Guide to Handling Airlock Leakage in Pneumatic Conveying Systems

Jonathan Thorn, M.S.
MAC Equipment, Inc.
7901 NW 107th Terrace
Kansas City, MO 64153, USA

Abstract

Pneumatic conveying systems utilize pressure differential created by a gas source to drive the transfer of material. Rotary airlock valves are the most common piece of equipment used to feed the material into or out of the air stream. The rotary airlock however, is not a perfect sealing device and there is an inherent leak of the convey medium proportional to the pressure differential across the airlock. The leakage volume can create a number of process issues if not dealt with properly. Airlock leakage has been known to limit flow of material into airlocks, create major housekeeping or environmental issues and pressurize upstream equipment. There is no single equipment arrangement that will properly vent all applications. Rather the best solution is a function of the available equipment, material characteristics, and proper pipe selection. The intent of this paper is to analyze six industry methods for handling leakage, where each can fail a user and the applications that best suit the individual method.

KEYWORDS: Pneumatic Conveying, Airlock, Leakage, Venting

I. Introduction

The use of rotary airlock valves (airlocks) in pneumatic conveying systems is accompanied by the leakage of convey gas medium through the airlock when differential pressure is created. In pressure conveying systems, the airlock resides toward the beginning of the system and vents the leakage air to the upstream process. This phenomena can cause a number of process issues if not handled properly. The issues include disruption of upstream processes, release to atmosphere (housekeeping and health issues) and limiting of the material flow to the airlock. An otherwise satisfactory design of a pressure pneumatic convey system can suffer operationally due to improper implementation.

Six different methods of handling leakage from rotary airlocks will be addressed with attention given to the material being handled, how the material is delivered to the convey system and what other equipment or processes are available for aiding this exploit. These methods apply to both pressure dilute phase and continuous dense phase convey systems, however pressure dilute phase will be the primary focus. Material types will be distinguished by powders (fine, fluidizable, <150 micron), granules (poor fluidization, 150-800 micron) and pellets (non fluidizable, >800 micron). The resulting analysis will place a general material type with a type of process and designate one or more acceptable methods for handling airlock leakage given that scenario.

II. Direct Connect to Storage

Description:
The airlock is attached directly to the storage of material and acts both as an airlock and a metering device to the convey line. The leakage air is released directly to the storage of material, passes through the head material and exhausts from the top of the storage bin. The storage bin often has a filter that can exhaust the relatively small volume of gas.

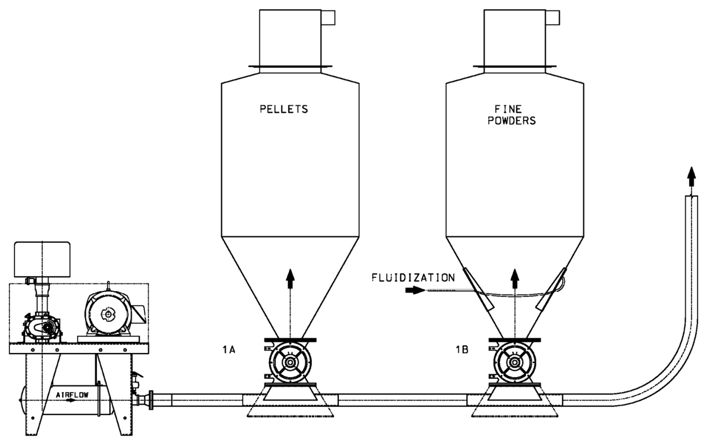

Figure 1. Direct connect of airlock to storage device

Advantages:
This is the simplest method for dealing with airlock leakage and requires the least amount of equipment and headroom to implement. Pellets are often very porous and the leakage air can easily pass through the material to reach the exhaustion point (Figure 1A). Powders, when in a fluidized state, also exhibit porous tendencies. Assuming fluidization air is provided to maintain this state, leakage air will mix with the fluidization air and pass easily through the material to the exhaust point (Figure 1B).

Potential Risks:
Granular products and powders in an unfluidized state conversely have a very low porosity and the leakage air cannot easily pass through the material. The static head of product causes a pressurized "bubble" of gas to form above the airlock which can significantly impede the flow of product into the airlock; even to the point of stopping flow altogether. The result is significantly reduced fill efficiency on the airlock and reduction of transfer rate. A similar fate is experienced with convey systems designed to operate at elevated convey pressures. The higher differential pressure across the airlock results in a higher volume of leakage. For lighter bulk density products (of all types), the upwards velocity of the leakage air through the throat of the airlock can restrict the flow of product and result in a reduced fill efficiency. The system often finds an equilibrium where the restricted flow of material reduces the convey pressure (and leakage volume) to a level that can be accommodated.

Recommendations:
Restrict the use of this method to systems that are designed to operate <8 PSIG and are handling pelleted products or powders fed from storage bins with significant fluidization.

III. Vented Inlet Hopper

Description:

The airlock is equipped with a surge hopper proportional to the size of the airlock that is equipped with a dedicated air vent for the purpose of filtering the leakage air. The vented hopper can be fed by another airlock, flood fed from storage or serve as the transition to a metered feed point[1].

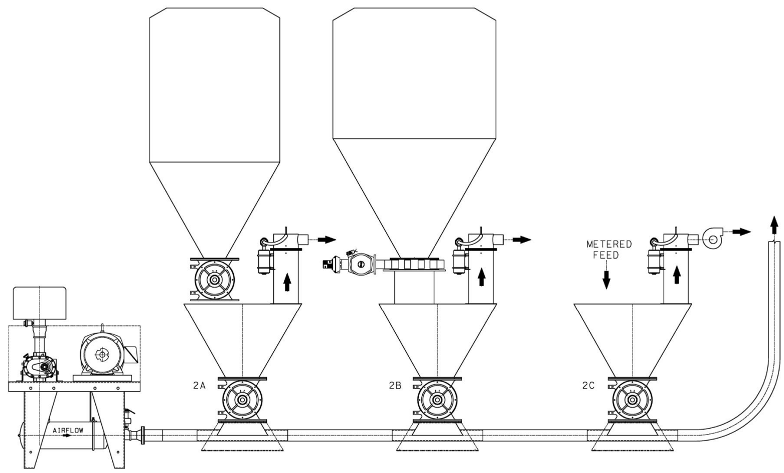

Figure 2. Airlock applied with a vented inlet hopper.

Advantages:

This method is often the surest the way to direct the airlock leakage to atmosphere provided conditions for use are met. When fed from a second airlock (Figure 2A), the surge hopper acts as a pass through unit and can become slightly pressurized to force the leakage air to leave through the filter provided. When fed from a larger storage device (Figure 2B), the surge hopper acts an in intermediate and limits the column head of product on the airlock and leakage air can easily pass through the material. The existing head of product from the larger storage makes the filter provided the path of least resistance for the leakage air. When fed from a metered feed (Figure 2C), the addition of a fan will draw the leakage air through the filter in addition to capturing ambient dust from the feed.

Potential Risks:

The most common mistake when employing this method is the use of a static sock filter on the vent hopper. This works properly as long as the sock remains clean. However, when the sock becomes dirty, resistance to airflow is created and the leakage air will find other paths or create flow problems as described above. Flow socks are acceptable when handling clean products with a negligible amount of fines. Another common oversight is employing the flood fed condition (Figure 2B) on powders. The leakage air combined with the flow of product can create fluidization which will cause the material level to attempt to equalize with the head pressure from the source. The inlet hopper becomes overfilled with product and the vent filter is clogged.

Recommendations:

Use a vented inlet hopper on system operating at pressures > 8 PSIG. When dealing with powders, provide a metered feed to the main airlock using scenarios shown in Figures 2A or 2C. Also use this method when trying to deliver product at a metered rate due to the inability to accurately control the feed of product with a standard airlock arrangement.

1. A metered feed consists of a mechanical means of delivering the product to the feed point whether by mechanical conveyor, metering device or process that delivers a metered feed such as a dryer or mixer.

IV. Vent to Silo Top

Description:
The leakage air is separated from the material by a vented inlet hopper that does not have a dedicated filter. The vent stub is piped to the top of the silo or storage device to be exhausted (Figure 3A). When a fan is present to create a negative draw on the storage device, its draw can be used to aid in the aspiration of the leakage air (Figure 3B).

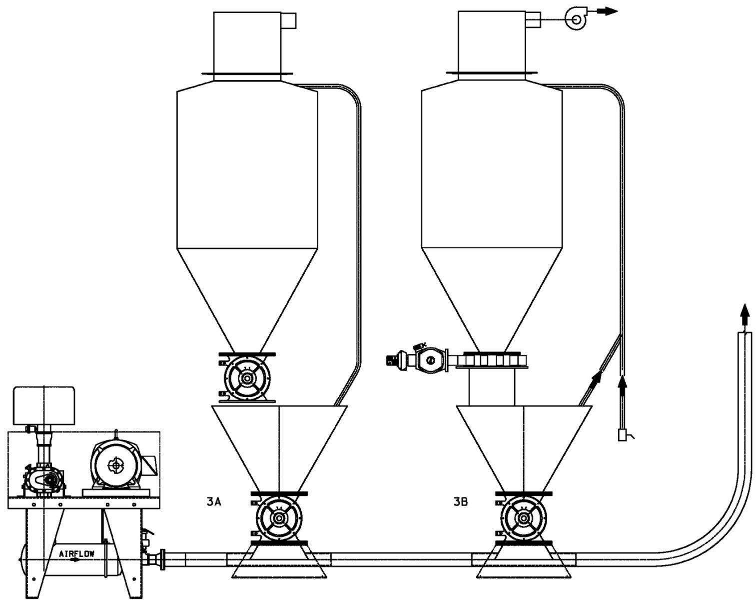

Figure 3. Airlocks vented to the top of a silo or storage device.

Advantages:
Allows the leakage air to get to the top of the storage device without having to pass through the material, therefore alleviating some of the concerns stated in Section II.

Potential Risks:
The diameter and routing of the vent line are very sensitive to the material and operating conditions. In this method, the leakage volume is the carrier gas for particles that are captured in the leakage air and must therefore be conveyed successfully through the line using this volume. However, the leakage volume fluctuates with convey pressure and is therefore inherently unreliable as a carrier gas and can often lead to plugged vent lines. Line routings with all steep vertical angles will allow material, that is unsuccessfully conveyed, to gravity flow back to the feed hopper. Therefore, horizontal piping in this vent line is discouraged. Flood fed conditions (regardless of the product type but especially in powders) tend to entrain the most product in the leakage gas. With this method, a negative draw on the storage is required to avoid plugging the vent. However, providing a hard connection will still limit the carrier volume to that which is leaked from the airlock. A lateral connection (Figure 3B) will allow the vent line to continuously draw sufficient air for conveying while capturing leakage air and entrained product.

Recommendations:
Use the method shown in Figure 3A only on pellets with negligible fines. Use the method shown in 3B on pellets and granules where a fan is present on the storage device.

V. Central Dust Collection

Description:

A separate dust collection system is available to collect the leakage gas from the feed point along with any entrained material. A negative draw is present to insure the leakage gas follows that path. A vent hopper without dedicated filtration provides the initial separation of material from leakage gas.

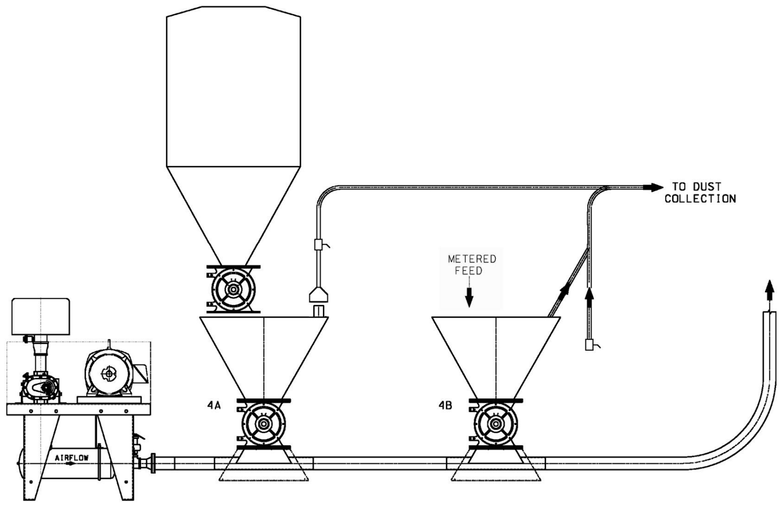

Figure 4. Utilization of central dust collection to capture airlock leakage.

Advantages:

This method does not rely on the leakage volume as the convey medium and the negative draw makes it the path of least resistance. Often these systems are existing and therefore require very little additional equipment. For applications with multiple airlocks, a single dedicated collection system can be provided to service all the feedpoints.

Potential Risks:

The most common fault found in these designs is a rigid piped connection to the vent hopper. The central collection system can only draw the volume of gas released by the rotary valve and is therefore subject to that volume for handling any entrained material. Two examples of soft connections[2] are shown in Figure 4A and Figure 4B. These piping arrangements allow the dust collection system to pull the required volume of gas regardless of the volume being released by the airlock. However, the duct will still capture any leakage gas or entrained material that is released. Even when properly employed, a drawback of this method is that entrained product is lost and often discarded as waste creating inefficiency. In certain cases this value can be large and other methods are preferred.

Recommendations:

Use this method when existing central dust collection systems are available. The exceptions are when powders are being delivered in a flood fed state or in the case of a valuable product that should be captured and reclaimed.

2. "soft connection" refers to a larger pipe that covers a smaller pipe but is not coupled to it or two pipes that are brought together through a lateral where one side is exposed to the atmosphere.

VI. Eductor Driven Capture

Description:
An eductor is a venturi device that can use pressurized gas to create a vacuum. An eductor can be used to draw leakage gas and entrained material into its housing and then positively convey the motive gas, leakage air and entrained material to a destination. An eductor can be used to inject the leakage air back into the pressurized flow of the pneumatic convey line (Figure 5A) or to drive it to the top of a silo (Figure 5B).

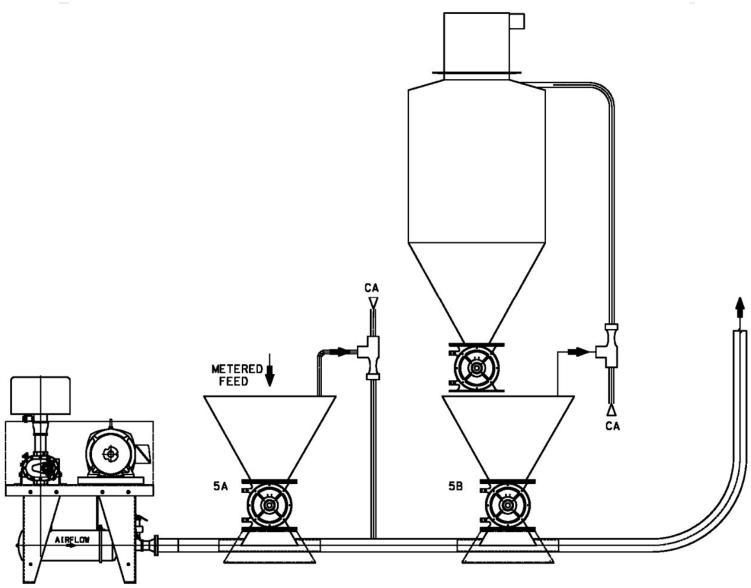

Figure 5. Utilization of an eductor to capture leakage air.

Advantages:
This method utilizes a dedicated device to capture the leakage gas and drive the mixture to the desired location. The device provides the necessary convey air capable of handling heavier material loadings: more so than some of the aspiration methods described above.

Potential Risks:
Eductors are inherently inefficient. Figures 5A and 5B designate compressed air as the motive gas and the required volume can be substantial. While the scenario described in Figure 5A shows the leakage volume injected into the convey line, this method is limited to applications with lower convey pressures.

Recommendation:
Use eductors when compressed air is available as a motive force and other methods are undesirable. Primarily the eductor should convey the mixture to the top of the storage device (Figure 5B). The need to reinject lost material into the convey line (Figure 5A) can be considered on systems operating at less than 5 PSIG.

VII. Airlock Boss (Body) Vent

Description:
Discussion of the boss vent is less of a methodology in itself and more of a feature that can be added to some of the methods previously discussed. A boss vent on an airlock is a port configured into the housing of the airlock to aid in the relief of leakage gas before the vanes of the airlock reach the inlet throat. Total leakage volume comes from two sources in the airlock: 1) air through the clearance between the rotor tips and housing and 2) the empty volume in the rotor is pressurized to the line pressure and expands back to atmospheric conditions when rotated. The boss vent releases the pressurized rotor pocket prior to rotating back to top center.

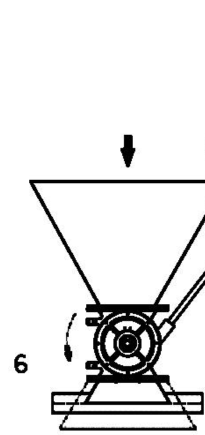

Figure 6. Body venting through an airlock boss vent.

Advantages:
Larger airlocks can have a substantial volume of pressurized air that will negatively affect the flow of product into the airlock throat. Releasing this volume early can relieve this issue. In addition, airlocks put into higher pressure service experience a larger disrupting pulse as the air trapped in the pocket is suddenly released. Lastly, airlocks that are rotating at a high RPM have a shorter exposure time of the airlock pocket to receive material at top center and the boss vent can increase fill efficiency as result.

Potential Risks:
The boss vent removes a portion of the sealing wall in the housing and can lead to somewhat higher leakage volumes as compared to airlocks without this feature. In addition, any material not deposited in the convey on the underside of the airlock is likely to be exhausted though this vent with the leakage volume.

Recommendations:
Utilize the boss vent on applications where the rotary valve is especially large (>2.5 CFR), rotating fast (>18 RPM) or high differential pressures (>12 PSI). Continuous dense phase convey systems will usually have a boss vent due to the elevated operating pressures. Use this method in combination with other methods described above.

VIII. Conclusions

The above information and scenarios cover a reasonable portion of the pneumatic conveying applications found in the industry. The recommendations are meant to provide general guidelines and provide insight based on industrial experience. The variation on materials being handled and the processes in which they are placed are infinite. While no paper can wholly cover the subject, the above information can be used to avoid common mistakes and initiate discussion toward a proper solution.

Figure 7 shows a selection chart that attempts to summarize the recommendations made above. A particular type of venting that is not recommended may suggest a modification to the application. For example, an unfluidized powder in a flood fed condition and operating above 8 PSI does not offer a selection. This lack of result would suggest that the material be fluidized or a metering device be added the equipment arrangement.

	Pellet				Granule				Fluidized Powder				Unfluidized Powder			
	Metered		Flooded		Metered		Flooded		Metered		Flooded		Metered		Flooded	
	< 8 PSI	> 8 PSI	< 8 PSI	> 8 PSI	< 8 PSI	> 8 PSI	< 8 PSI	> 8 PSI	< 8 PSI	> 8 PSI	< 8 PSI	> 8 PSI	< 8 PSI	> 8 PSI	< 8 PSI	> 8 PSI
Direct Connect			X								X					
Vented Inlet Hopper		X		X	X	X	X	X	X	X			X	X	X	
Vent to Silo Top	X	X	X	X	X				X				X			
Central Dust Collector	X	X	X	X	X	X	X	X	X	X			X	X		
Eductor Capture	X		X		X		X		X				X		X	
Boss Vent		X		X		X		X		X		X		X		

Figure 7. Recommended application selection chart.