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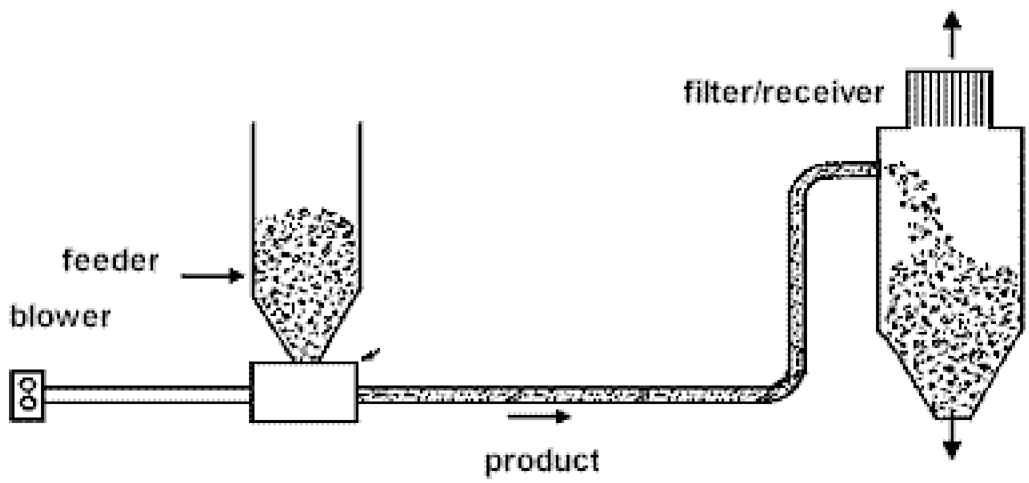
Ask Joe! Column

Is My Pneumatic Conveying System Causing Segregation

Guest article by Richard Farnish
The Wolfson Centre for Bulk Solids Handling Technology

Many plant engineers consider that if a pneumatic conveying system has been included within a process plant, and that there are problems with the quality of the powder or end product being manufactured, then the most likely cause of the problems can be associated with the pneumatic conveying system. It is often considered that segregation of the powder, in terms of size distribution variations, is as a direct consequence of the pneumatic conveying process itself. However, it is evident that many bulk handling systems employ a multitude of different components, all of which can effect the performance of a process and quality of the end product or powder.

Figure1: Shows the basic features of a positive pressure pneumatic conveying system.



The propensity for a blended powder to segregate is dependent upon the size ranges of the constituent powders or the variation in particle density for the blend components. In general terms, if there is a particle size ratio of greater than 1:1.3 then segregation problems can be anticipated (the greater the size range, the greater the propensity for segregation to occur).

Segregation of the powder or blend can occur after several or even just one handling operation. The most common area where segregation occurs in any powder handling plant is in the filling, storage and discharge of hoppers, bins and silos. Thus, segregation can occur irrespective of whether or not a pneumatic conveyor forms part of a powder handling system.

There are several mechanisms by which the segregation of particles can occur, but by far the common is that of rolling segregation. As the powder mixture builds up an ever-increasing inventory on an open stockpile or within a silo, the free surface forms a conical shape.

As the powder lands upon the apex of the free surface, the coarse particles tend to roll down the surface due to their momentum. However, the fines, due to their small size, tend to stay in the central area of the conical heap beneath the filling point. Thus, the sizes of the particles tend to increase as we move radially outwards from the centerline of the apex of the free surface towards the hopper wall. Thus, the likelihood of segregation to occur in even the most basic pneumatic conveying system (typical to that depicted in Figure 1) is high because of the presence a feed hopper at the very start of the system, and not because the pneumatic conveyor itself is present!

Depending upon the design and operational characteristics of the feed hopper, the effects of any segregation present within the hopper can manifest itself in different ways. In order to appreciate the importance of the design of the feed hopper it is essential that the two basic flow patterns that can develop is understood - these being “core flow” (Figure 2) and “mass flow” (Figure 3).

Figure 2: Core flow discharge pattern

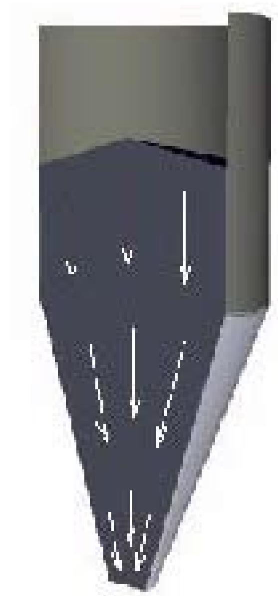


Figure 3: Mass flow discharge pattern

Core flow key features:

- “first in last out” discharge
- “dead” regions of product
- erratic discharge caused by product on product shear during emptying
- central discharge channel
- exaggerates segregation effects of particles
- hopper half angle typically greater than 25° (from vertical)
- poor stock rotation
- high storage capacity for a given headroom

Mass flow key features:

- “first in first out” discharge
- all storage capacity is “live”
- even discharge encouraged by the reduced levels of shear generated as the product discharges (shear takes place against the relatively smooth wall material - not the static or slower moving product)
- degree of remixing during discharge minimizes segregation effects
- hopper half angle typically less than 25° (from vertical)
- relatively low storage volume for a given headroom (but all the product can be retrieved)

Hoppers are often overlooked with respect to exaggerating segregation effects within a process, and the technique applied to fill these vessels is itself quite often a contributory factor in the segregation effects that develop. The issue of filling applies equally to both the feed hoppers in a system and the receiving hoppers at the end of a system.

Examples of the segregation effects that result from different filling approaches appear as Figures 4 - 7. From inspection of the illustrations it can be appreciated that even if the powder has not segregated prior to the pneumatic conveying pipeline itself, the interface at the receiving hopper could give rise to segregation effects itself.

The segregation effects resulting from the filling techniques shown above are:

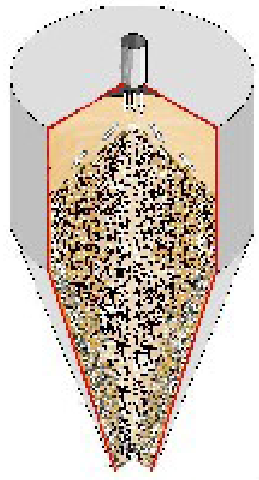


Figure 4: Fines concentrated in the central region, lack of fines evident at the periphery of the inventory - radial segregation.

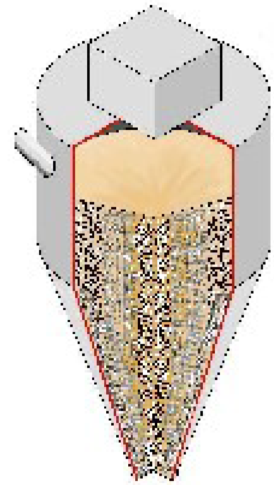


Figure 5: Fines concentrated around the periphery, lack of fines in the center (this effect is dependant upon particle characteristics and velocities) - radial segregation.

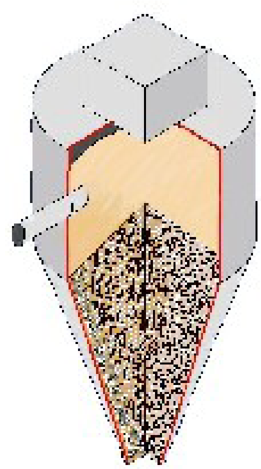


Figure 6: Fines evident on one side of hopper, coarser material apparent on opposite side (material build up through impact on opposite side of hopper can also be evident for some types of particles)

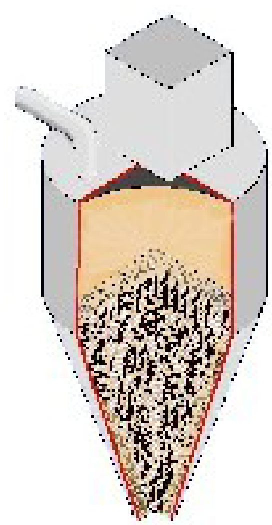


Figure 7: Excess of fines in top layer of inventory caused by “blast” effect of conveying line generating a cloud of fines that settle, lack of fines in lower section of inventory - stratified segregation.

Having briefly examined the segregation effects caused by filing a vessel, we will now look at segregation effects exacerbated by the emptying or interfacing to a system.

Any type of feeder that draws material preferentially from a vessel will revert that vessel to a core flow discharge pattern (see Figures 8a & 9a). Thus, careful consideration must be given to the overall scheme of the proposed conveying system and associated hardware.

The interface diagrams show:

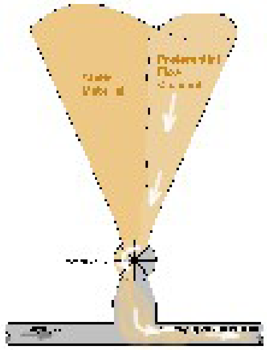


Figure 8a: Direct rotary valve installation resulting in a preferential draw (core flow)

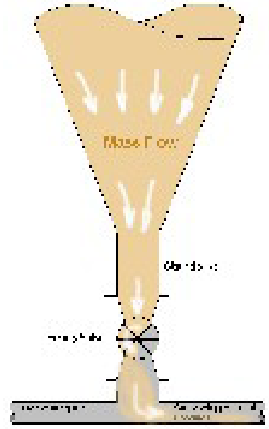


Figure 8b: Rotary valve installed with stand pipe to allow flow channel development to full outlet area (mass flow)

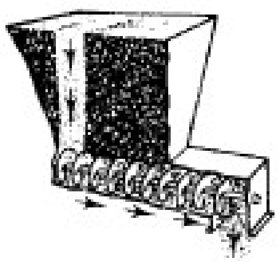


Figure 9a: Constant pitch screw giving preferential flow channel (core flow)

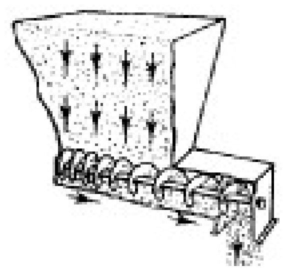


Figure 9b: Increasing capacity screw drawing from the full outlet area (mass flow)

It is very important to note that the above examples will only give mass flow if the hopper to which the discharger is installed has been design with appropriate geometry for this flow pattern to develop for the material being handled.

In terms of impact of the conveying line itself, the length and geometry of the conveying pipeline does not have a significant effect upon the extent to which the quality of a blended powder varies between the feed and discharge points of the conveying pipeline.

Dense phase conveying systems, by virtue of the pipeline being full of particles, are less likely to cause segregation. Since the particles are closely packed, they have less freedom being constrained by their neighboring particles and hence the propensity for the fines to be separated from the coarse fractions is minimized.

With lean phase systems the particles are widely dispersed and are free to move relative to their neighboring particles, and hence segregation is more likely to occur. However, it is the experience of the author that very few instances have been reported whereby the act of conveying the powder has caused segregation to occur within the pipeline itself.

It is hoped that this very brief overview of segregation effects commonly encountered in industry (and commonly associated rightly or wrongly with pneumatic conveying systems), will enable engineers faced with quality related problems to appreciated the holistic approach which is often required to address these issues.

For further information or advice on powder, contact:

The Wolfson Centre for Bulk Solids Handling Technology
The University of Greenwich.
Tel: +44 (0)20 8331 8646
Fax: +44 (0)20 8331 8647
e-mail A.N.Pittman@gre.ac.uk
URL: www.bulksolids.com

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Welcome to Ask Joe!, a monthly column by our resident materials handling guru, Joe Marinelli of Solids Handling Technologies. Joe addresses the issues that bug you the most. And Joe knows!! Formerly with Jenike & Johanson, Solids Flow and Peabody TecTank, Joe is an expert on materials handling.

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