The New York Blower Company • 7660 Quincy Street, Willowbrook, Illinois 60521 -5530

PNEUMATIC CONVEYING

INTRODUCTION

A well designed pneumatic conveying system is often a more practical and economical method of transporting materials from one point to another than alternative manual or mechanical systems. This Engineering Letter outlines some of the fundamental principals of pneumatic conveying systems and explains various special considerations for fan selection.

TYPES OF PNEUMATIC CONVEYING

Pneumatic conveying encompasses numerous different system designs, technologies, and pressure ranges; however, there are only three basic methods for moving material with air. These can be categorized into the following system types:

Dilute-phase conveying is the process of pushing or pulling air-suspended materials from one location to another by maintaining a sufficient airstream velocity to capture and convey the suspended particles.

Dense-phase conveying relies on a pulse of air to force a slug of material from one location to another. This form of conveying usually requires positive displacement blowers or compressors to generate the necessary pressure of 1.5 to 30 psig or more.

Air-film or **air-float conveying** is a means of moving product along a conveyor on a cushion of air.

The use of fans for pneumatic conveying is generally limited to dilute phase conveying and air film conveying.

DILUTE-PHASE CONVEYING

In this method of conveying, material is suspended in the airstream. Suction or vacuum are not factors in this type of system and fan static pressures are no greater than 60" WG. If the system uses a fan on the exhaust end and the material is collected or separated from the airstream before it reaches the fan, the fan itself can be of a more efficient type such as backwardly inclined. If the system is designed so that the combined material and air mixture passes through the fan, selection is limited to the more rugged but less efficient fan types intended for material laden airstreams. A number of radial-blade wheel designs are available to handle various concentrations, sizes, and types of airborne particles. Radial-tip wheel designs are tolerant of airborne contaminants, but radial-tip fans are not generally thought of as bulk material handling designs. In all cases, the fan manufacturer should be consulted to determine the most appropriate fan type available to handle the specific material quantity and type, but it must be understood that the fan manufacturer can neither control the variables in pneumatic conveying systems nor provide any guarantee of the service life of the fan itself.

Applications requiring fans for dilute-phase pneumatic conveying fall into one of three basic categories: dust collection, fume removal, or material conveying.

DUST COLLECTION AND FUME REMOVAL

Dust collection, fume removal, and material conveying systems each have unique characteristics, but all three are similar in their dependence upon proper air velocities.

Dust collection and fume removal are generally thought of as "housekeeping" systems that usually incorporate a hood at the system entry point. There are many types and styles of hoods in common use, and hood design is a subject in itself. Some state and local codes offer hood design criteria, and there are several reference texts, such as Industrial Ventilation - A Manual Of Recommended Practices, that can assist in the selection and design of hoods. In all cases the hood design should minimize turbulence and offer the lowest possible entrance losses.

Determining the minimum velocity for dust collection or fume removal is often a matter of practical trial-and-error judgment. State and local codes may dictate minimum velocities for certain materials. Where no codes apply, the velocities shown in Figure 1 can be used as conservative estimates. Since these velocities are conservative, it is often possible to reduce them through experimentation. Reducing the velocity to near the settling point will generate the lowest overall operating cost but raises the risk of system plugging, increased maintenance costs, and lost production.

Dust Collecting and Fume Removal Duct Velocities

Material	Velocity in FPM	Material	Velocity in FPM
1. Grinding Dust	5000		
2. Foundry Dust	4500	20. Jute Dust	3500
3. Sand Blast Dust	4000	21. Grain Dust	3000
4. Wood Flour	2000	22. Shoe Dust	4000
5. Sander Dust	2000	23. Rubber Dust	3500
6. Shavings, Dry	3000	24. Rubber Buffings	4500
7. Shavings, Wet	4000	25. Bakelite Moulding Powder	3500
8. Sawdust, Dry	3000		
9. Sawdust, Wet	4000	26. Bakelite Moulding Dust	2500
10. Wood Blocks	4500		
11. Hog Waste	4500	27. Oven Hood	2000
12. Buffing Lint, Dry	3000	28. Tail Pipe Exhaust	3000
13. Buffing Lint, Wet	4000	29. Melting Pot and Furnace	2000
14. Metal Turnings	5000		
15. Lead Dust	5000	30. Metallizing Booth	3500
16. Cotton	3000	31. Soldering Fumes	2000
17. Cotton Lint	2000	32. Paint Spray	2000
18. Wool	4000	33. Carbon Black	3500
19. Jute Lint	3000	34. Paper	3500

Figure 1

MATERIAL CONVEYING

Although the differences between dilute-phase material conveying systems and dust collection or fume removal systems might appear to be minimal, there are certain distinctions that are critical to the successful operation of material-conveying systems. These differences include the method of introducing the material to the hood, the velocity requirements, the duct configuration, and the fan type.

The introduction of material into a material conveying system can be difficult. The most important criterion is to feed the material into the airstream evenly. This can be accomplished by means of gravity or by a mechanical device.

A hood or hopper can be used as a gravity feeder. Use of these components is limited to dry, free-flowing materials. It is important to remember that it is the velocity moving around and past the material that induces it to flow. If the entry becomes plugged with material, the required velocity cannot be maintained, significantly impeding air and material flow.

A venturi feeder can be used to introduce material into the airstream. Like the hood, it has no moving parts so there is virtually no maintenance. However, the design of the venturi must be tailored to each application and even the best ones can be rather easily blocked if system conditions vary. Typical throat velocities are 2 to 3 times the velocity in the main duct . . . see Figure 2.

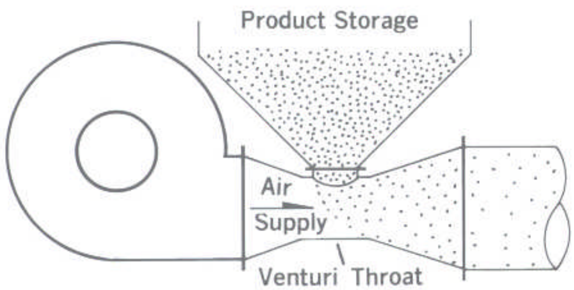

Figure 2 – Typical Venturi Feeder

Rotary valves and screw-type (auger) feeders (see Figure 3) are the most common mechanical devices used to introduce material into the airstream. Both types offer a controllable flow rate and are readily available in a number of standard designs to handle pressures common to dilute phase conveying. However, there are some precautions. Both are typically more expensive than gravity-feed alternatives. Rotary valves can experience internal air recirculation which causes a reduction in material through-put. The screw-type feeder is a relatively high maintenance device. In either case, the manufacturer of the specific feeder should be consulted for selection, equipment recommendations, and system limitations.

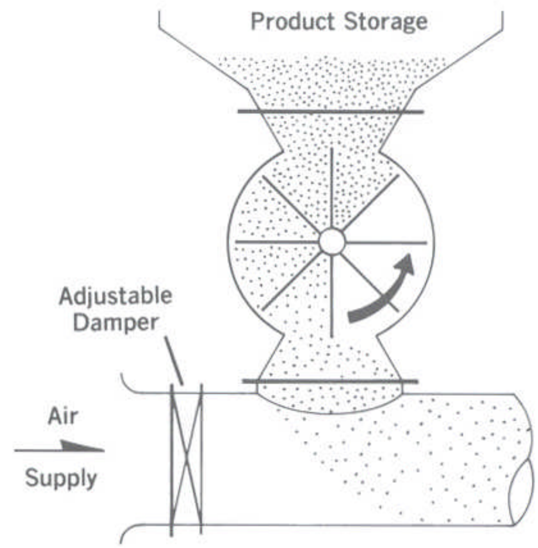

Figure 3 – Typical Rotary Valve Feeder

Since the purpose of a conveying system is to move quantities of material suspended in air, the ratio of material to air (by weight) is critical. The most common form of reference is to state the ratio according to the combined weight in pounds per hour. A conservative design approach is to keep the ratio of matter-to-air below a 1:2 proportion. However, successful systems have been designed using material loadings of 1:1 or more when the system components are well-designed and eliminate sharp turns, abrupt junctions, or other potential points of binding, clogging, or drop-out and the material being conveyed is well-defined and consistent.

Certain minimum conveying velocities must be maintained to keep the material in suspension and flowing. To some extent these velocities are dictated by, or at least related to, the material-to-air ratio. For example, conveying sawdust at a rate of 1800 lbs./hr. through a 6" pipe with a material loading ratio of 1:2 will result in an air velocity of 4073 FPM.

1800 lbs./hr. material = 30 lbs./min.

60 lbs./min. air ÷ .075 lbs./ft.^{3} std. density = 800 CFM.

6" pipe = .1964 ft.^{2} area inside.

800 CFM ÷ .1964 ft.^{2} = 4073 FPM.

Figure 4 provides conservative minimum conveying velocities to be used for some common materials. The velocity shown for sawdust is 4000 FPM. If the same 1800 lbs./hr. of sawdust had been introduced to a system with a 1:1 design ratio and there were no other changes to the system, the resulting velocity would only be half and the material would probably settle and clog. To compensate for the lower ratio, the pipe size could be reduced to 4", but this might introduce new problems in feeding the material to the pipe or transitioning to the fan. In this example, the 1:2 ratio would seem to be ideal.

Material Conveying
Duct Velocities

Material	Velocity in FPM	Material	Velocity in FPM
1. Wood Chips	4500	12. Cotton	4000
2. Rags	4500	13. Wool	4500
3. Ground Feed	5000	14. Jute	4500
4. Powdered Coal	4000	15. Hemp	4500
5. Sand	7500	16. Vegetable Pulp,	
6. Wood Flour	4000	Dry	4500
7. Sawdust	4000	17. Paper	5000
8. Hog Waste	4500	18. Flour	3500
9. Pulp Chips	4500	19. Salt	6000
10. Wood Blocks	5000	20. Grain	5000
11. Cement	6000	21. Coffee Beans	3500
		22. Sugar	6000

Figure 4

Sufficient velocities must be maintained throughout the conveying system to avoid material settling. All airborne materials, except the finest of dusts or fumes, can settle in a system or even in the fan itself. When settling occurs in the horizontal plane, it is known as *salt ation*. When settling occurs in the vertical plane, it is called *choking*.

Saltation is probably the most difficult to avoid because even the smallest ridge or duct seam can begin the process. Whenever possible, it is advantageous to employ the aid of gravity to minimize potential build-up by designing the piping or ductwork with a downward slope. This is particularly true with fine granular materials.

Choking in downward movement often occurs in the vertical line as a direct result of saltation in the adjacent horizontal line. Upward movement is often easier to control because all that is needed is sufficient momentum (velocity) to keep the material in suspension. All falling materials simply drop back into the airstream. However, choking in the upward flow directly above the fan discharge poses additional problems. If enough material is forced back into the fan where it recirculates, the fan will exhibit premature wear due to excessive loading.

To minimize the potential for saltation or choking, it is recommended that some provision be included in the system for bleeding in excess air through adjustable vents or dampers. See Figure 3. This excess air will effectively increase velocities in the system to assist material transportation. It is important to remember that the fan selection must account for the maximum potential excess air, and that handling more air then the minimum system requirements will result in increased power consumption.

FAN SELECTION

Just as designing around a velocity that is too low will impede the material conveying capability of the system, unnecessarily high velocities can also be detrimental. System resistance increases as the square of the increase in velocity. Therefore, additional energy is required to overcome that resistance. Also, the abrasive or erosive characteristics of the material being conveyed will increase with an increase in velocity, shortening the service life of all system components.

Only the air volume is considered in determining the velocity. The material volume is ignored to compensate for the periods of inconsistent material loading that occur during start-up and shut-down. However, the material content of the overall airstream mixture cannot be ignored when calculating system resistance or when sizing the fan.

Fans are constant volume machines that discharge a fixed volume of air at a fixed speed. If a fan is required to handle a given volume of air and a given volume of material, it should be sized to handle the combined volume. Using the previous example, 1800 lbs./hr. of sawdust at an average bulk density of 11 lbs./ft.^{3} results in 164 ft.^{3}/hr. or nearly 3 CFM. The fan should be selected to handle 803 CFM (800 + 3). In this example the 3 CFM is negligible. However, in situations where greater material volumes are being handled or when the bulk material density is much lighter, the volume cannot be ignored.

The effects of the material on system resistance must be considered. Since most materials usually exhibit a lower coefficient of friction than air, a simple density correction based on the combined weight and volume of the air/material mixture would result in an unnecessarily high correction. No dependable methods of determining the flow resistance of air/material mixtures have been proven, so only reasonable estimates are available. Some researchers have theorized that the bulk material content merely acts to reduce the effective area of the pipe or duct and so ignore the density effect by calculating air resistance through the resulting smaller pipe diameter. The best method for determining the resistance of the air/material mixture is through pilot-plant testing or experimentation. Figure 5 provides correction factors that can be used as reasonable starting points for estimating resistance.

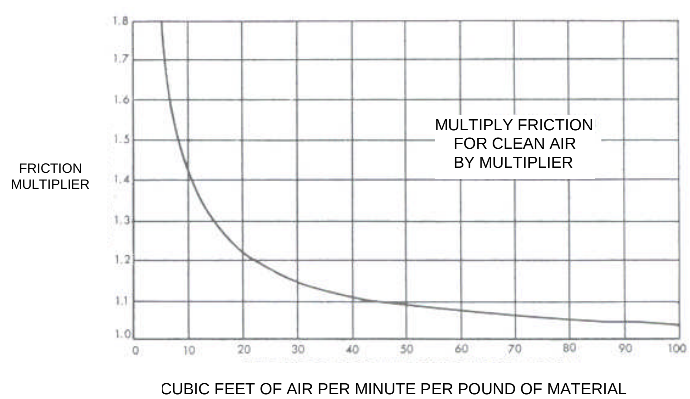

Figure 5 – Resistance Factors

Even though the air/material mixture does not follow the traditional laws of fluid flow as they apply to friction or resistance, it is suggested that the fan brake horsepower (BHP) will increase according to the bulk density of the mixture. The combined weight and total volume can be used to determine the maximum airstream density for selecting a motor that will handle the fan BHP at the bulk density.

Where,

> 1800 lbs./hr. material + 3600 lbs./hr. air =
> 5400 lbs./hr.
> 5400 ÷ 60 = 90 lbs./min.
> 90 ÷ 803 CFM = .112 lbs./ft.^{3} bulk density

To determine the approximate BHP for this example, multiply the rated BHP at standard density of .075 lbs./ft.^{3} by 1.5.

> (.112 ÷ .075) = 1.5

It is sometimes thought that a larger fan is naturally better than a smaller one. This is far from correct since material is just as liable to settle in a fan as in a duct. If the inlet and outlet velocities of a fan are at least as high as the minimum conveying velocity, no settling should occur in the fan. This is true for both dust collection and conveying.

AIR-FILM CONVEYING

This method of pneumatic conveying uses a film or cushion of air to move items such as cans, boxes, or plastic containers through a plant. Used primarily in the packaging industry, air film conveying usually requires fan static pressures of no more than 8" WG. In most cases, the system utilizes several smaller fans as opposed to one large fan. Because the air is clean, various fan types can be used in these systems, including backwardly inclined and radial-bladed designs. Selection is based on pressure and flow, but configuration is equally important.

Either positive pressure or vacuum can be used to move the containers. In a pressurized system, air is directed through a drilled or slotted surface, where the air is discharged at a slight angle in the direction of flow. The greater the discharge angle, the higher the velocity from one station to the next. Vacuum elevators are used to raise or lower containers to different levels in the system by holding them to a moving, perforated belt. Vacuum transfer devises allow fallen or damaged product to drop out of the system, thereby reducing downtime and maintaining efficient high-speed processing. Both techniques may be employed in different portions of complex conveying systems.

The benefits of air film conveying over conventional mechanical conveying include:

- Increased process speed.
- Lower maintenance costs (fewer moving parts).
- Reduced energy consumption.
- Reduced noise and safety hazards.
- Reduced downtime from jamming.
- Gentler handling of the product.

Many companies in the packaging industry use a combination of air and mechanical conveying systems in their manufacturing processes.

CONCLUSION

Pneumatic conveying systems have limitations, and alternate manual or mechanical means cannot be ruled out. However, pneumatic conveying systems usually require less plant space, can be easily installed in the available or wasted space, can be easily automated, can usually be easily altered for future change, and usually carry a lower capital cost. Beyond these economic advantages, pneumatic conveying systems can also be useful in controlling or minimizing product loss, improving dust control, and thus improving overall plant conditions.