

In past columns, we've discussed pneumatic conveying topics including system design, operation, equipment, and applications.^{1,2} Many of the columns have concentrated on one area of a pneumatic conveying system, such as the air (or other gas) mover, material supply vessel, material feeder (line charger), conveying line, or air-material receiver (or receiving bin), as shown in Figure 1. In this column, we'll focus on a topic related to the conveying line: introducing supplementary air to help aerate the conveyed material and prevent line plugs in dense-phase conveying systems.

Some dense-phase conveying background

Let's start by reviewing some dense-phase basics. Unlike in a *dilute-phase system*, in which the material is conveyed in suspension throughout the conveying line, in a *dense-phase system* the material is not conveyed in suspension and usually moves at a much lower velocity than in a dilute-phase system. The dense-phase system, in which the material-to-air ratio can be quite high, can be one of two basic types:

- **Permeable dense phase:** In this phase the material fills the conveying line and travels in intermittent, discrete, self-forming slugs while the conveying air passes through the material, fluidizing it and creating "waves" of flowing material.
- **Nonpermeable dense phase:** In this phase the conveying air doesn't pass through the material, so that the material flows more like a solid plug. Typically several plugs — separated by small gaps filled with conveying air — are in the conveying line at any given time.

Supplementary air is used primarily in permeable dense-phase systems.

Material fluidizability and supplementary air systems

As we've discussed in past columns, the type of pneumatic conveying sys-



Pneumatic points to ponder...

Paul E. Solt

Using supplementary air in dense-phase pneumatic conveying

Guest writer: Jack D. Hilbert

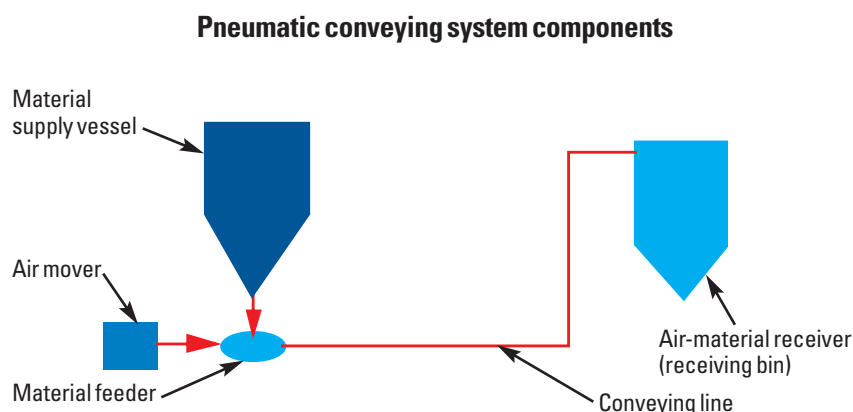
tem that's best suited to a material depends on the material's characteristics. Understanding all you can about your material, especially its *fluidization characteristics* (that is, its ability to become fluidized and retain fluidization), provides a sound basis for designing a pneumatic conveying system that will successfully handle the material. Your material's fluidization behavior also determines whether the material will benefit from the introduction of supplementary air to help fluidize it and prevent line plugs during dense-phase conveying.

This can be better understood by looking at the Geldart model, as shown in Figure 2, which classifies particles into four groups — A, B, C, and D — based on particle density (also called *true density*) in kilograms

per cubic meter versus mean particle size in microns.³ Typical examples of materials in each group and their fluidization characteristics are listed in Table I. Of these materials, those in Group B — many of which fluidize quite easily but deaerate quickly, giving them very low fluidization retention times — are most likely to benefit from supplementary air when conveyed in dense phase. This is because materials that tend to deaerate quickly can form line plugs at the low conveying velocity found in dense-phase systems. [**Editor's note:** For more information on the Geldart model and Group A, C, and D materials, see endnote 3 or contact the author.]

Many materials, including Group B materials, aren't natural candidates for dense-phase pneumatic conveying,

Figure 1



but they often are friable or abrasive or have other characteristics that make the lower-velocity conveying of a dense-phase system more desirable for them. Yet conveying a Group B material in a dense-phase system with a traditional pressure tank (described in the July 2000 column) and without some method for adding supplementary air can present problems. In such a system the air pressure at the conveying system's start must provide adequate energy to overcome the

resistance in the entire conveying line. All the conveying air is added at the system's start, as well, which often means that the system uses more air volume than necessary, producing a high terminal velocity and high overall conveying velocity, which nullifies the dense-phase system's major advantage — its lower velocity profile. Introducing supplementary air to the conveying line can eliminate these problems and keep the conveying velocity low.

Various technologies are available to introduce supplemental air to the conveying line and keep the material aerated. Which one is right for your material depends on the material's characteristics and your conveying application. Here are brief descriptions of some typical supplementary air systems, each available from multiple equipment suppliers:

Internal air line. In this system, an air line with fixed, regularly spaced openings is installed inside the conveying line. This internal air line has no external air supply; instead, small amounts of conveying air enter freely through the internal air line's openings, travel through it, and re-enter the conveying line, keeping material fluidized and preventing line plugs from forming. The internal air line cannot be installed inside bends, so the line consists of segments: Each segment starts after a bend and ends at the next bend entrance. This system has no external controls — the system's operating dynamics control the amount of air traveling through the internal air line, as well as where and when this air re-enters the conveying line.

Fluidizing media in the conveying line. In this system, fluidizing media such as permeable polyester cloth is installed inside the bottom of the horizontal conveying line sections. Fluidizing air, usually a portion of the conveying air rather than from an external source, continually flows upward through the media into the conveyed material to fluidize it and prevent line plugs. For an abrasive material, the media can be a wear-resistant woven wire mesh; for a high-temperature application, the media must be a heat-resistant media such as fiberglass or stainless steel.

External bypass line with air connections. This is by far the most common system for adding supplementary air to the conveying line, primarily because the external bypass line and air connections (often called *air boosters* or *air injectors*) are easier to retrofit to an existing conveying system and easier to adjust or replace than other sup-

Figure 2

Geldart model based on fluidization behavior

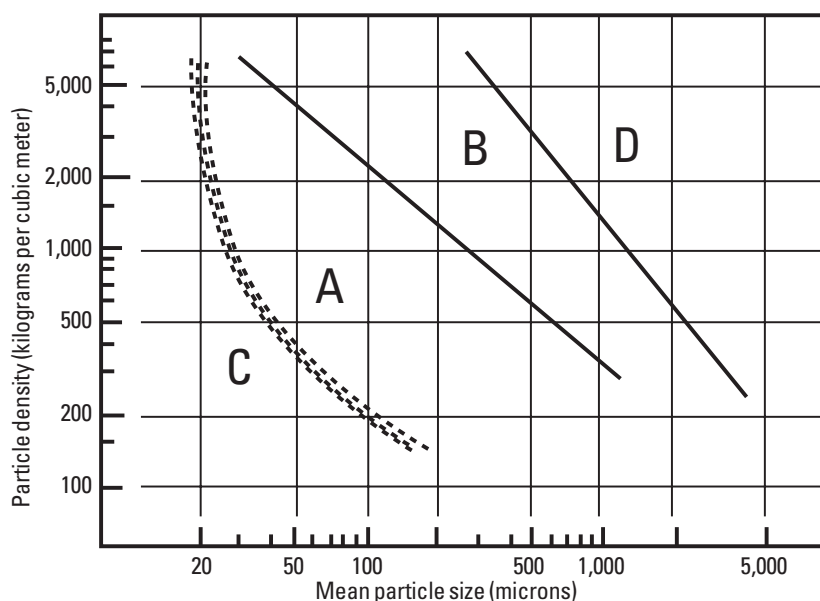


Table I

Typical examples of materials in Geldart groups and their fluidization characteristics

Geldart group	Typical materials	Fluidization characteristics
A	Cement Fly ash	Fluidizes easily and retains fluidization
B	Ores Sands Grains	Fluidizes quite easily but also deaerates quickly
C	Pigments Metallic oxides Some clays	Difficult to fluidize because particles often interlock and are cohesive
D	Plastic pellets Tablets Capsules Kernels	Fluidizes very poorly because voids between particles can be large, allowing air to escape

plementary air systems. The bypass line runs outside the conveying line and is connected to it by pilot pressure regulator valves at regular intervals. The ore is also abrasive, so conveying it in dilute phase could result in a maintenance nightmare for the conveying system operator. This makes dense-phase conveying a good choice for handling the ore, but the ore's poor fluidizability is a concern. A good solution is to use an external bypass line with air connections to inject supplementary air into the con-

veying line, thus keeping the ore aerated and preventing it from blocking the line.

A section of an external bypass system suitable for handling this mineral ore application is shown in Figure 4. In this configuration, two external air lines run parallel to the dense-phase conveying line. The larger line is the bypass line that supplies compressed

Any of these supplementary air systems has the added benefit of allowing the conveying system to stop and restart when the conveying line is full of material. Such a condition can occur when a power failure or mechanical failure unexpectedly shuts down the conveying system's air supply and causes the material to deaerate and fill a portion of the conveying line, which can result in a line plug when the operator tries to restart the system. Without some type of supplementary air, the operator would have to locate the plug and manually clear the line. But with a supplementary air system, the supplementary air can be introduced into the line to deaerate the dormant material, making it possible to restart the conveying system without manually clearing the line.

Of the supplementary air systems discussed here, we're going to concentrate on applying the most common one: the external bypass line with air connections.

Applying the external bypass system

Let's consider how using an external bypass line with air connections can assist the conveying of an example material: a mineral ore. The mineral ore's particle size distribution is about 1 percent passing a 20-mesh screen to over 98 percent passing a 325-mesh screen, with a mean particle size of about 60 mesh (250 microns), as shown in Figure 3. The material has a particle density of about 135 lb/ft³ (2,200 kg/m³), so it falls into Group B according to the Geldart model. Fluidization tests of the ore indicate that

Figure 3

Average particle size distribution of example mineral ore

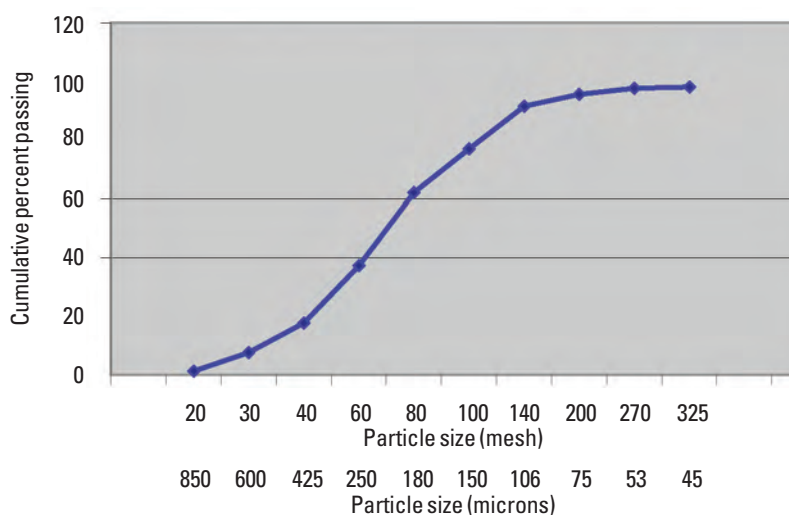
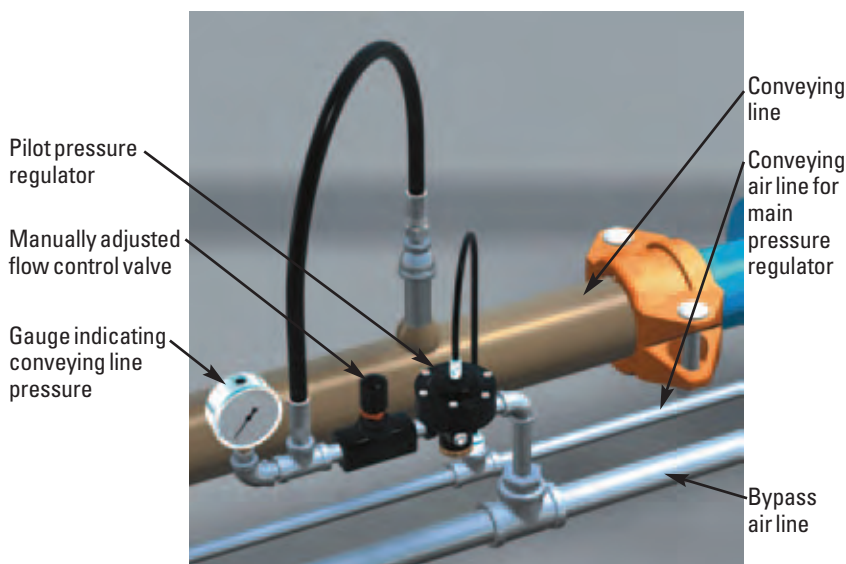


Figure 4

Typical external bypass system



air from the same source providing the conveying air. (This source can be a dedicated air supply or, in many cases, plant compressed air.) The bypass line is connected to the conveying line via pilot pressure regulators located at fixed intervals along the horizontal conveying line sections and downstream of each bend. The smaller line supplies conveying air (called *pilot air*) to the external bypass system's main pressure regulator. Once the main pressure regulator senses that the conveying system pressure has reached the preset pressure level, each pilot pressure regulator will open to allow a controlled amount of compressed air via a manually adjusted flow control valve into the conveying line. The external bypass system manufacturer can help determine the best location in the conveying system for each pilot pressure regulator based on previous experience with materials identical or similar to the conveyed material or, if necessary, on results of fluidization and conveying tests of the material run by the manufacturer. The manufacturer can also help determine what the supplementary air system control pressure should be.

More about the external bypass system

Because the external bypass system's air lines and air connections are external to the conveying line, the system is easier to retrofit, adjust, and replace than other supplementary air systems. This can make the external bypass system a more cost-effective choice for adding supplementary air in many dense-phase conveying applications.

Another important benefit is the external bypass system's ability to control the conveying system's terminal velocity and overall conveying velocity profile. The compressed air the external bypass system adds to the conveying line is considered part of the conveying system's total conveying air requirement, which prevents the conveying system from developing an excessive terminal velocity. By systematically injecting supplementary air along the conveying line's

length, the external bypass system also reduces the overall conveying velocity profile, which can prevent excessive wear from an abrasive material. The systematic air injection also controls the conveying system's slug formation and the speed at which the slugs impact line bends and the air-material receiver at the system's end, which can minimize the violent line forces that sometimes cause catastrophic failures of conveying line piping and supports. For a conveying line longer than about 200 feet, setting the pilot pressure regulators located near the line's end to inject less air than the regulators earlier in the line can further minimize or eliminate these violent line forces.

External bypass systems available from some manufacturers can detect the formation of line plugs by using pressure sensors in the conveying line. The pressure sensors monitor the pressure differential between two consecutive points in the conveying line, which will change when a line plug begins to form. When a sensor detects such a change, the external bypass system responds by injecting compressed air into the conveying line to prevent the line plug from growing and blocking the line.

A final word

Bear in mind that introducing supplementary air isn't the only solution to problems with conveying Group B materials in dense phase — and, for that matter, Group B materials aren't the only ones that can benefit from adding supplementary air to the line. Introducing supplementary air is just one of several innovative technologies available to solve pneumatic conveying system design problems and to optimize the performance of existing pneumatic conveying systems. **PBE**

Endnotes

1. Find topics, issue dates, and page numbers for previous "Pneumatic points to ponder..." columns in *Powder and Bulk Engineering's* comprehensive article index at www.powderbulk.com and in the December 2006 issue.

2. Three volumes of "Pneumatic points to ponder..." reprints are available from *Powder and Bulk Engineering*: Volume 1, 1989 to 1993; Volume 2, 1994 to 1996; and Volume 3, 1997 to 1999. For more information, contact Cindy Fischer at 651-287-5607, fax 651-287-5650 (cfischer@cscpub.com). Or visit www.powderbulk.com to purchase and download individual columns.

3. D. Geldart, *Gas Fluidization Technology*, John Wiley & Sons, New York, 1986.

For further reading

Find more information on introducing supplementary air into dense-phase pneumatic conveying systems in *Handbook of Pneumatic Conveying Engineering* by David Mills, Mark G. Jones, and Vijay K. Agarwal (Marcel Dekker, 2004) and in articles listed under "Pneumatic conveying" in *Powder and Bulk Engineering's* comprehensive article index at www.powderbulk.com and in the December 2006 issue.

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