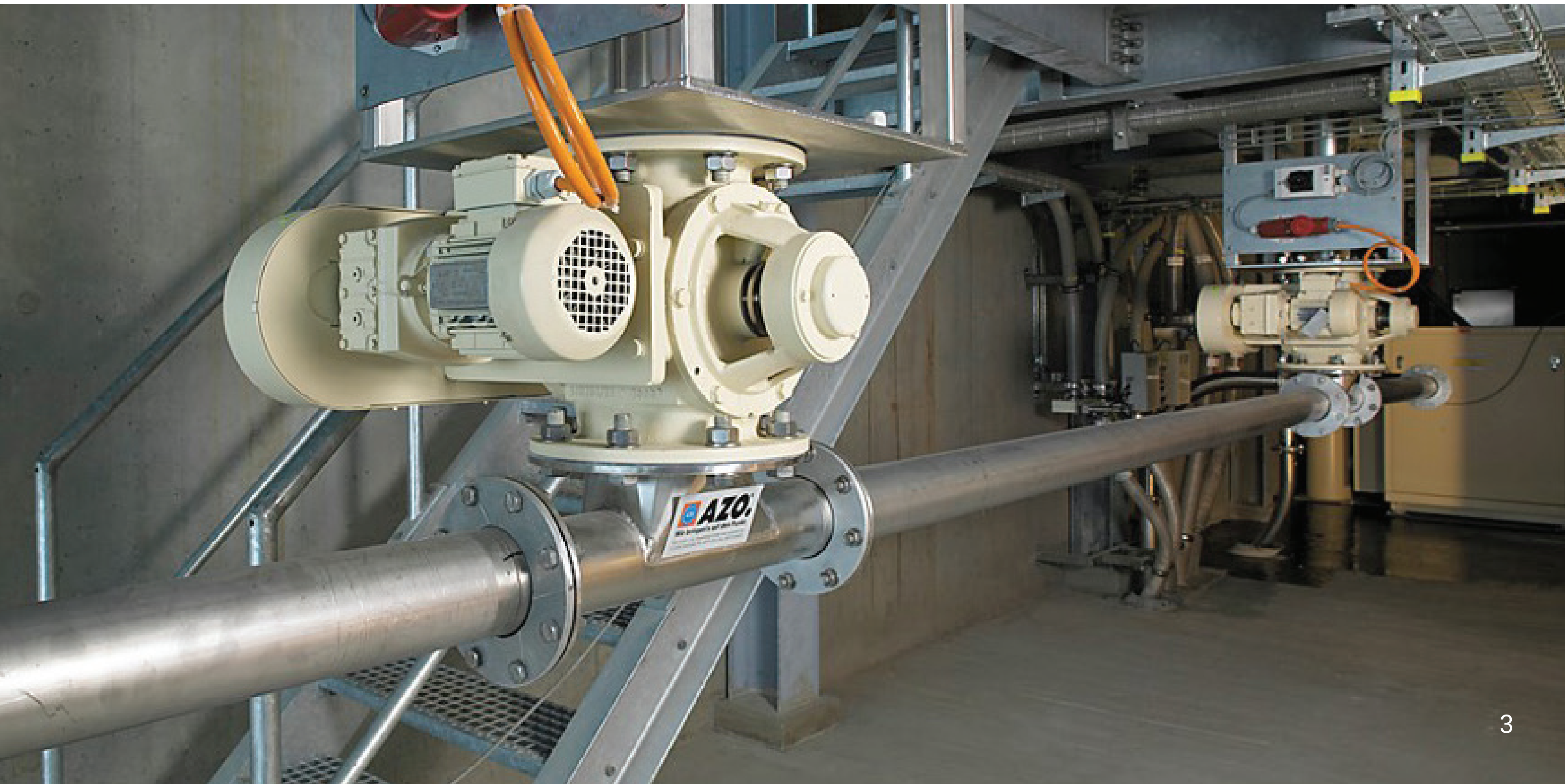
Oftentimes it's more efficient to vacuum convey. The only reason that it would be less efficient is if, under certain conditions, it becomes prohibitively expensive compared to pressure conveying.

Benefits of Pressure Conveying

Why do companies essentially choose to pressure convey in their operations? Two key factors that might call for pressure conveying are long distance and high rates. Distance is a limiting factor for vacuum conveying, and once the conveying range is past practical limits, it simply becomes more economical to pressure convey. There are situations in which opting for vacuum conveying becomes overly expensive, and with a high enough rate, there isn't much of a reason to choose this method. (Example: 400 feet is typically out of range for an affordable vacuum conveying system when the convey rate requirements are also high.)

While there remain many advantages to vacuum conveying (safety, cleanliness and greater flexibility to name a few), essentially there are situations in which you can push something further than you can pull it. Pressure conveying offers the right option for these extreme situations.

Another extreme situation involves a high requirement for resistance to contamination. As vacuum conveying brings air into the system with negative pressure, the only way to certifiably avoid any risk related to unfiltered air or foreign materials entering a convey line through a leak is to use positive pressure in the system. This requirement doesn't happen often, but for some plants, it remains a prominent concern. (Example: when an application requires an inert gas atmosphere for conveying.)
Still, there are even more points to consider between these modes of conveying than the benefits that each brings to the table.



Further Considerations Between Vacuum and Pressure Conveying

Leaks in the System

Pressure or vacuum conveying will yield different results in the event that there is a leak in your system. Any small pinhole or loose connection is an opening that can allow dust to blow out of a pressure system, creating undesirable conditions in a factory. If the same hole is found on a vacuum system, air is simply pulled into the system. Product in a vacuum system will not escape the system itself because the pressure on the outside is greater than what is inside.

In the event that you are handling toxic material, this fact becomes essential to minimize the risk of any outward leakage. Opting for a vacuum system is absolutely necessary when the leakage of toxic material is a concern in the process.

Air Temperature

One final major benefit to vacuum conveying is that it eliminates the product exposure to the heat of compression from the blower discharge. With pressure conveying, your product may be exposed to the heat of compression. This happens unless a heat exchanger is added to maintain the temperature of ingredients that are being conveyed.

Specifically, when using vacuum conveying, ambient or conditioned air enters the system in a controlled manner. That air (typically from the indoor area of a plant) does not add heat to the product being conveyed. With pressure conveying, a blower is used that forces air into a small space and releases it. In doing this, the air becomes hot and there is a risk that degradation can occur in certain ingredients that are temperature-sensitive.

Heat exchangers remedy this concern for temperature-sensitive products in pressure systems, but they do represent an additional piece of equipment for a plant to maintain. There are also extra costs involved, and the need for this equipment (in most cases) is eliminated in a vacuum system.

Still, for non-temperature-sensitive products, the addition of a heat exchanger may be unnecessary — again demonstrating that the choice to use vacuum or pressure conveying can be entirely situational.

Benefits of Dilute Phase Conveying

Most materials can be successfully conveyed in dilute phase systems. Dilute is essentially the default mode of conveying for most operations because it can easily adapt to materials with a wide range of product-flow characteristics (such as particle size and bulk density). This is because this mode of conveying is more forgiving and versatile.

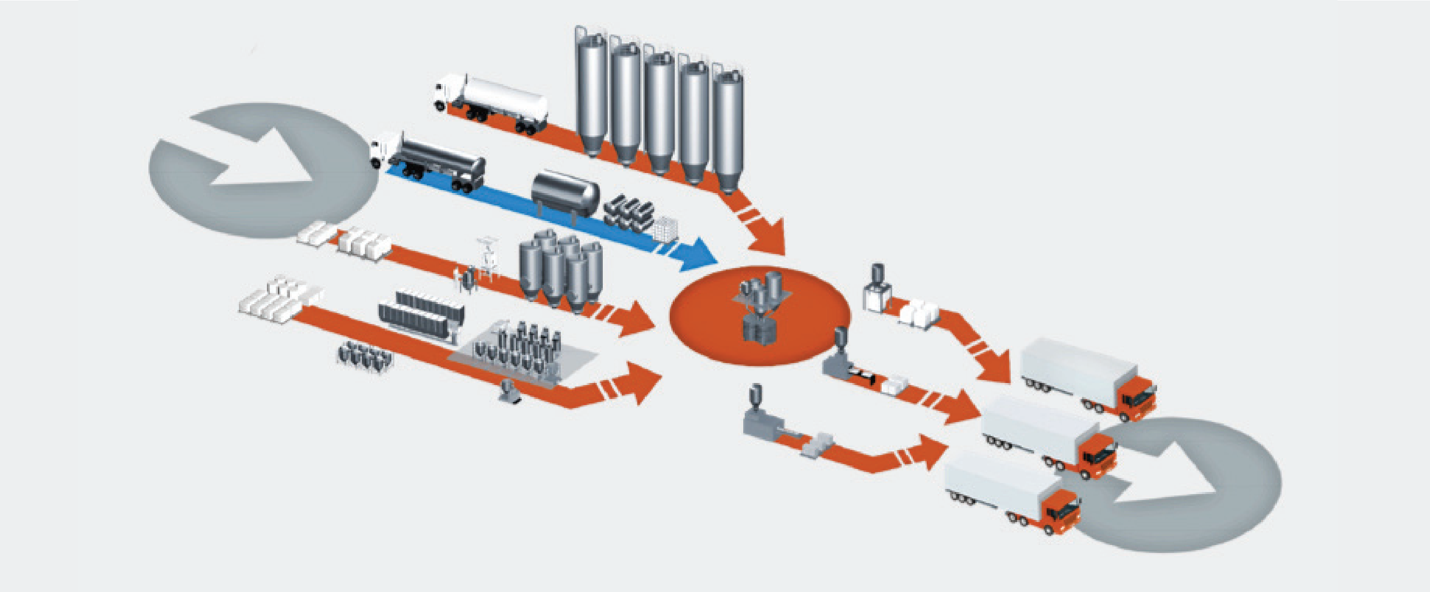
Dilute phase conveying is also the most economical mode in many cases because the equipment used in these systems are typically easier to clean and maintain. Dense phase systems typically require higher pressures, and vessels built to withstand these pressures must meet codes set by the American Society of Mechanical Engineers (ASME). These heavy vessels are more difficult to take apart and inspect (and therefore clean) due to the amount of extra flanges, bolts and fasteners required.

In the end, dilute phase conveying is most flexible, economical and readily expandable. From granular plastic to finely divided minerals, dilute phase tends to be the most efficient way to convey materials between the two.

Benefits of Dense Phase Conveying

Friable and abrasive materials benefit from dense phase conveying. In dense phase conveying, slugs of material are separated by alternating pockets of air to prevent segregation. Here’s how that translates to materials you might want to convey: Friable or abrasive products also benefit from dense phase conveying because it is gentle. Essentially, the benefits of dense phase conveying include gentle lower conveying velocity with little or no segregation.

Since the conveying air velocity is much lower in a dense-phase system than a dilute phase system, by comparison, particles are subjected to less degradation or segregation. The material is not moving as fast as dilute and not therefore at risk of breaking.



The Convey Path Determines Pairings of Dilute (or) Dense with Vacuum (or) Pressure Conveying

As distance is a critical factor that determines whether a vacuum or pressure system is suitable, the makeup of a material typically determines whether dense or dilute phase conveying is more appropriate.

Convey paths can often include "elbows," which are any bends or changes in the direction of a pipe. Operations that convey abrasive materials using dilute phase either have reinforced elbows or, alternatively, specially engineered "deflector elbows." These elbows deflect air and materials away from the corner of the elbow through their design. Abrasion-resistant or heavy wall piping will also be required in many applications.

If rates allow, dense phase conveying can be utilized in this scenario for an overall gentle process. Material will still abrade piping and elbows to a degree during dense phase transport because there will always be some kind of friction between the pipe wall and the product. Still, these abrasive effects are minimized in a dense phase system.

Though some operations may invest in abrasion-resistant elbows, even these become worn down and destroyed eventually. For example, conveying silica sand through a pipe will always result in some degree of abrasion.

Conveying Above Saltation Velocity Keeps Particles Suspended

Saltation velocity represents the point where product falls out of an airstream. Conveying above saltation velocity is an important factor as it allows particles to flow through the system with sufficient velocity to keep particles suspended.

Generally, a characteristic of dilute phase conveying is modeled by conveying in safe ranges above saltation velocity. By contrast, when conveying in dense phase, the majority of the system operates below saltation velocity.

How to Avoid Breakage When Conveying Delicate Material

For delicate products with specific sizes and shapes, any elbow or change in the direction of product flow within a conveying line represents a potential impact point. Fine powders are typically not affected by these conditions. Breakage can also occur when delicate materials enter a receiver, as there is typically an impact when material hits the hopper wall or product entry point. Practically any place where product is sliding against the surface or interior of the pipe will cause abrasion and possibly breakage. Luckily, there are methods to minimize these results.

Conveying as slowly and as gently as possible is ideal when there are concerns about product breakage. Essentially, there are two factors to minimize in these scenarios:

- Conveying distance
- The number of elbows/impact points

AZO can determine the minimum conveying velocity by feeding product gently into a convey line. For example, utilizing a vibratory feeder for these test trials instead of a screw or airlock is helpful because there are no rotating devices included. When utilizing a rotary airlock, there’s always a small, but existent chance that product will get chewed up at the inlet of the valve as blades pass the inlet of the housing. The same can be said for a screw feeder’s rotating shaft. As the shaft runs at a high RPM, there exists a chance of some product breakdown.

Another way to minimize breakage is to expand or “step” the pipe size diameter toward the end of the system. This method assists with deceleration of the material. At the receiver, an oversized tangential inlet could also be incorporated to help gently disengage the product from the airstream.

More on Avoiding Breakage: "Hybrid Conveying"

To avoid breakage, conveying at the lowest velocity possible while still ensuring that product is suspended is particularly ideal. Essentially, this is low-velocity vacuum conveying, which is neither dense phase nor dilute phase. At AZO, we refer to this method as "hybrid conveying." It is a hybrid of the two phases — halfway between them. In this mode, a vibratory feeder can be utilized to gently introduce material into the conveying line. The next step would be to design the conveying system to convey at the minimum velocity.

A "stepped" conveying line could be used so that the last section of the convey run would be one line-size larger. This would help keep the velocity profile down. A special tangential inlet at the receiver could also help disengage the product at the receiving point in a gentle fashion.

Utilizing proper couplings is critical to ensure piping is aligned correctly and there are not obstructions in the conveying line. Beveling the edge of the pipe ends also can ensure that there are no ledges after the pipes are joined together with a coupling. Obstructions such as bar magnets or grate magnets should also be minimized.

How to Avoid Smearing When Conveying Material

For products that have fat content (such as milk powder or cocoa powder), there exists the risk of smearing on the conveying line. Particularly, you can utilize "impulse conveying" in these situations. This dense-phase mode conveys products in alternating pulses of product and air. Material is moved through the conveying line at a very low velocity compared to dilute-phase conveying in this scenario, which helps prevent the separation of fat from the particulate onto the conveying pipe.

A polished interior of the convey pipe will also help prevent product smear. If surfaces within the pipe are slick, particles are less prone to adhering to it. This will help mitigate material sticking to the pipe.

Hidden Costs in Startups, Maintenance and Operation of Conveying Systems

How to plan for hidden costs during the startup, maintenance or operation of a conveying system is often difficult to pin down. Unforeseen problems can range from technical and mechanical issues to something as simple as saving time and travel. At AZO, we have sorted through some common hidden costs related to conveying systems that can become major concerns for any plant manager looking to properly set up, maintain or operate a conveying system. Acknowledging and preparing for these costs can make all the difference when pneumatically conveying bulk materials:

Hidden Costs of System Startups:

- Rotary valves running in the wrong direction and it getting damaged
- Infrequent IO checkout
- A change in the drawings that the electricians were not informed of
- Missing parts
- Material flow characteristics that are different than what was expected
- Issues with new explosion-proof aspects of systems
- Not having a spare or replacement rupture disk
- Leaks in the system
- Line plugs
- The cost of testing material during startup prior to going into production
- Temporary workspaces
- Working around existing production
- Waiting for downstream equipment that is not able to run
- Last-minute schedule changes

A lot of small items add up to big costs in the end when dealing with the startup of a system. Up-to-date drawings are critical. Many times electricians are completing the wiring of something, and new drawings are also just being completed. Changes like these that happen “on-the-fly” take extra time to implement. Missing parts are problematic during installation because once it becomes apparent that a part is missing, shipping the new part to the job site presents another period where progress is halted. Occasionally with newer explosion protection aspects of systems, isolation valves will shut during commissioning because of the vacuum pressure pulling the spring-loaded valve if they are not sized correctly.

Rupture disks are particularly sensitive during startup. If you over-pressure a disk, then the cost of replacing it becomes an additional concern. Also, wire leads that come off of these rupture disks can occasionally become pinched between a frame and a silo. When this happens, you won’t know that they are in this position until you start the system and they are suddenly cut as a result of the force from being pinched.

It’s imperative to check your IO to make sure everything is in the right position at the right time. Line plugs can occur when someone either forgets to turn on the compressed air or when a valve is placed in an incorrect position. A thorough IO check will prevent these and other mishaps that take up valuable time and resources in regards to startups.

Testing material during startup as opposed to going into production is important so that you can decipher how to improve the flowability and ensure that the system itself is well-equipped to run specific material. Still, you cannot use this test material as sellable product. Scale calibration test material is another cost that is often overlooked.

Working around existing production also poses necessary questions. Should barriers be put up in the work area? Frequently it's only communicated that barriers are required upon arrival to the job site. In a greenfield facility, this typically isn't a concern, as no product is being made in the surrounding areas yet, but in a sanitary production facility, there are contamination concerns to take into account. Forklifts that are brought in through the parking lot entering a CGMP-controlled area offer one example of these concerns. It is much easier to work in and install equipment in a greenfield facility as it is more akin to a construction site at that stage than a production plant.

Extensions to a conveying system can be costly. This is especially true when new lines need to be installed through an area where production is actively in operation. Another hidden cost associated with startups includes getting behind schedule because of downstream equipment that isn't able to run. Schedule change represents another challenge as rescheduling workers due to last-minute changes can take up valuable time and resources.

Hidden Costs of System Maintenance

- Not having a well-established and proactive maintenance plan
- Lack of operator training
- Lack of spare parts inventory

A well-established and proactive maintenance plan can make all the difference in a process material handling conveying system. Otherwise you are essentially waiting for something to fail, which will cost in downtime.

Lack of operator training can lead to bad batches and therefore, wasted product. Wasted product essentially means lost money. Something as simple as someone forgetting to flip a switch can be a result of improper training. Maybe compressed air is not turned back on and the filter gets backwash on the receiver. The line becomes plugged after the filter becomes plugged because the air needed to convey with is not accessible. An adequate amount of training could have properly prepared this operator to achieve proper system maintenance.

Hidden Costs of System Operation

- Cleaning the system
- Leaks in the system
- Inadequate compressed air supply
- Inconsistent raw material supply

Prior to putting product in the system, cleaning the system can be a major hidden cost. Just as they are a hidden costs in system startups, leaks in a system can detract from an ongoing operation's productivity. Most of the valves in a conveying system are located 30 feet in the air. It takes a substantial amount of time to retrieve a lift and then retrieve an electrician to fix leaks. Leaks in a system are found less often in vacuum systems because when you're pulling a vacuum, it's hard to see the air entering the pipe. This is as opposed to a pressure system where you can visibly ascertain that powder is exiting the system.

If there's an inadequate amount of compressed air supply, many mechanisms don't function properly. This is because compressed air is the utility that's required to make many parts of a system function. For instance, to make a valve open and close on the bottom of a weigh hopper (where material is dumped into a mixer), you have to have compressed air to open and close that valve. You also have to have compressed air to clean the filters while you're conveying.

Production downtime is wasted money in any production facility. From minutes to hours, management will equate any amount of time to lost company funds. Not having spare parts on hand for critical items can truly be an unexpected disaster during system operation. AZO is always willing and able to help you acquire the spare parts you need, but any time spent waiting on these parts is detrimental to time that could be spent making product. It's best to plan ahead and have spare parts on hand before an unexpected incident or failure in your process occurs.

Testing and Material Handling through AZO

Specifically, with AZO, there are various solutions we can provide with custom designs where dilute phase will surprisingly not cause damage to your delicate materials. Around 250 tests are conducted a year at the AZO Technology Center in Osterburken, Germany. Specific results can also be determined through lab tests at the Thorp Callaway Ingredient Automation Test Facility located in Memphis, TN. At this in-house lab, AZO technicians can properly assess if material can be successfully handled in a pneumatic conveying system. These technicians can also identify the most appropriate type of conveying method for your materials.

Testing is especially recommended when the optimum type of conveying solution for products where degradation and or segregation is a concern. We welcome you and recommend that you witness the tests trials in person, or videos can be sent demonstrating how they're conducted. AZO also provides vacuum-dense conveying, which many of our competitors don't offer.

AZO®

[Visit our website] to get started with the perfect pneumatic conveying system for your business.