In this column, we’ll look at selecting a feeding device for a pneumatic conveying system, which depends on the material’s physical characteristics and the application.

Material characteristics
In previous “Pneumatic points to ponder…” columns,1 we discussed using the Geldart classification model as a means of classifying materials by the relationship between their mean particle size and their particle density, which largely determines the material’s flow characteristics. For this discussion, we’ll classify all materials as free-flowing, fluidizable, or compactible.

A free-flowing material contains at least 90 percent particles larger than 60 mesh (250 microns) and 100 percent larger than 200 mesh (75 microns). Free-flowing material flows from a storage vessel at a controlled rate, depending on the vessel discharge opening’s size. The material exhibits an hourglass flow characteristic, which is both predictable and dependable. A free-flowing material would be a Type B or D on the Geldart model. Plastic pellets and coarse sand are examples.

A fluidizable material is usually finely ground, with most particles less than 100 mesh (150 microns). The material packs solidly when deaerated and, when piled on a flat surface, will stand up vertically when some material is scooped away from the pile’s base. Yet, when mixed with a small amount of air, the material fluidizes, or entrains air between the particles, eliminating interparticle friction and causing the material to act like a liquid. A fluidizable material will frequently bridge or compact in some areas in a storage container. When the bridging or compacted material breaks loose and falls, air can be entrained between the particles, causing the fluidized material to flow uncontrollably out of the container. Fluidizable materials are Type A on the Geldart model, and examples include cement, most fly ashes, and alumina.

A compactible material is cohesive. The material can consist entirely of very fine particles (100 percent less than 325 mesh [50 microns]) or primarily of very fine particles with some coarse particles. When the compactible material consists of 100 percent very fine particles, it can’t be fluidized because the very fine particles have an interparticle attraction that causes them to stick together. Attempting to fluidize the compacted material with air can form cracks or breaks in the compacted material; the fluidizing air escapes upward through the cracks or breaks, but does little to enhance flow. Geldart Type C materials, such as titanium dioxide, ink toner, and pigments used to manufacture paint are examples of compactible materials.

When the compactible material consists of very fine particles mixed with some coarse particles, applying a normal amount of fluidizing air tends to segregate the fine and coarse particles. Applying excessive fluidizing air can fluidize the coarse particles, but the fines act as a mortar to hold the coarse particles together, preventing either free flow or fluidized flow from the storage container.

Feeding device applications
A feeding device can be used in one (or more) of four major pneumatic conveying applications: controlling discharge from a storage container, controlling feed into a vacuum conveying system, controlling discharge from a vacuum receiver, and controlling feed into a pressure conveying system. As a general rule of thumb, if the pressure differential across the feeding device is less than 1 psig, we use the term feeder; and if the pressure differential is greater than 1 psig, we use the term airlock.

Controlling discharge from a storage container. When material is stored in a silo, day bin, holding tank, or feed hopper, we often need to control the material discharge. In such an application, there is little or no pressure differential between the container and the conveying system — typically only a few inches of water column from connecting the conveying system to dust collection equipment.

Because the material discharges from the container by gravity into a process, another container, or a mechanical conveying device, the feeding device will only control the material discharge rate. Thus we can use the term feeder for this application.
Controlling feed into a vacuum conveying system. Similar to the previous application, this application controls material discharge from a silo, day bin, holding tank, or feed hopper. But this time air flows into the conveying system in the same direction as the material feed. Although a slight pressure differential exists, it’s in the direction of the material feed and can affect the material flow by inducing fluidization or flooding.

We can also use the term feeder for this application because the material discharges by gravity into a vacuum conveying system, and the feeding device only controls the material discharge rate.

Controlling discharge from a vacuum receiver. Typically, a feeding device is used on a vacuum receiver’s discharge to prevent air leakage into the vacuum receiver, not to control the material discharge rate. The vacuum conveying system delivers the material to the vacuum receiver at a controlled rate, so the feeding device under the receiver only has to discharge material at that rate and doesn’t need to provide further flowrate control.

However, because the vacuum receiver may be under vacuum up to 18 inches mercury, a large airflow could be drawn into the receiver. Because material must discharge from the receiver at the same time air wants to flow in, the material and air are trying to pass in opposite directions, which can impair material flow. In this application, the feeding device is correctly called an airlock rather than a feeder. The device works like a revolving door at a building entrance, permitting entry and exit from the building but restricting airflow between the interior and the exterior.

Controlling feed into a pressure conveying system. This application is the most difficult of the four because it simultaneously controls material feed into the pressure conveying system and prevents air from escaping the conveying line. The difficulty varies with the material characteristics and the head (or depth) of material on top of the feeding device. The feeding device is usually referred to as an airlock but could more correctly be called a combination feeder-airlock in this application. Selecting the wrong device for this application has caused many conveying system problems and challenges; to choose the right device, we need a comprehensive understanding of the application.

Types of feeding devices

The most common feeding devices include orifice device, screw conveyor, vacuum nozzle, fluidized feeder, venturi, rotary valve, double flap valve, screw pump, and pressure vessel. Each device can be classified as a feeder, an airlock, or a combination feeder-airlock, depending on how the device functions and which material it will handle. Refer to Table I for guidelines for selecting a feeding device for your material’s characteristics and your application. Following are descriptions of each device.

Orifice device. An orifice device, as shown in Figure 1, controls material flow by controlling the size of the storage container discharge opening (or orifice). The orifice can be fixed, consistently restricting the opening, or variable, restricting the opening to various degrees by using a slide gate (Figure 1) or a throttling valve. An orifice device is suitable for atmosphere-to-vacuum applications.

In many cases, to optimize the vacuum system performance, the

| Table I |

<table>
<thead>
<tr>
<th>Feeding device</th>
<th>Feeder</th>
<th>Airlock</th>
<th>Combination feeder-airlock</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Free-flowing</td>
<td>Fluidizable</td>
<td>Cohesive</td>
</tr>
<tr>
<td>Orifice</td>
<td>Yes</td>
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<td>No</td>
</tr>
<tr>
<td>Screw conveyor</td>
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<td>Possible</td>
</tr>
<tr>
<td>Vacuum nozzle</td>
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<td>Possible</td>
<td>No</td>
</tr>
<tr>
<td>Fluidized feeder</td>
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<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Venturi</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Rotary valve</td>
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<td>Yes</td>
<td>Possible</td>
</tr>
<tr>
<td>Double flap valve</td>
<td>Yes</td>
<td>Yes</td>
<td>Possible</td>
</tr>
<tr>
<td>Screw pump</td>
<td>Yes*</td>
<td>Yes*</td>
<td>Yes*</td>
</tr>
<tr>
<td>Pressure vessel</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Notes: * Fluidizable material can flood through the screw.
* Material hangup in the vessel can cause feed problems.
* An oversized rotary valve can aid flow.
* This approach is expensive but can be used, if necessary.
* Material can compact in the pressure vessel.
orifice device is equipped with a variable-position actuator, which is slaved to the conveying system operating pressure. As the conveying cycle begins, the system operating pressure is at its lowest value, so the actuator increases the orifice size to increase the solids flowrate into the conveying line. As the system pressure rises and approaches the design value, the actuator will reduce the orifice size to decrease the solids flowrate. The actuator then continues to open or close the orifice as required to maintain a consistent conveying line pressure during operation.

**Screw conveyor.** A screw conveyor consists of a flighted shaft (or screw) rotating inside a tubular housing that’s located below a storage container. In operation, the unit draws material from the container at a controlled rate. The screw conveyor can feed materials from atmosphere-to-vacuum or atmosphere-to-atmosphere (feeder). However, a fluidizable material can flood through the screw even when the screw isn’t turning; thus, the screw conveyor may not be able to restrict flooding of the fluidizable material. A screw conveyor doesn’t typically make a good airlock into a pressure conveying system because the device can’t provide a positive shutoff to prevent air leaks if there’s positive pressure at the material outlet.

**Vacuum nozzle.** A typical vacuum nozzle, as shown in Figure 2, uses the air entering a vacuum conveying system to control the material feed to the system from a storage container. The vacuum nozzle typically consists of an inner conveying pipe inside an outer vacuum nozzle pipe inserted into a storage container. In operation, air enters the system by passing through an annulus between the inner conveying pipe and the outer vacuum nozzle pipe. The air flows toward the material feedpoint at the inner pipe’s end and entrains the material into the conveying system, depending on the airflow and how far the inner pipe penetrates beyond the outer pipe (which is based on the material’s angle of repose).

The vacuum nozzle can be any of several shapes, but must ensure an adequate air supply to the system’s material feedpoint. The vacuum nozzle is suitable for atmosphere-to-vacuum applications.

**Fluidized feeder.** A fluidized feeder, as shown in Figure 3, consists of a vessel with a material inlet, a fluidizing air inlet, a lift air inlet, and an air-and-material outlet (the pressure conveying system). In operation, fluidizing air enters the vessel and fluidizes the incoming fluidizable material as the lift air flows upward toward the conveying system. Because the fluidizable material behaves like a liquid, the pressure (called the fluidized head pressure) at the bottom of the fluidized bed introduces the material into the pressure conveying system. The material flows into the pressure conveying system until the conveying system pressure and the fluidized head pressure are equal; at this point, an equilibrium (or constant) flowrate is established. The fluidized feeder is suitable for atmosphere-to-pressure applications.

**Venturi.** A venturi, as shown in Figure 4, is a constricted section of pipe containing an air inlet, a material inlet, and an air-and-material outlet. The venturi creates a vacuum at the material inlet, so material is easily fed from a storage container to the system and no air leaks out the material inlet. But as the air velocity slows in the venturi, the venturi converts the kinetic velocity pressure into static pressure, thus establishing a pressure conveying system. The venturi is suitable for atmosphere-to-pressure applications.

**Rotary valve.** A rotary valve is mounted below a storage container and typically consists of rotating vanes inside a circular cavity with a material inlet and material outlet. As the vanes rotate, a fixed volume of material passes through the material inlet to the spaces between adjacent vanes and is metered through the material outlet.
The valve can function as a feeder, an airlock, or a combination feeder-airlock and, with proper valve selection, suits all vacuum and pressure applications within limits. Although various types of rotary valves look alike, they have distinct design differences that affect their application. For instance, selecting a rotary valve feeder when you need a combination feeder-airlock will produce an unsatisfactory pressure conveying system.

**Double flap valve.** Although it operates like a pressure vessel (discussed later), a double flap valve (or lock hopper), as shown in Figure 5, usually refers to a small-volume, frequent-cycle vessel. The double flap valve is mounted below a storage container and has top and bottom chambers; an air inlet and material inlet are located in the top chamber, a hinged gate or sliding disc is located between the top and bottom chambers, and an equalizing valve connects the top chamber to the conveying air source and the bottom chamber, which is open to the conveying line. In operation, the top chamber first fills with material while the hinged gate or sliding disc between the chambers is closed; then the material inlet closes and the equalizing valve brings both chambers to the same pressure; and finally the gate or disc opens and material drops from the top chamber to the lower chamber and feeds the conveying system. The gate or disc is closed after conveying, and the top chamber is repressurized. The double flap valve is suitable for vacuum-to-atmosphere, vacuum-to-pressure, or atmosphere-to-pressure applications.

**Screw pump.** A screw pump consists of a compressing screw with a pitch (or distance between flights) that decreases (rather than remaining constant) from the material inlet to the discharge. The screw is mounted inside a tubular chamber and has a hinged nonreturn style valve at its inlet. The screw pump can be located below a storage container but is typically more efficiently fed from a controlled feed device such as a screw conveyor or rotary feeder. In
operation, material passes through the material inlet and fills the space between the screw’s larger flights at the inlet end. As the screw turns, the material advances and is compressed by the screw’s decreasing pitch. The compressed material passing through the outlet prevents air leakage while the pump is operating. The hinged nonreturn style valve prevents air leakage when there’s no material feed. The screw pump, unlike the screw conveyor, normally operates at a high speed (900 to 1,160 rpm).

The screw pump is suitable for atmosphere-to-pressure applications and can introduce a fine material into a pressure conveying system operating at up to about 25 to 30 psig (2 bar) without leaking any conveying air back through the screw. A conveying system handling a coarse material, however, must be carefully designed to keep the conveying-line pressure low enough to prevent conveying air leakage back through the screw.

**Pressure vessel.** A pressure vessel (also called a pressure tank or a blow pot) is available in many shapes and configurations, and each has similar applications. A typical pressure vessel, as shown in Figure 6, has a material inlet at the top, a vent line at the top, and an air inlet. The air inlet is usually located at the vessel top if the material is free-flowing and at the bottom or lower vessel sides if the material is fluidizable; some pressure vessels include air inlets in both locations to handle either type of material. The material outlet is shown in the vessel’s center bottom, but in some pressure vessels the material discharges through a vertical top discharge line or an angled side discharge.

In operation, material fills the vessel by flowing through the material inlet, while the air displaced by the material exits the vessel through the vent line. Next, the material inlet and vent line are closed, and the vessel is pressurized as air enters through the air inlet. If the vessel includes a discharge valve, the discharge valve is opened, and the increasing air pressure inside the vessel moves the material through the material outlet into the conveying line. After the material has been conveyed, the vent line opens to depressurize the vessel, or the air is allowed to escape through the conveying line.

The pressure vessel is usually required for handling abrasive materials or introducing material into higher pressure conveying systems. The pressure vessel is suitable for vacuum-to-pressure or atmosphere-to-pressure applications.

**Other considerations**

An additional factor to keep in mind is that most feeding devices are volumetrically sized, meaning they are sized based on their ability to handle a specific volume of material per unit time — such as cubic feet per hour or cubic feet per revolution. The material’s density as it enters the...
feeder or feeder-airlock inlet is very critical and must be defined as accurately as possible. The typical approach is to use the material’s bulk density, which is fine if that’s the material’s density at that point.

Many times, however, depending on how the material arrives at the inlet, the density has been reduced through the use of fluidization or from air entraining as the material dropped through a long vertical chute or spout. If the material’s bulk density was used to size the feeding device, but the actual density has been reduced by 25 percent, for example, the feeder or feeder-airlock won’t be able to handle the system’s required mass flow rate.

The feeding device’s filling efficiency is another factor to consider. Supplier capacity charts provide a feeder’s volumetric capacity based on 100 percent efficiency. However, a rotary feeder’s filling efficiency is typically in the 85 to 90 percent range. For a rotary airlock, the range drops to 65 to 70 percent. When selecting a feeding device, be sure to determine the feeder’s correct efficiency based on your application and use that percentage to reduce the supplier’s stated volumetric capacity.

Reference
1. Find topics, issue dates, and page numbers for previous “Pneumatic points to ponder…” columns in Powder and Bulk Engineering’s article index in the December 2014 issue or the Article Archive at PBE’s website, www.powderbulk.com. (All columns listed in the archive are available for free download to registered users.) You may also purchase a CD containing all “Pneumatic points to ponder…” columns from 1989 through 2008 from the Store at www.powderbulk.com.

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