Problem-Free Air Conveying Systems I

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Clogged arteries

One of the most serious and frustrating problems in system operation is pipeline blockage. To rule out blockage, check the obvious features:

- Is the reception point clear?
- Are the diverter valves operating satisfactorily?
- Is the full conveying air supply available?
- Was the pipeline clear on start-up?

If the pipeline blocks during commissioning trials with the pneumatic conveying system, either there is a serious system design fault or some simple adjustment needs to be made.

If system design is suspect, it is most likely because the air mover was sized incorrectly. A minimum conveying air velocity must be maintained at the product pick-up point at the start of the conveying line. The velocity depends on the product being conveyed and, for products that can conveyed in dense phase, varies with the phase density at which the product is conveyed. Since air is compressible, it is important to account for air pressure at the product pick-up point when evaluating the free air requirements for the air mover specification.

Air velocity at the start of the conveying line is particularly important. If this velocity is too low, the pipeline is likely to block. For products conveyed in dilute phase, or suspension flow, a 12-15 m/sec minimum velocity is needed. If a pipeline becomes blocked and the conveying line inlet air velocity is too low, then an air mover with a higher volumetric flow rate will be required.

It is important not to over-rate any replacement -- the conveying line inlet air velocity need not exceed the minimum conveying air velocity value by more than about 20 percent.

Overfeeding vs. incorrect air mover specification

The pressure gradient in the conveying line depends primarily on the concentration of product in the pipeline. If too much product is fed into the conveying line, the pressure requirement will exceed available and the line will block.

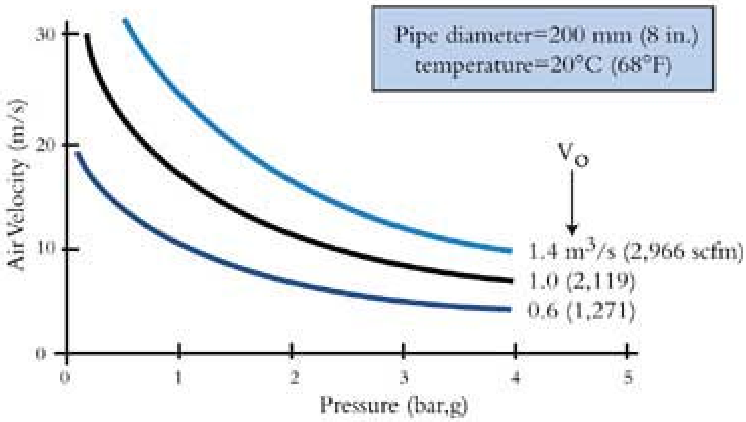
Each type of pipeline-feeding device has its own characteristic means of controlling product flow. In some cases, this is achieved by direct speed control, as with rotary valves and screws. With others, additional flow-control devices such as venturi feeders will be required. Control of blow tanks and suction nozzles is achieved by air supply proportioning.

Feed control is particularly important when a rotary valve feeds the pipeline, because a change of even one or two rev/min can have a significant effect on product flow rate.

It can be difficult to determine whether blockage results from an incorrect air-mover specification or over-feeding of the pipeline. For a positive-pressure system, this question can easily be answered by placing a pressure gauge in the air supply line at a point just before the product feed into the conveying line. In a negative-pressure system, the pressure gauge would be in the pipeline between the filtration unit and the inlet to the exhauster. Both cases will give a close approximation to the conveying line pressure drop.

If the reading on the pressure gauge is above the design value, the pipeline is being overfed, and the feed rate should be reduced. If the pressure is at the design value or below, then the volumetric air flow rate is insufficient. The gauge will be useful for monitoring system performance. However, air velocities also should be checked, since an increase in air supply pressure will lower the conveying line inlet air velocities, as shown in Fig. 1.

Figure 1. Pressure and Volume Influence Conveying Air Velocity



Maintaining the required air velocity for successful product transport requires additional volume to compensate for increased pressures.

Irregular feedrates

If the pipeline blocks only occasionally, this may be due to surges in product feed. In addition to determining the mean flow rate on startup, the regularity of the flow rate over short periods of time should be assessed. Differential pressure switches should be placed at all air movers and linked to the product feeder, to stop the feed in an over-pressure condition. This setup will give the system a chance to clear and can be arranged to bring the feed back online automatically. If a pipeline tends to block when the system is started up after a shutdown, some transient situation may be responsible.

Moisture and cold air

If product is blown into a cold pipeline, the inside surface could be wet as a result of condensation. This can occur in pipelines subject to large temperature variations, particularly where there are pipe runs outside buildings. If air drying is not normally necessary, the problem can be overcome by trace heating of exposed sections of the pipeline or by blowing the conveying air through the line to dry it out prior to introducing the product. Lagging may be sufficient in some cases.

In normal operation, the delivery temperature of air from a Roots-type blower could be 80 Degrees C higher than the inlet temperature. This means the volumetric flow rate and the conveying air velocity will be 25 to 30 percent greater than the value at ambient temperature. On startup, the air will be relatively cold for conveying the product and, if the resulting conveying air velocity is below that necessary for the product, the pipeline could block.

- Since air density increases with temperature decrease, it is essential that air requirements be based on the lowest temperatures likely. If this results in excessively high conveying air velocities during normal operation, then it will be necessary to control the air flow rate to the conveying line. Variable speed control of the air mover, choked flow nozzles in a by-pass air-supply line or discharge of air to atmosphere via a control valve could be considered.

Product in the line

If the pipeline is not purged during a plant shutdown, some product could be left in the line. On startup it's important to blow air through the pipeline before product is introduced. If the reference value of pressure drop for air blown through the pipeline is known, it can be compared with the air-purge value. If the actual pressure drop is significantly higher than the empty-line value, product may still be in the pipeline. It's also good practice to purge the line and check the pressure drop before shutdown.

Unexpected shutdown

If conveying stops unexpectedly due, for example, to a power-supply failure, it may not be possible to start the system again, particularly if there is a large vertical lift. If the bend at the bottom of the vertical section is taken out to remove the product, it may be possible to purge the line clear.

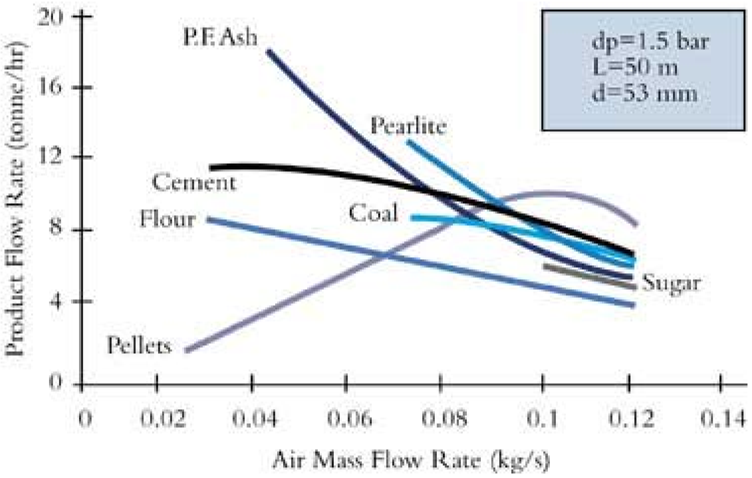
If this is a common occurrence for a plant, an air receiver can be installed between the air mover and product feeder. If the product feed into the pipeline stops at the instant the power fails, the air stored in the receiver could be sufficient to clear the line of product. Alternatively, a parallel line with valved connections to the pipeline could be fitted so that the line could be cleared slowly from the end, one section at a time.

When good systems go bad

If a system that has worked well for a long time starts to develop blockage tendencies, feeding device wear may be the cause. If air leakage across the feeding device increases, the air available for conveying the product decreases. The volumetric flow rate of remaining air may become insufficient to convey product and the pipeline will block. Worn screw flights, valve seats in gate lock valves, and rotary valve blades can all result in greater air leakage. Check these components regularly for wear and replace them when needed. Also check air movers against original manufacturers' specifications.

Keep in mind that a system that conveys one product well may be completely unable to convey another product. Minimum conveying air velocities differ from product to product, and air leakage across feeding devices is also product dependent. If a system has to convey more than one product, this requirement must be considered carefully at the design stage. Fig. 2 plots product flow rate against air flow rate for a range of products.

Figure 2. Product Influences Performance



The flow rates of various products in a 53-mm-diameter piping system, 50 m long with nine 90 elbows, show wide differences in required air mass flow rates.

Long distance charges

Remember that, for any given conveying line pressure drop, the conveying capacity of a pipeline decreases as distance increases. For a change in conveying distance, therefore, there must be a corresponding change of product feed rate into the pipeline.

For a given conveying line pressure drop, the product flow rate is approximately inversely proportional to conveying distance. For a given distance, the product flow rate is approximately proportional to line pressure drop.

If the conveying distance is increased, the product flow rate will have to decrease, so product will be conveyed at a lower phase density. For a product capable of being conveyed in dense phase in a conventional system, a slightly higher conveying line inlet air velocity will be required, in turn, demanding a higher air flow rate.

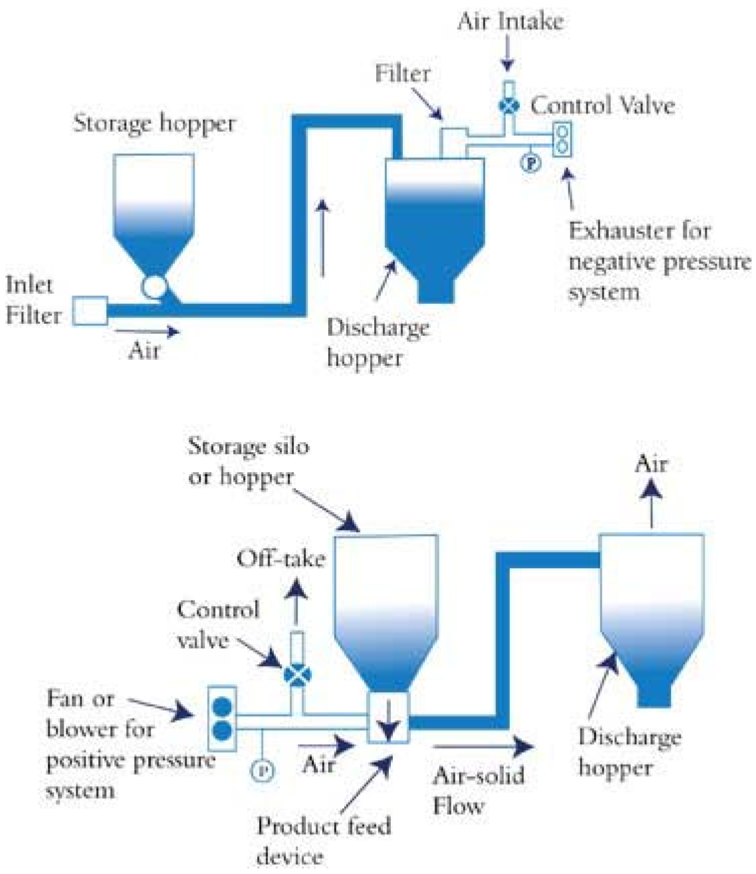
If the system cannot achieve its rated duty, determine whether the problem is due to product feeding, pipeline or air supply. Check on the conveying line pressure drop. If it is below the air mover's capability, product feed into the pipeline may be insufficient. If the maximum output of the feeder does not meet the conveying capability of the pipeline, however, it will probably be necessary to fit a larger feeder.

Before recommending a larger feeder, be sure that air leakage isn't the real culprit. Check rotary valves in particular, as well as air vents and clearances on all moving parts. Don't forget to check the filtration unit. If it has been incorrectly sized, pressure drop across the filter may be too high. Also check that the filter cloths don't need replacing or cleaning. It may be that an additional or a larger filter is needed. If these modifications don't bring the system to rated output, an air mover with a higher pressure rating or an increase in pipeline bore are indicated, but be sure to consider how this will influence other parts of the system.

Reducing air flow Rate

Improved performance can often be achieved by reducing the quantity of conveying air, particularly if the system is over-rated for volumetric air supply. This could be achieved with a tee and a valve in the conveying air pipework (Fig. 3). In a positive-pressure system, these would be positioned between the air mover and the product feed. In a negative-pressure system, they would be placed between the filtration unit and the air mover. The tee and valve would also allow you to monitor the impact of reduced air flow rate on system performance.

Figure 3. Well-Placed Tees



In a negative pressure system, place an intake between the filtration unit and the air mover to reduce draw through the system. In a positive pressure system, position an off-take between the air mover and the product feed to reduce air flow into the system.

Review routing

Review the pipeline routing and see if the number of bends might be reduced. Blind tees or sharp elbows should be exchanged for short-radius bends. For high-pressure systems with a single-bore pipeline, stepping the pipeline to a larger bore part way along, could also increase throughput.

Remember the potential role that equipment wear can play on system performance, particularly when abrasive feeds are involved, and also consider the fact that hygroscopic products can build up within pipe walls. Be proactive, and check on any changes in system performance to avoid problems later on.

Problem-Free Air Conveying Part II

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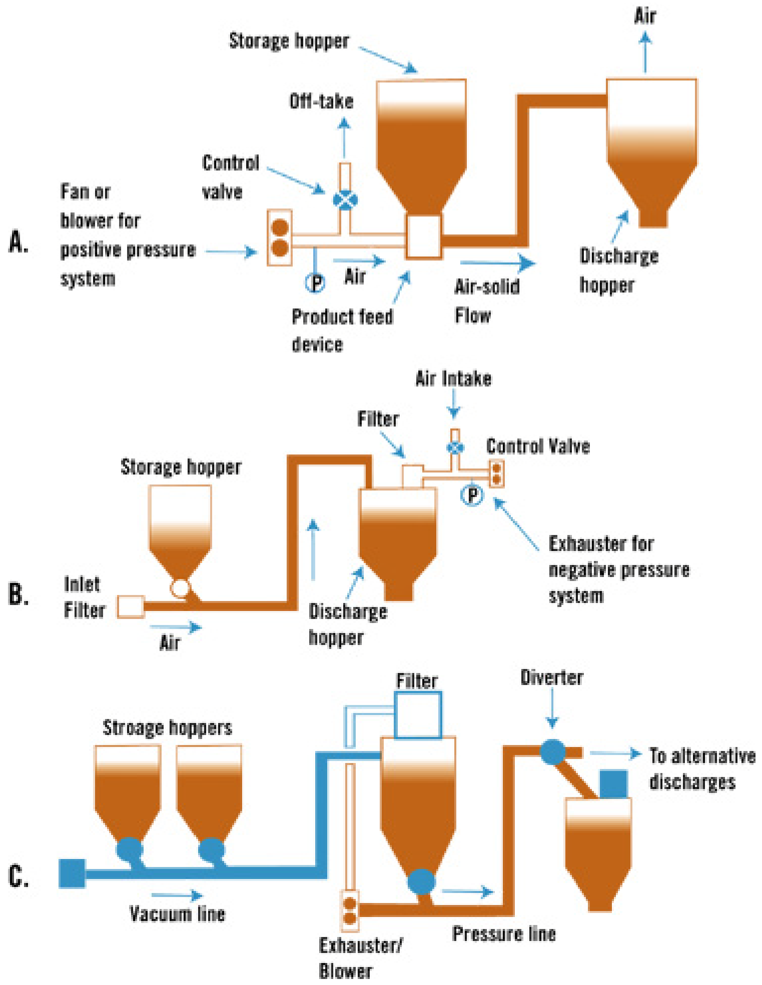
Positive pressure systems
The requirement for multipoint product feeding stations in many air conveying systems may define system selection. Figure 1 provides a schematic comparison of the three main options.

Figure 1. Choose Wisely



The choice of a positive pressure (A), vacuum (B) or combined (C) system will be defined by product feeding and/or discharge requirements.

Multipoint feeding of a positive pressure conveying system generally is not recommended. The air loss from a single feeder subject to leakage can be a significant proportion of that required for conveying the product. The loss from a number of feeders, if they are not isolated by additional valves, could be very high.

The air loss from a number of feeding points could be difficult to estimate accurately. So, the air available for conveying, which is a crucial requirement, could not be guaranteed. Apart from problems associated with having too little or too much air for conveying the product, the loss of a large quantity of air from a number of feeding points also would represent a very significant energy loss for the system.

Negative pressure systems
A common disturbance in "pull-through" systems is vacuum loss, particularly with batch and intermittently operating systems. The cause of the problem often is the failure of the discharge flap to seal at the base of the receiver vessel. Consider a secondary (policeman) filter prior to the exhauster (Roots-type) to safeguard lobes from worn or perforated primary filter elements, etc.

A vacuum conveying system is not the answer if multipoint discharging of product is needed, since such a system requires complex arrangement of pipework and isolating valves. These valves are sometimes found in low-pressure systems where ductwork is used. Valves in the ductwork, however, have to seal effectively, otherwise the air leakage into the system will adversely affect conveying.

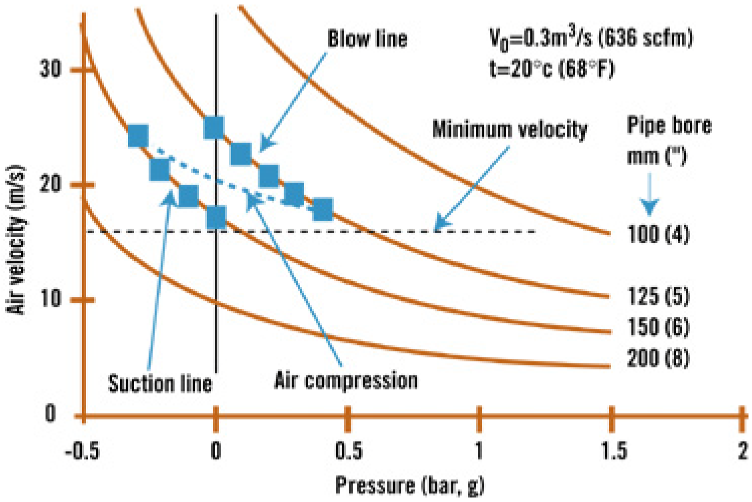
If air leaks into a negative pressure system, it will alter the balance of conveying air velocities along the length of the pipeline. If air ingress is not accounted for in the air mover spec, the line is likely to block. If the air mover is over-rated to allow for air leakage, product flow rate will be reduced. Air ingress is likely to occur along a pipeline at flexible sections such as those used in off-loading systems, particularly if the conveyed product is erosive and the joint is hard metal or ceramic material.

Combined systems
The available power for a combined system has to be shared between the two sections. If a Roots-type blower/ exhauster is used, the pressure capability on both the vacuum and blowing sides will be lower than what can be achieved with an equivalent machine used for single duty.

Operating pressures also will differ. With a Roots-type blower, for example, a pressure ratio of 2:1 is generally considered the upper operating limit. Thus for a positive pressure system the maximum delivery pressure is about 1 bar gauge. For a negative pressure system the maximum exhaust pressure is about -0.5 bar gauge. For a combined system, the limit on pressures is approximately 0.4 bar gauge on blowing and -0.3 bar gauge on vacuum.

Since the two parts of the combined system operate at different absolute pressures, the pipelines likely will be different diameters. Figure 2 illustrates this point.

Figure 2. Combined System Requires Two Pipe Sizes



Conveying air velocity as a function of air pressure, with lines of constant pipeline bore plotted, shows a typical negative-positive system superimposed for a free air flow rate of 0.3 m3/sec. Balance between the two parts of the system, in terms of conveying air velocities, is achieved with different pipeline bores.

Air also probably will leak across the feeding device on the positive pressure side, so the air flow rates will differ. An imbalance in product flow rates between the two halves of the system necessitates a full assessment of the operating pressures, pipeline bores and air flow rates.

System component problems
Many problems encountered relate to the various system components. The problems generally result from either incorrect specification, or a failure to take account of the conveyed product properties. Not all types of system components are discussed here. Most of the problems associated with screw feeders, for example, are common to rotary valves, so simple representative components are considered.

Blowers: The rotary lobes in blowers are machined to close tolerances. Any ingress of dust or product into the machine will have a serious effect on the performance of the blower. Downstream of the blower, or any other air mover, non-return valves should be included in the air supply lines to prevent the possibility of back-flushing of products.

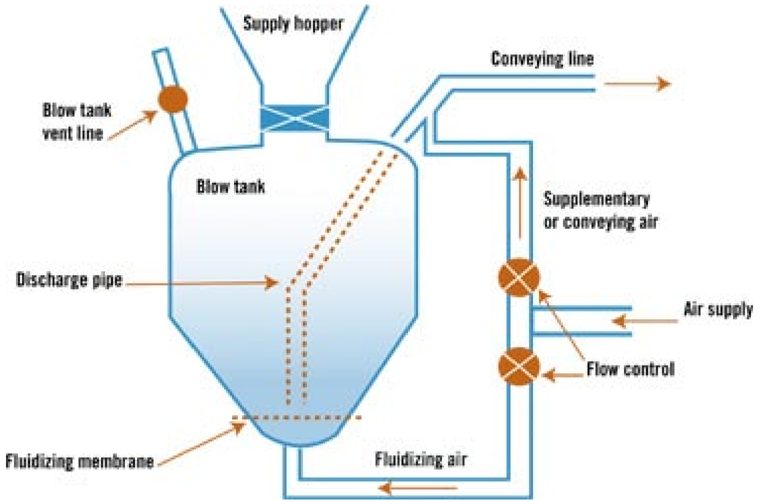
If a blower is operating in a dusty environment, a filter should be fitted to the air inlet. This filter should be cleaned or changed periodically. If it becomes choked with dust, the added resistance will affect blower performance. An outside air source is generally the answer.

In negative pressure and combined systems, blowers have to operate with air that has been used for conveying product. In these cases, the air must be effectively filtered. It might also be necessary to add a backup to the filter, to provide a measure of protection for the blower should the filter unit fail.

A change in conveying system performance over a period of time may indicate blower wear. A small diet of dusty air into a blower will cause a gradual change in its operating characteristics.

Blow tanks: Of all system components, blow tanks probably are least understood when it comes to operation and control (Figure 3). Single blow tank systems operate on a batch-wise mode and conveying is not continuous. Figure 4 depicts the transient nature of the flow.

Figure 3. Blow Tanks Batch It

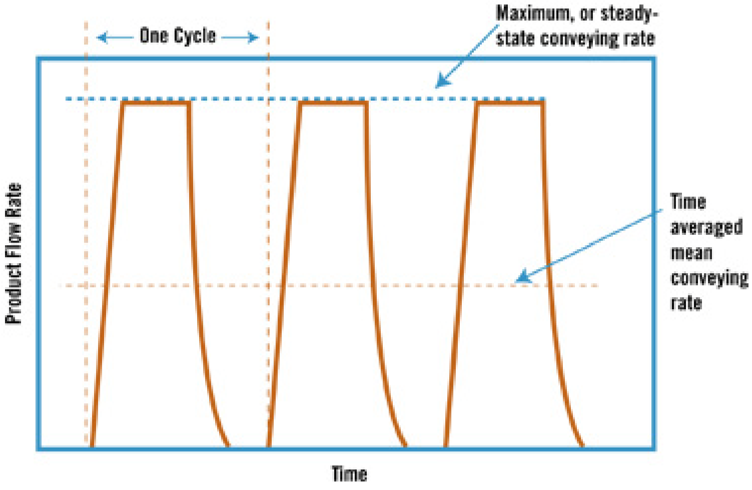


Single blow tank systems operate in a batch mode. Of all system components, blow tanks are probably least understood in terms of operation and control.

It is important to realize that to obtain a required time averaged mean value, the pipeline bore and air requirements must be based on the steady-state value achieved during the conveying cycle. If the desired product flow rate is not being achieved, consider means of increasing the ratio of the time-averaged mean to steady state values. Assess the times required for pressurizing, depressurizing and venting, valving and possible changes in operating procedures and conveying conditions.

Proportioning the air supply between the fluidizing and supplementary air lines controls the discharge rate of a blow tank. If insufficient product is being fed into a pipeline, the proportion of the total air supply that is directed to the blow tank should be increased. If too much product is being fed into a pipeline, this proportion should be reduced.

Figure 4. Blow, No Blow



For a given time-averaged mean value of product flow rate to be obtained from a blow tank, a very much higher value must be achieved during the steady-state portion of the cycle.

The discharge limit of the blow tank will be reached when all the air is directed to the tank. A further increase in product flow rate can be achieved by boosting the volumetric flow rate of the air, but this will have an adverse effect on the conveying of the product in the pipeline. The alternative is to increase the diameter of the blow-tank discharge pipe.

If a blow tank is to convey a product over a range of distances, the proportions of the air will change according to the distance conveyed. If this is not taken into account, the pipeline will be underutilized for shorter distances, and may block on longer distances. Here, a pressure gauge in the air supply line is particularly useful, for it can ensure the product flow rate through the pipeline is always the maximum that can be conveyed with the given air supply, regardless of conveying distance.

An automatic controller proportions the total air supply between the blow tank and the supplementary line. Control is usually based on pressure signals since, assuming that the blower or compressor operates within a prescribed range, any change in conveying rate, and hence phase density, will be reflected in a change of operating pressure.

If too much product is discharged into the conveying line, the pressure will increase and so the modulating valve will decrease the proportion of air passing to the blow tank to compensate. If the pressure drop across the conveying line is low, the modulating valve will reduce the supplementary air and so allow more air to pass to the blow tank and hence increase its discharge.

Air moisture is another concern. When air is compressed, its capacity for supporting water vapor decreases. Even relatively dry air will reach its saturation point and condensation will occur as the pressure is increased. Unless positive measures are taken to remove it, this moisture will be transported through the air supply lines with the conveying air. If a fluidizing membrane is used in a blow tank, this water will blind the membrane with certain products,"causing a gradual increase in pressure drop across the membrane and a resultant decrease in output of the system.

Most problems associated with moisture can be overcome by drying the air. If the product is hygroscopic, it will probably be necessary to incorporate a desiccant-type drier. If moisture and condensation are to be avoided, then a refrigerant drier should suffice.

Both the blinding of a fluidizing membrane and a restriction in the discharge pipe will add to the pressure drop across a blow tank. If the pressure drop across the product feeder increases, the pressure drop available for conveying the product in the pipeline will decrease and, so, cut conveying capacity.

Part of the blow tank pressure drop occurs in discharging the product from the blow tank. This is particularly a problem in top-discharge blow tanks requiring a long discharge line. The conveying air should be introduced as close to the tank as possible to minimize this pressure drop. In a tall blow tank it may be necessary to bring the discharge line out through the side to reduce its length.

The performance of a blow tank can be monitored quite easily by pressure gauges. A pressure gauge installed in the supplementary air supply line will effectively give a measure of the conveying-line pressure drop, and hence the use of the pipeline in conveying the product. A pressure gauge in the blow tank will then give an indication of the pressure drop across the blow-tank discharge line. If the blow tank has a fluidizing membrane, a pressure gauge in the air supply line to the blow tank will help monitor the state of the membrane.

With top-discharge blow tanks, there is also a minimum discharge limit, which relates to the fluidization air velocity in the discharge line.

If an attempt is made to convey a product at a low velocity from a top-discharge blow tank with only a small proportion of the air flow rate directed to the blow tank, the blow tank could "stall" and cease to discharge product into the conveying line. This is because the air velocity in the blow-tank discharge line will be very much lower than that at the product pick-up point. For a product having poor permeability and air retention properties, this could result in a blockage of the discharge pipe. If this occurs, use a smaller diameter discharge pipe.

Granular products can cause discharge problems from a top-discharge blow tank. Air permeates very easily through these products and it is possible that insufficient resistance will be built up to discharge the product. Bottom-discharge blow tanks are generally recommended for granular products.

Because of their high permeability, granular products require a higher proportion of air directed to the blow tank for a given rate of discharge than that needed for powders.

Granular products with a high percentage of fines are very much less permeable. They generally are not suitable for dense phase conveying in conventional systems. They will require very little air for their discharge from a blow tank, and so if the discharge line is unnecessarily long or has a long horizontal section, the discharge line is likely to block.

Rotary valves: Rotary valves come in a wide range of sizes and types, and probably are the most commonly used devices for feeding pipelines in low-pressure systems. The mechanism of feeding, however, gives rise to a number of problems, and in positive pressure systems allowance must be made for air leakage.

It is essential to feed a conveying line at the correct rate. If the feed rate is too low, the pipeline will be under-used; if too high, the pipeline could block. Varying the rotational speed of the rotor can provide flow control. There is an upper limit for any given size of valve, however, for the pocket filling efficiency will decrease with increase in speed.

If a variable-speed drive is used, the flow rate will be infinitely variable, as it is with a blow tank, up to its maximum capability with a product. If some form of gearing is provided, only step changes will be possible. Many rotary valves are dedicated to a single product and duty, with no speed control incorporated.

Conveying over a different distance requires a corresponding change in feed rate. If a different product is to be conveyed, it is quite likely that both the pipeline and rotary valve characteristics for the product will be different.

Granular products tend to shear in a normal drop-through rotary valve. The product might prompt considerable vibration, which could shorten the life of the rotary valve and the drive motor. Cohesive products can cause a problem with the proper discharge of product from the rotor pockets. In this case, a blow-through-type rotary valve would be recommended.

Air leakage across a rotary valve primarily depends upon the rotor-tip clearance and the pressure drop across the valve. Leakage also varies with the product being fed. A cohesive product, for example, will help to seal the various clearances and reduce leaks.

Air leaking across a rotary valve means less air is available to convey the product. In specifying the air requirements for the air mover, leakage must be considered. This leakage represents a total loss of energy from the system.

The air leaking across the valve may interfere with the feeding of product into the rotary valve. In this case, venting might solve the problem. A certain amount of product could be carried over with the vented air, so the vent line must be kept clear. Air leakage will also increase in tandem with valve size. A larger-than-necessary valve probably will generate unnecessarily high air leakage as a result.

Rotary valves are not generally recommended for handling abrasive products. Apart from abrasive wear of the sliding surfaces, erosive wear will be severe due to the very high velocities of air leaking through the valve. Wear will increase rotor-tip clearances and boost air leakage. This, in turn, causes air loss in the conveying line that could ultimately result in pipeline blockage.

Filters: Most problems with filters generally result from incorrect specification of either the air flow rate or the expected particle-size distribution. Filter cloths and screens will rapidly block if they have to cope with unexpectedly high flow rates of fine, degradated powder. The net result usually is an increase in pressure drop across the filter, meaning a reduction in the pressure drop available to convey the product.

Be aware that the sample of product you supply to a filter manufacturer for selection and sizing could differ significantly from that to be handled by the plant filter. If it is a friable material and the conveying air velocity is high, the product at the end of the conveying line could be very different.

Cloth filters will gradually block with fine product that cannot be shaken free, and performance will be less effective. Filter bags, therefore, require periodic replacement.

Operators can monitor performance of the filters to a certain extent by noting the empty-line pressure-drop values. A pressure gauge in the air supply or extraction lines enables checking of the empty line pressure drop. This pressure drop represents the combined resistances of the pipeline and filtration unit. If the pipeline is purged of product, any changes in pressure drop can generally be attributed to the filter. An increase in this pressure drop would indicate that filter cleaning is not effective and should be checked.

Alternatively, an additional pressure gauge could be positioned in the receiving hopper. A positive pressure system exhausting to atmosphere will give a direct reading of the pressure drop across the filtration unit. It also will let operators record an on-load assessment of the pressure drop on a regular basis. In a negative pressure system, the difference in pressure between the gauge in the receiving hopper and the gauge in the air extraction line will have to be taken.

With reverse-air-jet filters, ensure that the air supply for the filter bag is correctly connected and of adequate capacity, and the cleaning cycle timer is set and operating correctly.

The surface area of filter cloth required is largely based on the volumetric air flow to be handled. The ratio of flow rate to area provides an approximate face velocity. However, if the filter is in a negative pressure system, the volumetric flow rate will be significantly higher, necessitating a much greater cloth area to maintain the same face velocity as an equivalent positive pressure system exhausting to atmospheric pressure.

A check on the empty line and filter-unit pressure drop is important during commissioning and before any product is conveyed to baseline the pressure drop across the filter against the design specification.

In batch conveying cycles, air flow rate per unit time is not uniform. At the end of a cycle, when the blow tank is just empty, a large volume of air is stored under pressure in the blow tank and pipeline. Venting this air, together with the compressor output for conveying, generates a significantly higher filter duty. Take this high air flow rate into account in the specification of the filter. Isolating the blow tank from the conveying line when it is empty, and venting it separately can reduce this surge.

Problem-Free Air Conveying Part III

Consider the possible effects of ambient conditions on operations and the potential impact of the system on product characteristics

Part I of this series discussed general problems such as pipeline blockage and how they might occur in most types of conventional pneumatic conveying systems. Part II focused on troubleshooting specific kinds of systems and their key components. This final part delves into other potential difficulties and how to get the necessary data to properly address them.

Pneumatic conveying systems can suffer from a variety of systems-related problems besides the throughput ones that we have discussed previously. Environmental factors, such as temperature variation, can cause operating troubles, as can erosion and other conditions that affect the physical state of the system. In addition, any number of product-related problems may arise. This final part of the series looks at such issues, as well as the parameters and measurements essential for successful troubleshooting.

Many of these problems are caused directly by the product being conveyed. They are considered here, however, because such problems may not initially be recognized in terms of the product itself.

The plant environment

Several factors related to ambient conditions can produce problems.

Altitude. The operation of a pneumatic conveying system at altitude should present no problems at all, provided that due account has been taken of the local air pressure and, hence, density of the air. This will influence the specification of the air mover [1], because the volumetric flow rate is generally quoted in terms of free air. It also will affect the size of the filter required, as discussed previously [2].

Temperature variations. Plants subject to extremes of temperature, from summer to winter, and even from day to night, may face problems due to changes in conveying air velocity as well as condensation. Air density increases as temperature decreases. For instance, a conveying air velocity of 15 m/s at 40 Degrees C becomes about 12 m/s at -20 Degrees C for the same free-air flow rate. Condensation may occur in pipelines subject to large temperature variations, particularly when there are pipe runs outside of buildings and air drying is not employed. More details are provided in the first installment.

Electrostatics. Pneumatic conveying systems are known to be prolific generators of static electricity. In a large number of cases, the amount of charge generated is too small to have any noticeable effect. Sometimes, however, appreciable generation can occur. Very often, this is just a nuisance but, occasionally, it can present a hazard. Grounding the pipeline and ensuring that electrical continuity is maintained across all flanged joints can reduce the problem. In addition, the humidity of the conveying air can be adjusted to control static build-up. The use of humidity for charge control is not suitable, of course, if the product being conveyed is hygroscopic.

Erosion effects

If the hardness of the particles being conveyed exceeds that of system components like feeders and pipeline bends, erosive wear will occur at all surfaces against which the particles impact.

The conveying air velocity is a major factor in erosion. Lowering the velocity at which the product is conveyed will help to reduce the problem. Because the conveying air velocity increases along the length of a pipeline, the bends at the end of the pipeline are likely to fail first. Enlarging the bore over the last part of the pipeline could reduce erosion here.

Various solutions are possible for bend erosion. One method is to reinforce the bend with a channel backing. This will solve the problem with respect to the outer bend wall surface. However, the deflection of the product out of the wear pocket formed could result in failure of the inside surface of the bend, or of the straight length of pipeline following the bend. So, you must exercise care in applying this technique.

The use of a very hard surface material such as Ni-hard cast iron, basalt or a ceramic will help to prolong the bend life. These materials are generally brittle, however; so, short radius bends should be avoided. Blank tees can provide a cheap and effective solution to the problem, but may cause an increase in pressure drop.

Erosion of straight lengths of pipeline rarely is a problem. Should such erosion occur, however, possible causes are misaligned flanges and welded joints, and proximity to valves and bends, as mentioned above.

Even products with hardness value less than that of mild steel can pose problems. Indeed, relatively soft products such as coal, barites and wood chips can cause severe erosive wear, as a result of naturally occurring contaminants such as silica.

Impact angle effects. Figure 1 illustrates the influence of the impact angle of particles against surfaces and the response of different surface materials to erosive wear. It shows that ductile materials such as mild steel and aluminum suffer maximum wear at an impact angle of about 25 Degrees but offer a reasonable degree of resistance at normal impact. In contrast, brittle materials such as glass, basalt, concrete and cast iron suffer maximum wear under normal impact yet offer a reasonable degree of resistance to low angle impact.

Variation of Erosion with Impact Angle

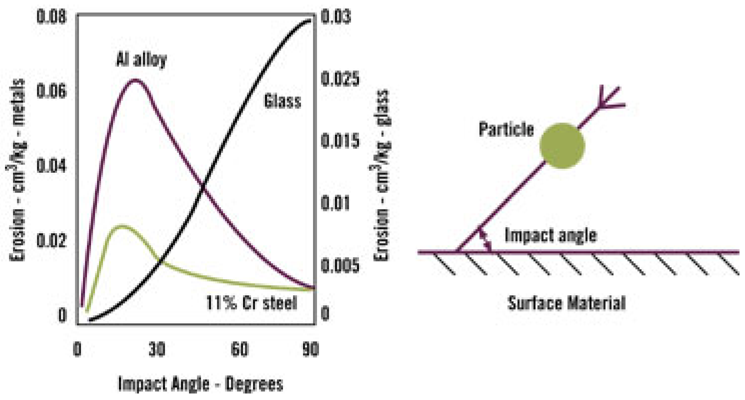


Figure 1. Ductile materials such as aluminum suffer most severe wear at impact angles of about 25 Degrees , but reasonably withstand normal impact; brittle materials like glass offer the opposite performance.

This explains why misaligned flanges and poorly welded joints can cause such problems. Any situation in which turbulence or deflecting flows can occur could cause low angle impact and, hence, rapid failure of a ductile material. It also points up why brittle materials should not be used for short radius bends. The impact angle of particles against a short radius bend will be very high, generally resulting in rapid failure of a brittle material.

Explosions

There is a wide range of materials, which, in a finely divided state dispersed in air, will propagate a flame through the suspension if ignited. These materials include many chemicals, plastics, foodstuffs, metal powders and fuels such as coal and wood. Research has shown that the particle size must be below about 200 for a hazard to exist.

It is virtually impossible to avoid dust cloud formations in pneumatic conveying. Even when the product being conveyed consists of particles larger than that threshold, you must consider the possibility of the production of fines during conveying. Such fines may result in an explosion hazard being created in the receiving vessel.

Two sources of ignition frequently encountered in industrial plant are a hot surface and a spark. For example, rotary valve bearings, if not properly protected and maintained, could overheat and thus provide the necessary source of ignition. There is always the possibility of spark generation by metal-to-metal contact; therefore, all valves and feeding devices with moving parts should be checked. Sparks are often associated with electrostatic generation, as discussed above.

In truly dense phase systems, the concentration of the product in the air is well above the upper explosive limit and so explosions are unlikely. Solids concentrations in cyclones, filters or receiving hoppers, however, could be in the explosion risk range. Also during startup and shutdown, dilute phase conditions are likely to exist in the conveying line.

Explosions can either be prevented by reducing the percentage of oxygen in the conveying air to an acceptable level, or they can be contained. Detection and suppression equipment can be employed or relief venting can be used with appropriate safety measures.

Product-related problems

In the previous section, we discussed some problems that directly result from the product being conveyed but that have an impact on the system. This section covers problems the system can cause in the product being conveyed. These include:

Angel hairs. The formation of angel hairs is a problem that can occur with plastic pellets such as nylon, polyethylene and polyesters. The presence of angel hairs is undesirable because they can cause blockages at line diverters and in filters. The problem can be overcome to a large extent by pipeline treatment. Conveying air velocity is a major variable; decreasing the velocity at which the product is conveyed will help to reduce the problem.

Cohesive products. Such materials may experience problems in hopper discharge. If difficulties are encountered in achieving flow rates with a system and the conveying line pressure drop is below the expected value, the problem could well relate to the discharge of the product from the hopper rather than the capability of the feeding device. In this case, the use of a suitable bin-discharge aid should be considered. In the case of rotary valves, a blow-through type should be used if there is any difficulty in discharging a cohesive product.

Granular products. If a granular product has to be conveyed, difficulties may arise in discharging the product into the conveying line. Rotary valves and blow tanks may cause problems here, as discussed previously [2].

Hygroscopic products. A hygroscopic product may absorb moisture from the air used to convey it. Although the specific humidity of air will decrease if it is compressed isothermally beyond the saturation point, its relative humidity will increase and is likely to be 100 percent after compression. The added moisture will not only affect product quality but could cause subsequent handling problems. The problem can be overcome by drying the air used for conveying the product.

Large particles. Such particles can be conveyed quite successfully in pneumatic conveying systems. It is generally recommended that the diameter of the pipeline should be about three times greater than that of the particles. This is simply an expedient measure to ensure that the pipeline will not block by the wedging action of two rigid particles. There are exceptions to this rule, of course. For instance, with very pliable products such as fish, it is possible to convey "particles" that actually are larger than the pipeline bore. With rigid particles, a problem may arise if a mean particle value is used in sizing and particles have an irregular shape. (Care must be exercised in feeding in all cases).

Particle degradation. Pneumatic conveying can cause the fracture and breakage of friable materials. Even if the presence of fines in a product is not a problem with respect to product quality, the fines produced will add unnecessarily to the duty of the filtration unit. The problem is influenced to a large extent by conveying air velocity. Any possible reduction in the velocity at which the product is conveyed will help to decrease the problem.

Product quality. If a conveying system is dedicated to a single product and has been optimized to the lowest specific energy, a change in product quality can cause operating difficulties. Handling a product of a slightly different shape or size could be sufficient to cause the pipeline to be blocked.

Temperature. High temperature products can be conveyed quite successfully and conveying gas at any temperature can be used. Compatibility with system components is the determining factor. Conveying air velocities also have to be guaranteed if there are significant temperature changes.

The evaluation of gas and product temperatures presents the difficulty. At the feeding point, for example, cold air may be used to convey a high temperature product. Along the conveying line, there will be a move towards thermal equilibrium between the air and product, as well as heat transfer from the pipeline to the surroundings. Since conveying times are very short, it is unlikely that equilibrium will be established. It is quite possible, therefore, for the surface of the particles to be "cold" and the inner core to be "hot." Because of this, it is often possible to use filter cloths in these high temperature situations. By the same reasoning, the product in the reception hopper could be very hot once equilibrium has been established there.

The maintenance of conveying air velocities is particularly important in these situations, but their evaluation can be difficult. Particle temperature transients represent a complex three-dimensional heat-transfer conduction problem and should only be attempted by an expert. However, since air density increases as temperature decreases, the maintenance of air velocities is only likely to be a problem when a very high temperature gas is used to convey a cold product. In this case, the temperature gradient effect could override the pressure gradient influence on air density.

Wet products. Fine products that are wet will tend to coat the pipeline and gradually block the line. If the product is not too wet, heating the conveying air can relieve the problem. Difficulty may be experienced in discharging a wet product from a hopper.

The conveying characteristic

As in many plant situations, troubleshooting would be relatively straightforward if you know what information is required, and can obtain high quality data.

The three major variables that specify the operating point of a pneumatic conveying system are: solids mass-flow rate; gas mass-flow rate; and pressure gradient (pressure drop per unit length).

One way of presenting these variables is to plot solids mass-flow rate against the mass flow rate of gas, as shown in Figure 2. This graphical form is referred to as the conveying characteristic or performance map. A conveying characteristic applies to a particular bulk material and a particular pipeline.

A Typical Conveying Characteristic

Figure 2. This performance map for cryolite plots the three major pipeline variables: solids mass-flow rate, gas mass-flow rate and pressure drop per unit length.

In this representation, the third variable, conveying-line pressure drop, is presented as a set of curves. Each curve represents a line of constant conveying-line pressure drop. The shape of these curves varies and depends on the conveying capability of the particular material. A comparison of different conveying characteristics shows that the shape of the curves is governed by the mode of conveying, which itself is determined by the physical properties of the material being conveyed.

The extent of the performance envelope for a conveying characteristic is bounded by four limits:

1. The lower limit due to the air-only pressure drop for the pipeline;

2. The right-hand limit, which is governed by the volumetric capacity of the air mover; (Using a larger capacity machine would increase this limit but rarely offers an advantage, because this simply limits the rate at which material can be conveyed.)

3. The upper limit can be due to either the pressure rating of the air mover or the maximum rating of the solids feed device (which is the case here); and

4. The limit to the left-hand side of the characteristic is normally the most important as it marks the boundary between flow and no flow. For a system to operate without possibility of a blockage, the operating point must be to the right of this boundary.

Some materials possess physical characteristics that prohibit conveying in non-suspension modes of flow in conventional pipelines. In such cases, the limit of the pressure drop curves to the left-hand side of the graph corresponds to a minimum velocity. In this case, the material remains predominantly in suspension. Typically, this minimum velocity would be about 15-18 m/s (3,000-3,600 ft/min). These systems are often referred to as dilute phase systems.

The conveying air velocity is a critical parameter. The velocity at the point where material is fed into the pipeline is particularly important. If the velocity is too low, pipeline blockage may occur. If the velocity is too high, the rate at which material can be conveyed will be restricted and problems such as particle attrition and erosion may result. It, therefore, is essential to know the conveying air velocity in order to assess the performance of a system and the potential for optimization and uprating.

On-line measurement

To determine the system operating point on the conveying characteristic graph, you must have data on the air flow rate, the material flow rate, and the conveying line pressure drop. In addition, depending on the application, measurements of temperature may be required.

However, most pneumatic conveying systems include very little diagnostic instrumentation. In many cases, a simple pressure gauge mounted on the air supply line is all that is available.

Material mass-flow rate is certainly the most difficult measurement. Generally, only an average conveying rate can be obtained. An estimate of the air flow rate can be found if performance curves for the air mover are available. In some cases, these estimates can provide enough information to identify a particular problem. In other cases, estimates can be so inaccurate that at best they are unhelpful and at worst are actually misleading.

These difficulties, however, can be overcome by taking a series of relatively simple measurements that provide high quality data.

Pressure transducers. The choice of the transducer depends on the operational range, whether gauge, absolute or differential pressure measurement is required. Accuracies of +/-0.25 percent are readily achievable.

For a sensor mounted inside a pneumatic conveying system, a distinction has to be made as to whether it will be used in the single-phase or two-phase section of the system. If there is the possibility of solid particles being in the pipeline, the gauge should be protected either by the choice of location or by the use of baffles or protection plugs. Another method is to use a wire in the port, the principle being that the mainstream flow will vibrate the wire and thus dislodge any clogging in the port.

Temperature measurement. Standard RTD and thermocouple sensors can be used. These provide an accuracy of 1 Degrees C. which is generally acceptable.

Gas flow. In pneumatic conveying systems, the product flow rate depends on the mass flow rate of gas into the system. Many techniques are currently used for measuring gas flow.

Differential pressure meters, which generally employ orifice plates, now are the most widely used and accepted method of measuring air flow. An overall system with density measurement can provide accuracies of between 2 and 5 percent. There is always a permanent pressure loss associated with these devices.

Vortex shedding meters offer a lower pressure drop and accuracies of about 1.5 percent and turndown ratio of 40:1. These meters have no moving parts and have a low pressure drop. However, they are very sensitive to swirl and to flow pulsations.

Thermal meters measure mass flow rate directly and can provide accuracies of 1 to 2 percent of full scale. They have a wide working range, with turndown ratios of around 50:1. Pressure drop is relatively low compared to differential pressure devices. Thermal meters, however, are sensitive to flow profile, and are relatively costly.

Proper handling of the data generated is crucial. Recent advances in portable data-acquisition hardware and associated software, along with the advent of smart sensors, mean that it is feasible to install a measurement system capable of recording a time history of plant operating conditions that can significantly enhance troubleshooting.

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