

# Flow of Solids

Bulk Solids: Science / Engineering / Design

The Newsletter of Jenike & Johanson, Inc.

**Fall** 2004

## The Inside View

### Easy handling of fine limestone at relatively high rates

#### Background

A major manufacturer of floor and ceiling tile products planned to expand the limestone storage system at one of its plants in the Southwestern US. Through many years of experience, engineers at the company knew that particle size segregation of the limestone could cause significant quality control problems and limit production rates. Based on their previous collaborations with Jenike & Johanson to solve limestone segregation problems at other plants, the company's engineers again contacted us for assistance with the new system.

#### Problem

The pulverized limestone is considerably finer, with much lower permeability than coarser limestone used in the company's other plants. Because of the low permeability of the pulverized material, the limiting design condition was governed by the requirement for an extremely large outlet to achieve the required flow rate. To reliably achieve the maximum usage rate of 25,000 lbs./hr., a conical mass flow hopper at the bottom of the silo would require a 6 ft. diameter outlet!

#### Solution

Portland cement, flour, alumina, and many other fine powders are routinely fed from storage containers at high discharge rates by using air-assisted dischargers. In these systems, air (or other gas) is injected into the material near the outlet to overcome the conditions that cause the rate limitation. In fact, material in the lower region of the hopper takes on fluid-like properties and can achieve discharge rates much higher than a deaerated solid. In this case, an air-assisted system would work for both the coarser material, which was still fine enough to be handled in an air-assisted system, and it would overcome the severe rate limitation with the pulverized material. However, the system still had to achieve the primary goal of the design, which was to reliably deliver non-segregated limestone to the process. To do that, the silo and feed system had to be designed to achieve uniform, mass flow.

The plant planned to install a new 750 ton capacity storage silo. In addition to the coarse limestone normally used in the process, the new system also had to handle pulverized limestone consisting of over 80% minus 325 mesh particles. Limestone would be delivered by railcar and pneumatically conveyed into the silo. From the storage silo, limestone would be discharged and pneumatically conveyed to a surge hopper feeding the downstream process at rates ranging from 8,000 to 25,000 lbs./hr. The process would be shut down each weekend and annually for one week.

Tests were run in one of our labs on both types of limestone to determine cohesive strength, bulk density, wall friction angles, and permeability. The tests measured properties during

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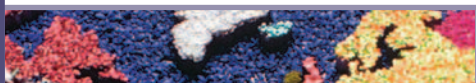
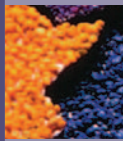
ust like our clients, we at Jenike & Johanson don't stand still. This issue describes two examples. The cover article is about an application of our air-assisted discharger technology. We developed this approach several years ago as a means to achieve high discharge rates of fine powders through small outlets while maintaining mass flow.

We pride ourselves in being able to duplicate almost any industrial condition in our testing laboratories. While the Jenike Shear Tester is still the workhorse for much of our testing, we have recently added new equipment to measure other significant bulk solids properties as described on pg. 3.

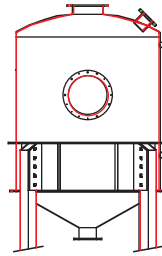
Give us a call to discuss how we can be of service to you.

*John W. Carson*

John W. Carson, Ph.D.,  
President, Jenike & Johanson, Inc.



## Easy handling of fine limestone at relatively high rates



15,000 lb  
Second  
Stage  
Vessel



continuous flow and after three days at rest to simulate the normal weekend shutdown period. Knowing both materials' handling characteristics, we then engineered a silo system utilizing a unique two-stage air-assisted discharge feeder arrangement to achieve mass flow and minimize segregation, while overcoming the need for a large outlet opening. Once this handling method was determined to be the most appropriate, air-assisted discharger tests were run to confirm the design/handling parameters.

cylinder, 40 ft. tall with a conical hopper that converges to an 8 ft. diameter, below which is an air-assisted discharger. Air flows into a permeable membrane covering the discharger over the entire 8 ft. cross-section. Aerated material then discharges through an 8 in. central opening.

The smaller, second stage vessel is 6 ft. in diameter and holds about 15,000 lbs. of material. It also uses a permeable membrane air-assisted discharger, which is the same 6 ft. diameter. A rotary valve controls discharge from the lower vessel into the pneumatic conveying line.

The stage two vessel operates between high and low level sensors. When the level reaches the low level probe, the valve below the upper, stage one discharger opens and refills the stage two hopper to the high level. Using the wall friction and cohesive strength data, the upper storage silo is designed to achieve mass flow, thereby minimizing particle size segregation. The air-assisted discharger is designed to activate the entire silo outlet, which is also a requirement for mass flow. The stage two vessel is small enough that its contents can be completely fluidized, allowing flow in the entire vessel cross-section even though the outlet is restricted by the rotary valve. There is little opportunity for segregation to occur since the vessel is nearly emptied during each fill cycle. The refill charge of the lower vessel is approximately 10,000 lbs. between the high and low level probes, resulting in slightly less than three cycles per hour for a flow rate of 25,000 lbs./hr.

In addition to measuring properties of the limestone and developing functional designs for the new system, we also performed the detailed engineering design of the approximately 93 ft. tall silo system. Our engineers provided a complete design package for the silos including a structural design based on loads from the flowing solids, wind, and seismic conditions. The design package also included specifications for the valves and air-assisted dischargers.

### Result

The plant reports that the silo storage system worked well immediately upon startup in 1999, and continues to operate trouble-free. The system provides the needed storage capacity and flow rate and effectively minimizes segregation of the pulverized limestone, all within the plant's logistical constraints. Since the system became operational, it has not been shut down other than for scheduled annual plant maintenance.

## Behind the Scenes: Meet Scott Clement

**Title:** Senior Project Engineer  
**Joined J&J:** 1997

**Job Description:** Since joining Jenike & Johanson, Scott has been involved in the design and supply of reliable bulk solids handling systems for the food,

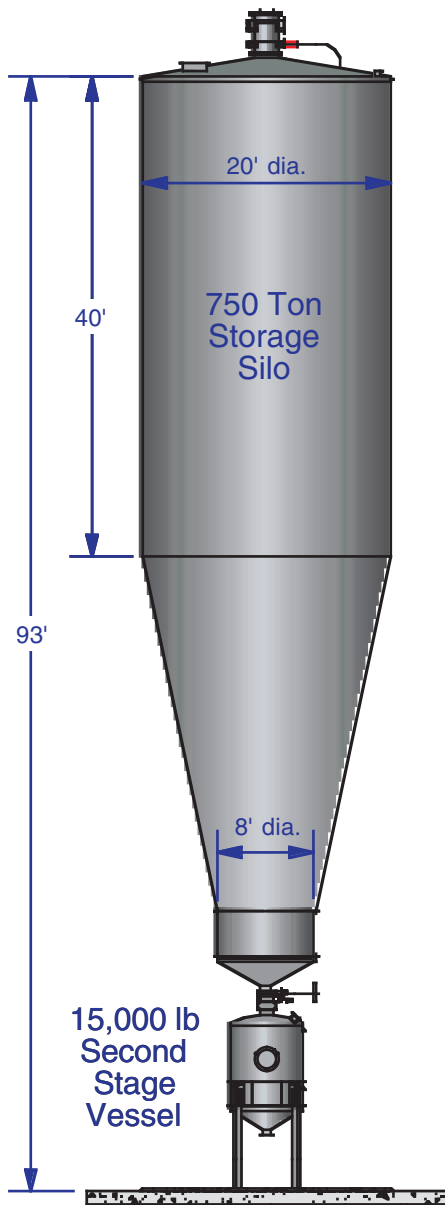
pharmaceutical, glass, mining, and powdered metallurgy industries, to name a few.

**Of note:** Scott earned a Bachelor of Science degree in Mechanical Engineering from California Polytechnic State University in San Luis Obispo, California. He has published several papers on solids flow issues and holds



two U. S. patents related to transfer and analysis of bulk solids. Scott is a registered professional engineer and is a professional member of the Institute of Food Technologists (IFT).

**"While my focus is primarily on the food industry, I am frequently involved in projects in pharmaceuticals manufacturing, chemical processing, mining and metals refinement, glass manufacturing, and others. I find it very rewarding to have the opportunity to work in such diverse manufacturing environments. I enjoy seeing a wide range of innovative processing solutions, and being able to bring value to our clients by adding our solids handling expertise to their processing expertise."**

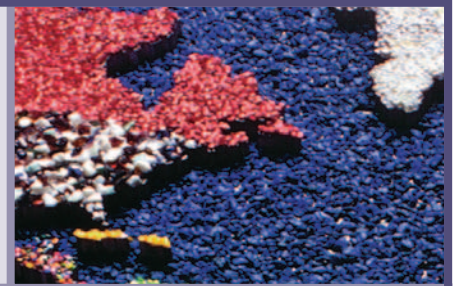


The two-stage system consists of a primary storage silo and a smaller, second stage vessel, both of which use permeable membrane, air-assisted dischargers. The primary silo consists of a 20 ft. diameter



## Solids Handling Course at J&J

We thank those who participated in our one-day seminar, covering common handling problems and solutions, with laboratory demonstrations. Given the response, this seminar will be repeated in the coming year. Please let us know if you have an interest in participating in a future course at J&J, or any of our courses offered in-house and through ASME/AIChE (email: [courses@jenike.com](mailto:courses@jenike.com)).



## J&J expands lab capabilities with new equipment

Those familiar with our services know that our work is based on sound engineering principles, as well as nearly 40 years of experience in solids handling. A vital part of developing reliable solutions for our clients is characterizing bulk solids to obtain relevant properties under conditions that duplicate process conditions.

All of our recommendations start with laboratory testing, to ensure that the important characteristics of your particular material are well defined. These characteristics cannot be found in a book, because like snowflakes, no two bulk material handling processes are the same. Even sister plants invariably have different equipment or processing conditions that keep them from producing the exact same material. With this in mind, we conduct tests on every material, at conditions that most closely duplicate processing conditions. In general, this means duplicating variables such as process temperatures, atmosphere, humidity, and storage times.



For duplicating extremely high process temperatures, we have specially designed test equipment within a furnace capable of reaching temperatures of up to 1,800°F

(1,000°C). We also have an environmental chamber in our lab, capable of cooling to 14°F (-10°C). While this equipment has served our needs for many years, we recently were asked to conduct tests at -300°F (-184°C). To meet this temperature requirement, we developed test equipment which utilized liquid nitrogen.

In some plants, such as in most pharmaceutical and food production facilities, ambient relative humidity and temperature are controlled. In other cases, the in-plant ambient conditions can vary with the season. Both of these cases can be simulated in our environmental chamber. However, usually more important than the humidity that a material may be exposed to, is the change in moisture content of the material

due to exposure to a given humidity, and its effect on material behavior. To determine changes in moisture content as a function of temperature and relative humidity, we offer moisture sorption/desorption tests. The test results not only indicate the response of moisture content to varying humidities, but also allow us to determine appropriate moisture contents for the samples to be characterized. The results can also be used to study process variability, caking, storage issues, as well as determining process control limits (temperature and relative humidity), and providing supplier comparisons.



As the problems we solve for clients become broader and more complex, we continue to add to our laboratory testing capabilities. One of the more recent additions is a tester capable of measuring, among other properties, the hardness of a tablet, agglomerate, or even a single particle. The device is particu-

larly useful in identifying differences in materials, and the effects of conditions and processing variables on particle characteristics.

Being able to obtain data at process conditions is paramount to a successful solids handling system design. Our ability to conduct necessary tests at the proper conditions, ensures that our engineered solutions are based on the best available data. We wouldn't have it any other way, and we would not expect our clients to demand anything less.

## Q&A with

**Q** From reading your publication, I understand that the test methods you use provide critical design parameters. I have also seen indices used for design guidelines. Can you explain the difference?

**A** For some applications, reducing the test data to a single index provides a simple way to rank or compare materials. However, for the purpose of designing bulk solids handling equipment, a single index can be a costly oversimplification. As an example, the slope of a converging hopper is critical in obtaining reliable flow with most bulk solids. An index for the hopper slope would indicate that there is only one critical value. In reality, the critical hopper slope often varies with the pressures being applied. A hopper with a larger outlet may be able to use a less steep cone angle. This translates to greater bin capacity for a given height, and usually a lower cost to supply.

Our flow property data gives you the complete picture, allowing various design options to be considered. However, if a simple comparison of materials is all that is required, the data can also be easily used in that manner.

## Did you know?

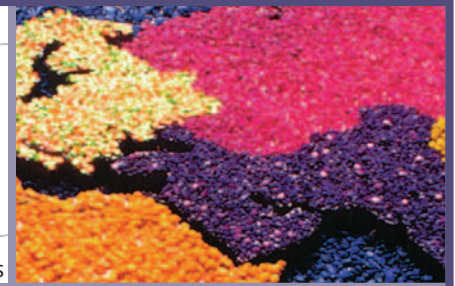
Our California facility is equipped to model pneumatic conveying systems. This allows us to investigate specific issues such as buildup, attrition, or even splitting flow to multiple receivers. Having this equipment allows for an independent investigation into these issues, as well as troubleshooting existing pneumatic conveying problems and designing new pneumatic conveying systems.

If you have any bulk solids handling questions, or if you have suggestions for future articles, please contact:

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# Flow-of-Solids Industry Calendar

"You get the benefit of years of experience."  
"Instructors were very knowledgeable, well prepared, and professional"  
- From course attendee evaluations of recent Jenike & Johanson presentations



## February 1-3, 2005 Las Vegas, NV

Advances in Tableting Technology - Senior project engineer Roger Barnum will give a presentation on a proactive approach in designing mixing and flow processes.

## February 23-24, 2005 Cleveland, OH

P/M Parts Compacting/Tooling - Senior consultant Brian Pittenger will give a presentation titled, *Impact on Product Quality by Hopper Design and Conveying System*.



## March 9, 2005 St. Hyacinthe (Quebec), Canada

Food Research and Development Centre/AAFC - Senior consultant Brian Pittenger will be discussing several food powder flow topics.

## April 5-7, 2005 Chicago, IL

Electric Power Conference, PRB Coal Users Group Annual Meeting - Roderick Hossfeld will be presenting a paper on coal degradation.

## April 18-20, 2005 Houston, TX

J&J engineers will present the following ASME/AIChE courses<sup>†</sup>:

- *Flow of Solids in Bins, Hoppers, Chutes, and Feeders*
- *Pneumatic Conveying of Bulk Solids*

## April 24-29, 2005 Princeton, NJ

Formulation and Process Development for Oral Dosage Forms - Senior consultant Jim Prescott will deliver a presentation.

## April 26-28, 2005 New York, NY

INTERPHEX - Senior consultant Jim Prescott will deliver a presentation titled, *Preventing and Solving Blend and Content Uniformity Problems*. Come see us at booth #974.

## May 11-12, 2005 Atlanta, GA

Powder and Bulk Solids Southeast



J&J engineers will present the following sessions:

- *Fundamentals of Bulk Solids Handling and Pneumatic Conveying*
- *Design of Transfer Chutes for Bulk Solids*
- *Understanding Particle Segregation*
- *Blending of Bulk Solids*

Come see us at booth #721.

## May 15-20, 2005 Kansas City, MO

IEEE/PCA Cement Conference - Senior project engineer Eric Maynard will give a one-day tutorial, *Effective Practices for Bulk Solids Handling at a Cement Plant*.

## May 16-18, 2005 Las Vegas, NV

Advanced Practices in Pharmaceutical Tablet and Capsule Technology - Senior consultant Jim Prescott will deliver a presentation on how interstitial air affects powders.

## June 13-15, 2005 Chicago, IL

J&J engineers will present the following ASME/AIChE courses<sup>†</sup>:

- *Flow of Solids in Bins, Hoppers, Chutes, and Feeders*
- *Pneumatic Conveying of Bulk Solids*

## July 10-14, 2005 Glasgow, Scotland

7th World Congress of Chemical Engineering - Dr. John Carson, president of Jenike & Johanson, will present the following two papers:

- *Proven Techniques for Air-assisted Handling of Powders in Bins and Hoppers*
- *A Valuable New Tool for Inventory Analysis of Bulk Solids Storage Vessels Operating with a Funnel Flow Pattern*

<sup>†</sup>For more information, please visit [www.asme.org](http://www.asme.org).

More complete course information is available at [www.jenike.com/pages/education/dates.html](http://www.jenike.com/pages/education/dates.html)

## Hot Off the Press

### Effects of Particle Segregation on Solids Handling and Product Quality

by H. Purutyan and T. A. Royal

### Avoiding Common Solids Handling Pitfalls in Food Processes

by R. A. Barnum, K. E. Bengtson, and S. A. Clement

### Proven Techniques for Air-assisted Handling of Powders in Bins and Hoppers

by T. G. Troxel, J. W. Carson, and K. E. Bengtson

### A Valuable New Tool for Inventory Analysis of Bulk Solids Storage Vessels Operating with a Funnel Flow Pattern

by T. A. Royal, J. W. Carson, and B. H. Pittenger

### Assessing Your Coal Silo for Reliability and Safety

by R. J. Hossfeld

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