FAN ENGINEERING

Fan & Blower Twin City

Information and Recommendations for the Engineer FE-3300

The Use of Fans in Pneumatic Conveying

Introduction

Pneumatic conveying is the transport of material from one location to another using air as the conveying medium with which the material is moved.

Energy is needed to transport the material from one place to another. This energy can be supplied by a mechanical method (such as conveyor belts, buckets, etc), fan, blower, or a compressor. This newsletter will focus on the use of a fan to convey material.

Methods of Pneumatic Conveying

There are several methods of transporting materials using pneumatic conveying. In general, they seem to fall into three main categories: air conveying, dense phase, and dilute phase.

Air conveying is the use of air to create a thin film of air between the material and the surface it is being conveyed on. Air film or air cushion is the use of air injected from below a porous surface such that the conveyed material "floats" along the system. This is somewhat like an air hockey table. Air can be directional causing the material to be transported along a desired path. The advantage to a system such as this is that it requires very little force to move the conveying material and it can be moved or rotated in any direction easily.

Another type of air conveying uses air nozzles with ball valves such that the air only flows through the valves when the conveying material makes contact with the valve depressing the ball. This, of course, reduces the operating costs of the system. However, the first cost of such a system would be higher.

Dense phase conveying is the transport of a slug of material by using high pressure (>15 psig) to essentially push the material along the desired path. Compressors or pressure blowers are typically used in this type of conveying system. It is similar to extruding and material is conveyed at relatively low velocities.

Dilute phase conveying uses a relatively large amount of air to convey a relatively small amount of material and at lower pressures than dense phase systems. The material is transported at high velocities through the system while being suspended in air. Dilute phase systems are the most commonly used method of transporting materials. Dilute phase will be the focus for the remainder of this article.

Positive Pressure – Dilute Phase

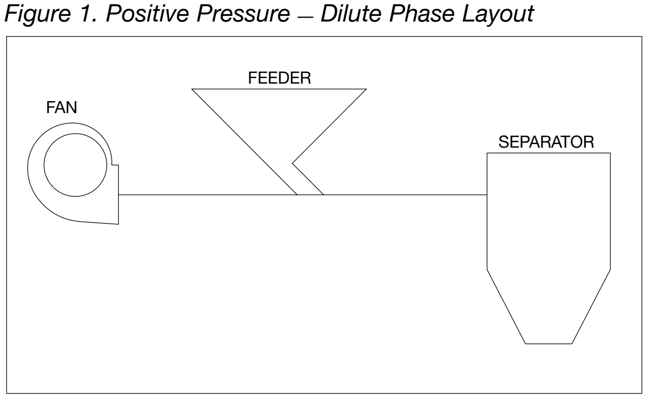
Positive pressure systems are normally used for transporting material from one entry point to one or more exit points. The orientation of components in this type of system is fan, feeder, and then separator as shown in Figure 1 below. Cement, fly ash, and dry chemicals are examples of products that have been conveyed using this method.

There are several different methods to introduce the material into the air stream for positive pressure systems. Screw feeders compress the material and force it into the air stream. Rotary valves drop material into the air- stream a little at a time.

Using the positive pressure layout, one has to be careful of high velocity impact of introducing material into the air stream. Depending on the material being handled, this could be damaging to the material. Also, if dust is a potential problem with the material, leaks must be eliminated. Since it is pressurized, leaks will be out of the system, so dust can escape through any leak.

In this type of system, the material does not go through the fan. There are two advantages to this. First, the fan wheel does not damage the material. Second, the fan does not experience any wear and tear from the material.

Figure 1. Positive Pressure – Dilute Phase Layout



Negative Pressure – Dilute Phase

Negative pressure systems are generally used for transporting material from one or more entry points to a single exit point. The configuration of components in this type of system is feeder, separator, and then fan as shown in Figure 2. This type of system is almost always used where toxic materials are being handled because any leakage is into the system.

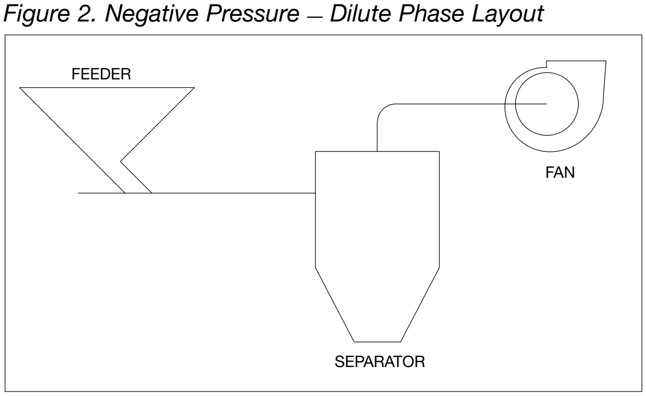
Material is fed into a negative pressure system (fan downstream of feeder and separator) using one of several methods. Mechanical methods may be used, such as in the positive pressure setup. Alternatively, a simple feeder, such as a duct opening, may be sufficient if the material is light enough for the amount of vacuum the fan creates. Hopper fed elbows can be useful as any extra material not collected in the air stream will fall down the elbow and can be re-used.

The negative pressure system is well suited for applications such as unloading rail cars. Another application would be for handling toxic materials so that any leakage would be into the system. Grains, seeds, granular chemicals, and pellets have been successfully transported using this method.

In this type of system, since the fan is downstream of the separator, the amount of material going through the fan is minimized. Therefore, the wear and tear on the fan is limited. Another advantage to this type of system is that any leakage is into the system, thereby eliminating dust problems.

The disadvantage to this type of system is that if the loading is high or the length of the system is large, the components must be designed for high vacuum. This adds cost to the components and must be considered when comparing methods of transport.

Figure 2. Negative Pressure – Dilute Phase Layout

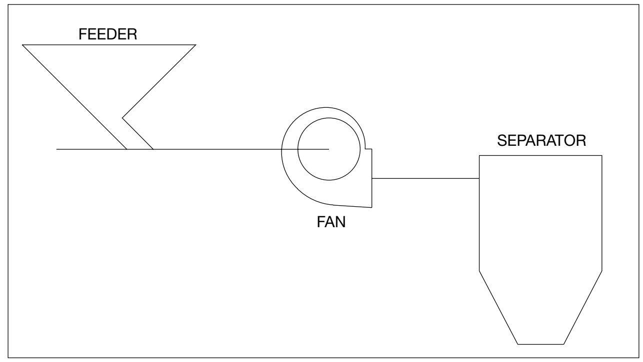


Combination – Dilute Phase

The advantages of both systems described above may be obtained by placing the fan between the feeder and separator. However, all the material must pass through the fan so wear on the fan and impact of the material going through the fan must be considered. This configuration can be used where there are multiple entry points and multiple exit points of material.

Combination dilute phase is where the fan is placed between the feeder and separator such that part of the system is under vacuum and part is pressurized as shown in Figure 3. This is the most common configuration of the three dilute phase systems. In this system, material goes through the fan and special fan construction may be required. Refer to the Fan Modifications section for more information on fan design for material handling.

Figure 3. Combination Dilute Phase



Feeders and Separators

There are many different types of feeders that are used to introduce the material being conveyed into the air stream. Some common feeders are screw, venturi, and hood feeders.

Cyclone separators are typically used to recover the solids from the air stream. Various types of filters are also used to clean up the air leaving the separators.

Material Loading

The material loading is the ratio of the weight flow of the material to that of the air. For any given material, there is a minimum transport velocity required to convey the material. Therefore, the airflow rate will depend on the size of the pipe or duct. For any given system, several different pipe/duct sizes may be used, but only one will be the most economical.

There is quite a range of suggested material loadings for a particular setup, so it is recommended to consult with a pneumatic conveying expert prior to making any calculations. Typically, a material loading of anywhere from 2:1 to 1:1 or less is acceptable for standard industrial fans. Pressure blowers may be used up to material loadings of 6:1. Over that, more specialized designs, such as multiple fans or multiple stage blowers, may be required.

Once a pipe size has been selected, the airflow rate can be calculated based on the minimum transport velocity of the material being handled.

Table 1 lists some materials that are commonly conveyed and the corresponding conveying velocities. In general, materials up to approximately 50 lb/ft^3 can be conveyed with an air velocity of 5000 fpm.

Table 1. Common Conveying Velocities

MATERIAL	VELOCITY (FPM)	MATERIAL	VELOCITY (FPM)
Paper	5000	Cotton	4000
Powdered Coal	4000	Wheat	5800
Dry Vegetable Pulp	4500	Wool	5000
Cement	7000	Oats	4500
Sand	7000	Corn	5600
Salt	5500	Sugar	6000
Sawdust	4000	Flour	3500

Losses and Fan Performance Adjustments

Bends in dilute phase conveying systems are undesirable and should be minimized. The bends increase the pressure drop in the system. Also, and more importantly, the material going through a 90-degree bend can impact the wall of the pipe causing damage to the material as well as excessive wear on the pipe.

Many systems do not have the luxury of having only straight runs of duct. Therefore, to minimize the effect of bends, large radius bends may be used. Alternatively, some studies have shown that blind tees are better than 90-degree elbows. The material that collects at the tee absorbs some of the impact of the material and acts like a cushion to reduce wear on the pipe.

The additional loading from the material going through the fan requires adjustments to the performance to account for the loading. There does not seem to be a reliable method to determine these adjustments, so only reasonable estimates can be used. Below are suggested guidelines for making adjustments to horsepower and system pressure.

The horsepower can be adjusted by adding the material loading factor to one. Then multiply the fan horsepower by this number to get the horsepower with material loading. Below is an example:

Horsepower Sample Problem
ACFM = 26,000
Material Loading = 19,500 lb/hr
Inlet Density = 0.05 lb/ft^3
BHP @ conditions = 112 BHP

Mass flow rate of air = 26,000 * 0.05 = 1,300 lb/min
Mass flow rate of material = 19,500/60 = 325 lb/min
Material Loading = 325/1,300 = 0.25
BHP correction = 1 + material loading = 1.25
BHP w/material = 112 x 1.25 = 140 BHP

The steps to correct the system pressure for material loading are shown below:

1. Find material loading = R (0.25 in example above)
2. Find SP loss due to acceleration of material = R x VP
   Where VP = velocity pressure of standard air
   This may have to be added more than once if the material is decelerated and then accelerated again in the system.
3. Find SP loss due to lifting material = R x L/69.2
   Where L = Height in feet
4. Find SP loss due to friction = F x R x H/69.2
   Where F = friction factor of material against steel
   H = length of duct in feet
5. Find SP loss for elbows (90 degree) = π x F x R x VP
   Add this loss for each elbow.
6. Add all losses to SP requirement for airflow though the duct.

Material Settling

Material that settles in the horizontal plane of a system is referred to as saltation. In the vertical plane, it is referred to as choking. Special care must be taken to minimize settling. For a particular pipe size and flow rate, the saltation velocity is higher than the choking velocity, so designing for the saltation velocity will also avoid choking (Rhodes 2001).

It can be difficult to avoid saltation since even the slightest seam or ledge can cause material to settle. Material tends to settle at bends also, so minimizing bends is recommended. The particles slow down at the bend and then are re-accelerated after passing the bend. This slow down can cause some material to settle. One other way to help avoid saltation is to remove any leaks because velocity will be less downstream of leaks.

At the same time, one does not want to select a velocity much higher than needed just to avoid settling. The additional velocity would be detrimental to the system by causing increased friction, wear, and operating costs.

Fan Selection

Once the calculations for the system have been performed and the appropriate pipe size has been selected based on material being conveyed and system resistance, the fan operating point is a simple calculation. The required flow rate of the fan is simply the velocity multiplied by the area.

Fan Considerations for Material Handling

If the material being conveyed will be going through the fan, special considerations must be given to the fan design. Several factors must be considered in order to select the appropriate fan for the application being considered.

The fan blade type selection is very important because one does not want to select a blade type that is prone to collecting material. Backward curved and airfoil blades are efficient, but are better suited for clean air applications because they often collect material on the blades. Radial blades are better suited for material handling applications. Backward inclined blades and blades that have a radial tip have also been used successfully in certain material handling applications.

Fan speed is also important in selecting a fan for material handling. The operating speed should be minimized as much as possible. High-speed fans with high tip speeds create higher velocities that correspond directly to the level of erosion and impact on the fan and system components.

The fan should be selected with the critical speed significantly higher than the operating speed. A good rule of thumb for material handling fans is to keep the rigid support critical speed at least 1.5 times greater than the operating speed.

Special materials may be required to resist corrosion, abrasion, and impact depending on the material being handled. In some applications, liners are added to the fan wheel at locations where the most abrasion will occur. These liners can then be replaced periodically without having to replace the entire wheel. The level of abrasion of the material will determine the level of erosion protection needed. Some applications may only require a special coating, while others may require special material liners to be installed on the fan wheel and/or housing.

Special coatings may also be required to resist corrosion or to make cleaning easier. Oversized access doors may be used to make maintenance and cleaning easier to accomplish. Special construction of the housing, known as swing-out and clamshell, allow for easy access to the fan components for cleaning and maintenance. In swing-out construction, the fan wheel, shaft, bearings, and motor are mounted on a door. The door can be opened for easy cleaning of fan components without removing ductwork.

Shaft seals may be required to resist materials from leaking out around the fan shaft.

If the material being handled is explosive or flammable, spark resistant construction is required. AMCA Standard 99 specifies Type A, B, and C spark construction, which are available for many fan designs. If materials such as coal are being transported, the National Fire Protection Association requires the fan housing design to withstand an explosion.

If high temperatures are present, such as an application where pneumatic conveying and drying are both being performed, high temperature construction may be required. This may include shaft seals, shaft coolers, motor heat shields, special materials, and/or insulated housings.

Special consideration may need to be given to bearing selection. The fan arrangement should be selected such that the bearings are out of the air stream. Also, higher capacity bearings may need to be used to allow for loads created by the material impacting on the impeller.

Fan orientation can also be important in material handling applications. In centrifugal fans, bottom horizontal or bottom-angular-up discharges are preferred. In other configurations, if material settles in the fan housing, it drops to the bottom and stays there. With bottom horizontal or angular up discharges, material tends not to settle due to high velocities at the bottom of the housing.

Conclusion

Pneumatic conveying is one of several methods of moving material from one location to another. Each individual case must be evaluated for multiple methods of transport before deciding on the best method. Pneumatic conveying, when designed correctly, can provide many benefits over other methods of material transport. The space required for a pneumatic conveying system is typically less than a mechanical method of transport. It can be modified without significant cost. Also, the amount of material lost can be minimized.

Selecting the fan for pneumatic conveying can range from easy to very involved depending on the location of the fan in the system. Special construction may be required to handle the additional loading and wear caused by the material being handled. If you are in need of help in determining what type of fan to use or if special construction is required, consult your fan manufacturer.

References

1. Pneumatic Transport of Powders by Martin Rhodes, 2001

2. Bulk Materials Handling Handbook by Jacob Fruchtbaum, 1988

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