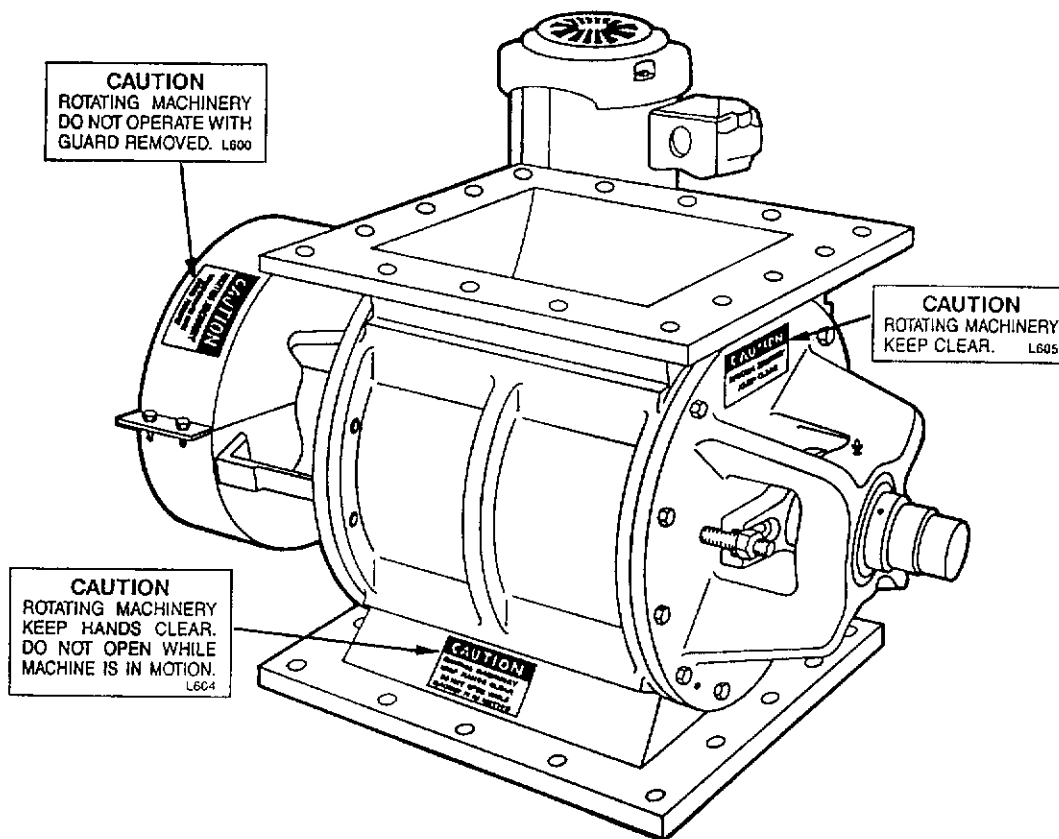


DESIGNING VENTING SYSTEMS FOR BETTER ROTARY VALVE PERFORMANCE



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DESIGNING VENTING SYSTEMS FOR BETTER ROTARY VALVE PERFORMANCE

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Introduction

In the author's experience, inadequate venting of rotary valves is one of the most common yet least understood of problems occurring with pneumatic conveying systems. The incidence of conveying problems caused or contributed to by inadequate rotary valve venting is greatest in positive pressure conveying systems. However, venting problems can also occur when handling certain materials when no pressure differential exists across the rotary valve.

This paper explains why venting of rotary valves is necessary, how to recognize venting inadequacies, and what must be done to obtain a trouble-free venting system for rotary valves.

Why is venting necessary?

Rotary valves are feeding devices that are commonly employed for feeding granular solids between fluid atmospheres that must remain more or less isolated from each other. The reasons for the use of rotary valves are basic; rotary valves are simple, rugged, durable, relatively inexpensive and require only simple controls for effective operation. The price we pay for these desirable characteristics of rotary valves is less-than-perfect isolation of the fluid atmospheres separated by the rotary valve. In a word, leakage.

Leakage of gas into the source of the bulk solids being fed by a rotary valve can cause significant impairment of the feeding efficiency of the valve, especially when the material is readily fluidizable. The flow of leaking gas, when it is counter to the flow of the solids, can greatly reduce the material's bulk density or even suspend the solids at the rotary valve's inlet, causing reduced solids feed rate, intermittent feed or even a no-feed condition.

By correctly designing a venting system to capture and redirect valve leakage flow away from the material being fed, the resulting feed rate can be at or near the rotary valve's theoretical capacity based on displacement and shaft speed.

Why do rotary valves leak?

Rotary valves have two characteristics that contribute to the passage of fluid medium from one side of the valve to the other. These characteristics are (1) necessary clearance or gap between the rotor and the valve housing and (2) the fact that a rotary valve is a fixed-displacement rather than a positive-displacement device.

Clearance leakage is a function of valve size, pressure difference across the valve, the amount of clearance present and the design of the rotor. Clearance in rotary valves is necessary for reliable operation and is, for the most part, unavoidable, though many design attempts have been made to eliminate or minimize clearance to reduce leakage. Manufacturers are challenged with selecting a rotor/housing clearance small enough to limit leakage but still large enough to prevent contact between the rotor and housing in all foreseeable modes of operation. When specifying clearance, the manufacturer's design engineer must consider unequal thermal expansion of the rotor and housing, rotor deflection under differential pressure, internal clearance and runout in rotor support bearings, and housing deflection under load. Manufacturing capabilities and economies must also be considered.

Rotor design has an influence on clearance leakage, as the arrangement and number of the rotor vanes has a labyrinth seal effect that affects leakage flow. For example, clearances, pressure, size and number of rotor vanes being equal, open-ended rotors often give less leakage compared to closed-end (shrouded) rotors. This is attributed to the labyrinth seal effect of the vanes against the ends of the housing compared to the single leakage barrier (the shroud rim) at each end of a shrouded rotor.

Rotor displacement also contributes to total leakage flow. As noted before, the rotary valve is not a positive-displacement device. Solid particles entering an empty pocket of the rotor must displace an equal volume of gas. If a pocket of the rotor, when it is emptying, is exposed to pressure, this pressure remains sealed within the rotor pocket until the pocket reaches the valve

inlet. At that point, excess gas is released until the pocket pressure equals the gas pressure present at the bottom of the solids feed hopper. The total amount of rotor displacement leakage is determined by pressure differential across the valve, rotor pocket volume, product feed rate and valve shaft speed.

Total leakage through the rotary valve is the sum of the clearance leakage plus product displacement and pocket gas expansion per unit time.

Can leakage flow be predicted?

Leakage through valve clearances can be predicted using a common formula for flow through circular or infinite rectangular orifices. This formula, while intended for subsonic flow, yields good leakage estimates for design of venting even if the absolute pressure ratio across the rotary valve exceeds the critical.

This formula is:

$$Q = K A (\Delta P)^{0.5} \quad (\text{Ref. 1})$$

where Q = SCFM leakage flow, K = a lumped coefficient (see Tables 1a and 1b), A = orifice area in in² and ΔP = pressure difference across the rotary valve in pounds per square inch.

Table 1a FLOW FORMULA COEFFICIENT, VACUUM CASE
(HIGH PRESSURE SIDE OF VALVE AT 14.7 PSIA)

ΔP psig	TEMPERATURE OF HIGHER PRESSURE GAS				
	50F	100F	150F	200F	250F
-8	69.03	65.87	63.12	60.68	58.50
-6	72.30	69.00	66.11	63.55	61.28
-4	75.57	72.12	69.10	66.43	64.05
-2	78.84	75.24	72.09	69.31	66.82

Table 1b FLOW FORMULA COEFFICIENT, PRESSURE CASE
(LOW PRESSURE SIDE OF VALVE AT 14.7 PSIA)

PRESSURE psig	TEMPERATURE OF HIGHER PRESSURE GAS				
	50F	100F	150F	200F	250F
2	84.45	80.59	77.22	74.24	71.58
4	86.81	82.85	79.38	76.31	73.58
6	89.17	85.10	81.53	78.39	75.58
8	91.51	87.33	83.67	80.44	77.56
10	93.82	89.54	85.79	82.47	79.52
12	96.10	91.71	87.87	84.48	81.45
14	98.35	93.85	89.92	86.45	83.35
16	100.56	95.96	91.94	88.39	85.22

The value used for A is usually taken as the plan view perimeter length 2 x (W + D) of the valve rotor in inches multiplied by the nominal rotor/housing clearance, also in inches. This formula illustrates the importance of maintaining close internal clearances, as the clearance leakage is a linear function of clearance. Thus an increase of only 0.001 inches average clearance in a

valve having an original clearance of 0.005 inches will result in a 20% increase in clearance leakage flow rate.

Solids displacement leakage is simple to calculate, being the pounds per minute feed rate divided by the solid (not bulk) density of the material in the feed hopper.

Prediction of pocket gas expansion leakage requires knowing the working volume of the rotor and its speed, as well as the gas pressure on both sides of the rotary valve. The net excess volume of gas picked up by the empty pocket on the high pressure side of the valve and released on the low pressure side is calculated using the ideal gas law. Assuming constant temperature for the process, the formula for this leakage is:

$$Q_{\text{excess}} = \text{RPM} (V_2 - V_1) \quad \text{where}$$

$$V_2 = P_1 V_1 / P_2$$

where P₁ is the higher absolute pressure in PSIA, P₂ is the lower absolute pressure in PSIA, V₁ is the rotor displacement per revolution in cubic feet, V₂ is the total volume of the expanded gas in the rotor in cubic feet, (V₂ - V₁) is the net volume of gas expanding outside the rotor per revolution and Q_{excess} is the calculated leakage flow from this source in ACFM at P₂.

How to determine if venting is needed

Manufacturers of rotary valves and of pneumatic conveying systems using rotary valves occasionally encounter complaints that a valve or system is not delivering capacity. When the installation is inspected, it is often noted that capacity is uniformly low or that (particularly when the valve is feeding a positive pressure pneumatic conveying system) the valve appears to feed well for a short time, feeds poorly for a while, then feeds well again in a continuing cycle. This is a prime symptom of either inadequate rotary valve venting system design or of a worn rotary valve.

For new installations, assume venting is necessary at any rotary valve feeding a column of material into positive pressure, especially if the material to be fed through the valve is a powder. Venting is less often needed if the rotary valve is operating as an airlock with no head of material over the valve, although the valve may need to be oversized to compensate for reduced material bulk density.

When evaluating the need for venting in an existing installation, it is wise to investigate and eliminate other possible reasons for the observed performance. Did the valve or system always operate this way or did performance deteriorate over time? Did the nature of the material being metered by the valve change? If the performance deteriorated with passing time, the problem may be a result of wear in the rotary valve rather

than inadequate venting. If the material itself has changed from a pellet or granule to a more powder-like form, the reduced permeability of the material mass and its tendency to fluidize may be at fault. Another possible reason for poor performance of a rotary valve may be the flowability of the granular product itself in the feed hopper. Arching or ratholing in the feed hopper above the rotary valve may be the result of a poorly-designed hopper rather than a rotary valve venting problem.

Do not assume that pressure must be below the rotary valve to make venting necessary, particularly when handling very fine powders. A need for venting has been observed when handling certain powders at zero pressure differential across the rotary valve. Excess ventable gas in this case was attributable to solids displacement entering the rotor coupled with handling of a fine, light powder with low gas permeability. See Case Study #6 at the end of this paper.

Types of rotary valve vent

There are two physical ways a rotary valve may be vented. In selecting which is to be used, one must know if the valve is already existing (or if the manufacturer can economically modify the valve) and how much head room is available above the valve. The types of vent are (1) a separate vent hopper or spool piece installed above the rotary valve as in Fig. 1a or (2) a built-in vent nozzle in the side of the rotary valve's cylindrical housing as in Fig. 1b. Vents in side entry type rotary valves fall into the former category, even though the vent is usually built into the valve housing.

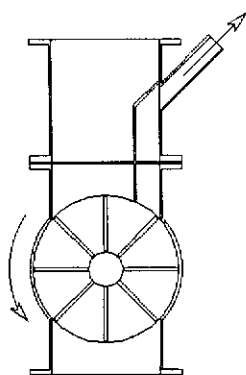


Fig. 1a
Vent Spool

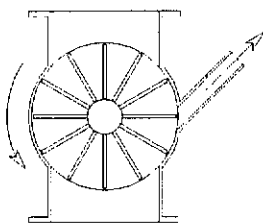


Fig. 1b
Vented Housing

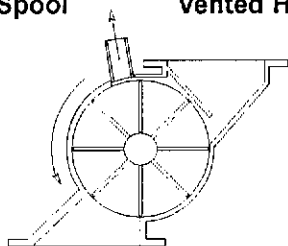


Fig. 1c Side Entry Valve with Vent

Some rotary valve manufacturers will supply, on application, a vent nozzle built into the side of the rotary valve housing. This is best incorporated at the time the valve is initially manufactured, as the addition of a vent opening to a finished valve housing can distort the precision-machined cylindrical housing and make it unusable. A built-in vent has the advantage of requiring less head room than a vent spool. Because the vent is machined into the housing adjacent to the "clean", or upward-moving side of the rotor, there is a reduced chance for the solids being metered by the valve to enter the venting system and cause problems. The built-in vent does have the disadvantage of improving only the pressurized gas expansion portion of the total leakage plus half or less of the clearance leakage (depending whether closed or open type rotor). When using a built-in vent in the housing as shown by Fig. 1b, it is often necessary to increase the quantity of rotor vanes to maintain adequate sealing between the valve's inlet, outlet and vent port. Clearance leakage at the ends of shrouded (closed-end) rotors and of the downward-moving side of all rotor types is unaffected by a housing vent.

The vent spool or hopper, as shown by Fig 1a, is usually the most effective way to vent standard drop-through type rotary valves. The dividing panel of the vent hopper must extend down into the valve's inlet to within 1/16 to 1/8 inch clearance with the rotor. Some valve suppliers make this dividing panel a part of the valve inlet with a close clearance with the rotor tips, but it is doubtful if there is a measurable advantage to having an extremely close clearance between the divider and the rotor unless the divider is made wide enough to prevent flow of fluidized solids backward through the rotor pocket from the solids feed channel to the vent chamber. In practice, when handling powdery or fine granular materials the vent air chamber of the vent hopper fills with fluidized material that may also fill the vent pipe up some distance. More on this later.

Types of venting systems

For the purpose of discussion, let's divide venting systems into two categories; active and passive.

Active systems are those using a vacuum or vacuum/pressure pneumatic conveying to carry away vented air and entrained solids to a suitable disposal point. Active systems can serve a purpose when installation of a passive vent system is impractical. Remember that there is a cost for providing energy to an active venting system, whether to power a vacuum blower, a centrifugal fan or a venturi ejector. The concept of using an ejector to pump rotary valve leakage back into a pressure conveying system is appealing, but may be extremely expensive if plant compressed air is used to power the ejector. Even a low pressure centrifugal blower will eventually cost much more to operate than its purchase price, considering the combined

costs of energy, installation, maintenance and control.

Something else to consider when applying an active type venting system is whether the venting system is open to the material passing through the rotary valve. If the material being metered is a fluidizable powder, an active type vent system should only be used if the vent at the rotary valve is a built-in type vent in the valve casing. Use of an active vent system with a fluidizable material and a vent spool can easily result in a vent system either completely plugged or at best conveying away several thousand pounds per hour of fluidized product. As with many things in this world, simpler is better, and the selection of an active venting system should be carefully evaluated both technically and economically by someone with knowledge and experience designing pneumatic conveying systems as well as rotary valve venting systems.

Passive venting systems are usually preferred because of their simplicity and their negligible ongoing cost of operation if designed and installed correctly. There are two ways a passive vent system can be designed - high velocity and low velocity.

A high velocity passive vent uses a small vent pipeline and employs the leakage flow to pneumatically convey any particles mixed with the leakage gas back to the top of the material source silo or to a dust collector. There are incentives for using a high velocity passive vent. Installation cost is reduced because smaller pipe costs less and installs more easily. Also, since the velocity is sufficient to convey the incidental dust in the vent pipe, the routing of the vent pipe is not quite as critical as it is for a large diameter low velocity passive vent.

While successful high velocity passive vent systems exist, more operating problems have been experienced with non-functioning high velocity passive vent systems than with low velocity vent systems. One problem with high velocity passive vent systems is that the velocity of the gas in the vent system pipe is not constant but varies with the pressure at the rotary valve. When the pressure at the valve is high, there may be adequate gas flow in the vent system to convey particles. When pressure and thus leakage are low, however, particles in the vent system settle and eventually plug the pipe.

The small pipe diameter and the tendency of high velocity vent lines to be installed with horizontal sections of pipe make a plug more likely to form and less likely to be cleared when high pressure at the rotary valve is reestablished. Because of the tendency to plug, high velocity vent systems should only be used with rotary valves vented from the housing, and never for valves equipped with a vent hopper unless the material being fed by the rotary valve is so coarse that it cannot

be entrained into the vent system. High velocity passive vent systems, if used at all, should be kept as short as possible with few bends and using bends of smooth radius. Since the objective of a venting system is to provide an alternate flow path for leakage gas, the pressure drop of the vent system must be minimized.

A low velocity passive vent uses larger diameter vent duct and does not attempt to convey vented particles. A low velocity passive vent pipe must be installed as near vertical as possible with absolutely no horizontal sections where material can settle and form a plug. At the top of the feed source bin where the vent enters the bin roof, an inverted-vee 180° bend must be used instead of a radiused bend. See Fig. 2. The larger pipe and its couplings cost more initially and are thus more difficult to install than the high velocity vent pipe.

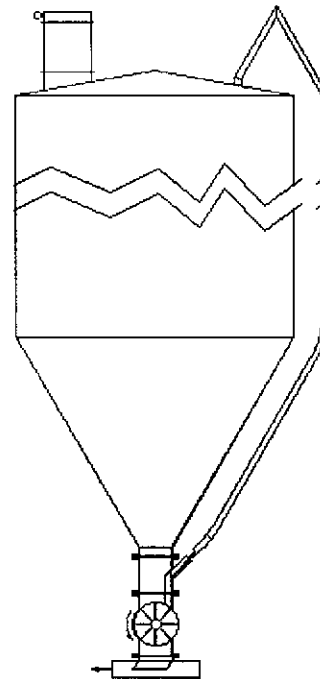


Fig. 2 Passive Vent System

Low velocity passive vent systems for rotary valves are suitable for most types of bulk solid materials, including powders. Several design rules must be observed for a successful low velocity vent system:

- The vent system pipe must be installed as close to vertical as possible, no less than 60 degrees angle above horizontal and with steeper slope if possible. There must be no horizontal section of vent pipe, including the elbow where the pipe turns to reenter the material source hopper.

- The vent system piping must be sized properly in relation to the anticipated amount of leakage. As discussed previously, this is a function of rotary valve size, clear-

ance and the pressure difference across the rotary valve.

-For difficult materials, particularly if the rotary valve is feeding into a positive pressure dilute phase pneumatic conveying system, install an automatic shutoff valve between the material supply hopper and the rotary valve. By closing the shutoff valve and allowing the rotary valve and the conveying system to clear, the reduced conveying back pressure will cause a corresponding reduction in vent system flow and will allow some or all of the material in the vent line to settle and be discharged through the rotary valve.

-If the material is a powder or fine granule, always pipe the venting system so its discharge point is well above the highest level of material expected in the material source hopper or silo. If the material being handled by the rotary valve can be fluidized, it will fill the vent line at least to the same level as the material in the source hopper. If the vent system terminates below this point, it can act as a dense phase conveying system and transfer a significant amount of material from the source hopper to the end point of the venting system. This is a good reason to terminate the vent system into the same hopper or silo the material is being fed from by the rotary valve. See Case Study #3.

- The vessel where the vent system terminates must be vented and equipped with a pressure relief device to prevent pressure buildup. This is necessary to maintain flow in the vent system as well as for safety.

One additional warning is necessary regarding low velocity passive venting. This type of venting is not generally the best choice for rotary valves vented through the housing sidewall. The reason is the dust falling back down the vent pipe may not easily reenter the valve housing at the vent port unless the port is made specifically to allow material reentry.

Sizing of low-velocity passive vent systems can be recommended by the manufacturer of the rotary valve. The vent size is based on expected valve leakage and on a rule-of-thumb velocity allowance for the vent pipe. A value that has been used for most bulk materials is 350 feet per minute, or slightly more.

Always remember that a passive vent system attempts to redirect flow of leakage gas away from the outlet of the material source hopper. It accomplishes this by providing a path of less resistance for gas flow than up through the material in the source hopper. Flow into the source hopper is never really eliminated totally, but is reduced to a sufficiently small proportion of the total leakage flow that the bulk material enters the rotary valve without sufficient aeration or suspension to significantly reduce capacity. Because the gas flow resistance of the mass of material in the source hopper is related to the depth of the stored material and to its de-

gree of aeration, the behavior of the rotary valve feeder may not be consistent. That is, if the source hopper is freshly loaded with aerated material, the permeability of the material mass will be much lower than for settled material, and feeding problems may occur. Likewise, when the hopper is nearly empty, the resistance of the material to gas flow is reduced and more of the leakage will enter the hopper, possibly causing feeding capacity problems.

If a vent pipe is too small or too long for the amount of leakage, gas velocity and pressure drop will be high and the proportion of gas entering the source hopper will be high. This is what happens to a vent system that worked satisfactorily when the rotary valve was new but quit working when the rotary valve became worn. If the vent pipe becomes dented or bent, or if something becomes lodged in it, the same symptoms as a too-small vent system will become apparent.

It is not uncommon for a vent system to work well the first time it is used when newly installed or after a cleaning, but then fail to work soon afterward. This is caused by the settling of material in the vent pipe into a solid, impermeable plug. On first operation, the material is well aerated and permeable to air flow. This occurs most often in high velocity passive vents, particularly those that are not installed correctly (horizontal portions), but it can happen in correctly-installed low velocity vents that are not allowed to empty out when conveying is halted. Sometimes a momentary injection of compressed air into the vent pipe when conveying is started will be sufficient to re-aerate the material, but such measures are not universally successful, add complexity and should be avoided by following proper design and operating procedures.

Venting systems will act as particle classifiers, with the lightest fraction of the material being aspirated into the vent pipe. Consequently, the material in the vent system may not resemble the material routinely passed through the rotary valve. This is often noted when handling plastic pellets. Fines from the pellets such as dust, whiskers and "snake skins" from conveying operations can separate and form masses resembling birds' nests in the venting system. Such obstructions can be avoided when conveying plastic pellets by using fines separation equipment.

Sometimes rotary valve leakage is excessive but because of a good vent system does not make itself evident. In such cases, the first evidence of excessive leakage consists of a gradual conveying capacity loss and finally in plugging of the pneumatic conveying system. This is found in both positive pressure and negative pressure conveying systems. As leakage increases, the conveying gas velocity decreases until it is unable to convey the desired rate. When handling abrasive materials, always incorporate the checking of rotary valve

condition into the plant's periodic maintenance program.

Vent Socks

A commonly-seen method of venting rotary valves is to simply clamp a fabric bag or filter sock to the rotary valve's or vent spool's vented air outlet connection. In most applications the bag will quickly fill with material and become ineffective. This will occur even if the material is a relatively clean plastic pellet. If a vent sock seems to be an expedient solution for a particular venting problem, support the sock adequately, be sure it will empty itself out (or have it emptied frequently) and protect it from the weather.

Reducing Leakage at the Source

For handling materials shown to have exhibited problems caused by rotary valve leakage or for situations where a better degree of gas isolation is needed, valves are available which incorporate leakage-reducing features. End-seal type valves can reduce overall clearance leakage by 50%. Using rotors with more numerous vanes can reduce circumferential leakage by reducing the pressure drop across each vane tip. For constant-temperature applications, so-called "zero clearance" valves are available that use non-galling, self-lubricating rotor materials to make reduced rotor/housing gap practical.

Case studies

The following case studies are just a few of the interesting and challenging situations observed by the author. A few are fairly typical, others illustrate how sometimes expedient solutions to vent system problems can result in odd occurrences.

Case Study #1 "Now it does - Now it doesn't"

The problem - A manufacturer of plastic resin wanted to convey the relatively coarse resin powder a short distance from a storage silo to a truck filling operation. A 14 inch rotary valve was selected to feed the powder. No vent system was used. Capacity when the system was started up was less than half the design rate and powder flow to the truck was intermittent.

The diagnosis - This is a classic example of inadequate venting. When the rotary valve is first started, the conveying system is empty and the pressure differential across the rotary valve is low. Consequently, leakage is low and for a short time the material feeds reasonably well from the storage silo. As the conveying system becomes loaded, however, the pressure across the valve - and leakage - increase, the material aerates or suspends and material feed slows or stops. When the conveying system empties out, pressure falls, feed begins again and the cycle repeats.

The solution - A low velocity passive vent system was designed and installed. Because the valve was not

equipped from the factory with a housing vent, a vent spool was used. The vent system was terminated at the top of the feed silo. The silo was equipped with a bin vent filter, so emission of dust and the chance of pressurizing the silo was avoided. With the vent system installed, the system delivered design capacity at a constant rate.

Case Study #2 "It worked at first, why not now?"

The problem - A user of plastic powder installed a small-diameter, high velocity passive vent system on a housing-vented rotary valve under a storage silo. The valve fed a positive pressure conveying system. Capacity was poor.

The diagnosis - Inspection of the vent system revealed that it was an afterthought which was installed with a long and convoluted path to avoid structural obstacles around the silo. Two 20 foot long horizontal sections of vent pipe were found, as well as water pipe elbows and shallowly-sloped pipe sections. The vent pipe was well plugged from beginning to end. Initial success was experienced because the plastic powder was well aerated when the system was first operated. When the system was stopped, the powder settled and packed in the small pipeline and venting no longer was possible.

The solution - Because of the structural obstructions, it was not possible to install a low-velocity vent system with a good routing. In this special case, a powered vent system was recommended, along with incorporation of an air inlet tee at the rotary valve to ensure adequate conveying velocity and to enable the system to clear itself of dust when the rotary valve and pressure conveying system were stopped.

Case Study #3 "No wonder it filled up!"

The problem - A manufacturer of a very fine chemical powder installed a rotary valve, vent spool and small diameter high velocity vent system under a storage silo. The vent pipe was not routed back to the top of the silo, but to a grade level dust collector. The collected powder was then conveyed back to the source silo by a separate positive pressure pneumatic conveying system. The dust filter regularly filled with the powder, requiring a vacuum cleaning truck to get it back into operation.

The diagnosis - Because of its fineness, the powder being fed by the rotary valve was readily fluidized. The powder was being conveyed through the vent system in a dense stream to the dust filter whenever the conveying system under the rotary valve was operated. Measurement of the material flow rate in the 2 inch vent system was about 5000 pounds per hour, which exceeded the capacity of the conveying system under the dust filter.

The solution - A recommendation was made to use a large diameter passive vent system piped directly to the top of the silo, as there were no significant structural

obstructions.

Case Study #4 "This one works. That one doesn't"

The problem - A user of pebble lime containing 1% abrasive sandstone particles had two identical silos with side-entry rotary valves and well-designed low-velocity passive vent systems feeding a common positive pressure dilute phase conveying system. One of the silos was used as a day-to-day operating source of lime while the other silo was kept as an emergency standby. After a year of continuous operation, the performance of the conveying system began to fall off noticeably when feeding from the operating silo. When the standby silo was used, the performance of the conveying system was within specification.

The diagnosis - Since the operating silo and rotary valve had handled many more tons of material than the standby silo and valve, erosion was suspected in the operating valve's interior. This was verified by removing a section of vent pipe at each valve, closing the gate valves between each rotary valve and its silo, pressurizing the conveying system under both valves and comparing the clearance leakage of both valves using a Pitot tube. There was much more leakage from the valve which had more hours of operation. Though the vent system was working satisfactorily, the loss of conveying air through the rotary valve was causing the conveying problems.

The solution - Rebuild or replace the rotary valve on the operating silo and make the checking of leakage rate a periodic maintenance item.

Case Study #5 "But it has a vent system already!"

The problem - A manufacturer of plastic pellets experienced feed rate problems with pellets being metered by a side entry type rotary valve into a positive pressure conveying system.

The diagnosis - The rotary valve was connected to an active type vent system using a centrifugal blower to scavenge conveying gas and rotary valve vent gas com-

ing from several sources. Theoretical analysis of the relatively complex venting system indicated that the header into which the side entry valve's vent was connected was pressurized. This was confirmed when the vent pipe was disconnected and flow in the vent was toward the rotary valve instead of away from it. The air flow into the pellet feed hopper was actually greater than if the valve had been unvented.

The solution - A fabric sock was tried on the rotary valve's vent, which resulted in satisfactory feed from the rotary valve, but the sock quickly filled with pellet fines. The permanent solution was to replace the centrifugal blower on the active vent system with another having increased pressure output.

Case Study #6 "It shouldn't need a vent."

The problem - A company processing a very fine powder installed a rotary vane feeder valve to meter the powder into a vacuum dilute phase conveying system. The feed rate through the rotary valve was significantly less than anticipated. Some symptoms of inadequate venting were present, but were discounted because of the zero differential pressure (across the rotary valve) application.

The diagnosis - Rotary valve leakage flow is the combination of clearance leakage, expansion of pressurized gas from empty rotor pockets and gas displaced from empty pockets by incoming solid material. Since there was no pressure differential in this case, the source of excess gas interfering with product feed had to be solely from product displacement. This happened because the material being fed was a fine powder, with much poorer gas permeability than materials made up of larger particles.

The solution - This situation was solved by putting rotor clearance and pocket expansion leakage to a positive use. A slight restriction was added to the conveying system in the clean air channel ahead of the rotary feeder and material inlet manifold. By experiment during system operation, the clean air channel restriction was increased until the downward leakage balanced the material displacement leakage, and reliable feed was established.

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- 1) T.G. Beckwith and N.L. Buck, *Mechanical Measurements*, Reading, Mass., Addison-Wesley Publishing Co., 1969