Building on the information presented in his first series of columns, Paul E. Solt—a private consultant with more than 25 years of experience in installing and troubleshooting pneumatic conveying systems—presents a second series of columns discussing pneumatic conveying basics and how to apply them when designing a pneumatic conveying system.

In this first column of the second series, we’ll discuss types of pneumatic conveying systems. The types include vacuum, pressure, and combination vacuum-pressure systems. To help you understand what each system includes and how complicated systems of each type are designed, we’ll discuss each system’s design, advantages, and disadvantages.

Before discussing each system, let’s examine some common misconceptions about how the systems work. Many people believe that a vacuum system draws material into the conveying line’s center and separates the material, and that a pressure system forces material toward the conveying line walls and compacts the material. However, neither is true. At any point in either a vacuum or pressure system, the air’s dynamic action on the material is the same. The particles are moved through the conveying line by the airflow, which is established by a pressure differential. In a vacuum system, air flows from atmospheric pressure to a reduced pressure; in a pressure system, air flows from an elevated pressure to atmospheric pressure. In other words, air always flows from a higher pressure to a lower pressure and always expands through the conveying line.

Vacuum system

A vacuum system, as the term suggests, operates below atmospheric pressure. The system’s primary design requirement is to locate the air mover, usually a fan or blower, at the system’s end (Figure 1), after the air/material separator (typically a transfer receiver/filter or a simple settling chamber). The pressure differential established by the air mover causes air to enter the system’s conveying line near the material feed point and to flow through the system. After entering the system, the air entrains the material and flows past the air/material separator, which serves as a primary filter by separating the air from the material. The air/material separator allows the material to discharge below the separator, typically through a rotary airlock valve or discharge gate. The air continues to flow toward the system’s end, through a secondary in-line filter that further cleans the air, and then out the air mover.

Choosing a fan or blower air mover depends on the pressure differential needed to operate the system: typically, a fan provides a smaller pressure differential than a blower.

Advantages. First, a vacuum system’s major advantage is its feeding ease. Since the conveying line operates below atmospheric pressure, air enters through any system opening. This airflow into the system is frequently used to entrain material feeding the system. For instance, inserting the conveying line’s open end into material in a bin, drum, or hopper allows the airflow into the conveying line to entrain the material, which feeds the material to the system.

Second, a vacuum system’s feeding ease allows multiple feed points. For instance, in a railcar-unloading application, a manifold pipe that’s linked to a vacuum...
system and located on the rail siding parallel to the tracks is fitted with several lateral pipe connections. The lateral pipe connections, located at appropriate intervals, connect to flexible hoses that run to the railcars to unload the material and feed it into the vacuum system. Using multiple flexible hoses means the railcars don’t need to be precisely positioned for unloading.

Third, a vacuum system’s leakage — typically at couplings and hose connections and in piping — is primarily inward, allowing some air to leak into the system but minimizing material leakage into the plant area. This keeps the area around the feed point and conveying line clean, which is especially important when handling a toxic material.

Disadvantages. First, because the maximum pressure differential that can be created across a vacuum system is atmospheric pressure, 30 inches mercury, and the system’s practical operation limit is 20 inches mercury, a relatively small amount of work can be accomplished in a vacuum system. Thus, a vacuum system typically isn’t suitable for high-capacity, long-distance applications.

Second, the air mover’s location at the system’s end slows any change in vacuum. This is because the conveying line and air/material separator act as accumulators that must be evacuated as the system vacuum increases. Thus, a vacuum system responds sluggishly to material feed changes and is usually designed for higher velocities and lighter material-to-air ratios.

Third, fine material is difficult to filter from the air with the air/material separator and thus can pass through the air mover and damage it. To prevent such damage, a secondary in-line filter is placed on the conveying line between the air/material separator and the air mover.

Fourth, the air/material separator’s mechanical design must withstand the system’s pressure differential. For instance, if a cloth filter is used in the air/material separator, the filter’s housing must withstand the forces created by the pressure differential.

Fifth, air leakage into the vacuum system can damage a material that can’t contact oxygen or moisture.

Advantages. First, a pressure system’s major advantage is how simply it can be designed for delivering material to multiple points. For instance, the system can be equipped with several diverter valves for delivering material to many bins or silos.

Second, the work a pressure system can accomplish is virtually unlimited, because the maximum pressure differential that can be created across the system is virtually unlimited (pressure is commonly up to 60 psig). Thus, a pressure system is usually required for high-capacity, long-distance applications.

Third, because the air mover is near the feed point, any change in the material feed rate results in an immediate pressure buildup. This makes the system very responsive to material flow changes, which is the primary reason that most dense-phase systems are designed as pressure systems.

Fourth, because the air mover is located before the feed point, the only filtration the pressure system requires is to prevent foreign material from entering the air mover’s inlet.

Fifth, the air/material separator’s mechanical design must withstand only the pressure differential created by the airflow through the air/material separator. For instance, if a cloth filter is used in the air/material separator, the filter’s housing must only withstand 1 to 2 psig.
Sixth, because all leakage in a pressure system will be outward, the system is ideal for conveying a material that can’t contact oxygen or moisture.

Disadvantages. First, a pressure system’s major disadvantage is its feeding method. Because the conveying line’s pressure is above atmospheric pressure, air escapes through any line opening. The highest pressure is at the feed point where air can leak outward, causing the conveying line to resist material feeding and limiting the system’s capacity. Thus, feeding material to a pressure system requires some type of airlock that can feed material into the conveying line while preventing the uncontrolled escape of the conveying air.

Second, because feeding a pressure system is difficult, multiple feed points in one common conveying line are expensive. An example of this arrangement is a conveying line passing under a row of storage silos or bins; a rotary airlock feeder can be installed under each of the bins to feed the common conveying line.

Third, a pressure system leaks outward, so that small leaks at couplings and hose connections and in piping allow air and fine material to leak into the plant. This can create a dirty plant area and can be especially hazardous when conveying a toxic material (though a toxic material is typically conveyed in a vacuum system).

Combination vacuum-pressure system

A combination vacuum-pressure system, as the term suggests, combines a vacuum system and a pressure system. The vacuum system (called the vacuum leg), discharges into the pressure system (called the pressure leg), as shown in Figure 3, thus combining a vacuum system’s feeding versatility with a pressure system’s delivery to multiple points.

A combination system can use the same air mover for both legs. In such a case, atmospheric air enters the vacuum leg, passes through the conveying line and the air/material separator, and then passes through the air mover and discharges to the pressure leg. In other cases, a combination system uses a separate air mover for each leg.

The air/material separator at the vacuum leg’s end can be a transfer receiver/filter or a simple settling chamber, depending on the conveyed material. A fan can serve as the air mover if the material isn’t abrasive or its particles can be broken without affecting the material’s handling characteristics or the final product’s quality.

Advantages and disadvantages. All the advantages and disadvantages listed for vacuum and pressure systems apply to the corresponding leg of the combination system. The combination system’s major advantages are its easy feeding from multiple feed points, provided by its vacuum leg, and its delivery to multiple points, provided by its pressure leg. The combination system also can be designed for high-capacity applications by running a short-distance vacuum leg followed by a long-distance pressure leg.

Paul E. Solt (now retired) worked as a private consultant specializing in pneumatic conveying. In addition, he was course director on pneumatic conveying for both the American Institute of Chemical Engineers (AIChE) and the Center for Professional Advancement. He also was employed by Fuller Company in various research and test engineering capacities. Paul holds a BS in mechanical engineering from Lehigh University and has several patents for pneumatic-conveying-related apparatuses and devices.

Editor’s note: Paul started Pneumatic Conveying Consultants in 1984 and sold the company to Jack D. Hilbert in 2010. Jack and Paul worked as partners until Paul retired in 2014.