I n this eleventh column on the general application of pneumatic conveying, we’ll review the meaning of some commonly used pneumatic conveying terms. The terms, loading, saltation velocity, pickup velocity, terminal velocity, and unstable conveying zone, are sometimes used in different ways by pneumatic conveying authors and practitioners, which can be confusing. As we review what these terms mean, it may be helpful to arm yourself with previous columns discussing them, including July 1991, November 1991, March 1993, and November 1997.1,2

**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 confusion can result because sometimes the ratio indicates air to material and sometimes it indicates the opposite. When describing very dilute-phase conveying, this ratio is often given as pounds of air per pound of material to produce a positive number greater than one (unity). 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.

When pneumatic conveying suppliers and consultants talk to users, they 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. Many different equations have been derived for calculating the saltation velocity. 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 great.

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 feedpoint, 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, density, and shape and the conveying system’s conveying rate, line 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 superficial 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 feedpoint by the conveying line’s cross-sectional area; it doesn’t account for the volume of material fed into the system.

If the pickup velocity is above the saltation velocity, the conveying system will be in dilute phase.

Sometimes pickup velocity is used to define the air velocity that’s required to pick up particles already resting in a layer at the line’s bottom. This air velocity is typically two times the saltation velocity, but it’s greatly influenced by the particle shape of the accumulated material.

The air velocity at the material feedpoint 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.

**Terminal velocity**

The term *terminal velocity* can also 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, so it's often measured to determine if the system will be prone to material degradation or line wear.

In its other 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.

**Unstable conveying zone**

To understand what the *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, as you can see in Figure 1. 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.

Understanding your material’s characteristics is key to designing a system that will operate well in the unstable conveying 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 (called the air-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. But do avoid conveying such materials in an unstable-conveying-zone system that operates continuously.

Endnotes


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 Mary Watt at 612-866-2242, fax 612-866-1939 (mwatt@cscpub.com).

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