

# PNEUMATIC CONVEYING SYSTEM CLASSIFICATION

Understanding the strengths and limitations of different types of pneumatic conveying systems can help you choose the system best suited to your application. This article explains basic terms used to describe and classify pneumatic conveying systems. Some terms describe the system type (based on airstream used to convey material), and others describe the conveying phase (based on degree of material concentration in the airstream).

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All pneumatic conveying systems can be classified into one of three system types based on the kind of airstream used to convey material: vacuum, pressure, or a combination of vacuum and pressure. The following sections define and describe each system type and further classify their operating components.

## Vacuum systems

Vacuum systems, also called negative-pressure systems, use vacuum-generating devices to produce medium- to high-velocity airstreams in the conveying lines. These systems are generally used to pick up material from several sources for delivery to one discharge destination. Vacuum systems are also used to unload material from bulk transport vehicles such as railcars, barges, and ships.

In a typical vacuum system, as shown in Figure 1, material is drawn directly into the conveying line from the pickup source, which is maintained at atmospheric pressure. The pickup source can be a bin equipped with a rotary airlock or a process device like a mixer or mill. The conveying air moves the material to a destination (filter-receiver), which is maintained below atmospheric pressure. The filter-receiver separates the material from the conveying air, discharges the material through a rotary airlock to storage or process, and passes the conveying air through a dust filter into the vacuum-generating device.

Vacuum systems can be further classified by the device used to generate the vacuum and by the vacuum level at which each system operates. Four common vacuum-generating devices are the low-pressure fan, the lobe-type blower, the screw-type blower, and the venturi.

**Low-pressure fan systems** generate vacuum with centrifugal fans or regenerative blowers and are generally used to collect fugitive dust; to vent silos, belt conveyors, or bagging operations; or to collect nuisance dust within a plant. Vacuum levels range from

2 to 60 inches mercury. Capacities range from several pounds per hour to several hundred pounds per hour.

**Lobe-type blower systems** generate vacuum with positive-displacement lobe-type blowers and are generally used to convey material over short distances. Vacuum levels range from 3 to 15 inches water gauge. Capacities range from 100 lb/h or less to 100 t/h or more.

**Screw-type blower systems** generate vacuum with positive-displacement screw-type blowers and are generally used to convey material over long distances. Ship unloading is a typical application. Vacuum levels range from 16 to 26 inches mercury. Capacities range from several to several hundred t/h.

**Venturi systems** generate vacuum with venturis, which use positive-pressure air supplies. These systems are generally used to convey abrasive or friable material over very short distances (up to 20 feet). A typical application is vacuum-loading a conveying vessel, which is then discharged by pressure. Vacuum levels range from 4 to 20 inches mercury. Capacities range from 1 to 50 t/h.

Some venturi systems convey material directly through the venturi bodies. These systems operate at very low capacities but can convey material several hundred feet or more. Venturis used in this manner are commonly called *eductors*.

## Pressure systems

Pressure systems, also called positive-pressure systems, use air discharged from pressure-generating devices to produce low- to high-velocity airstreams in the conveying lines. These systems are generally used to pick up material from one source for delivery to one or more discharge destinations. In a typical pressure system, as shown in Figure 2, material is conveyed from the pickup source, which is maintained above atmospheric pressure. The conveying air moves the material to storage bins or packaging silos, which are maintained near atmospheric pressure.

Pressure systems can be further classified by their equipment configurations and by the pressure levels at which they operate (low, medium, or high). Four common equipment configurations are rotary airlock/blower, pressure vessel/blower, screw feeder/compressor, and pressure vessel/compressor.

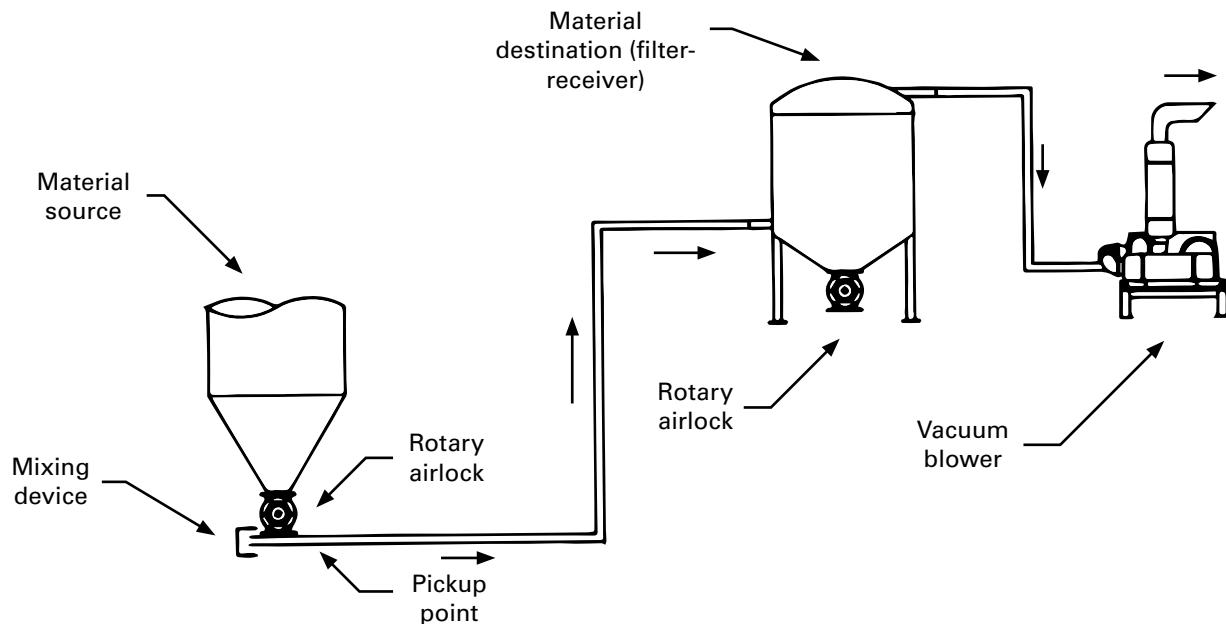
Each equipment configuration uses a mechanical device or pressure vessel to mix the air and the mate-

rial to be conveyed. In addition, each system's blower or compressor has an atmospheric air inlet where filtered air is drawn in to be compressed. Unlike a vacuum system, the conveyed material can't be drawn into the blower or compressor, even if the inlet's filter fails.

**Rotary airlock/blower systems** use low-pressure blowers to pressurize the conveying lines. Rotary airlocks (maintained at atmospheric pressure) separate

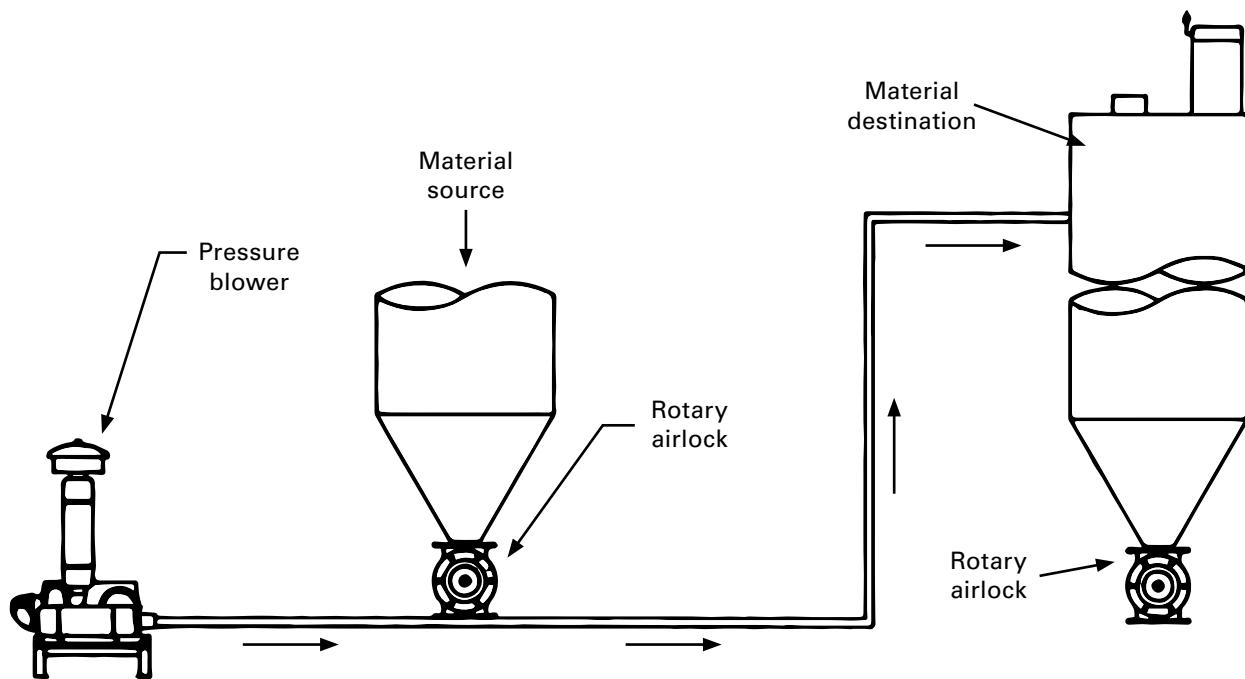
**FIGURE 1**

Vacuum system



**FIGURE 2**

Pressure system



the pressurized conveying lines from the material source. The airlocks continuously meter material into the conveying lines and control the mixing of air and material. Air leakage and wear can be a problem with these systems. Pressure levels range from 2 to 12 psig. Capacities range from less than 1 t/h to 25 t/h or more.

**Pressure vessel/blower systems** use low-pressure blowers to pressurize the pressure vessels after they are filled with material. These systems convey in batches and experience less air leakage and wear than rotary airlock systems. Pressure levels range from 10 to 15 psig. Capacities up to 50 t/h or more are possible.

**Screw feeder/compressor systems** use medium-pressure (single-stage reciprocating or rotary vane) compressors to pressurize the conveying lines. Mechanical screw feeders rotate the material, continuously forcing it into the pressurized conveying lines. High conveying rates are possible with these systems, but a great deal of horsepower is needed to turn the mechanical screws. In addition, these systems are unsuitable for conveying abrasive materials due to the screws' high maintenance needs. Pressure levels range from 20 to 45 psig. Capacities up to 200 t/h are possible.

**Pressure vessel/compressor systems** are available with either medium- or high-pressure compressors. Systems that use medium-pressure (reciprocating or dry screw) compressors convey material over longer distances and at higher rates than pressure vessel/blower systems. Pressure levels range from 30 to 60 psig. Capacities up to 200 t/h are standard.

Systems that use high-pressure compressors (or that operate from existing plant air supplies) convey material from a few feet up to several thousand feet. Pressure levels range from 50 to 80 psig. Capacities range from several hundred lb/h to several hundred t/h.

Some medium-pressure compressor systems and all high-pressure compressor systems require pressure vessels that meet the codes of the American Society of Mechanical Engineers (ASME). In addition, both types of systems can be designed with two pressure vessels. In medium-pressure compressor systems, two-vessel configurations achieve conveying rates similar to screw feeder/compressor systems but with lower energy requirements and reduced component wear.

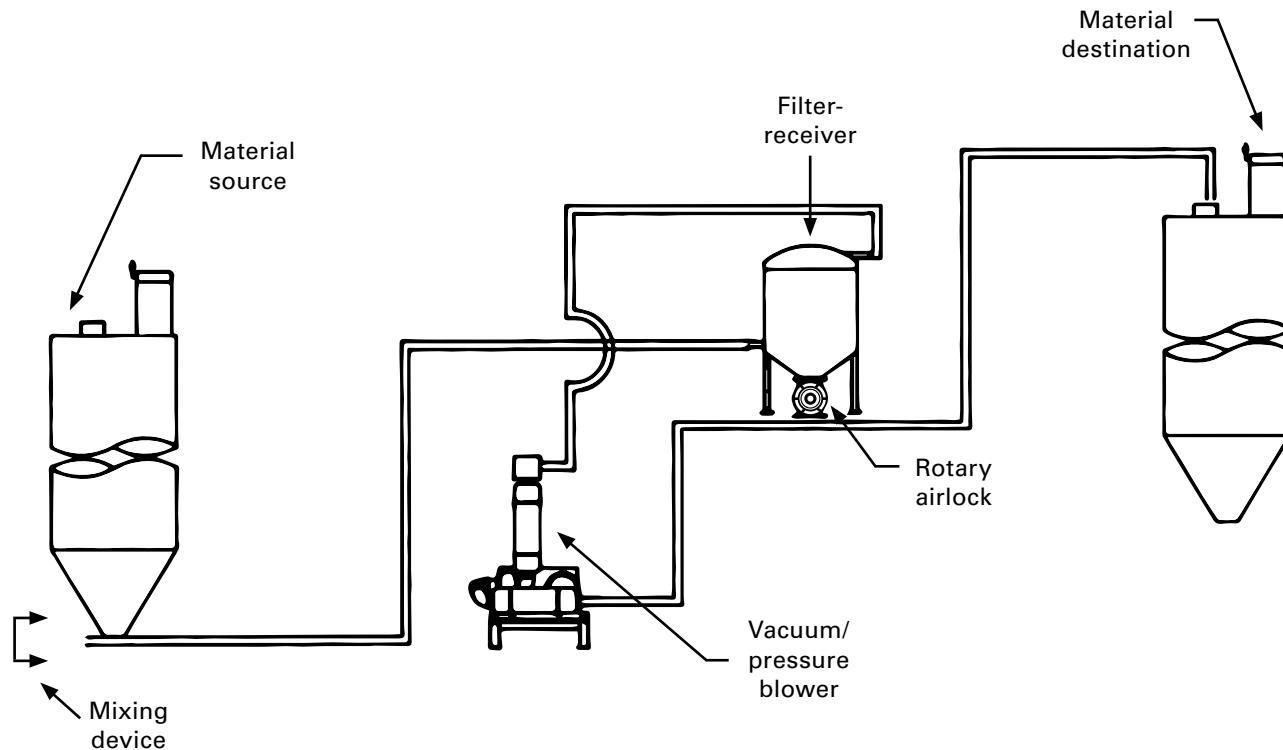
### Combination systems

Combination systems, also called vacuum/pressure systems, combine vacuum and pressure operation. These systems are generally used to pick up material from several sources for delivery to several discharge destinations. Combination systems are also used where vacuum pickup is most desirable but where pressure delivery is most suitable — for instance, when material is unloaded from bulk transport vehicles for delivery to several locations.

In a typical combination system, as shown in Figure 3, both the material source and the material destination are maintained near atmospheric pressure. In operation, material is drawn from the pickup source into the conveying line and transferred to a

**FIGURE 3**

Combination vacuum/pressure system



filter receiver. The receiver separates the air and the material. The filtered air is discharged to a vacuum/pressure blower, which then discharges it into the pressure system. The material is simultaneously discharged through a rotary airlock into the pressure conveying line for delivery to the desired destinations.

The critical area in coordinating vacuum and pressure operation is the point where the material leaves the vacuum zone and enters the pressure zone. In many cases, an airlock is used to separate the two zones. A pressure pot, alternately placed under vacuum and pressure, also can be used.

### Material conveying phases

The way material moves through the conveying line is another way to classify pneumatic conveying systems. Dilute-phase and dense-phase are the two most common conveying phases. Some equipment suppliers also define a third phase — medium-phase or semi-dense-phase.

Equipment suppliers and consultants generally describe the differences between these phases by the material-to-air ratio, the conveying air pressure, or the material flow characteristics. This article focuses on material flow characteristics. These characteristics within an operating system vary and often fluctuate, depending on the permeability, average particle size, particle shape, and density of the material, as well as on the air velocity within the conveying line and the conveying pressure at any given point in the line.

### Dilute-phase conveying

In dilute-phase conveying, the air velocity within the conveying line is high enough to suspend individual material particles in the airstream, as shown in Figure 4a. The airstream carries the material much the same way as blizzard winds carry snowflakes. Because the particle sedimentation velocity is lower than the air velocity, the material doesn't settle in the conveying line.

In a typical dilute-phase system, a large quantity of air carries a small amount of material. The system's air velocity ranges from 4,000 to 8,000 (or more) ft/min, so the corresponding material-to-air ratio is very low, typically less than 5 pounds of material per pound of air.

A typical dilute-phase system consists of a rotary airlock and a positive-displacement blower. The rotary airlock drops the material to be conveyed into the airstream at a steady and consistent rate. Since the system operates at a low conveying pressure (usually less than 10 psig), the material flow experiences very little acceleration due to air expansion while moving through the conveying line. Therefore, the material's discharge velocity is only slightly greater than its pickup velocity.

### Dense-phase conveying

In dense-phase conveying, the air velocity within the conveying line is too low to suspend individual material particles. Instead, the material is allowed to

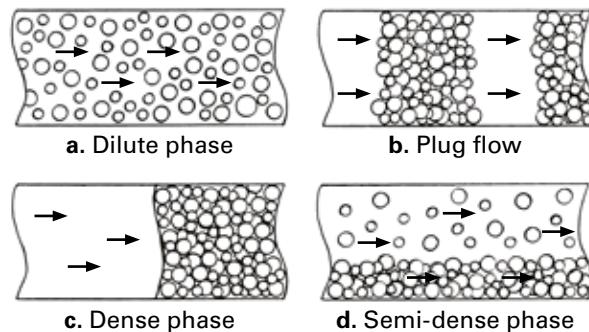
settle in the conveying line. As the pressure starts to build, the material forms a plug that fills the conveying line, as shown in Figure 4b. The conveying air then pushes the plug through the line in much the same way that toothpaste is pushed from its tube.

In a typical dense-phase system, the air velocity at the material pickup point is less than 200 ft/min. The system requires low air volume to produce this velocity, so the material-to-air ratio is high, typically 100 pounds of material per pound or more of air.

A typical dense-phase system consists of a pressure tank conveyor and a screw-type or reciprocating compressor. Precise control of the pressure and airflow push the conveyed material into the conveying line. Since the system operates at a high conveying pressure (usually 20 to 80 psig), the material flow experiences some acceleration due to air expansion while moving through the conveying line. In operation, seeing a material discharge velocity of 2,000 ft/min when the pickup velocity is 200 ft/min is common.

**FIGURE 4**

Material conveying phases



### Dense versus dilute phase

Dense-phase conveying has several operational advantages over dilute-phase. The smaller conveying air volumes associated with dense-phase conveying decrease energy consumption and permit the use of smaller dust collectors at the material destination. In addition, the slower conveying velocities reduce material degradation or breakage as well as wear on the conveying line. The heavier line-loading capability of dense-phase conveying also permits the use of smaller-diameter conveying lines.

In many applications, problems that occur when material is conveyed in dilute phase don't exist when the material is conveyed in dense phase. In addition, many applications that previously used mechanical conveyors — a consequence of the high energy requirements of dilute-phase systems — now find dense-phase systems more cost-effective.

### Plug-flow conveying

In practice, most dense-phase systems actually use a plug flow to move material. While the term *plug-flow conveying* is often used synonymously for dense-phase

conveying, this article classifies it as a subcategory.

In plug-flow conveying, the material forms several individual plugs, which travel through the conveying line picking up material at their leading edges and dropping material at their trailing edges, as shown in Figure 4c. As the plugs form, air is sealed across the conveying line's cross section, and this trapped air propels each plug.

The conveying pressure decreases as the plugs travel through the conveying line. (While the conveying pressure at the beginning of the line is nearly the same as the pressure inside the conveying vessel, the pressure at the line's discharge is about the same as the atmospheric pressure.) This pressure decrease causes the plugs to accelerate slightly due to air expansion. In most plug-flow systems, the empty space between plugs accommodates the expanding air and maintains each plug's integrity as it passes through the line. The spacing between each plug actually increases as the plugs move closer to the discharge point.

### **Medium- or semi-dense-phase conveying**

While industry definitions of medium-phase conveying differ, discussing this conveying mode is important for several reasons. First, the classifications for dilute- and dense-phase conveying aren't discrete. A continuum of variations exist between the two. Second, since semi-dense-phase conveying exhibits both dilute- and dense-phase characteristics, systems that use this hybrid technology should be considered separately.

In semi-dense-phase conveying, a significant amount of material moves slowly along the bottom of the conveying line, while the high-velocity air above the material simultaneously picks up and suspends a certain amount of particles, as shown in Figure 4d. Depending on the material's properties, a plug can also form in the conveying line and be pushed along for short distances.

In a typical semi-dense-phase system, the conveying air velocity ranges from 1,500 to 3,000 ft/min at the pickup point and from 3,000 to 5,000 ft/min at the discharge point. The material-to-air ratio ranges between 10 and 20 pounds of material per pound of air. Conveying line pressure varies from 15 to 30 psig. Like a dilute-phase system, the typical semi-dense-phase system uses a positive-displacement blower (15 psig) or a medium-pressure dry-screw compressor (30 to 40 psig). Like a dense-phase system, the typical semi-dense-phase system uses a pressure vessel to inject the material into the conveying line.

### **Conclusion**

As you consider pneumatic conveying systems, remember that different equipment suppliers and authors may use vastly different terms to describe similar systems, so when you ask a supplier or consultant to help you determine which system type or conveying phase best

suits your application, be sure you understand the terminology before contractual discussions begin. **PBE**

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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 2018 issue or the Article Archive at *PBE*'s website, [www.powderbulk.com](http://www.powderbulk.com). (All articles listed in the archive are available for free download to registered users.)

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