UNDERSTANDING AND PREVENTING FINE POWDER FLUSHING

When a fine powder traps air between particles, it may exit the bin like it is in a pneumatic conveyor system, shooting through any crack or crevice, including poorly fitting or worn rotary valve vanes, screws, feeders, bolt holes, vibratory feeder pans or belt feeders, until the powder is depressurized. Yet once the powder settles and air is squeezed from voids between powder particles, in can plug feeders, arch over hopper outlets or cling to hopper walls and form a stable rathole, which creates equally unstable process conditions downstream.

Materials most susceptible to flooding and flushing are talc, lime, powder cleansers, flyash, pulverized coal, resin, plastic powders, iron ore and cement.

SOURCES OF POWDER FLUSHING

Flooding and flushing problems are caused by the interaction of powder and air, and always require a source of pressurized air. Some of these sources include collapsing ratholes, back pressure from baghouses, free-falling powder, air-purges feeder bearings and seals, air pads, improperly set air permeation units, rotary valves that feed pressurized pneumatic conveying systems, especially those that are not vented, back pressures from a baghouse, and gas/solids units with gas counterflow. The three most common sources, however, are collapsing ratholes, free-falling powder and uncontrolled air injection.

Collapsing ratholes

The most frequent source of powder flushing is a flow pattern within a hopper that results in a rathole [Fig. 1].

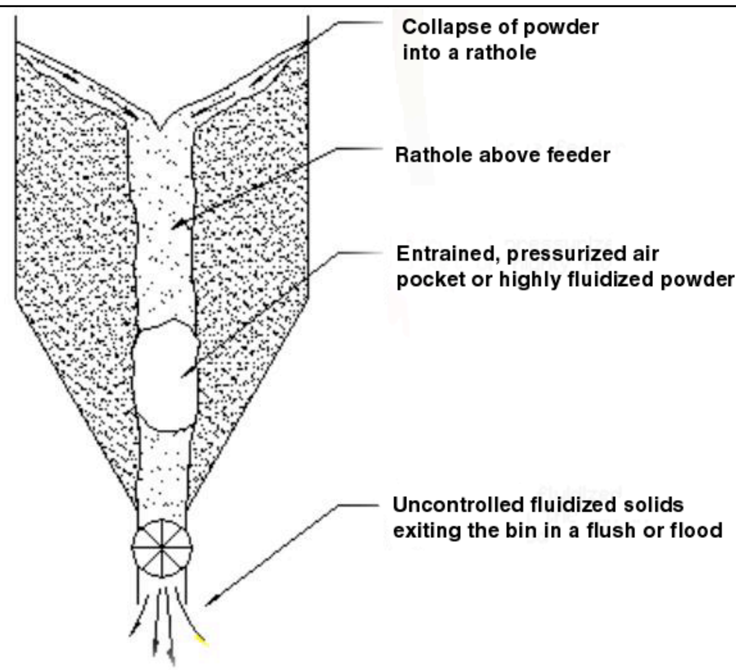

Figure 1: Rathole-type Flow Pattern

Usually this happens in conical hoppers when hopper walls are not steep enough to cause flow along the walls. As a result, flow is directed to a narrow central flow region while the non-flowing material accumulates at the sides and eventually becomes and integral part on the hopper structure. If the rathole collapses or a high rate of powder is then introduced into the hopper, the incoming powder can entrain pressurized air, which will fluidize the powder and result in flushing through screw, belt and vibratory feeders, and even in rotary valves with an entrained air pressure of several psi.

Depending on the hopper's outlet diameter and the strength of the material, a rathole may become destabilized and can peel off and collapse into the hopper, essentially flushing a large quantity of powder through the outlet and into any feeder below.

Free-falling powder

A second cause of flushing results when powder free falls into a hopper in a stream and traps air from the surrounding environment between particles [Fig. 2].

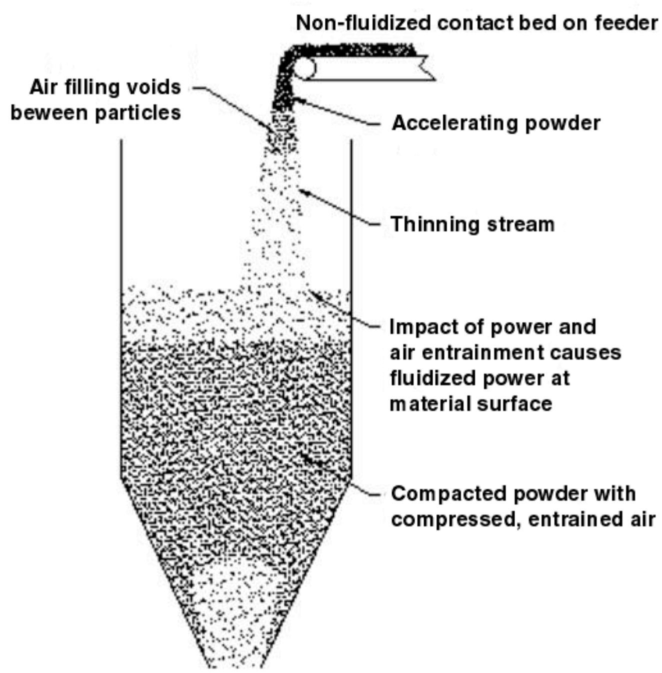

Figure 2: Free-falling Powder

The faster the powder flows, the larger the void or space between particles, and the greater the entrained air. As the powder accelerates, so does the air. When the powder strikes the top level of material in the bin, some air is dispersed into the atmosphere and results in dust. The rest of the air is trapped within the powder. If the hopper is small relative to the flow rate out and if the material within the hopper has a short retention time that doesn't allow the trapped air to escape, fluidized powder can flow through the outlet at an uncontrolled rate.

Uncontrolled air injection

A third cause of flushing is uncontrolled air injection or a chemical reaction within the powder that produces gas [Fig. 3]. Both can fluidize powder. The only circumstance in which uncontrolled air injection should be considered is in a pneumatic conveying system that transports powder, although with wide fluctuations in the feed rate, or into a closed container such as a blow tank, which may require a high charge rate to reduce the cycle time.

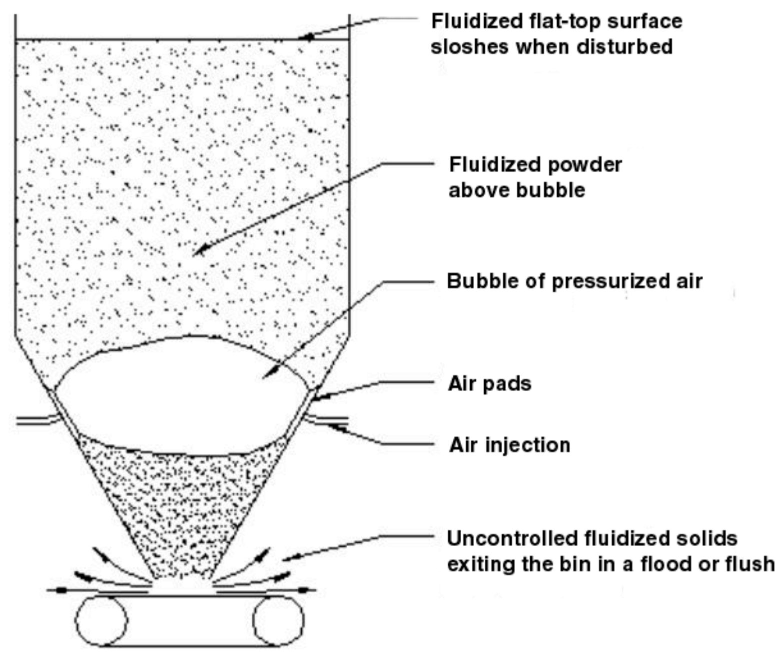

Figure 3: Uncontrolled Air Injection

REDUCING POWDER FLUSHING

Providing a guaranteed solution for fine powder flooding and flushing should involve testing the powder's material flow properties to understand how a particular powder interacts with air and what its potential is for flooding and flushing before taking steps to correct the problem. Often, only minimal adjustments are required. However, the typical approach for controlling or eliminating excess air that leads to flushing is a rotary valve placed at the hopper outlet. Unfortunately, the rotating vanes actually pump air into the hopper outlet, and instead of reducing excess air, the rotary valve supplies additional air. Eventually, the close tolerances between vanes wear down and flushing can occur.

Other ways plants deal with the powder flushing is by building a settle chambers at each feeder, increasing a dust collector's capacity, over-filling packages to compensate for occasional underflow, and putting in an automatic closing shut-off gates that activate whenever a paddle switch senses flushing.

Fortunately, there are better methods for preventing powder flushing. An air permeation system, a sloping let-down chute, a vertical pipe below the hopper, a deaeration cylinder and hopper retrofits to correct flow patterns are all potential solutions with costs that vary considerably.

Air permeation system

Powder will not flow at consistently high rates without some entrained air. When totally deaerated, flow rates may fall significantly below the required rate. When totally fluidized with indiscriminate air injection, as may be the case with air pads or pulse jets, the flow rate may increase, but so will the potential for sudden uncontrolled flushing.

An air permeation system with injection nozzles placed at critical positions in the hopper, can control both the air pressure and rate of injection, and provide consistently high powder flow rates without the potential for severe flushing. Such a system can replace air lost when a powder compresses, and thereby prevent an inrush of air from the outlet that could impede flow The small amount of air needed to fill voids and increase the flow rate ten or more times is not enough to create dust or fluidization.

An air permeation system needs to be designed and carefully placed to prevent over-pressure pulses as powder enters the hopper from plugging the ports and to ensure powder flows both above and below the system [Fig. 4]. It's very important to adjust air permeation system settings properly.

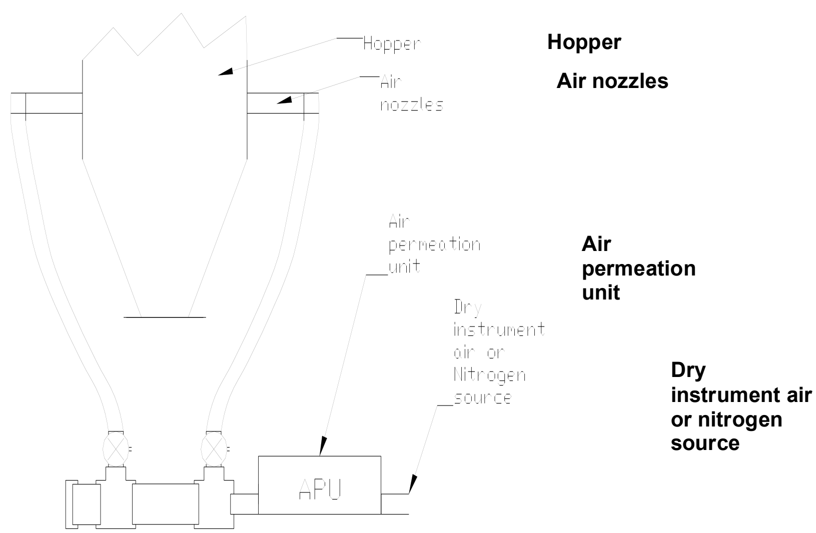

Figure 4: Air Permeation System

Vertical pipe below the hopper

A vertical, non-converging pipe placed below a hopper designed for flow at the hopper walls can substitute for an air permeation system since it tends to create a vacuum at the hopper outlet that pulls powder out [Fig. 5]. This solution also increases the flow rate, sometimes by a factor of 10 or more, because the vacuum pressure can be as great as the height of the vertical section multiplied by the powder's bulk density.

When using this solution to increase powder flow rates, it is essential to use a feeder that controls the flow slightly below the limiting rate. Without a feeder, the high rate of powder flow created from using the vertical section is sustained only as long as it is full of powder. Once the vertical section empties, the limiting flow rate is governed by the void above it and powder flow can slow dramatically.

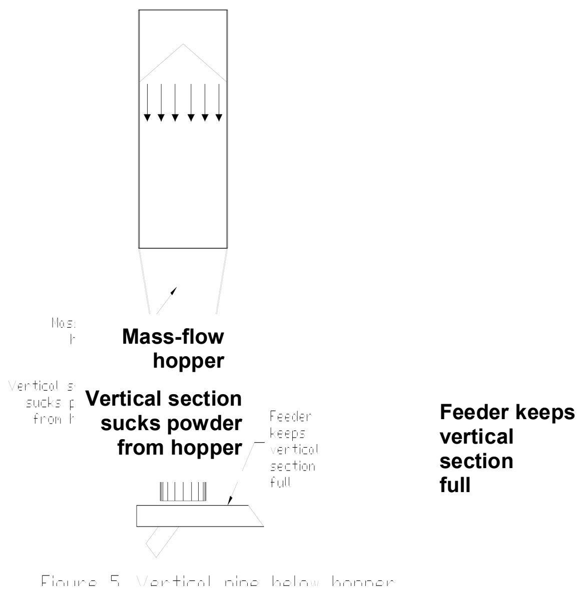

Figure 5: Vertical Pipe Below Hopper to Increase Flow

Sloping let-down chute

Another reasonably inexpensive solution for powder flushing is an open let-down chute that protrudes into the powder surface at the top of the hopper and prevents air from circulating through and becoming trapped between powder particles, as it is the case with a free-falling powder stream [Fig. 6]. Although powder in the chute accelerates and thins as it descends, air entrainment is reduced or eliminated because it is in contact with the chute surface. When placing a let-down chute, it is critical that the chute protrude into the surface of the powder so there is absolutely no powder free-fall. Even a minor free-fall drop of a few inches can severely aerate a powder and increase its potential for flushing.

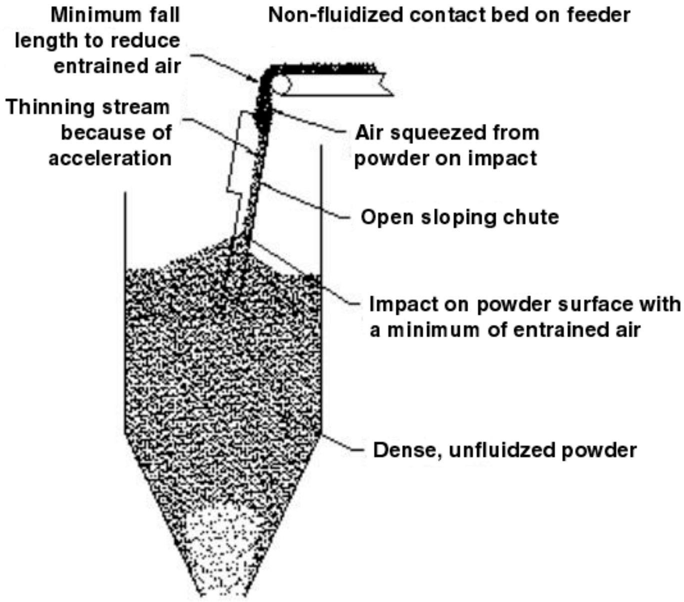

Figure 6: Sloping Letdown Chute

Deaeration cylinder

A deaeration section, composed of a perforated interior cylinder and a vented section in a cylindrical outer section, will remove excess air before it causes flushing at the outlet [Fig. 7]. The best placement of the deaeration section is just above the air permeation region. As the powder drops through the open cylinder bottom, it is reentrained in the flowing powder below, which keeps holes within the cylinder from plugging. If both an upper and lower air permeation region is used, it may be necessary to use a deaeration section in both regions. Generally, the deaeration section will have a pressure regulation device set at approximately the same pressure as the air permeation unit.

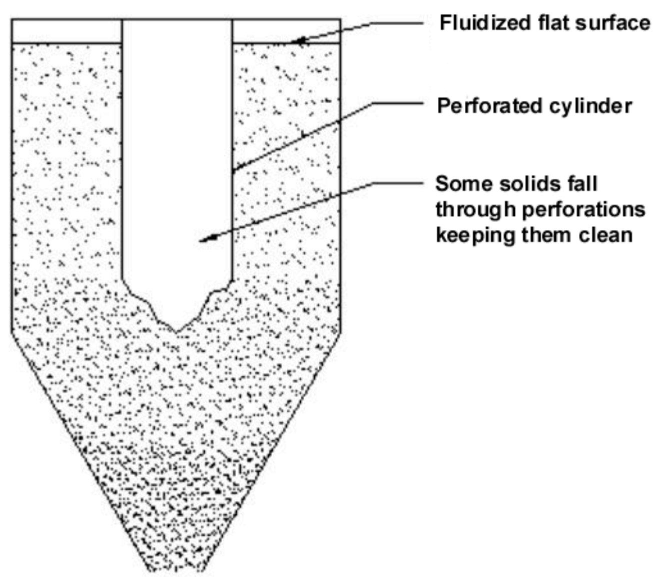

Figure 7: Deaeration Cylinder

Screw feeder

Using a screw feeder provides continuous feed without introducing additional air and can also seal against air pressure in the hopper, provided it is properly designed. If can also deaerate powder by squeezing excess air from the compacted material.

In some cases, installing a compacting screw above the hopper to remove air before the powder enters the hopper will work, but it will still require an open let-down chute to provide surface contact for the descending powder to prevent reaeration. One design includes a weighted flap plate and air disengaging section that seals against most pressures generated by collapsing ratholes.

Hopper retrofits

If a hopper does not produce flow at the hopper walls, commonly called mass-flow, retrofitting the existing hopper can eliminate the source of flushing while improving segregation, process flow rates and feeder performance. While this is a more expensive options, it is often the most reliable and cost-effective in the long run.

Retrofitting a conical bin outlet with a properly sized small hopper that produces flow along hopper walls or with a small con-in-cone hopper and as shown in [Fig, 8] allows a high flow rate without flushing. It's important the retrofit is large enough to eliminate ratholes (flow channel greater than the critical rathole diameter), but small enough to prevent powder over-compaction in the flow channel.

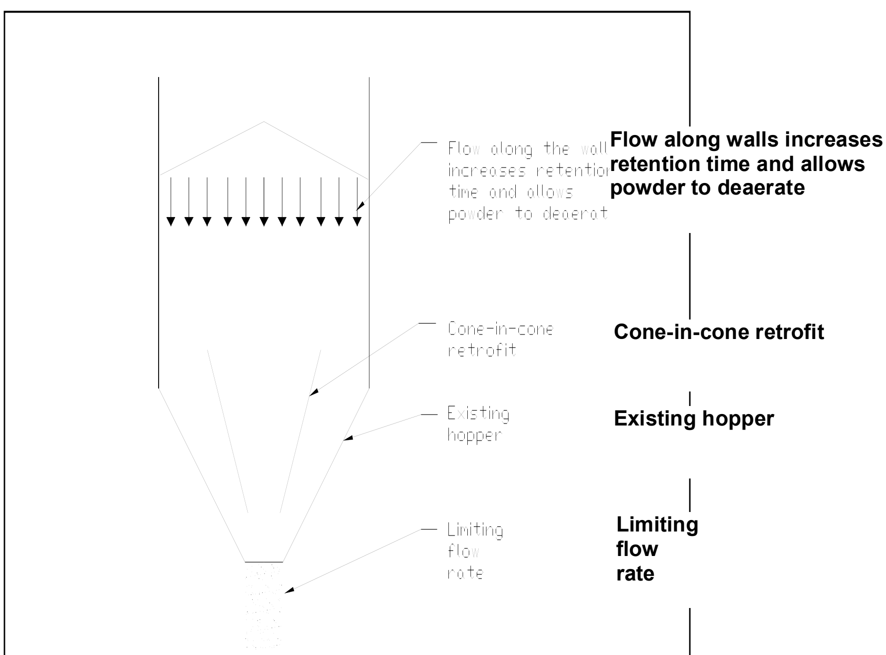

Figure 8: Cone-in-Cone Retrofit

A one-dimensional convergence hopper [Fig. 9] reduces flushing potential by increasing the solids contact pressure at the outlet to about two times that of a two-dimensional conical hopper. This increased pressure allows powder flow without excessive voids expansion, thereby reducing the air vacuum created when voids expand. Reducing the vacuum can double or triple the flow rates.

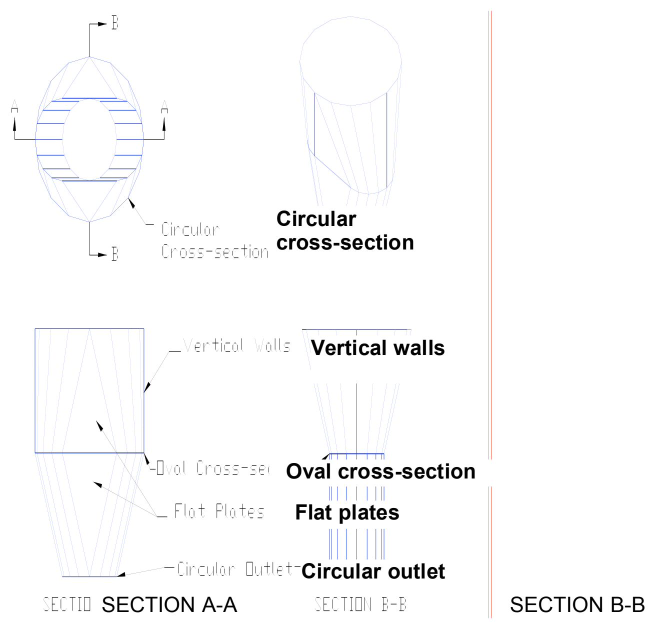

Figure 9: Patented One-dimensional Convergence Hopper

Other solutions include:

- Keeping the solids level high in the bin.
- Reducing bearing purge pressure as low as possible or replacing the air purge seal with a packing gland where possible.
- Venting rotary valves both on the high pressure return side and at the level where powder enters.
- Maintaining rotary valves to minimize air leakage.
- Eliminating air pads.
- Introducing process gas higher in the hopper to allow powder below to pressure seal the hopper.

EXAMPLES OF FLUSHING AND SOLUTIONS

Flyash

Flyash is an example of the bimodal flow rates of fine powder. With entrained or injected air, flyash flows like water, but with deaerated, it hangs up. Unfortunately, too much air injection causes uncontrolled flow that oscillates from extremely slow or no-flow to sudden flushing, and too little air limits the rate.

A company stored flyash in a 26-foot-diameter bin equipped with a 12-foot-diameter vibrated hopper which fed into a vibratory feeder and from there into a 40-foot-long conveying screw. A rathole frequently formed above the vibrated hopper in one or two quadrants and then collapsed, flushing flyash over half the bin contents through the conveying screw and into an adjacent building. The result was a cleanup nightmare.

The company solved its problem using a one-dimensional convergence hopper retrofit equipped with an air permeation system to condition the flyash and provide controlled, consistent flow. The retrofit hopper was mounted to the lower half of the vibrated hopper, just below the interior baffle. In effect, the one-dimensional convergence hopper with air permeation replaced the vibrating feeder by feeding directly into the conveying screw. This arrangement increased the flow channel and flyash retention time in the flow channel to prevent rathole formation.

Cement

Cement is another example of material susceptible to limiting and erratic flow rates. When stored in the bin, it consolidates under its own weight and when discharged, it expands near the outlet, creating an extremely low flow rate this is often misidentified as an arching condition.

A company that transported cement form barges to shore-side silos used a clamshell crane to unload the cement from the barge to an outside gravity-flow surge hopper that fed twin blow tanks. Because dustiness was a major concern, the crane operator lowered the clamshell to the top of the cement in the surge hopper before depositing his load. Unfortunately, this action compressed the cement, leaving it in a totally deaerated state, pressurizing some of the air trapped in voids between particles and dispersing some of the air from the top of the bin. As the cement was discharged and began to flow, the air entrained in the cement expanded. This reduced the air pressure to less than atmospheric, so when air from outside the hopper outlet rushed in and filled the voids, it created an upward force that retarded flow.

The recommended solution was a one-dimensional convergence hopper with controlled air injection. The hopper increased solids contact pressures at the outlet by two times that of a conical or two-dimensional hopper, which allowed cement flow without excessive voids expansion. A vertical section was added between the hopper outlet and feeder to provide additional suction, which completely eliminated any vacuum at the hopper outlet. As a result, the company increased its cement flow rates by one or two orders of magnitude