Bulk Solids Innovation Center
Journal

KANSAS STATE UNIVERSITY | Bulk Solids Innovation Center

CHEMICAL PROCESSING

July 2020

Center Focuses On Industrial Issues

The need for research led to a facility with several unique characteristics

Prolong the Life of Material Handling Equipment

Troubleshoot Your Feeder for Optimal Performance

PutmanMedia®

Bulk Solids Innovation Center Journal

Editor in Chief
Mark Rosenzweig
mrosenzweig@putman.net

Executive Editor
Todd Smith
toddsmith@k-state.edu

Associate Editors
Raju Dandu
rdandu@k-state.edu

Kevin Solofra
solofra@k-state.edu

Contributing Editor
Tom Blackwood
tblackwood@putman.net

Art Director
Jennifer Dakas
jdakas@putman.net

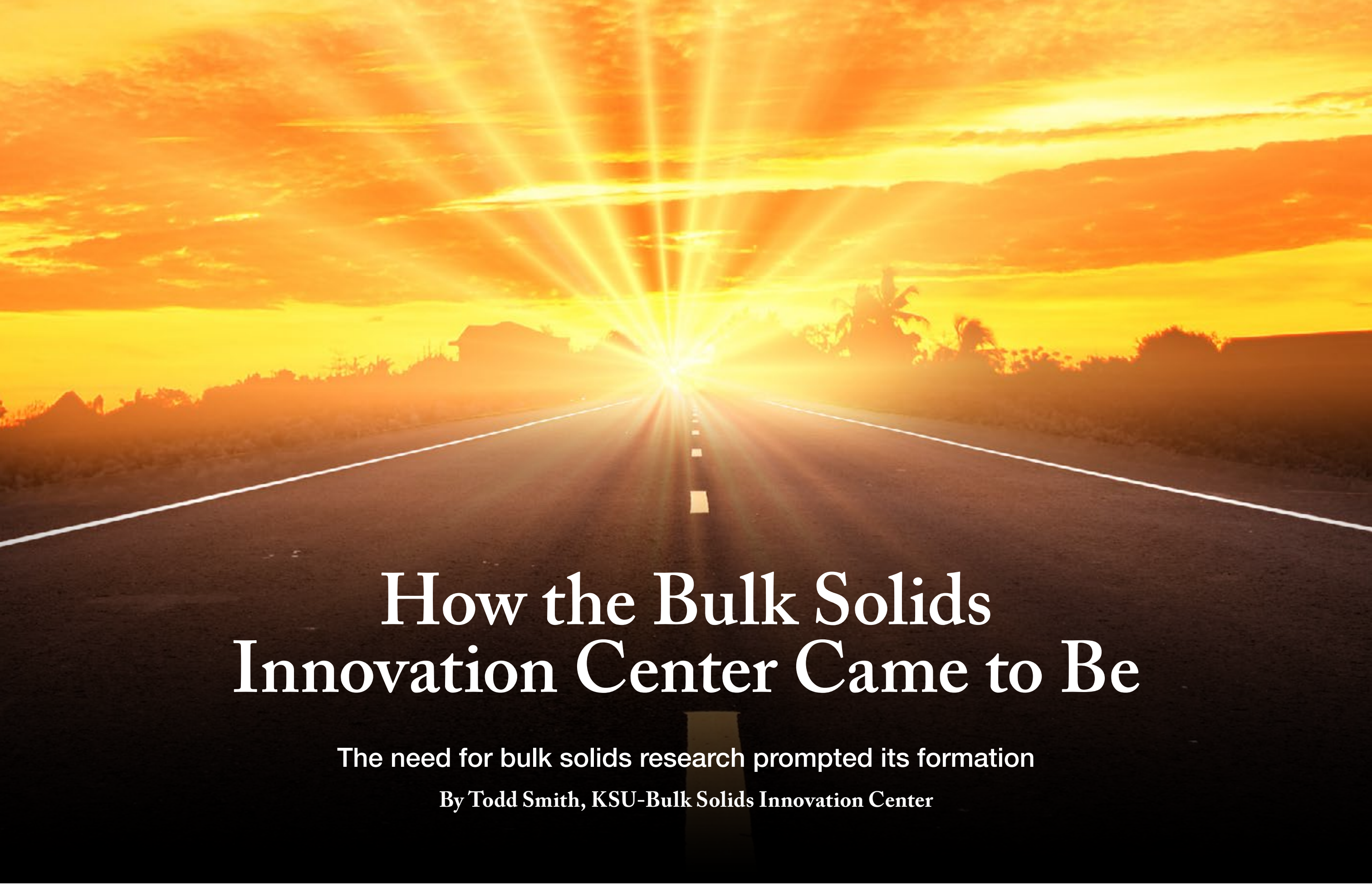
Production Manager
Daniel Lafleur
dlafleur@putman.net

Publisher
Brian Marz
bmarz@putman.net

Bulk Solids Innovation Center Journal is published jointly by the Kansas State University Bulk Solids Innovation Center, 607 N. Front Street, Salina, KS 67401, and Putman Media, 1501 E. Woodfield Road, Suite 400N, Schaumburg, IL 60173.

CONTENTS

AD INDEX



How the Bulk Solids Innovation Center Came to Be

The need for bulk solids research prompted its formation

By Todd Smith, KSU-Bulk Solids Innovation Center

Everyone who has worked with bulk solids knows that they are a challenge and are much less predictable than liquids or gases. By comparison, pump and piping systems for liquids and gases are simple. They are so straightforward that you can measure a couple of variables and then use equations from your high school chemistry class to figure out the sizing requirements.

The same is not true for bulk solids because they have so many important variables, not just two. Moreover, the importance of those variables changes with the material and application. Methods that work with one material don't work with another and may not even work in the same process if environmental conditions change, if you try to run it in a different season of the year, or if you change material vendors.

Determining which variables and material characteristics are most relevant when designing a system for bulk solids depends on the industry and environmental factors as well as whether you are focusing on material at the beginning, middle or end of the process.

Because 80% of everything we use is, or has been, a bulk solid at some point, the challenges are widespread. Issues with bulk solids affect most manufacturing plants. What's more, projects dealing with bulk solids are several times more likely to have startup issues than projects handling liquids or gases. And a year after startup, they are up to 10 times more likely to still have some residual problems with basic aspects such as reliability and achieving desired flow rates.

Why is bulk solids handling not taught in most engineering classrooms? Maybe it is because it is so complex and therefore not so well understood!

BEGINNINGS OF THE BULK SOLIDS INNOVATION CENTER

Approximately a dozen years ago, in early 2009, a group of people in the bulk solids industry were discussing the industry's needs. We all realized that not enough progress

was being made to eliminate the issues that arise when handling bulk solid materials. Furthermore, we realized that the issues were bigger than any one company or even one industry could address. It would require a unique collaboration of industry, academia and government participation.

Early discussions about a bulk solids research center involved lunch meetings with three individuals: one each from industry, a university and the local chamber of commerce. Industry was the most familiar with the needs and shortcomings but often was too focused on a short-term problem or project of the day rather than in making a long-term investment that would provide solutions over time.

The university was just the opposite. It offered more rigorous and robust research methods for addressing technical issues but knew little about practical aspects of what works and what doesn't in real industrial applications.

The third member, the chamber leader, brought yet another essential strength: He knew how to network with all the other groups and had the contacts to help make it happen.

Everyone agreed that a joint project was a great idea. But how could each group be convinced, as each party had different needs and goals? Most important, how could the project take advantage of each entity's strengths to realize all of the synergies that could be achieved by working together?

Not enough progress was being made to eliminate issues.

FUNDING AND SETUP

One of the challenges was funding. Some of the help came from government. In fact, the U.S. Department of Commerce Economic Development Administration, State of Kansas Economic Development and the City of Salina together contributed approximately 30% of the total funding for the project. The project never would have occurred without their critical support. But none of those entities had ever heard of bulk solids or understood any of the issues, so they required a lot of explanations and convincing!

The remainder of the funding came from industry. While some companies needed to be persuaded through ongoing discussions, many other company leaders heard about the project and asked, "How can we help?" and "What do you need from us?" The result was wonderful: 26 industrial companies donated equipment, money or services to make BSIC the best-equipped research center in the world for bulk solids.

All of these companies realized that the Center can help them and their industries. Best of all, many still are contributing regularly in the areas of financial support, equipment supply and maintenance, teaching courses, input, consulting and

sending people to classes. The Bulk Solids Innovation Center could not function well without them.

The university has been a key partner throughout the effort. In addition to becoming the anchor tenant (the facility is owned by Salina Economic Development Corporation), the university understood building requirements and knew how to establish consistent and safe research and laboratory practices. And we were able to take advantage of already-established procedures for setting up and handling proprietary information, ownership of intellectual property, short-course education classes, online education and publicity such as website development.

Finally, the university came through on its commitment to provide researchers, staff and student interns who could perform high-quality research and consulting in an unbiased and professional manner. No other entity but a university could provide an independent, nonprofit source for long-term applied research, education and technology improvement.

CURRENT STATE OF THE K-STATE BULK SOLIDS INNOVATION CENTER

The resulting facility is the best one of its kind for studying and improving our handling of bulk solids. The two-story building, which measures 13,000 sq. ft., houses six laboratories for university and industry-sponsored research; training, education, conference and lecture rooms; a material properties test lab; and a full-scale test bay. Even more important, the Center is filled with state-of-the-art equipment, systems, instruments and controls for handling and studying bulk solids.

The Center opened in June 2015. Since then, hundreds of problems and projects have been considered. Dozens of short courses have been taught, with nearly 1,000 participants from almost every state in the nation, as well as eight other countries. Students from industry have come from many backgrounds, including engineering, sales, maintenance, operations and accounting. All of them have gained information to help them run their processes and businesses better.

The BSIC has taught and employed many undergraduate engineering interns who now will be ready to go out in the real world, i.e., industry, with the considerable advantage of being familiar with bulk solids technology and terminology. Research challenges, along with materials and testing requests, have come from many industries, including food, beverages, animal and pet food, pharmaceuticals, plastics, chemicals and minerals.

The Kansas State University Bulk Solids Innovation Center is thriving in its role. BSIC is the only facility of its kind in the Western Hemisphere and the only university-centered facility dedicated to research and handling of bulk solid materials. All of this is making it extremely interesting and fun for the Center's personnel. Keep those projects and challenges coming!

TODD SMITH is Business and Strategy Manager at KSU-Bulk Solids Innovation Center. He can be reached at toddsmith@k-state.edu.

What Is Unique About the Bulk Solids Innovation Center

Several important characteristics distinguish the center

By Todd Smith, KSU-Bulk Solids Innovation Center

The Kansas State University's Bulk Solids Innovation Center offers a variety of unique services for clients looking for assistance with their bulk solids challenges.

MATERIAL TESTING SERVICES

The BSIC houses an array of important equipment to test bulk solids materials (Figure 1). More important, we know which tests to recommend and how to interpret the results for many applications. When standard tests aren't the answer, we can determine which parameters are most critical for your process and then develop customized test methods specifically for your use.

SHORT COURSES

Bulk solids handling is one of the most common practices in industry, but it is not taught at most colleges. Therefore, short courses for industry are the best option. At BSIC, students receive a lecture about the topic from some of the country's experts (Figure 2). Then, unique to the BSIC, students participate in actual material testing demonstrations to determine how different material characteristics affect the theory they learned in class.

Testing

Figure 1. A variety of equipment is available for testing purposes. Customized testing also is available.

Lectures

Figure 2. Educational opportunities abound when students attend lectures by industry experts.

Hands-On Demos

Figure 3: Students can see how theories they learned in the classroom are applicable to real-world situations.

They then go out into the full-scale lab to find out whether the real world matches the model (Figure 3). They get to experience the equipment first hand, learning through seeing, feeling and hearing it as it operates. Our hands-on demos are the favorite part of every course. If standard courses aren't what you are looking for, then we can offer custom education either at your place or ours.

Research And Consulting

Figure 4. The Center is equipped to help clients with research and consulting needs, from resolving existing problems to carrying out trial runs of new processes

FULL-SCALE RESEARCH AND CONSULTING SERVICES

Where else can you experiment and improve your methods without shutting down your own process? We have the space, equipment, instrumentation and staff ready for a variety of projects (Figure 4):

- Troubleshoot and resolve process issues such as flow, wear, rate, breakage, quality, mixing, segregation and filtration.
- Scale up from lab scale to pilot plant, or from pilot plant to full production, without shutting down your plant.

- Make trial runs. Try different process parameters or recipes without stopping production.
- Evaluate different product formulations to find out how they will affect your process.
- Resolve problems that are harming your customers.

You must evaluate several key product performance factors.

If you make or buy equipment, evaluate product performance factors such as efficiency, rate, energy use and pressure drop.

OUR FACILITY

The BSIC (Figure 5) has six laboratory rooms available for use by the university or industrial sponsors. Bench-scale equipment is set up in a couple of rooms, while full-scale equipment is set up in the large bay, ready with hoppers, chutes, air filtration, dust collection, conveying, scaling, instrumentation and a silo. A variety of equipment already is in place, and we have the ability and know-how to customize equipment when needed.

Facility

Figure 5. The Center is equipped with lab rooms and a variety of equipment.

PERSONNEL

The staff at BSIC has experience with a variety of industrial applications, including food, beverages, chemicals, minerals, plastics, animal and pet food, pharmaceuticals, ceramics and recycling. They have visited and worked with hundreds of industrial clients. Additional staff members bring decades of academic experience, including teaching, research and laboratory testing. The combination of industrial and academic experience lets you benefit from the best of both worlds.

TODD SMITH is Business and Strategy Manager at KSU-Bulk Solids Innovation Center. He can be reached at toddsmith@k-state.edu.

Powder Handling: Beware of Blending Myths

But first determine if blending really is required

By Tom Blackwood, Contributing Editor

The problem with particulate solids is they segregate every time we turn around. Why? Because they are a two-phase material and only about half is the solid we're interested in. In my days as a troubleshooter at corporate engineering, the most common call I got from plants was about blenders that didn't blend. The problems arose because people believed some myths.

The most common myth is that increased blending time results in a better blend. One of our customers mixed an inert ingredient with our product in a ribbon blender. Prior production with a different active ingredient gave an acceptable blend in 15 minutes — so the customer used that time for the new product. The resulting mix was highly variable in composition. To compensate, the plant increased the blend time to a half hour and then an hour with no improvement. In fact, the mix got worse. We found that seven minutes gave a perfect blend. What happened was that friction with the inert ingredient caused a surface charge to develop on the new active ingredient; this friction was unexpected. Most materials reach a perfect blend in a very short period of time.

Another common myth is that all blenders are created equal. We made a catalyst by an extrusion process that gave a slightly variable particle size. The catalyst was to be put into very long tubes that had to have the same pressure drop; blending was believed to smooth the distribution so the pressure drop would be uniform. Without conducting any flowability tests, the plant opted for an available twin-cone blender with 45° walls. Even after changing blend time, the product came out in linear

order of size. Testing for angle-of-slide showed the 45° wall held the smaller particles and concentrated them on the top of the mix. Another twin-cone blender with a steeper cone and an internal ribbon solved the problem.

The idea that fluidization will mix solids well is another myth. Density and particle size determine how easily a material will fluidize or defluidize — a "Geldart" classification often is used as an indicator. Several ingredients were added to a blender that operated at very high speed to mix the materials. The speed was dropped to a crawl to aid in discharge. The mixture deaerated slowly and the ingredients separated almost in layers. All the ingredients but one were Geldart Group A. To demonstrate how the mixture responded, I put it in a graduated cylinder, which I shook. Then, I dropped into the mix a coin, which went all the way to the bottom. A half-hour later, I dropped another coin, which went half way down. It took two hours before I could drop a coin and have it stay on top. Jogging the blender (short fluidization times) and increasing the discharge speed maintained the blend and avoided segregation. In this case, fluidization was working well but keeping the solids fluidized was the real problem.

The most common myth is that increased blending time results in a better blend.

Many other myths exist involving agitator type, multiple ribbons and attrition in blenders. It's hard to mechanically move particulate solids without incurring some sort of damage, so it's often better to avoid blending. However, sometimes attrition in a blender can be put to good use. We had developed a new disinfectant product that outperformed our current offering. However, it was lighter and caused problems for the formulator. We added a twin-ribbon blender to the production line to slightly grind the product, which allowed the final material to match the density of the former product.

Not only dry blenders suffer from these types of problems. Crystallizers, solid/liquid mixers and conveyors can have similar issues. Particulate solids want to settle in a fluid whether gas or liquid, so always keep that in mind.

TOM BLACKWOOD is a Chemical Processing contributing editor. You can email him at TBlackwood@putman.net

Prolong the Life of Material Handling Equipment

A variety of techniques can prevent wear and abrasion

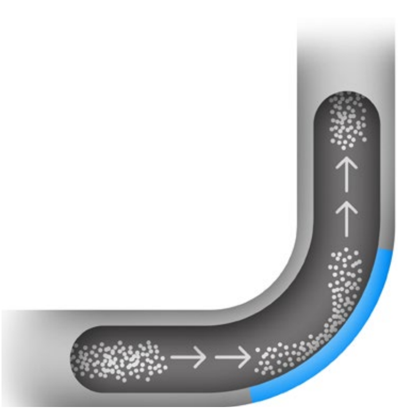
Austin Anderson, Vortex

Worldwide, there are thousands of dry bulk solid materials being handled — all with vast differences in material characteristics. Many materials also possess abrasive characteristics of varying complexities. To prolong the useful life and functionality of the components used to handle these materials, it is of utmost importance to equip slide gates, diverters and loading spouts with application-specific features to ensure their success when handling abrasive materials.

THE PHYSICS: CONVEYING ABRASIVE MATERIALS

Be it a gravity flow or dense- or dilute-phase pneumatic conveying application, the physics of dry bulk material movement will have dramatic impact on the degree of wear a system is subjected to. This necessitates assessing which system areas are more susceptible to material impact and designing the system carefully to protect these areas from rapid wear.

Generally speaking, a manufacturing process likely will realize its highest degree of wear in areas where material flow pattern or air pressure is subjected to dramatic change or disruption (Figure 1).



Wear-Prone Areas

Figure 1. An elbow in ductwork is prone to wear because material flow patterns can be altered.

This includes elbows in system ductwork, directional changes from diverting or converging, sudden halt in material flow, aspiration of displaced air and many other variables in system design.

Depending on application parameters, several techniques can be used to protect a system from rapid wear and abrasion.

HANDLING POWDER, DUST, GRANULES, PELLETS AND MODERATE ABRASIVES

Valve Construction Options. For abrasive powders, pellets and granules — such as sugar, salt, chemicals and others — 304 and 316L stainless steel options are available to provide a valve with appropriate abrasion resistance. Another way to address extreme abrasion is to construct the inlet and outlet weldments from schedule 10, 20, 40 or 80 pipe,

A-Style Diverter

Figure 2. This style diverts similar material quantities toward each destination.

K-Style Diverter

Figure 3. Use this diverter when most of the material is going to one destination.

depending on the application and material handled. In some instances, this option provides customers with the dual benefits of increased abrasion resistance and better match-up with an existing system.

Straight Leg Diverting. In traditional (A-style) diverters, rapid abrasion and wear are concerns because as materials flow through the inlet, they often make direct impact where the outlet legs meet. In flap-style diverters, this form of abrasion can cause significant damage to the blade shaft and to the outlet legs. For pneumatic conveying diverters, this form of continuous abrasion will wear rapidly through the valve's inlet, leaving holes in the valve body. If left unaddressed, holes in the valve body will facilitate material leakage and, in pneumatic conveying applications, air loss.

Ceramic Backing

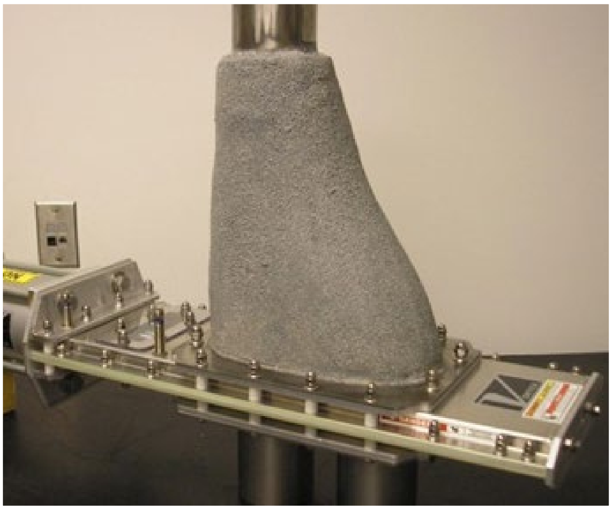
Figure 4. Using a ceramic coating helps to protect a diverter's inlet weldment when that weldment is subject to wear from material flow. It is particularly useful when used in dilute-phase applications.

To avoid continuous abrasion to the inlet, diverters often are constructed using a straight leg (K-style) design. The K-style diverting design is preferred because it allows a straight-through channel for material flow. This design also prevents the outlet legs from meeting in the direct path of travel as materials flow through the inlet.

Generally, A-style diverters (Figure 2) are used when similar material quantities are being diverted toward each destination and K-style diverters (Figure 3) when the majority of material is being routed toward a single destination. Opinions on this concept differ, so it is advised to consult with industry professionals to determine which design is most suitable for use in your specific application.

Ceramic Backing. Most beneficial in pneumatic conveying applications, ceramic wrappings can be used to protect from continuous wear and abrasion, which is typical when materials are conveyed in dilute phase.

The purpose of ceramic backing (Figure 4) is to offer additional protection for a diverter's inlet weldment in applications in which material flow will create substantial wear to the weldment itself. Ceramic backing helps so that when materials abrade through the steel, thick layers



Pneu-Wear

Figure 5. This epoxy-based coating protects a diverter's inlet weldments from fine particle abrasion only.

Read the case studies below on Vortex solutions and their enhanced reliability and life cycle in abrasive applications.

- **Case Study: Wye Line Diverter Handling Polymer Pellets**
  https://www.vortexglobal.com/wye-line-diverter-handling-polymer-pellets/
- **Case Study: TLD Diverter Handling Wood Chips & Saw Dust**
  https://www.vortexglobal.com/tld-diverter-handling-wood-chips-saw-dust/
- **Case Study: Aggregate Diverter Handling Industrial Sand**
  https://www.vortexglobal.com/aggregate-diverter-handling-frac-sand/
- **Case Study: Loading Spout at Ash Grove Cement**
  https://www.vortexglobal.com/loading-spouts-ash-grove-cement-plant/
- **Vortex Quantum Series**
  https://www.vortexglobal.com/quantum-valves/
- **Vortex Titan Series**
  https://www.vortexglobal.com/titan-valves/
- **Vortex Loading Solutions**
  https://www.vortexglobal.com/loading-solutions/
- **Vortex Engineered To Order Products**
  https://www.vortexglobal.com/engineered-solutions/

of ceramic remain, which maintains conveying line pressure and prevents material leakage. In essence, ceramic backing allows a valve to continue operations in the midst of abrasion, rather than constantly replacing components in troublesome areas.

The need for ceramic backing is application-specific. Depending on system setup, similar handled materials can react very differently when exposed to system configurations and air pressure.

Ceramic coating is a very calculated process. To avoid turbulence or friction against material flow (which could damage material or accelerate wear to the ceramic), the layers of ceramic are smoothed in the direction of material flow. On average, ceramic coatings will enhance steel durability for a 30-40% longer service life.

Pneu-Wear. Similar in purpose to ceramic backing, Pneu-Wear (Figure 5) is an epoxy-based coating that is applied to a diverter's inlet weldment to provide greater abrasion resistance. It is designed to protect equipment from fine particle abrasion only; the coating is less effective when handling larger material granules.

HANDLING HEAVY-DUTY AND ABRASIVE MATERIALS

Valve Construction Options. In heavily abrasive applications such as industrial sand, cement, limestone, glass and fly ash, a valve's body and material contact areas often are constructed from carbon steels and other abrasion-resistant steels. Several gauges of steel exist, so when selecting valve construction materials, it is important to assess handled material characteristics and determine which Brinell hardness number (BHN) of steel is most appropriate for withstanding the abrasion of certain handled materials.

Angle of Diverter Outlet Legs. In gravity flow applications, certain materials achieve optimal

flow rates if they are processed through a diverter with steeper, more dramatic outlet leg angles. The flowability of materials has much to do with the material's bulk density and can also play into wear and abrasion's severity.

If a diverter has more subtle outlet angles (approximately 45° from vertical), material velocity will slow, causing materials to "drag" along the bottom of the diverter as they flow through.

However, steeper angles (approximately 30° from vertical) typically are used to flow heavier, denser materials such as aggregates. With steeper outlet angles, material can suspend and flow freely through the channel, which reduces the likelihood of in-line material build-up or material plugs. Additionally, when materials are suspended, the diverter makes little contact with materials and thus is subjected to less wear and abrasion.

In essence, equipping a diverter with the outlet angles necessary to achieve optimal flow rates can reduce need for maintenance and prolong a valve's useful life.

Abrasion-Resistant Liners. In flap-style and bucket-style diverters, the valve's inlet and outlet legs can be fitted with replaceable abrasion-resistant liners. Abrasion-resistant liners often are made from abrasion-resistant steels (Figure 6), chromium carbide or UHMW polymer (Figure 7). While the diverter body may be capable of handling abrasion, abrasion-resistant liners allow materials to abrade upon replaceable parts rather than the body itself, which significantly extends the diverter's useful life. For return-on-investment purposes, abrasion-resistant liners are of great value because they are the difference between maintaining replaceable parts or replacing a whole diverter.

Abrasion-Resistant Liners

Figures 6. This liner is made with an abrasion-resistant steel.

Figure 7. Chromium carbide or UHMW polymers also can be used.

Rock Box Blade Design

Figure 8. he "rock box" blade design, also known as a honeycomb design, decreases wear by letting materials accumulate such that material impacts on itself as it flows instead of on the diverter.

"Rock Box" Blade Design. A honeycomb ("rock box") design (Figure 8) allows materials to accumulate in specially designed areas at the inlet, on the blade and on the outlet legs so that as material flows, it impacts upon itself instead of abrading upon the diverter's mechanical parts continuously. This decreases wear and prolongs a diverter's useful life.

Diverters that feature removable wetted parts and an external access panel allow for ease of inspection, maintenance or repairs to be made without removing the diverter from service. Even so, the honeycomb design makes diverter maintenance a much less frequent process.

LOADING SOLUTIONS — SPOUT CONE CONSTRUCTION

To ensure a sturdy, reliable material flow, loading spouts intended to handle abrasive materials can be equipped with stackable cones constructed from abrasion-resistant steels, such as Hardox (BHN 400). In doing so, cones are less susceptible to rapid wear and abrasion, which otherwise could lead to metal contamination, loadout inefficiencies and downtime for frequent maintenance of worn cones.

Various grades of abrasion-resistant materials available for cone construction. However, in some applications, it may be more cost-effective to use cones constructed from lesser-grade abrasion-resistant materials, while planning for periodic cone replacement.

WHICH TECHNIQUE IS MOST SUITABLE FOR YOU?

Selecting proper equipment is critical to the success of any manufacturing process. Misapplied components and deficient designs can cause unexpected maintenance costs and process inefficiencies that negatively impact a company's overall profitability and performance.

AUSTIN ANDERSON is the Content Manager for Vortex. You can email him at austinanderson@vortexglobal.com.

Understand the Key Role of Bulk Solids Testing

Getting suitable data underpins success in material handling

By Raju Dandu, KSU-Bulk Solids Innovation Center

Advance understanding and testing of bulk solids material properties is necessary when specifying, designing and operating material handling systems. Testing solid materials at a facility that has both lab-scale and full-scale pilot test capabilities can help in designing efficient systems and preventing costly mistakes. Conveying conditions of solid materials change from day to day or week to week because of material property variability — whatever the cause. This impacts successful solids handling operations.

As such, material properties testing is vital so you know the characteristics and behavior of solids (powders, pellets, granules). Several properties influence material behavior, but we will focus primarily on key properties that are essential for design and operation — bulk density; particle size analysis; cohesive strength; wall friction; flow characteristics; and operating parameters such as pickup velocity, air mass flow rate, solids flow rate and pressure drop.

IMPORTANCE OF MATERIAL PROPERTIES

Handling bulk solids is an important process in industries such as chemical, plastic, mineral and food. Handling usually refers to conveying from one process to another, transit, storage, shipping, loading and unloading. One of handling's most common problems is insufficient flow rate, that is, less material flow in the system than intended.

In addition, material flow behavior sometimes can change because of slight variances in a process environment, such as the relative humidity or temperature of ambient air. More important, changes can occur in the material itself, such as particle size distribution, mean particle size, particle shape and roughness, and even a change in the chemical formulation that alters the material's electrostatic properties. Most common flow problems are no-flow or erratic flow, and some of the reasons for these problems are ratholing, bridging (arching) and caking.

Further, the flow problems will cause throughput variation-based plant downtime, equipment failure and material rejects. When we do a quick analysis of these

problems, we may find that empirical knowledge was used in the design of bulk solids handling systems. Some of the difficult material may not flow well in the hopper, bin, silo or conveying lines if it is not designed properly. This may lead to insufficient flow rate in the system.

Many of the system and equipment design procedures and accompanying knowledge belong to original equipment manufacturers (OEMs) and engineering consultants, and these tend to be protected as part of their business. As per the RAND report, only 30% of dry bulk solids handling processes run successfully after installation for the first time. The remaining 70% of the time, companies have to retrofit and modify them to make them work, which is a significant loss of money and time.

Material and flow characteristics will have a major influence when specifying and designing a material handling system of a specific material. The key to reliable and sustainable handling of bulk solids materials is in specifying, designing and operating based on measured material, flow and conveying properties of that material. These tests performed in advance should be part of the routine engineering process for successful and reliable design and for operation of material handling systems.

KEY PROPERTIES AND TYPES OF TESTS

The first step in designing material handling equipment is to measure the properties that influence the material flow. This involves testing a material's physical properties and the equipment used for handling and storing the material. Particle properties such as size and shape; density; friction between the particles; and bulk properties such as bulk and tap density, particle size distribution, angle of repose and cohesive strength are some of the common properties that interest equipment and system designers. Therefore it is important to be familiar with the following common flow properties terminology.

Density. Bulk solids have two types of densities — bulk (loose/poured) and tapped. Bulk density is determined by the mass of bulk material divided by the graduated cylinder volume it occupies. The tapped density is the bulk mass divided by the mechanically tapped graduated cylinder volume it occupies.

Particle size, shape and size distribution. Particle size distribution refers to a list of particle size values used to illustrate the relative amount of particles sizes in a sample of a particulate material to be measured.

Internal Friction. This is conditioned by solid particles moving against each other and is characterized by the angle of internal friction and the effective angle of internal friction.

Cohesive Strength. This is a measure of the strength a powder retains after it has been compacted to a given consolidation level. It also indicates a bulk material's resistance against failure or flow.

Wall Friction. This type of friction is the sliding of particles along a particular wall surface finish and is expressed as wall friction angle.

These material flow properties can be measured using lab-scale instruments. Further, to design pneumatic conveying in a dilute- or dense-phase system while ensuring satisfactory operation and achieving maximum efficiency, it is important to know the material's conveying characteristics.

The two types of pneumatic conveying are dilute phase and dense phase. The systems' performance characteristics are given in the phase diagram.

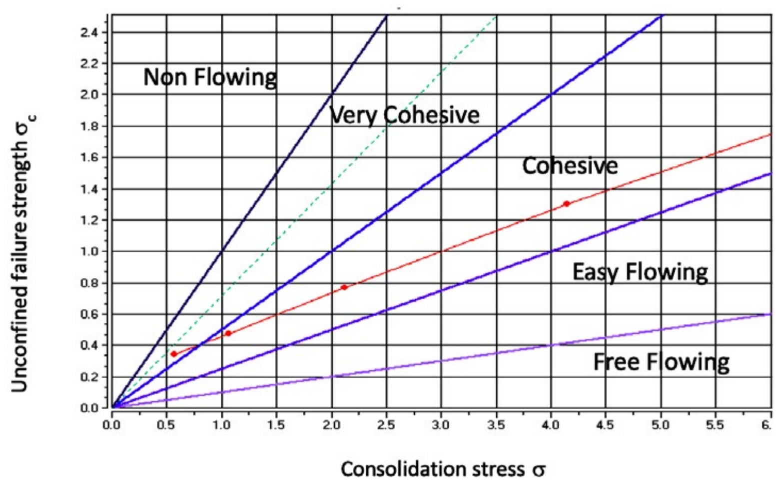
For a particular feed rate, the pressure drops change for various

pick-up velocities. The system design is complex, so the parameter feed rate, pressure drop and optimal pick-up velocity are needed to design of a pneumatic conveying system effectively. Without full-scale pilot testing, the system could be over- or underdesigned. Underdesign leads to blockage, while overdesign leads to energy waste

The conveying characteristics depend on pipe size, conveying distance, available pressure, conveying air velocity and material properties. These characteristics will help designers or plant operators identify required minimum air velocity, expected material throughput and optimal running conditions. If previous material conveying history is available, that provides a baseline when designing new systems or making modifications to existing systems.

If there is no prior history of these characteristics, then it is necessary to conduct pilot testing trials of the materials. These pilot tests will provide information on minimum pickup velocity and expected system performance. This requires understanding some basic velocity terminology.

Saltation velocity is the gas-conveying velocity below which the particles start to settle at the bottom of horizontal pipes.



Flow Function

Figure 1. Bulk solid flowability is characterized by flow function as a ratio of consolidation stress to unconfined failure strength. The boundaries of the ranges of flowability are shown as straight lines and the red line is the flow function of a tested powder sample.

Pickup velocity is the gas velocity at the conveying system's pickup point (solids loading point) where the solids are fed into the conveying gas stream.

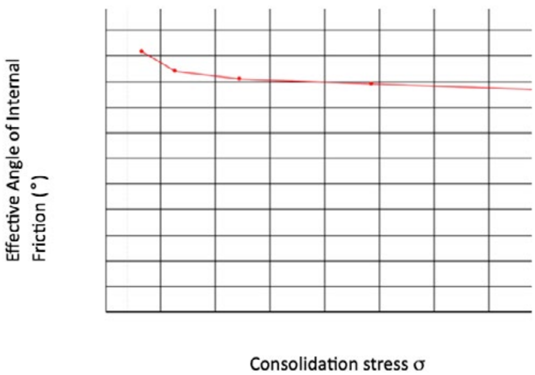
Choking velocity is the air-conveying velocity below which the solids being conveyed starts to settle at the bottom of vertical pipes.

WHY TESTING CAN HELP AND HOW THE RESULTS ARE USED

Understanding the need for material flow and optimal conveying characteristics will help address costly material handling problems. When evaluating the equipment and system, it is vital to replicate actual or expected process and operating conditions. These tests are specific to a plant's equipment, taking the sensitivity of equipment performance to variability of material properties.

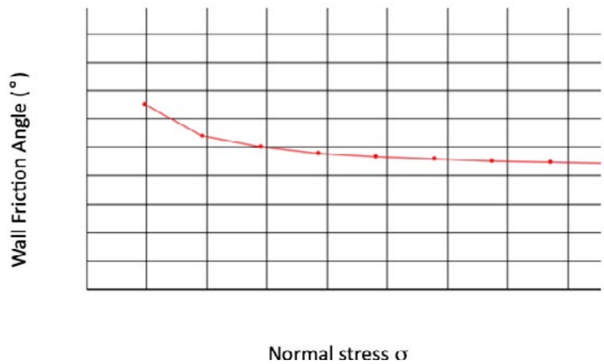
Shear cell and powder flow testers are used to measure cohesive strength, flow function, internal friction and bulk density of materials. Cohesive strength is used to calculate a bin's minimum outlet size to prevent flow problems caused by arching (bridging) and ratholing for a specific material. Also, potential impact of material time storage issues can be identified by conducting similar flow tests with time consolidation.

Flow function tests are used to characterize the relative cohesive strengths of powders and flow behavior of powders at low and high consolidation strengths. Measured data of flow function is used to understand powder gravity flow behavior through hopper and bins (Figure 1).



Internal Friction

Figure 2. This chart shows the relationship between bulk solid internal friction angle and consolidation stress. It indicates that the internal friction is higher at low consolidation stresses.

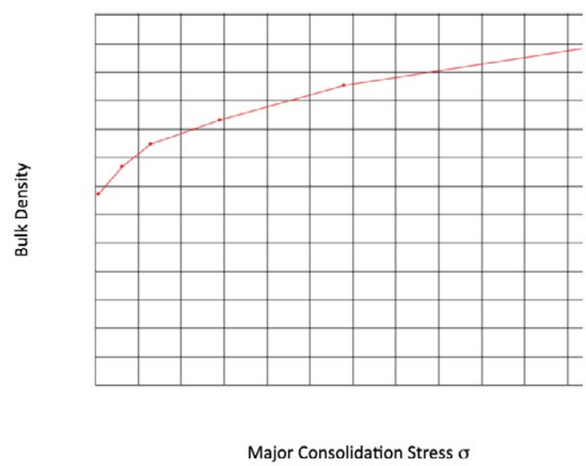


Wall Friction

Figure 3. . The wall friction angle varies with normal stress, decreasing with increasing normal stresses.

Measured internal friction caused by particles of material flowing against each other at increasing consolidation stresses gives an understanding of shearing among particles and the cohesiveness of the material. Also, the internal and wall friction values are used for calculating hopper angles to prevent flow problems (Figures 2 and 3).

Bulk density or compressibility data is useful in designing optimal material handling systems; determining storage capacity for process; and for calculating stresses in hoppers, bins, and pressure vessels. Free-flowing powders show a small change and cohesive powders a large change in bulk density between initial fill and final consolidation (Figure 4)



Density

Figure 4. Major consolidation stress affects bulk solid density, with density increasing with higher consolidation stress.

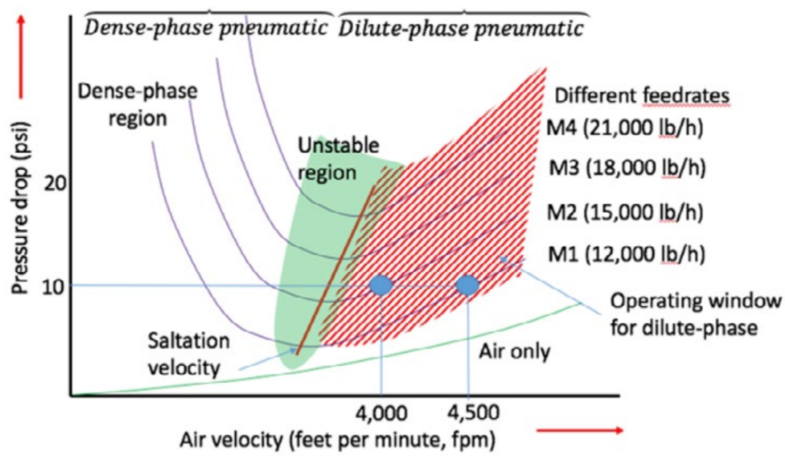
In addition to flow characteristics, the pneumatic conveying system plays an important role in material handling systems. Despite several systems being designed and operational, there are still conveying characteristics that remain open issues. Conducting full-scale tests replicating the operational environment is necessary, and the phase diagrams can provide vital information relating pickup velocity and pressure drop.

The overall system design is complex, and the theoretical calculations provide a baseline of system performance. The phase diagram information is used for understanding flow patterns, optimal system performance, throughput and cost savings (Figure 5).

For a set material feed rate and pickup (air) velocity, the system pressure drop of actual conveying process can be measured to plot a system phase diagram. Determining the pickup velocity is challenging and needs to be determined by trial runs. In the conveying system, material moves from higher

pressure to lower pressure, and the pickup velocity increases from the feed point to material exit. Pickup velocities usually are 20% more than the saltation velocity at the material feeding point. Pickup velocity depends on material properties such as particle density variation, particle size distribution and solids loading ratio.

With pilot testing, we can determine for a particular feed rate the drop in pressure, pickup velocity and the material conveying issues. Testing will help to study optimal system performance at different pickup velocities and feed rates. It is always recommended to conduct tests and document conveying characteristics to maintain successful conveying operations.



Pneumatic Conveying Phase Diagram

Figure 5. The phase diagram shows the relationship between key operating parameters such as material mass flow rates (referred to as M1, M2, M3 and M4), air velocity and pressure drop of a dilute or dense phase pneumatic conveying modes.

Handling bulk solids is solving a wicked problem that is complex.

FINAL THOUGHTS

Whether you are specifying, designing or improving a poorly run conveying systems, conducting tests for flow properties and conveying characteristics will result in avoiding material flow problems; costly mistakes; increasing the sustainable, reliable and smooth operations. Always know your system or the system you need and identify the key properties that are important to operate your system efficiently. Remember, handling bulk solids is solving a wicked problem that is complex and cannot be addressed using only experience and existing broad-based knowledge. It needs continuous attention because the conveying issues can't be completely resolved.

REFERENCES

Schulze, D. 2008. Powders and Bulk Solids. Pub: Springer New York, USA

David Mills, Mark Jones, and Vijay K Agarwal. Handbook of Pneumatic Conveying Engineering. CRC Press, Taylor and Francis Group.

David Mills. 2016. Pneumatic Conveying Design Guide. Butterworth an-Heinemann (Elsevier).

McGlinchey, D. 2000. Characterisation of Bulk Solids. Pub: Blackwell Publishing Ltd, Oxford, U.K.

RAJU DANDU is the Director of the KSU-Bulk Solids Innovation Center. He can be reached at rdandu@k-state.edu.

BSIC Helps Chemical Company Solve Sticky Situation

Field failure pinpointed with no production downtime

By Kevin Solofra, Bulk Solids Innovation Center

The Bulks Solids Innovation Center receives a number of interesting and unique projects. We would like to share some that encompass issues and challenges that many companies face.

THE PROBLEM: INTERMITTENT FIELD FAILURE

A global chemical company with a fine sticky material wanted to replicate a field failure that occurred intermittently and resulted in costly downtime. It was unsure of which parameters in the process was the lynchpin for causing the failure. As with every other production process out there, the company could not afford to give up production time for any testing. This is where the BSIC was able to support its efforts and perform a variety of testing without interrupting standard production. The testing ranged from material property tests to full-scale testing.

THE TESTING PHASE

Starting with small sample tests to characterize material properties, the BSIC investigated the potential impact of moisture on the material's properties, especially as it related to powder flow parameters. The test results then could be applied to the full-scale testing.

With the customer's support, equipment was set up to duplicate its production environment. This allowed testing to be performed mimicking the company's equipment with the ability to change and monitor parameters while attempting to duplicate the field failure. The full-scale lab equipment was able to control air pressures, air flow, moisture levels and equipment rates in various combinations.

In addition, weight consolidation was investigated using more than just the material weight. A mechanism was developed to put additional dead weight on the material during hopper storage. This combination of testing procedures enabled repeated replication of the field failure, allowing key parameters and target ranges to be identified.

With the field failure identified, the next phase was a hopeful path to eliminate these intermittent field failures. Using the same basic setup, the chemical company supplied new equipment it had been using for production. We tested this equipment at full scale and production speeds successfully, again without interrupting the company's standard production. The previously identified parameters also were applied to the new equipment successfully, avoiding the failure mode.

PARTNERSHIP YIELDS DESIRED RESULTS

Together, the two groups replicated the desired field failure through use of lab and full-scale testing. Even further, the partnership allowed for new equipment to be tested at a full production-level scale to prove effectiveness and determine appropriate run parameters. At the end of the process, the global chemical company and the BSIC have developed a partnership that we look forward to continuing and growing as more projects arise.

KEVIN SOLOFRA is laboratory manager for the Bulk Solids Innovation Center. He can be reached at solofra@k-state.edu.

Troubleshoot Your Feeder for Optimal Performance

Understand key factors affecting volumetric and loss-in-weight units

By John Winski, Coperion K-Tron

With the uncertainty of today's unprecedented times and tough global economy, the pressures for proper maintenance, increased longevity of process equipment and optimal performance are higher than ever before. Feeders that are not feeding accurately typically produce off-spec finished products and require extended periods of downtime to recalibrate or fix, resulting in decreased production rates and lost profits. In all industries, the improvement in accuracy performance by even 0.25% of ingredient feeding can result in significant overall profit yields.

Proper installation, ideal weighing configurations and appropriate choice of weighing controls can eliminate a variety of future feeder problems. For complex feeder systems (e.g., multiple loss-in-weight (LIW) feeders feeding powder and pellets into mixers or extruders), external influences such as vibration, platform stability and upstream/downstream equipment connections all can affect a feeder's performance. Knowing the significance of these influences is key to optimizing its performance. By training your operating and maintenance workers thoroughly and familiarizing them with effective troubleshooting and maintenance practices, a variety of these problems can be mitigated.

Feeders typically are engineered to address a specific material at a specific discharge rate. Changes in your material, operating conditions such as ambient or material temperatures, plant vibration levels and material characteristics all can affect feeder performance. Choosing a feeder that can be reconfigured easily in your plant to handle new conditions can help you solve these problems.

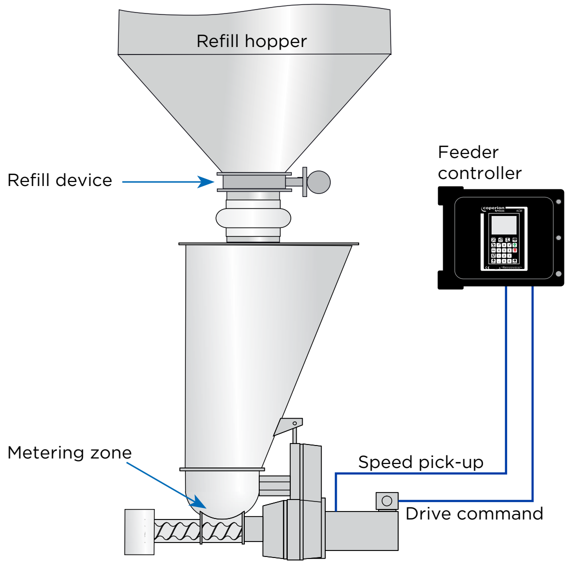
By definition, most feeders can be categorized as volumetric and gravimetric. This article will investigate both principles and review the significance of a number of parameters and their direct significance on feeder performance. The following sections discuss the operation of common feeder technologies and then explain how to optimize a feeder based on its operating principles.

VOLUMETRIC SCREW FEEDER PRINCIPLE OF OPERATION

A volumetric screw feeder (Figure 1) feeds a certain material volume per unit time (such as cubic feet per hour) to a process. The volumetric screw feeder consists of a hopper, material discharge device and controller. This is the most common volumetric feeder, and its material discharge device is a screw that rotates at a constant speed to meter material at a predetermined volume-per-revolution discharge rate from the hopper to the process. The controller monitors and controls the feeder's screw speed, which determines the material's discharge rate.

An optional agitation system located between the hopper and the screw can facilitate material discharge from the hopper. Various agitation systems and screw designs, sizes and geometries are available to suit your application.

Because the volumetric screw feeder cannot detect or adjust to variations in a material's bulk density, the feeder is most effective with relatively free-flowing, uniform-density materials, such as pellets, and in applications in which high feeding accuracy is not crucial.



Volumetric Feeder Principle

Figure 1 A volumetric screw feeder feeds a certain material volume per unit time to a process.

DIAGNOSING A VOLUMETRIC FEEDER

Volumetric screw feeder problems are relatively easy to diagnose. Most problems relating to the feeder's discharge rate stem from a faulty screw-speed control sensor (Figure 1) or motor drive, a change in the discharge rate's volume-per-revolution ratio or material flow problems from the hopper. Precise discharge rate control will be impossible if the feeder's screw-speed control sensor doesn't register the screw speed accurately (or at all). If the feeder's discharge rate is a problem, first check for loose sensor wiring and electrical connections. If the connections are sound, you may need to clean or replace the sensor. You easily can evaluate the sensor if the motor speed is stable.

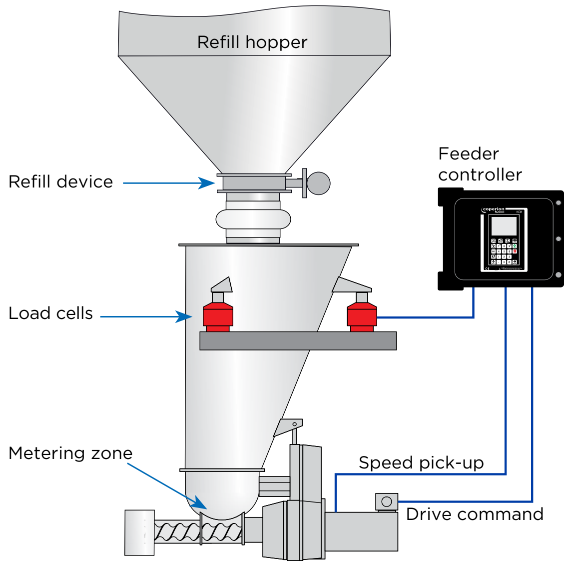
If the screw-speed sensor is not causing the problem, then the cause probably is a change in the discharge rate's volume-per-revolution ratio. Such a change typically is caused by material buildup on the screw or in the discharge tube or by a blockage in the hopper that prevents a consistent material supply to the screw. The buildup or blockage reduces the material volume that the screw discharges in each revolution at the constant screw speed.

An immediate, but temporary, remedy is to clean the screw, discharge tube or hopper — or all three. To permanently solve the problem, you may have to change the screw or hopper design or add an agitation system to help move material from the hopper to the feed screw. Coating or polishing the internal metal surfaces also may alleviate the problem, but consult your manufacturer for guidance.

THE BASICS OF LOSS-IN-WEIGHT FEEDING

Unlike the volumetric screw feeder, a loss-in-weight (LIW) feeder is a gravimetric feeder that measures the material's weight directly to achieve and maintain a predetermined feed rate that's measured in units of weight per time. The LIW feeder (Figure 2) consists of a hopper, refill device, weight-sensing device (typically either a digital or analog scale or load cells), material discharge device (typically a volumetric screw feeder powered by a variable-speed motor) and controller. Before operation, an operator programs the controller to discharge material at a predetermined feed rate (or setpoint) measured in units of weight per time (such as pounds per hour).

The bulk material or liquid is discharged from a hopper with a constant weight per unit of time by weighing the hopper and regulating the speed of the feeding device depending on the rate of weight loss.



Gravimetric Loss-in-Weight Feeder Principle

Figure 2. A loss-in-weight (LIW) feeder is a gravimetric feeder that measures the material's weight directly to achieve and maintain a predetermined feed rate that's measured in units of weight per time.

The weighing control system compensates for non-uniform material flow characteristics and variations in bulk density, therefore providing a high degree of feeding accuracy. When the hopper reaches a predetermined minimum weight level, the LIW control is interrupted briefly and the hopper is refilled.

With some manufacturers, during the refill period, the controller regulates the feeding device's speed based on the historic weight and speed information that was accumulated during the previous weight loss cycle. This prevents overfeeding of material during the refill cycle because of changes in headload of material and filling of material into the screws. This also is critical for maintaining feed rate performance within specification on a second to second basis. The LIW feeding principle is most accurate when using a high-resolution, fast-responding and vibration- and temperature-immune weighing system.

LIW feeder performance is dependent on three areas that are linked closely:

1. The feeding device's mechanical configuration and any material flow-aid used in the feeder hopper.
2. The weight measurement's accuracy and speed and the weighing system's immunity to in-plant vibration and temperature fluctuations.
3. The control algorithm's response and its available features.

VALIDATING THE MECHANICAL CONFIGURATION FOR LIW FEEDER PERFORMANCE

The mechanical feed device and its configuration are the starting point in any LIW feeding system and include feeders and vibratory trays:

Single screw feeders can be applied when feeding granular free-flowing materials. When running

at lower setpoints, single screw feeders may produce a pulsating discharge that will affect second-to-second performance. Some manufacturers have developed software to compensate for this pulsation and achieve consistent accuracy.

Twin screw feeders can be applied when feeding difficult-to-flow and sticky materials and reduces the pulsating discharge even at lower setpoint rates.

Vibratory trays are used for granular free-flowing materials providing a uniform discharge.

Single and twin screw feeders have different screw profiles and configurations that also can be tailored to the material being fed as well as the setpoint turndown requirements. The key is to select the proper feeder and configuration to give the most uniform and reliable volumetric feeding of the material. By doing this, the weighing and control system does not have to work as hard to provide optimal performance.

The same holds true for any flow-aid device that may be required in the feeder's hopper. This will assure that the process material flows into the feeding device as uniformly as possible. Stability of the feeding system allows for the weighing and control system to provide optimal second-to-second performance.

Several types of material flow aids are available:

1. Flexible side walled feeders gently agitate materials. However, they don't have stainless steel surfaces and may wear or create contamination concerns.
2. Mechanical hopper agitators stir the material and break down any bridging or rat-holing of the material. However, these devices require additional headroom for the feeder and may become a cleaning concern.

Smart Control Vibration Device

Figure 3. Coperion K-Tron ActiFlow Bulk Solids Activator gently promotes material flow in feeder hoppers.

3. A smart control vibration device such as ActiFlow applies vibration to the hopper using an external drive at a variable frequency and amplitude based upon the weighing and control system detecting nonuniform material flow by weight (Figure 3). This technique eliminates headroom and cleaning concerns and avoids process material compaction because only the necessary amount of vibration is applied to the material to assure uniform material flow.

SIGNIFICANCE OF THE WEIGHING SYSTEM ON LIW FEEDER PERFORMANCE

Any LIW process controller requires accurate high-speed measurement of material weight changes to provide optimal feeder control and performance, especially on a second-to-second basis. The weighing system also must be able to filter out erroneous measurements that plant vibrations or disturbances may cause and be stable over changes in process room or process material temperatures.

Two types of weighing technology typically are used in LIW feeders: analog strain gauge technology and

digital vibrating wire technology. The key is that the higher the resolution of weight measurement and the faster those weight measurements are taken, the better the information that will be provided to the control algorithm to work and the better any vibration-filtering algorithm will work. Almost all weighing systems provide temperature compensation. However it should be verified over your application's temperature range, as this can affect the long-term stability of the feeder performance.

TROUBLESHOOTING AND IMPROVING YOUR LIW FEEDER PERFORMANCE

Because the LIW feeder typically uses a volumetric screw feeder to meter material, many of the volumetric feeder problems and solutions in the previous section also apply to the LIW feeder. But as the LIW feeder's operation is based on the weight loss rate per unit time rather than the screw speed, the controller automatically compensates for material buildup on the screw or in the discharge tube or a blockage in the hopper by increasing the screw speed to maintain the setpoint.

The controller continues to increase the screw speed until the feeder reaches an alarm condition, such as when the screw speed exceeds the recommended operating speed. If an alarm condition occurs in your LIW feeder, check first for material buildup on the screw or in the discharge tube or a blockage in the hopper. Understanding and configuring your controller's alarm settings properly will allow users to perform preventive maintenance before to a catastrophic failure.

If you find no material buildup or blockage, check the hopper to ensure that it has material in it. If the hopper is empty, you then need to check the upstream material delivery system for a blockage or other malfunction. The LIW feeder's operation depends on accurate weight measurements of the material in the hopper, and vibration can impose artificial forces on the feeder that cause weighing errors.

To avoid this, isolate the feeder and weight-sensing device from any external vibration created by other equipment in your process. This requires installing the feeder so that the weight-sensing device is shielded from vibration effects. Do this by ensuring that the feeder has a stable mounting, using flexible connections and shock mounts and eliminating strong air currents near the feeder.

Vibration problems can result later from installing new equipment near the feeder or refitting the feeder's flexible connections improperly during maintenance. For example, if your LIW feeder has feed rate problems that appear to correlate with the operation of newly installed machinery or that occur after feeder maintenance, external vibration probably is affecting the weight-sensing device.

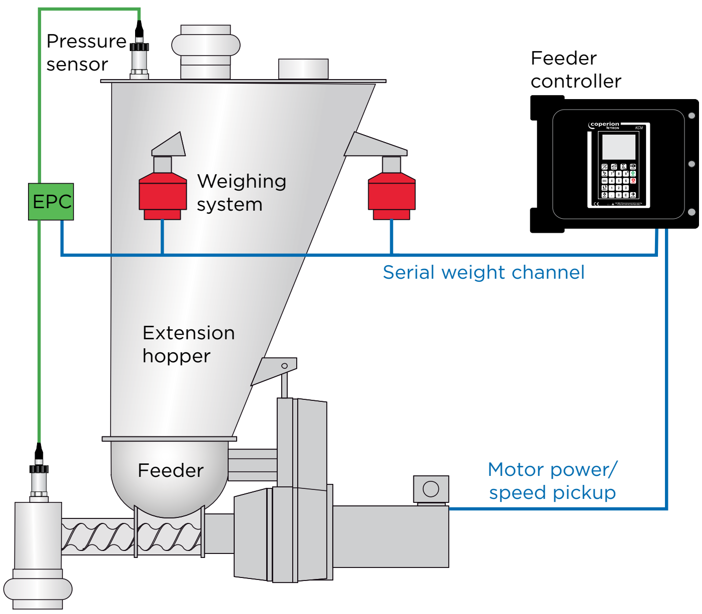
To solve these problems, make sure that the feeder and weight-sensing device are isolated from any vibration the newly installed equipment is creating. If the problems occur after maintenance, recheck the flexible connections to ensure that they're connected to the feeder properly.

The weight-sensing device itself can cause performance problems if you don't select it properly for your application. Carefully evaluate the weight-sensing device's capabilities — resolution, stability, responsiveness, weight signal integrity, vibration sensitivity, reliability, and data communications — before purchasing the LIW feeder. After installing your feeder, maintain its performance and find any problems such as drift (a gradual deviation from a set adjustment) as

early as possible by calibrating the weight-sensing device regularly.

Other performance problems can result from a defective refill device or a leaky seal at the feeder's discharge. If an automatic refill device loads material into the hopper, any leakage in the refill device at the hopper's inlet will produce a feed rate error because material will continue leaking into the hopper after the refilling process has stopped. This creates a weight loss rate change; the controller senses that not enough material is being discharged from the hopper. To compensate for this, the controller increases the screw speed to meet the setpoint, discharging more material per unit time.

Also, if the LIW feeder discharges material to a nonambient pressure environment such as a pressurized or vacuum conveying line, a pressure pulse (air leaking from the downstream system through the feeder's discharge tube to the weight-sensing device) can cause a feed rate error. A pressure pulse affects the hopper's instantaneous weight measurement by exerting a vertical force on the weight-sensing device opposite the hopper's downward force, in effect, slightly lifting it so that its weight reads less.



Electronic Pressure Compensation System

Figure 4.: Coperion K-Tron's solution monitors and compensates for pressure influences.

Traditionally the solution is a complex arrangement of pipes and flexible connections to compensate for known pressure differentials within the system. As an alternative to traditional mechanical compensation systems, instrumentation and control algorithms to monitor and compensate for pressure influences electronically can be supplied. An electronic pressure compensation system can be used to detect changes in pressure automatically within the feeder hopper or outlet tube and adjust the weight signal accordingly to compensate for any errors caused by pressure fluctuations (Figure 4).

AN OUNCE OF PREVENTION

You can do several things to prevent feeding problems and keep your feeders performing at peak levels. First, consult the feeder supplier to ensure that the feeder you choose can handle your material and process and then install the feeder correctly in your process. Finally, train your operators and maintenance workers thoroughly to provide effective feeder troubleshooting and maintenance.

JOHN WINSKI is Director of Sales, Americas at Coperion K-Tron. He can be reached at john.winski@coperion.com.

The Puzzler

Offer your inputs on a problem that started after switching suppliers

In each of the *BSIC Journal* editions, there will be a little puzzle related to various aspects of working with bulk solids. The BSIC staff would like to hear everyone's thoughts on the situations presented. To get things started, some answers will be presented, but we would like to hear your other options or even just why you picked one provided. As a thank you for taking the time to participate, there will be drawings for prizes ranging from BSIC paraphernalia all the way up to free registration to a BSIC short course. All submitted answers will be summarized for presentation in the next edition. Good luck and we are looking forward to hearing from you!!!

CONVEYING CONUNDRUM

Congratulations! You have been successfully maintaining a dilute phase conveying system for unloading material into a silo around the clock for weeks on end without issues. Unbeknownst to you, a new vendor has been selected to supply the material and its certificate of conformance shows that it meets the required specifications. Two days later, the conveying system begins to show signs of plugging with decreased material flow rates. Upon measuring the unload times, you realize that your "stable" system now is working at a rate 50% of what it was just a few days before. What are the first three things that you would do to remedy the situation?

1. Ignore the situation and hope it goes away.
2. Accept the 50% drop in material flow rate because you are still unloading fast enough to keep up with production.
3. Review and refine material specifications to better match previous material.
4. Increase the conveying air until the higher unload rates return.
5. Inspect the system for "blockage" points.
6. Check Preventive Maintenance on equipment (air locks, blowers, etc.)
7. Investigate material transport containers and feeding equipment for proper functionality.
8. Turn the lights off and go home to get some good sleep so you can fix it tomorrow.
9. What else changed? Ask the equipment operators what they (or other shifts) are doing differently.
10. Contact BSIC for support options.

Please submit your response to bsic@k-state.edu

Provide your answers and a brief explanation. While a full explanation for answers is not required, anyone with a full response will be entered into a drawing for free registration to a Bulk Solids Innovation Center Short Course. The lucky winner will be selected at random from full submissions. Additional winners will be selected at random from all submission as well. Please submit your response to bsic@k-state.edu and put Conveying Conundrum in the subject.