This month’s column addresses how I worked on solving a client’s pneumatic conveying system problem. To arrive at the solution, I used many of the principles and practices discussed in previous columns. The information here can also be applied to a range of pneumatic conveying applications.

**Presenting the problem**

The client, who operates a plastics converter plant, described the problem this way: “We have a pressure pneumatic conveying system operating in dilute phase that was originally designed to move 30,000 lb/h of plastic pellets to a day bin, from which we feed our extruders. The pellets have a bulk density of 35 lb/ft³. Now, because we’ve made some production improvements to our process equipment, we can actually feed 35,000 lb/h of the pellets to our process. However, our existing conveying system is having difficulty keeping up with the higher rate. We’ve been told we need a whole new conveying system, but can we just make changes to the current system to increase its capacity?”

**Analyzing the problem**

The first step in tackling this apparently simple problem is to review a pneumatic conveying system’s five basic components, as shown in Figure 1. Let’s take a look at each component and consider how the conveying system’s capacity problem will affect it.

**Material supply.** The only change to this part of the system is that the feed rate is changing from 30,000 to 35,000 lb/h. So let’s see how the system’s hardware — the material feeder, air mover, conveying line, and air-material receiver — reacts to this change.

**Material feeder.** The existing material feeder (line charger) is a rotary airlock with a speed of 11 rpm and a volume displacement of 1.8 cubic feet per revolution (ft³/rev) at 100 percent efficiency. Because the material is discharging into a pressure dilute-phase conveying system, the efficiency won’t actually be 100 percent. A safe efficiency value to use in our calculations is 75 percent.

If we consider the new 35,000-lb/h feedrate, we determine that 35,000 lb/h of material weighing 35 lb/ft³ results in a 16.66-ft³/m volumetric flowrate. By using a volumetric displacement of 1.35 ft³/rev (that is, 75 percent of 1.8), we can see that the rotary airlock feeder’s new speed needs to be ±12.5 rpm. Because this increase is a minimal change, we can accomplish it by simply making a sprocket change to the feeder’s drive.

The rotary airlock feeder’s dynamic air leakage (leakage through the rotor-to-housing clearances when the rotor is turning) will increase in direct proportion to the feeder’s increased speed, which results in 2.7 scfm more than the original dynamic leakage rate. Until we see how the higher feeder speed affects the conveying line pressure, we’ll assume for now that the feeder’s static air leakage (leakage through the clearances whether the rotor is turning or not) isn’t affected.

Because the next two system components — the air mover and conveying

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**Figure 1**

Pneumatic conveying system components
line — depend on each other, let’s consider them together:

**Air mover and conveying line.** The configuration of the conveying line in the existing conveying system is shown in Figure 2. The 6-inch-diameter conveying line has 270 feet of horizontal line and 130 feet of vertical line, for a total of 400 feet of line, and has five 90-degree bends. Before we make any calculations about what impact the system’s feedrate increase will have on this configuration, let’s review some of the basic principles we’ll need to make these calculations.

**Conveying capacity:** Conveying capacity in a pneumatic conveying system is inversely proportional to the conveying distance. So:

- If the conveying line length decreases, the conveying capacity will increase.
- If the conveying line length increases, the conveying pressure will decrease.

**Conveying pressure:** Conveying pressure in a pneumatic conveying system is always highest at the material feedpoint (pickup point) and lowest at the terminal (discharge) point at the air-material receiver, and it’s directly proportional to the conveying distance. So:

- If the conveying line length increases, the conveying pressure will increase.
- If the conveying line length decreases, the conveying pressure will decrease.

**Pressure-to-volume relationship:** The relationship of actual conveying pressure to actual air volume remains constant throughout the conveying system and follows the ideal gas law:

\[ P_1 V_1 / T_1 = P_2 V_2 / T_2 \]

where \( P \) is actual conveying pressure, \( V \) is actual air volume, and \( T \) is temperature.

Because temperature isn’t a factor in most dilute-phase conveying calculations, we can remove the variable \( T \). This gives the conveying system’s pressure-to-volume (PV) relationship:

- \( PV \) at the feedpoint = \( PV \) at any point in the conveying line = \( PV \) at the terminal point
- \( P \) at the feedpoint > \( P \) at any point in the conveying line > \( P \) at the terminal point
- \( V \) at the feedpoint < \( V \) at any point in the conveying line < \( V \) at the terminal point

**Making the calculations.** Now let’s calculate the conveying system’s total pressure drop (the decrease in pressure from the system’s start [the pickup point] to the system’s terminal point [the air-material receiver]) at the old feedrate of 30,000 lb/h. These calculations will be based on the equations and procedures covered in earlier columns, including March, July, and December 1992, March 1993, and March 1996 ("Solt answers your questions"). Basing our calculation on the system’s pickup velocity of around 3,500 fpm (July 1989), we find that the system’s existing blower requires an inlet air volume of 1,200 inlet cubic feet per minute (icfm) and will deliver it at a discharge pressure of 11 psig, which is the total system pressure drop. The blower’s performance curve for these values, as shown in Figure 3a, shows that this performance is close to the blower’s maximum rated performance. So we know that getting more air volume from this blower may not be possible.

The next step is to calculate the blower’s required performance at the increased feedrate, which is 1,300 icfm at a discharge pressure of 13 psig. The existing blower’s performance curve with the new feedrate requirement, as shown in Figure 3b, shows that, sure enough, this exceeds the blower’s recommended performance envelope.

**Getting more volume and more pressure.** We see now that the conveying system needs both more volume and more pressure. However, the typical options for achieving this — increasing the blower speed or using a larger blower motor — aren’t open to us because the existing blower operates too close to its maximum operating point. This problem could have been avoided during the conveying system’s design stage by selecting a blower that would provide the originally required volume and pressure at a much lower operating point — a problem previous columns have warned against (see the July 2005 and March 2006 columns).
While one option is to replace the existing blower package with a completely new blower package (including the blower, motor, intake filter, intake and discharge silencers, and flexible connectors), let’s consider whether modifying another system component — the conveying line — can produce a way to help us meet the new feedrate requirement.

If we shorten the existing conveying line by replacing the two 100-foot sections (Figure 2) with one 141-foot section, as shown in Figure 4, we find that we not only eliminate 59 feet of straight conveying line but one bend, as well. If we now recalculate the blower requirements for this conveying line configuration, we find we need only 1,200 icfm at a discharge pressure of 11 psig. Voila! We’re back to where we were with the original conveying line design and the lower feedrate. Since the pressure drop didn’t increase, the rotary airlock feeder’s static air leakage would be no more than the original level, as we predicted in the previous “Material feeder” section.

With the new conveying line configuration incorporating both the shortened line and the stepped line diameter, we calculate the blower requirements as 1,150 icfm at 10 psig — even lower than before.

Let’s take this investigation one step further and consider the effects of stepping (increasing) the diameter of the last 70 feet of conveying line from its nominal 6 inches to the next commercially available nominal diameter of 8 inches, as shown in Figures 5 and 6. The advantages of line stepping (January 1990) are not only to keep the conveying system’s overall conveying velocity profile under control, but to reduce the total system pressure drop. With the new conveying line configuration incorporating both the shortened line and the stepped line diameter (Figure 6), we calculate the blower requirements as 1,150 icfm at 10 psig — even lower than before.

To see how the blower requirements, including brake horsepower, have changed as a result of these capacity and conveying line changes, see Table I. The information in the table makes it easy to compare the effects of different changes by providing blower requirements for these options: the existing conveying system both at the original capacity (column A) and at the new capacity (column B), and the modified conveying system at the new

![Figure 3](image_url)
The table shows that we’ve found a solution that not only doesn’t require replacing the blower package, but requires less energy at 35,000 lb/h than the original system when it was running at the lower 30,000-lb/h capacity!

**Air-material receiver.** The existing conveying system ends in a typical air-material receiver at the day bin’s top. The receiver won’t be affected by the system’s higher capacity. The dust collector that vents the day bin won’t have to handle any more air volume than it does now either, so neither the air-material receiver nor the dust collector requires changes to continue to function with the modified conveying system.

**More about this solution and additional options**

If you’re facing a pneumatic conveying system problem similar to this one — determining how to increase an existing system’s capacity — you may want to consider not only the changes discussed in this column but other options, as well.

The reconfigured conveying system’s rotary airlock feeder can handle the new feedrate with a simple speed increase that requires only an inexpensive sprocket change, as we discussed here. Or, for more flexibility, you could replace the feeder’s drive with an inexpensive variable-speed drive.

The existing blower package could be modified to meet the new blower requirements, such as by increasing the blower speed to get more air volume or exchanging the motor for a larger size model (within the blower’s limits) to get more pressure. However, the blower would then have to run at...
speeds that could produce high noise levels, increased pressure drops through the blower silencers, and reduce bearing life. Increased discharge temperatures could also be a problem. Depending on the existing blower and the desired system changes, just changing the blower motor could also require changes to electrical cables, starters, motor control centers, and other components.

The system changes outlined in this case won’t apply to every conveying system that must handle a capacity increase. Instead, you need to follow the step-by-step approach described here for looking at each system component to determine just how it may have to be modified.

Finally, you shouldn’t jump to the conclusion that you need a “whole new system,” as this client was originally told. Instead, making a combination of component changes and replacements is usually the most cost-effective approach. Better yet, when you design and install a pneumatic conveying system, don’t base the system design solely on your current capital cost concerns. Instead, give your system some opportunities for growth by completely evaluating each system component to determine what advantages and cost savings you could receive later by making minimal changes to the project’s parameters now. —J. D. Hilbert

### Endnotes

1. Find topics, issue dates, and page numbers for previous “Pneumatic points to ponder...” columns in *Powder and Bulk Engineering*’s comprehensive article index at www.powderbulk.com and in the December 2007 issue.

2. Three volumes of “Pneumatic points to ponder...” reprints are available from *Powder and Bulk Engineering*: Volume 1, 1989 to 1993; Volume 2, 1994 to 1996; and Volume 3, 1997 to 1999. For more information, contact Cindy Fischer at 651-287-5607, fax 651-287-5650 (cfischer@cscpub.com). Or visit www.powderbulk.com to purchase and download individual columns.

3. Brake horsepower is the actual power required at the blower shaft, including all the loads imposed on the blower by the downstream process as well as by the blower itself. The brake horsepower is then corrected for the drive motor’s efficiency and the type of drive arrangement to come up with the necessary motor horsepower.

### Table I

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<tr>
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<th>Existing system</th>
<th>System modifications</th>
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<tr>
<td>Blower requirements</td>
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<tr>
<td>A</td>
<td>30,000 lb/h, 400 feet of 6-inch line</td>
<td>35,000 lb/h, 341 feet of 6-inch line</td>
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<tr>
<td>B</td>
<td>35,000 lb/h, 400 feet of 6-inch line</td>
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<tr>
<td>C</td>
<td>35,000 lb/h, 341 feet of 6-inch line</td>
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<td>D</td>
<td>35,000 lb/h, 400 feet of 6-inch line</td>
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<tr>
<td>E</td>
<td>35,000 lb/h, 341 feet of 6-inch line</td>
<td>35,000 lb/h, 400 feet of 6-inch line</td>
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- Inlet air volume and discharge pressure:
  - A: 1,200 icfm at 11 psig
  - B: 1,300 icfm at 13 psig
  - C: 1,200 icfm at 11 psig
  - D: 1,260 icfm at 12 psig
  - E: 1,150 icfm at 10 psig

- Brake horsepower:
  - A: 79
  - B: 102
  - C: 79
  - D: 92
  - E: 71

### For further reading

Find more information on pneumatic conveying system capacity and related topics in articles listed under “Pneumatic conveying” in *Powder and Bulk Engineering*’s comprehensive article index at www.powderbulk.com and in the December 2007 issue.

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