Since the first Pneumatic Points to Ponder column appeared in March of 1989, Paul Solt and I have made educating end users on the technical aspects of their pneumatic conveying systems our primary concern.

While numerous OEM suppliers have provided equipment to meet customers’ requests, suppliers typically aren’t a source of technical information about general system concepts and terms because each supplier deals more with the specifics of their equipment. Right now there’s more academic information available via the internet, technical conferences, specific training courses, and more. We strongly believe that our columns have helped bring the whys and the why nots into the working knowledge and vocabulary of the end users.

In that same spirit, this column will discuss some of the specific terms used on a daily basis when talking about pneumatic conveying and terms you’ll see as you review available information from other sources.

**Solids loading**
A pneumatic conveying system’s *loading* is the material-to-air (or other gas) ratio, but this ratio can be represented in different ways.

In articles on pneumatic conveying theory, this ratio is typically given in pounds per pound, but this can be confusing because sometimes the ratio indicates the system’s amount of air to material and sometimes it indicates the opposite. When describing dilute-phase conveying, this ratio is often given as pounds of air per pound of material to produce a positive number greater than one. But when discussing dense-phase conveying, this ratio may be inverted and presented as pounds of material per pound of air, also producing a positive number greater than one.

Pneumatic conveying suppliers and consultants frequently use the ratio as either pounds of material per standard cubic foot of air or as standard cubic feet of air per pound of material. When consulting others about your application, be sure you understand which units, in which order, are being discussed.

**Saltation velocity**
As discussed in previous columns, dilute-phase (stream-flow) conveying takes place above the *saltation velocity*, the gas velocity in which particles begin to fall from their state of suspension and are deposited at the bottom of the conveying tube.

Many different equations have been derived for calculating the saltation velocity, and, while none of them gives an exact saltation velocity value for any given bulk solid material, the equations can help determine a reasonable guideline for establishing your material’s saltation velocity.

Typically, two factors determine whether conveying is above the saltation velocity. First, the conveying system’s air velocity must be adequate, and second, the system loading must not be too high.

Since air always flows from a higher pressure to a lower pressure — whether in pressure or vacuum conveying — and is thus expanding, the velocity from the beginning to the end of the conveying line is always increasing. If the air velocity and loading combine to produce conveying above the saltation velocity at the system’s feed point, then conveying will be above the saltation velocity throughout the conveying system unless the system has an air leak or the conveying line diameter changes.

Saltation velocity for each material and conveying system is different because the velocity is a function of the material’s particle size, particle density, and shape. It’s also influenced by the system-related parameters, as well, such as the gas density and viscosity being used to transport the material, solids conveying rate, conveying line inside diameter, and operating pressure.

**Pickup velocity**
Some confusion exists about how to apply the term *pickup velocity*. In this series of columns, pickup velocity means the air velocity at the point where material is introduced into the conveying line. The superficial air velocity is obtained by dividing the conveying system’s actual air volume (corrected for pressure and temperature) at the feed point by the conveying line’s cross-sectional area. This calculation doesn’t account for the volume of material fed into the system.
The air velocity at the material feed point determines the conveying system type. If the pickup velocity is above the saltation velocity, the conveying system will be in dilute phase. A pressure conveying system has a pickup velocity about 10 percent above the saltation velocity, while a vacuum conveying system is usually designed to operate at about 20 percent above the saltation velocity.

Your conveying system’s pickup velocity is critical only if the system must convey material in dilute phase. This is typically required for conveying nonabrasive, nonfriable materials or for delivering a material in a steady flow to a process. I’ll discuss other modes of conveying later in this column.

**Terminal velocity**

The term *terminal velocity* can be applied in different ways. Frequently, the term refers to the velocity of the air as it exits the conveying system. This is the highest air velocity in the system assuming only one diameter conveying line was used and there’s no line stepping implemented. Terminal velocity is often measured to determine if the system will be prone to line wear or cause material degradation.

In the term’s other primary use, terminal velocity describes a particle’s free-fall terminal velocity in a vertical conveying line section. If a particle is dropped, it will fall at a maximum velocity at which the gravitational pull on the particle is equaled by the air drag on the particle. If the upward conveying air velocity is the same as the particle’s free-fall terminal velocity, the particle will float at a fixed point in the line. If the air velocity is less than the particle’s free-fall terminal velocity, material will collect at the vertical line section’s bottom and cause choking. This would move the material upward in the form of slugs, pistons, or surges.

A material’s free-fall terminal velocity is usually much lower than its saltation velocity, so dilute-phase conveying in a horizontal line section requires a higher air velocity than in a vertical line section. This means that there’s usually more than enough air velocity in the system for conveying in a vertical section. In dilute-phase conveying, conveying material in a vertical section is seldom a problem.

The material’s free-fall terminal velocity can also be used to determine if some problems experienced in dust collectors is related to the interstitial velocity (the velocity of the gas between the filter elements) is too high and doesn’t allow the dust to freely fall into the dust collector hopper when it’s pulsed off of the elements during the cleaning operation.

**Unstable conveying zone**

To understand what an unstable conveying zone is, let’s look at a phase diagram. A typical example of this familiar diagram is shown in Figure 1 for a hypothetical material. In the diagram, an air-only line is plotted on a logarithmic scale, making it a straight line. This line is typically used for determining the conveying line pressure drop for air only. The U-shaped curve on the diagram is one of an infinite series of curves that could be drawn for this material when the conveying system is operating at different feedrates.

As the feedrate (and, hence, material loading) increases, the curve will rise, indicating that more pressure is required to convey more material. The vertical line on the diagram indicates the material’s saltation velocity. Any part of the U-shaped curve to the right of this vertical line is above the saltation velocity, indicating that the system is conveying in dilute phase. The curve portion to the left of the vertical line indicates that the system is conveying in dense phase, moving the material in a pulsating flow of slugs or pistons through the conveying line.

Now look at the portion of the curve labeled “unstable conveying zone.” Here, conveying is in two-phase fluidizable flow — that is, material flows in dilute phase in the line’s upper section and in fluidized flow in the bottom section. The advantage of conveying in this zone is that it requires the least system pressure for conveying at a given capacity. And because the required airflow is slightly less than that for the saltation velocity, the system will require less horsepower and produce less material degradation and line wear.

Yet problems frequently experienced in such systems lead many users to ask, “Can I design a system to operate dependably in this zone?” Problems in unstable-conveying-zone systems often stem from differences in their predicted performance (based on laboratory tests) and actual production performance. Results of tests in a laboratory pneumatic conveying system can be used to produce a curve like the one in Figure 1 for any material. However, the test system’s operation won’t correspond perfectly to a production system’s operation. This is because the tests typically run for a short time and the laboratory system is purged or cleaned out after each test, essentially resulting in batch operation. When these laboratory conditions are duplicated in a plant in a continuously running unstable-conveying-zone system, occasional line plugs, inadequate conveying
capacity, or other unsatisfactory operating conditions can result.

But this doesn’t mean that you can’t design a system to operate satisfactorily in the unstable conveying zone. In fact, a material such as cement is almost always pneumatically conveyed in this zone.

Understanding your material’s characteristics is key to designing a system that will operate well in the unstable conveying zone. A fluidizable material will work best in the system. A small volume of air flowing upward through a bed of fluidizable material, such as cement, fly ash, or wheat flour, eliminates the interparticle friction, causing the bed to expand and the material-air mixture to behave like a fluid. The material also retains air after the fluidizing air supply is turned off, remaining in a fluid-like state for a time — this is called the air- (or gas-) retention time. A fluidizable material with a long enough air-retention time will remain in a fluid-like state through the entire conveying system, enabling you to confidently design the system to operate in the unstable conveying zone.

But if your material is coarse and has a uniform particle size and thus can’t be fluidized, or if it has a short air-retention time, it can be difficult to convey in a system operating in the unstable conveying zone. To solve this problem, you can operate the system in batch mode, which requires using a pressure tank to feed material to the system at intervals. This enables the conveying line to clean itself out as the airflow increases at the end of each conveying cycle, allowing you to dependably convey the nonfluidizable material or material with a short air-retention time. Utilizing one of the numerous technologies that exist for distributing air to multiple points along the convey line to prevent the formation of slugs or waves of a length, which could result in conveying line blockages, is another way to move materials in an unstable-conveying-zone system that operates continuously.

As we have said many times, one of the very first discussions you want to have when thinking about a pneumatic conveying system for your plant is the discussion with your material! You need to understand how that material wants to be conveyed and how it does not want to be conveyed. The finest system design and best engineered equipment won’t compensate if you are trying to get a material to be conveyed in a mode or mechanism that’s incorrect.

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For further reading

Find more information on this topic in articles listed under “Pneumatic conveying” in Powder and Bulk Engineering’s article index in the December 2017 issue or the Article Archive at PBE’s website, www.powderbulk.com. (All articles listed in the archive are available for free download to registered users.)

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