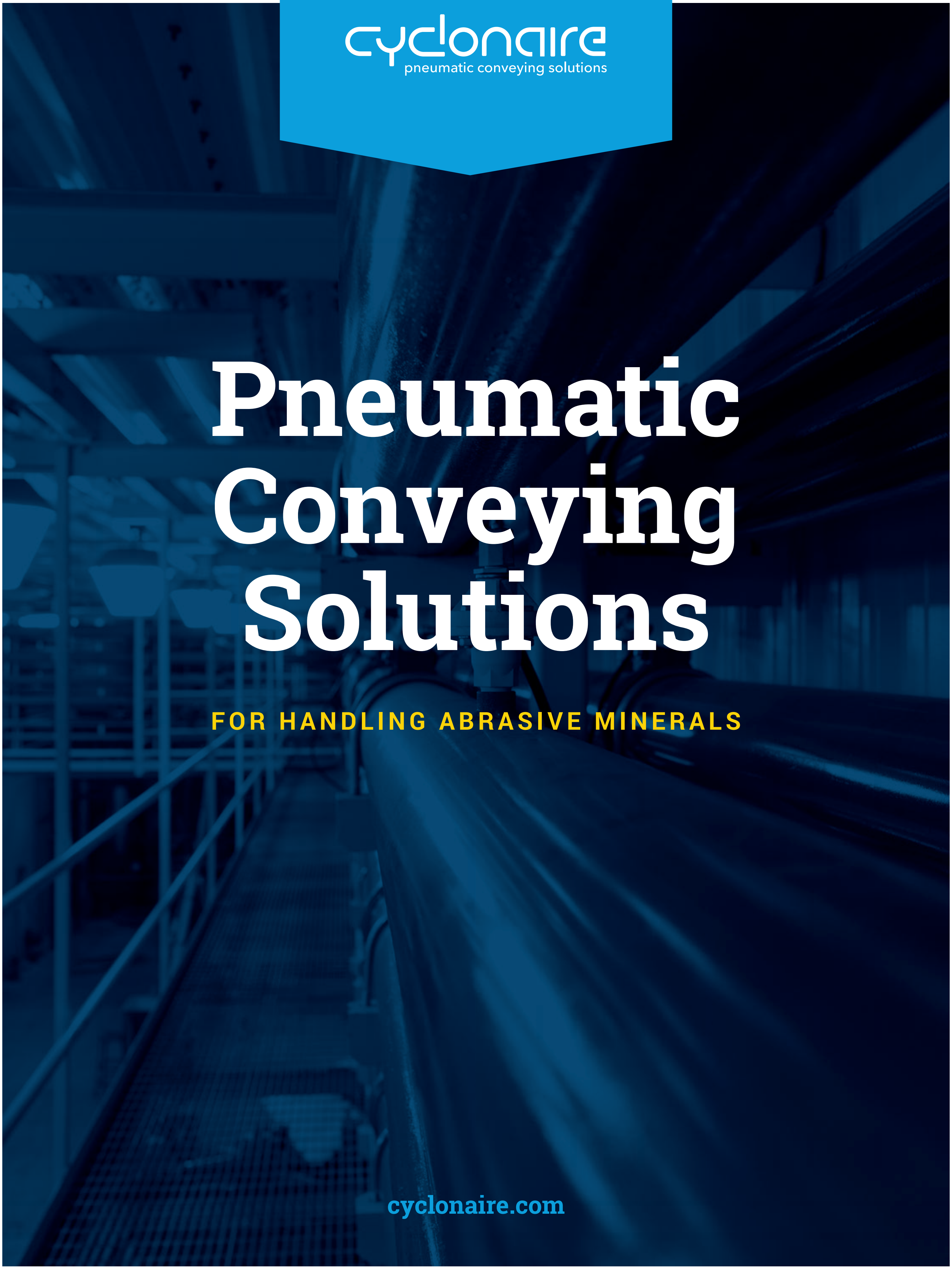
cyclonaire
pneumatic conveying solutions



Pneumatic Conveying Solutions

FOR HANDLING ABRASIVE MINERALS

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Many industrial raw bulk materials exhibit abrasive characteristics. Most mineral base raw materials require some level of crushing, milling, grinding and other sizing processes to transform these raw materials into a powder or granule form. As these materials are processed from raw to granular form, and then distributed to industrial processes, the materials must be repeatedly moved and stored.

Pneumatic conveying is often the preferred best-practice method for moving these materials. Pneumatic conveying systems ensure that dust is contained, allow flexible transports of the minerals to multiple locations and ensure that the transport system is largely comprised of simple pipes which require little cost or maintenance. A well designed pneumatic conveying system can provide years of service with low cost of ownership. However, with abrasive minerals, several design considerations must be made to protect against erosion at key locations in the process flow. If such considerations are not made, the equipment life-cycle can be shortened from years to days.

Cyclonaire has been conveying abrasive materials from day one of our 45+-year history. Cyclonaire was founded on a patented railcar unloader, specifically designed for handling abrasive minerals. Most mineral products are eventually shipped from mine or mill to end-use customers in large quantities, often by rail, which quickly exposed Cyclonaire to the full range of abrasive materials as our client list expanded. More than four decades of working in this environment has led to the development and incorporation of many best-practice techniques.

Many of these techniques are very simple and low cost to implement. Others are more involved and expensive. The goal of this article is to introduce the types of solutions available and the concepts behind them to ensure that the most appropriate selection is incorporated; more extreme situations are considered as well.

How Abrasive Is It?

One of the challenges when handling abrasive minerals is to identify "how abrasive is it"? This will often drive decisions about the degree of design fortification. There are four physical characteristics that contribute to the abrasiveness of the material:

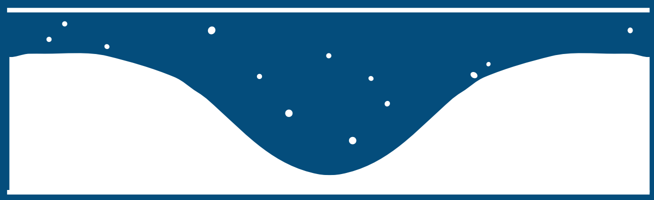
1. Particle Hardness
2. Particle Shape
3. Bulk-Material Density
4. Particle Size

Factors can be applied to each of these parameters and multiplied to determine an overall abrasive index of one material as compared to another. This can help to objectively describe why Talc (Moh's hardness of 1, low density, small particle shape) is much less abrasive than Silica Sand (Moh's hardness of 6-7, higher density, larger and more sharp particle shape). Because such a range of abrasiveness can be encountered, the effect on the material handling equipment will vary significantly as well. Accordingly, if careful consideration is not taken when selecting/designing the equipment, what might be a highly successful installation for one material might be considered a catastrophic-failure for another.

Another very important concept to understand is that abrasive wear has been shown to be proportional to the conveying velocity raised to the X power, where X varies between three and five. To put that in perspective, increasing the velocity 10 percent can increase wear by up to 70 percent. Understating this phenomenon is the key to most of the effective design solutions for abrasive minerals – identifying localized velocities and reducing them wherever possible.

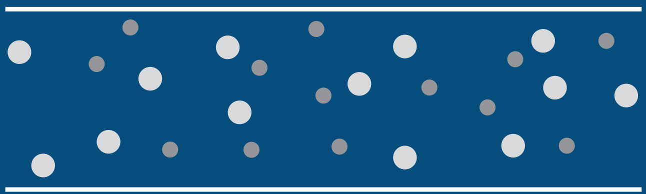
Main Transport Velocity

First, it is important to consider the main transport velocity. Pneumatic conveying systems can be designed across a wide range of flow types.
At the far extremes are:



Dense Phase

Dense Phase uses lower air velocities, and at the extreme end of the spectrum, relies entirely on differential pressure rather than velocity to extrude slugs of minerals through the pipe. Velocities typically range from 100-4,000 ft/min for these system types. (think: toothpaste out of the tube)



Dilute Phase

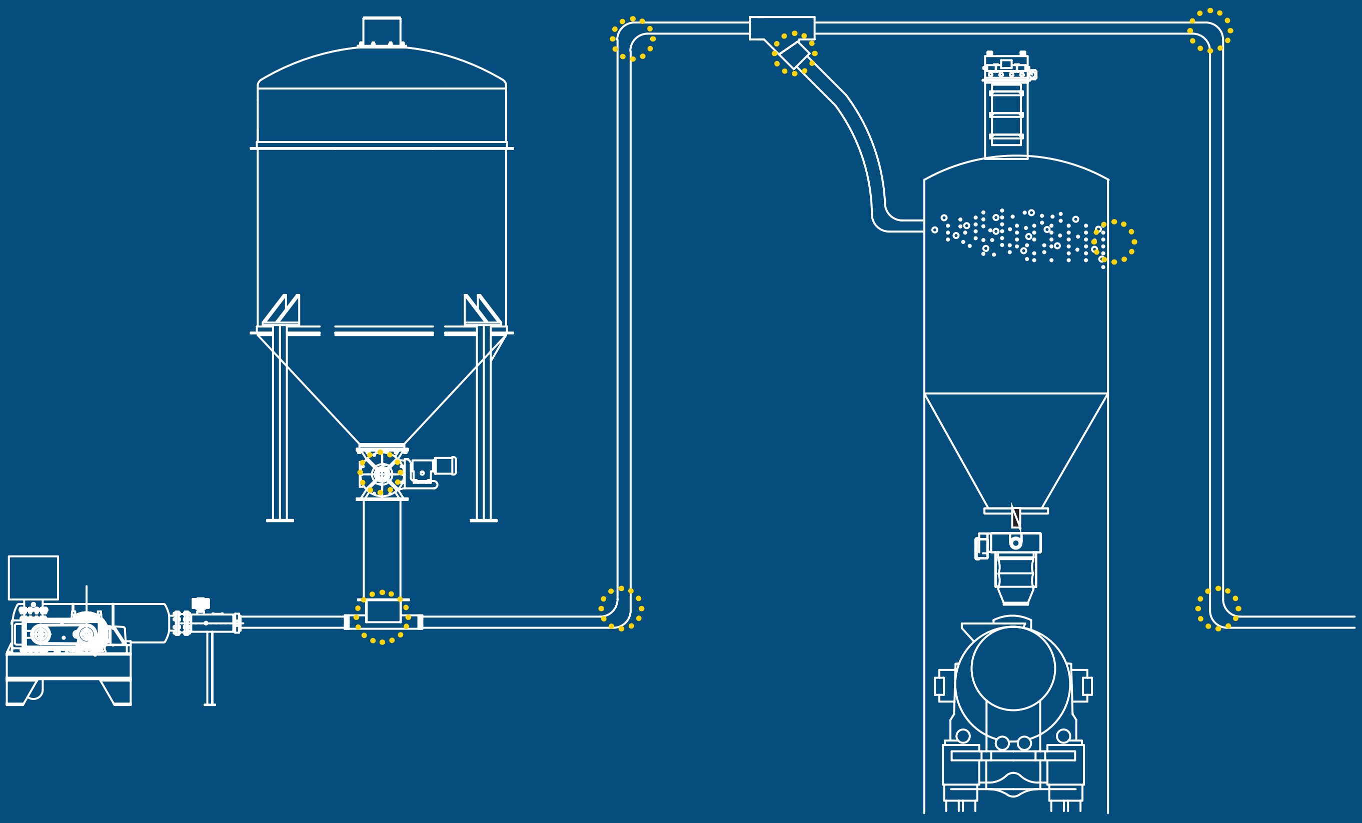
Dilute Phase uses high air velocities to carry each individual particle suspended in the airstream. Velocities typically range from 4,000-9,000 ft/min for these system types. (think: sandblaster)

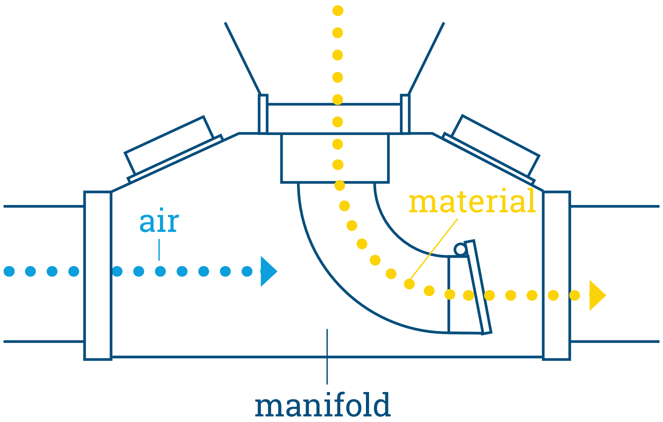
One simple technique to reduce wear is to design the systems to use a lower velocity, whether that is at the lower end of the dilute spectrum for mildly abrasive materials or the extreme low end of the dense spectrum for highly abrasive materials.

Regardless of the flow regime selected, there will be common wear locations where higher velocities or media contact points are locally concentrated. These can generally be identified as shown below:

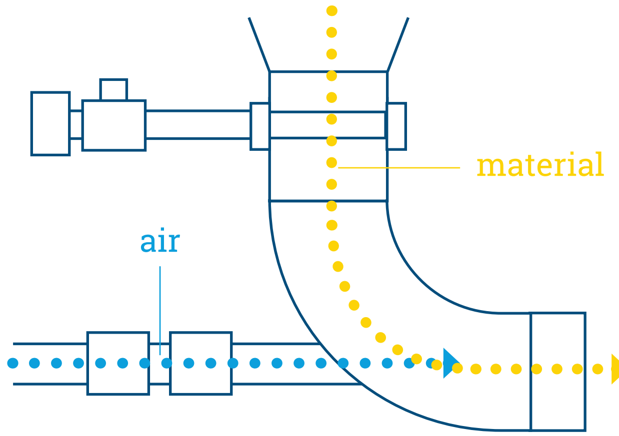
Typical Dilute Phase System

= Wear Area





Mixing chamber for
velocity-dependent systems



Compressed air source
for low-velocity systems

Feed Devices

Mechanical-feed devices such as rotary airlocks and feed screws experience leakage when feeding into pressure systems. By design, they must incorporate tight tolerance openings to prevent the air from leaking out while the abrasive mineral is fed into the system. Such small openings where a pressure differential exists result in localized high velocities right where the abrasive material is present. This creates a scenario where erosion can be highly concentrated.

Steps can be taken to fortify the contact surface (hardened steels, coatings, ceramics). This can extend the life of the feed device, but at high costs. Generally, these fortifications only delay the inevitable erosion rather than avoid it.

Alternative solutions utilize feeders that do not experience leakage, such as feed vessels, commonly called pressure pods. With a feed vessel, the internal vessel pressure is equalized with the convey line so no blowback occurs at the feed point where the mineral is fed into the transport convey line.

For systems utilizing a fixed flow blower as the air source (low velocity end of dilute or high end of dense phase spectrums), the vessel generally feeds into a mixing chamber or manifold. The chamber has no close-tolerance components for localized wear or leakage back to the source and hence, very few abrasion points. There can still be turbulence in such a location so, for more abrasive materials, these manifolds may be fortified (thicker, harder steel or ceramic linings) for additional wear resistance.

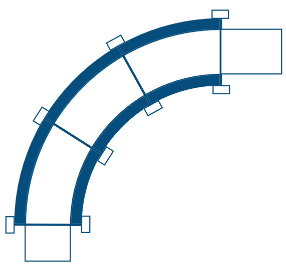
For systems using compressed air, the volume (and velocity) is generally very low at the feed point. Simple piping transitions are therefore used to construct the feed adapters. Fortification is possible, but rarely needed due to the low velocities encountered.

Convey Line

As previously demonstrated, using a lower convey velocity should always be the first step to minimizing convey-line wear. The next step is to select convey-line components suitable for the job.

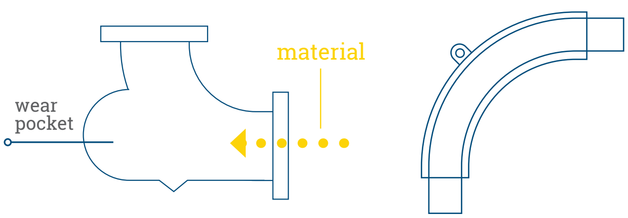
Abrasive wear in convey lines is generally concentrated at the bends, where significant impact occurs as the material changes direction. The straight piping sections are not generally problematic expect in extreme applications. Hardened-wear-resistant straight sections can be implemented, but this is a rare requirement.

Selecting the right bend design is a bit less straight forward. There are hundreds of convey-line elbow designs and variations available, but they all generally fall into three categories:



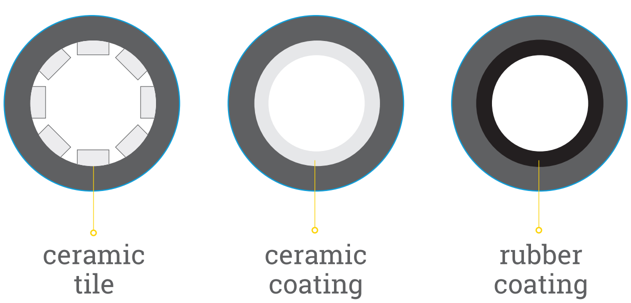
Fortified Materials of Construction

Elbows can be constructed from thicker-walled and hardened materials, such as specialized castings or heat-treated steels.



Pocket-Backed or Chambered Designs

These designs incorporate oversized chambers in the flow path where the abrasive material fills in, covering the impact zone and causing material to wear against itself rather than the walls of the bend. This includes designs with external chambers (cavity back) which fill with minerals after the interior walls are breached.

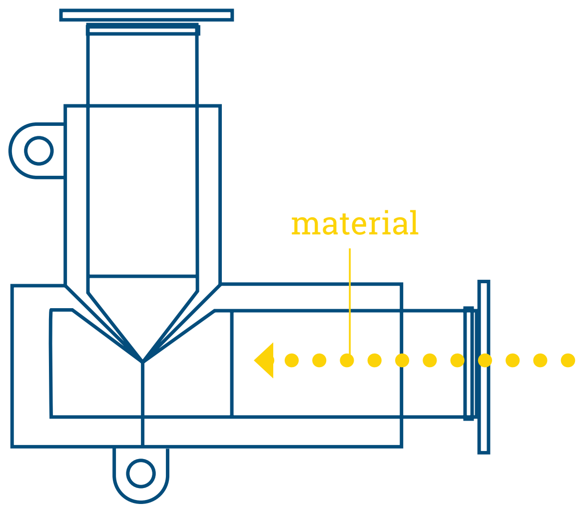


Coated/Lined Designs

A wide arrangement of abrasion-resistant coatings and linings are available, including rubber linings, tungsten carbide and various ceramics. Ceramic linings are widely used for extreme duty applications, but they can be costly and add considerable mass/weight to the elbows.

Combined Solutions – Cyclonaire Tee-Bend with Cavity Back

Additional solutions are achievable by combining methods. As an extreme example, a cavity-backed Tee-bend constructed of Schedule 80 hardened pipe with a ceramic filled cavity. Such a design would likely out-perform all others, but the cost, lead-time and weight may not be justifiable for most applications.



A typical practice for new abrasive-service installations is to select a mid-range solution with lower cost (such as cavity backs) to determine life expectancy. Often, these mid-range solutions are adequate and provide acceptable life-cycles. Upgrades can be considered for extreme applications.

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Vessel Entry – Destination Connections

In any pneumatic conveying system, the velocity is always highest at the destination end (due to the expansion of conveying gas) as pressure moves from high to low. Subsequently, the higher velocity of the mineral entering the destination vessel can be problematic.

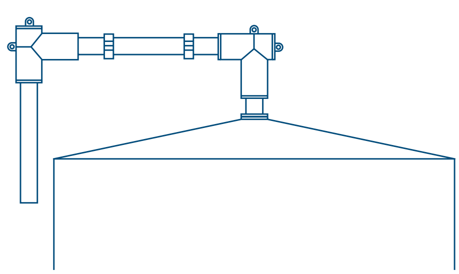
In many cases, the best solution is to simply borrow from the previous section discussion and terminate with a final (fortified) elbow on top of the vessel. This directs the mineral discharge downward, where it can land on a pile of like mineral. As long as the elbow is sufficiently abrasion resistant, this is the most common method.

For other applications, where the extra elbow is not preferred, or the where side entry is required due to space limitations, a dead-head receiver is recommended. A deadhead receiver utilizes the pocket back concept to create an impact zone which will fill with the abrasive material, protecting the walls of the receiving vessel from impact. An oversized slot in the bottom of the deadhead directs the mineral downward, away from the walls of the receiving vessel and onto the mineral pile below.

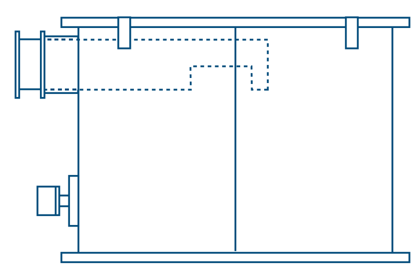
Further benefits can be achieved by stepping up the diameter of the approaching convey line and deadhead (larger) to further reduce the localized velocity.

Making the deadhead section removable allows easy replacement. The receiver can be used for side-entry on smaller vessels or can be adapted to a target box for top entry.

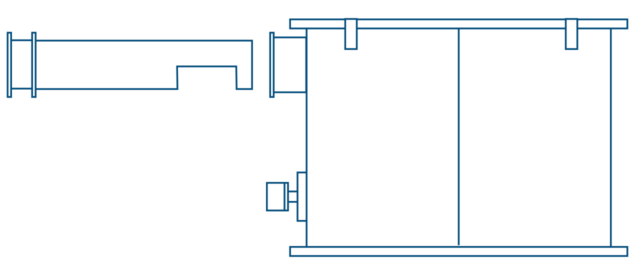
Cyclonic or tangential inlets should always be avoided for abrasive minerals, as they direct the flow directly against the vessel walls, leading to high-abrasive wear.



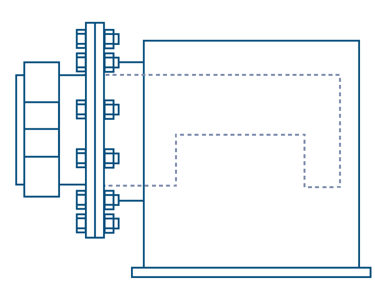
Final Fortified Elbow



Deadhead Receiver



Removable Side Entry



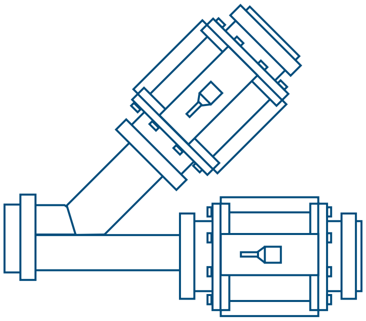
Top Mount - Target Box

Diverting Valves

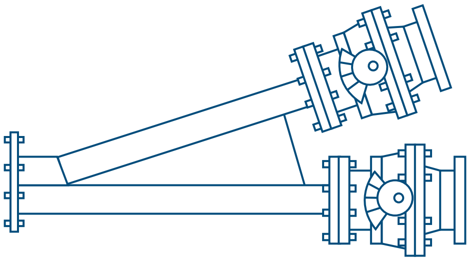
It is often necessary to convey the material to multiple destinations. Diverter valves can be used to accomplish this. However, similar to elbows, these valves are subject to high-abrasive wear due to the contact caused by the local directional flow changes.

Similar solutions effective for elbow design are employed here, particularly the pocket-back/ chambered methods where the flow chamber is purposely oversized or otherwise designed to capture minerals and use them to protect the walls of the valve against direct impact or abrasion.

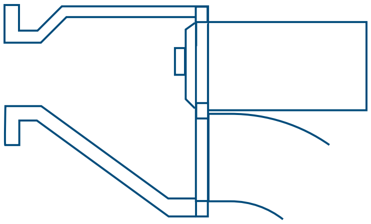
Valve seals will be either inflatable elastomer or hardened steel to prevent grinding the abrasive mineral into the seal as the valve switches positions.



Dual Pinch Valves



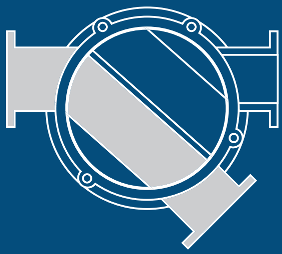
Dual Dome Valves



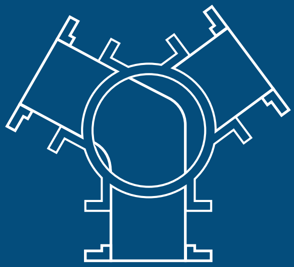
Sliding Disc Valve

Ported-diverter Designs

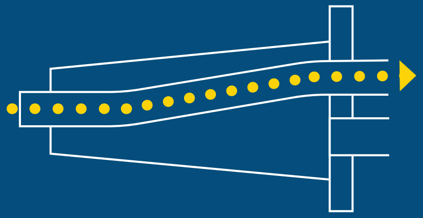
There are many other ported-diverter designs, but the port always forms a non-straight path to divert the material, which becomes directly exposed to the abrasive flow. Ported designs are therefore not typically good for handling abrasive minerals.



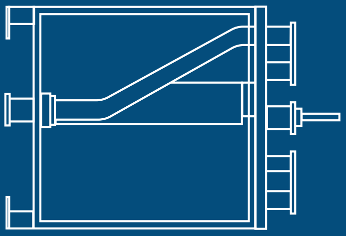
Plug Type



Ball Type



Sliding Hose Type



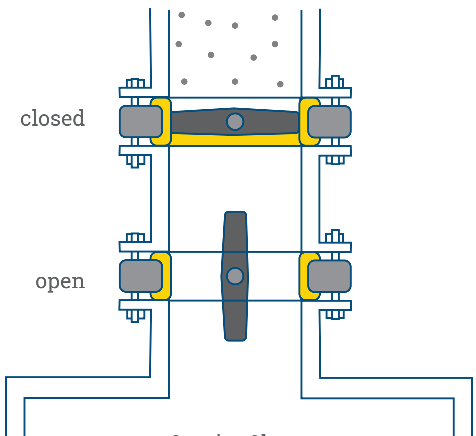
Multi-Port (Gatlin Gun)

Other Wear Points

The discussion above covers the most common wear points through the actual mineral-convey path, but additional challenges can exist while feeding the abrasive material into or out of the system.

Examples would be inlet valves or vent valves on a feed vessel. These valves are shifting directly through abrasive minerals (inlet valves) or against high-pressure differentials which can cause localized velocity with dust-laden air where erosion can occur (vent valves).

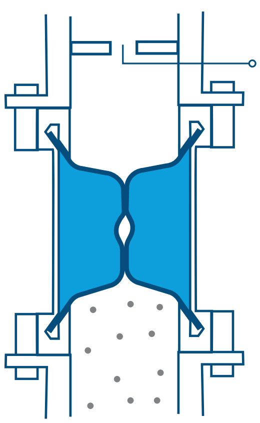
Again, inflatable seals or hardened/treated metals generally provide the best service life for these applications.



Gravity Chute

Gravity Chutes

It is common to utilize a sacrificial valve above for opening/closing through the direct mineral stream (standing or moving column). This protects the lower valve, allowing it to open and close through an empty chute. For high-abrasive service, the upper valve need not be fortified as its sealing performance is unimportant. The lower valve often will utilize the inflatable or hardened seals for extended life.



Pinch Valve

Vent Valves

Applications where a valve must open against a pressure differential, consideration must be made for the instantaneous velocity that can be encountered both as the valve starts to crack open and as the sustained flow velocity as/after the valve opens against the pressure differential.

A flow-limiting orifice is often added to help limit the localized velocity. The orifice can be hardened or coated for extreme abrasion service.

Even with this countermeasure, the local velocity can be high as the vent seal begins to crack open. The higher the pressure differential when the valve opens, the more of an issue this can create (can be especially important when handling higher-density minerals at higher convey pressures). This generally requires a hardened/fortified seal or a very fast-acting pneumatic inflatable seal. Many inflatable seals actuate too slowly and will be damaged by high local velocities as they unseat.

At Cyclonaire, this consultative and collaborative approach is our standard business practice.

Summary

As this discussion has made apparent, the devil is in the details when designing for abrasive mineral transfer, and striking the balance between under-designing or over-designing can be the most difficult challenge when specifying a pneumatic conveying system for abrasive minerals.

Under-designing, or simply failing to consider abrasion protection, can result in high abrasive wear resulting in material leaks, high repair costs, and frequent down time.

Over-designing can inflate capital costs which might make such projects cost prohibitive.

This is why it is important to fully consider:

- How abrasive is my mineral?
- How can velocity be appropriately selected for the abrasive service?
- How can local velocity concentrations or high contact components be effectively fortified/protected?
- What will be the full life-cycle cost of operation of this system? (Low capital cost with failure to invest in properly fortified components will lead to high operating costs of repair and downtime).

Working with a partner who understands these issues and helps you to select the right level of system fortification is important. At Cyclonaire, this consultative and collaborative approach is our standard business practice.

For more information on handling abrasive materials, please contact sales@cyclonaire.com or (800) 445-0730.