Flow of Solids

JENIKE & JOHANSON INCORPORATED

Bulk Solids: Science / Engineering / Design

The Newsletter for Jenike & Johanson, Inc.

Fall 1999

Using silos as processing vessels

Introduction

Gravity flow processing vessels are used for numerous functions within chemical processing plants. One common application is as a purge column, such as used just after a reactor in a polyethylene or polypropylene facility to reduce volatiles to acceptable levels. Compared to processing vessels which involve mechanical agitation or a fluid bed, gravity flow processing vessels provide numerous benefits, including relatively gentle handling of particles, significant surge capacity while processing takes place, and reasonable cost.

Typical Problems

In spite of their benefits, problems can occur with gravity flow processing vessels that limit their effectiveness. Incomplete purging or non-uniform conditioning, caused by localized fluidization, non-uniform gas distribution, non-uniform velocity profiles of the solid particles, and poor handling characteristics of the bulk solid, result in off-grade product, fire/explosion risks, environmental compliance issues, or downstream handling problems. Other problems include excess gas usage and cross-contamination during grade changeovers.

Solutions

While the given problems are common, they can be prevented or minimized. The first steps are to define the process requirements and to determine the properties of the solids and gas that are being used. The key properties of the bulk solid are those which relate to how it flows in the vessel. These include its cohesive strength, wall friction, range of bulk density, and permeability.

Constraints on the vessel design must also be considered. Parameters such as minimum residence time, maximum storage capacity, vessel diameter, hopper geometry, and gas distribution method(s) are all important. The interrelationships between these parameters are also critical.

Once the material's flow properties are known, one can calculate the type of flow pattern which will occur in a vessel having a particular geometry and size. One of two basic flow patterns may exist: funnel flow and mass flow. The conditions under which each occurs have been well documented in the literature and proven through 40+ years of field experience.

Mass flow requires that the walls of the converging hopper section be sufficiently steep and low enough in friction such that particles find it easier to slide on the hopper wall surface than along each other. If this condition is not met, stagnant regions of particles will develop, resulting in a funnel flow pattern, which is one of the primary causes of problems in gravity flow processing vessels.

Simply achieving mass flow is not sufficient if one is to optimize the design of such a vessel, since mass flow requires only that there be no stagnant regions, not uniform particle velocities. One way to provide more uniform velocity is to select a combination of hopper wall angle and material of construction which results in conditions which are far within the mass flow limit. Thus, relatively steep hoppers and/or very low friction hopper surfaces are often required.

A second way in which the mass flow velocity profile can be affected (positively as well as negatively) is by the design and implementation of internals. Access doors, rod-out ports, gas inlet pipes, thermocouples, etc. should be placed, whenever possible, within vertical cylindrical sections, as opposed to in the converging hoppers.

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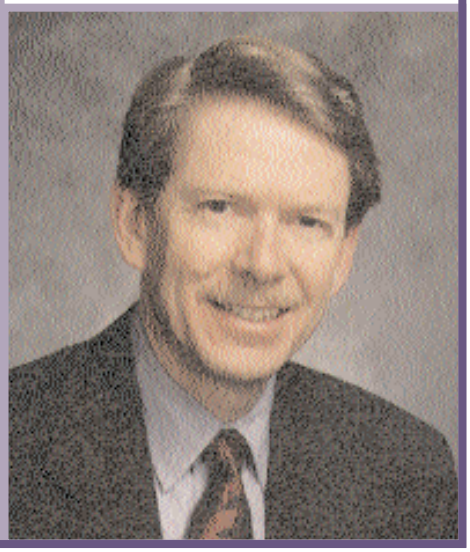
The Inside View

While many industries use bins or silos only for storing bulk solids, there are also quite a few that use these types of vessels for processing their materials. The lead article discusses the requirements for reliably operating these systems. An example of a solution we provided is also given.

This issue also introduces the Jenike-Schulze Ring Shear Tester™. If you must conduct your own tests, and you require an automated tester, this is the one for you.

As always, we hope you find this reading interesting as well as informative, and we appreciate your comments and suggestions.

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



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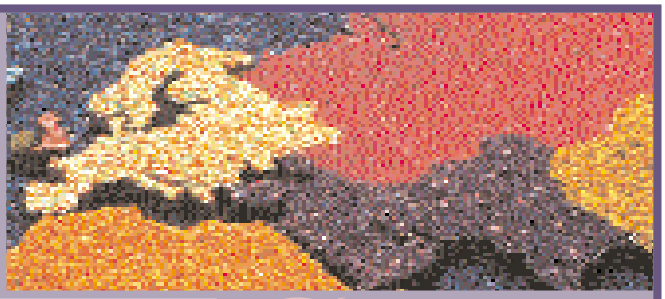
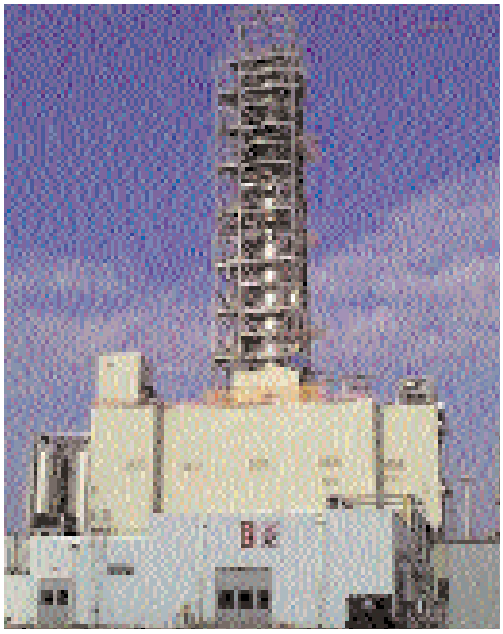
Using silos as processing vessels, and BP Amoco polypropylene purge column case history



Direct injection of gas through inlet pipes should usually be avoided, since this results in highly localized and hence very non-uniform gas distribution. Gas introduction through porous surfaces such as screens helps to minimize this problem, but often results in highly frictional surfaces which can hold up solid particles and thereby prevent mass flow. Cross-beams within vertical cylindrical sections avoid this problem.



Various types of inserts are often used in these vessels, to expand the flow channel as well as to provide a means for gas introduction close to the vessel's vertical centerline. Inverted cones are sometimes used; however, experience has shown that the size and positioning of such inserts and their supports are critical.

Using a BINSERT® (a cone-in-cone insert) can result in a much more uniform velocity profile than is possible with either a single cone hopper or an inverted cone insert. The outer cone walls can be made less steep than would be required if such an insert were not used, thereby resulting in a significant headroom savings. In addition, this insert's supports can be located within the vertical (cylindrical) portion of the processing vessel, where they have less detrimental effect on the flow pattern.

Conclusions

With new materials, and newer reactor technologies coming on line, current solids handling systems are being pushed beyond their capabilities. Therefore, these systems are being given new design attention, in regards to both throughput and to their ability to achieve system processing goals. Using a practical, engineering approach, gravity flow processing vessels can be economically designed or retrofitted to provide optimal performance.

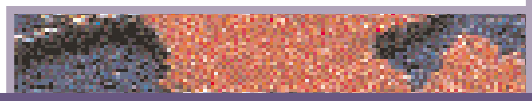
Case History - BP Amoco

A new polypropylene (PP) plant was built by BP Amoco Chemical at Geel, Belgium in 1995/96. This project involved construction of a 200,000 tonnes/year PP unit using the BP Amoco gas phase process and BP Amoco's high-activity supported catalyst. The plant produces random and blocked copolymers, and a wide range of homopolymers. When it came on line in late 1996, it doubled BP Amoco's European PP capacity.

A purge column was included in the design following the reactors. The purge column provides several important functions in a gas phase process. First, it reduces residual volatiles to an acceptable level using nitrogen as the purge gas. Second, it deactivates the trace catalyst residues, by using a small quantity of steam. Third, it provides surge capacity between the reaction and pelletization sections of the plant.

Engineers at BP Amoco specified the minimum and maximum purge duration (i.e., time of exposure to purge gas). They also specified the required solids and gas flow rates as well as the gas temperature and pressure at the top of the vessel. Based on material flow property data generated during previous projects for BP Amoco, engineers at Jenike & Johanson developed the functional design of this purge column. It consists of a tall, narrow cylinder section, below which is a steep-sided conical hopper. Purge gas is introduced just above the top of the conical hopper section using our patented technology. The design provides a uniform distribution of the purge gas, with no adverse effects on the flowing solids.

The purge column has been in operation now for over two years and has performed very well, meeting the design basis. According to Jim Lee, Research Associate for BP Amoco Chemical, "The performance of the purge column has exceeded our expectations. In fact, it did not require any modification when the rest of the PP unit was debottlenecked by 40% in 1998." This technology has been incorporated into three other plants which use BP Amoco's gas phase process: BP Amoco's Chocolate Bayou No. 4 PP, shown in the photo, and two licensees.



Behind the Scenes: Meet Randall St. Pierre

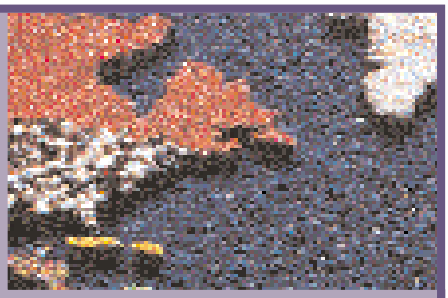
Title: Senior Lab Technician
Joined J&J: 1976
Job Description: Randy is responsible for conducting flow properties tests, reviewing lab data, and training new technicians.
Of note: With over 23 years of experience conducting flow properties tests on every conceivable bulk solid material, there is not much that Randy has not already seen. In fact, over 6,500 materials have passed through the lab since Randy started. As state troopers are trained to determine just by eye how fast a car is traveling, Randy can predict the arching capabilities of a bulk solid just by compressing some of it in his hands. This of course does not negate the need for testing, but it does provide a double-check of the data.

"I find it interesting that some people feel that a Jenike shear test is difficult to run. Although I disagree, I also don't apologize. I was taught that there are no shortcuts in life. If you use an alternate 'simplified' testing approach, you can usually expect simplistic results. And besides, when a company has a handling problem, they usually need an immediate solution, not a new lab. Why reinvent the wheel? Put our experience to work for you, to provide that solution."

Upcoming AIChE Course Dates

For over 20 years, experienced engineers from Jenike & Johanson have presented one of AIChE's most successful courses, Flow of Solids in Bins, Hoppers, Chutes, and Feeders. Upcoming dates and locations are as follows: Nov. 4-5, 1999 in Dallas; March, 2000 in Atlanta; June, 2000 in Boston or Washington, D.C. (TBD); Nov., 2000 in Los Angeles.

This course is offered through AIChE's continuing education program. To register, call AIChE at (800) 242-4363. The fee is $895 for members and $995 for non-members.

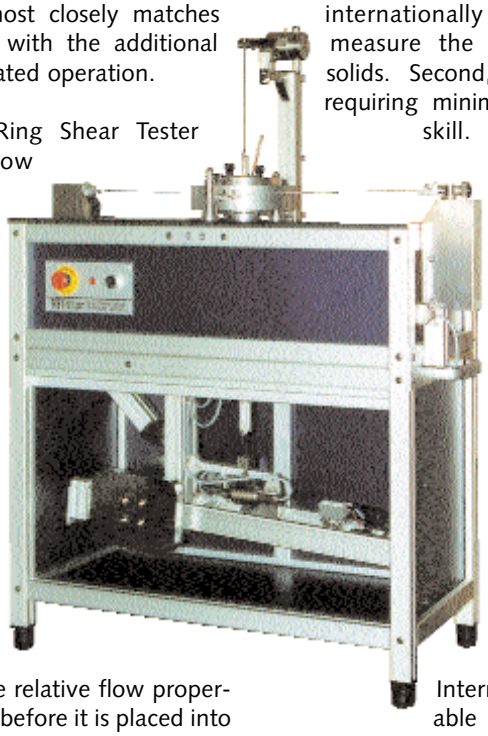


Introducing the

Jenike-Schulze Ring Shear Tester™

We are pleased to announce that the Jenike-Schulze Ring Shear Tester has been added to the list of test equipment that we offer. This tester, originally developed by Dr. Dietmar Schulze in Germany, most closely matches Jenike shear test data, with the additional benefit of a fully automated operation.

The Jenike-Schulze Ring Shear Tester measures important flow properties such as cohesive strength, internal friction, wall friction, and compressibility. A material's flow properties determine how it will behave in bins, hoppers, feeders, and other handling equipment. Knowing these properties is essential in product development, so that flow problems can be avoided. Flow properties are also important for quality control. By checking the relative flow properties of a given bulk solid before it is placed into your system or sent to a customer, you can reject or recycle unsatisfactory batches, thereby preventing costly handling problems from occurring downstream.



Why choose the Jenike-Schulze Ring Shear Tester? First, this is a real shear tester. This is important, since shear testers are the only internationally recognized means to measure the flow properties of bulk solids. Second, this tester is easy to use, requiring minimal operator training and skill. Third, this tester is extremely versatile. Materials which are free flowing, very poor flowing, or require large shear deformation can all be tested.

For an objective evaluation of the various types of flow properties testers available, we suggest reading "*Testers for Measuring the Bulk Properties of Particulate Solids*" by Prof. J. Schwedes. This paper was recently presented as the opening lecture at the International Symposium "Reliable Flow of Particulate Solids III" (RELPOWFLO III), in Norway, in August. For additional information on the tester, contact Don Ploof at (978) 392-0300, or daploof@jenike.com.

Did you know?

Bin specifications to a fabricator may include detailed drawings and a note that the bin is to promote mass flow. However, unless the proper design work is done up front by those providing the specifications, it is unlikely that the supplier is going to check the design in any way to ensure it will provide mass flow. Their expertise is in shaping metal, not bulk solids handling.

On a related subject, who is responsible for the structural integrity of the bin? If you specified details for the structural elements, it is unlikely that fabricators would perform their own check. Even if they perform a structural check, loading on a bin, due to a bulk solid (unlike a liquid), is not as simple as knowing the stored material's density (See related "Q&A with J&J").

In summary, don't rely on a metal fabricator to provide bulk solids handling expertise. Go to Jenike & Johanson, where bulk solids handling is our forte and our passion.

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Q&A with J&J

Q Is it safe to assume hydrostatic load conditions when performing a structural check on my limestone silo?

A No. Bulk solids are significantly different than liquids. Liquid loads are simply a function of density and height. A liquid analysis will predict highest loads at the outlet of a silo. Bulk solids handled in mass flow silos exhibit their highest loads in the region just below the interface between the vertical cylinder and converging hopper. The outlet of a typical mass flow silo has relatively low loads.

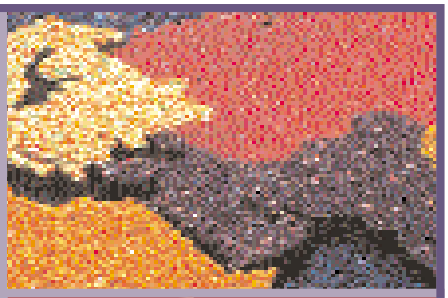
Other factors that determine the loads applied by a bulk solid to silo walls are: friction of the solid against the walls, initial fill versus discharge conditions, whether the material is flowing in a mass flow or funnel flow pattern, eccentric loading, and loads caused by collapsing voids.

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

Flow of Solids Newsletter
Jenike & Johanson, Inc.
One Technology Park Drive
Westford, MA 01886-3189
Voice: 978-392-0300
Fax: 978-392-9980
E-mail: newsletter@jenike.com

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



October 27-28, 1999, Atlanta, GA
POWDEX† Exhibition 1999.
Eric Maynard, project engineer with Jenike & Johanson, will present courses titled "Solve Solids Flow Problems in Bins and Hoppers," and "Design of Transfer Chutes to Minimize Buildup, Abrasive Wear, and Dust Generation." Stop by and see us at Booth 632.

November 15-18, 1999, New York, NY
The 99 CHEM SHOW conference & 48th CPI exposition. Eric Maynard, project engineer at Jenike & Johanson, will present a 1-day course titled "How to Ensure Reliable Flow in Bins, Hoppers, and Feeders."

December 1-2, 1999, Nashville, TN
MPIF: Innovations in powdered metal storage, feed, and transport designs. Brian Pittenger, senior project engineer with Jenike & Johanson, will give a presentation on powdered metal flow behaviors, flow properties, and feed system equipment considerations.

March 21-23, 2000, New York, NY
Interphex†, the International Pharmaceutical Exposition & Conference.
James Prescott, senior project engineer with Jenike & Johanson, will present courses titled "Pharmaceutical Powder Handling Part I: Providing Consistent, Reliable Flow," and "Part II: Maintaining Solid Dosage Form Quality."
Stop by and see us at booth 1370.

April 5-7, 2000, Santiago, Chile
Two in-house courses presented at Jenike & Johanson, Chile S.A.
- Bin and Feeder Design
- An Introduction to Pneumatic Conveying

May 8-11, 2000, Chicago, IL
25th annual Powder and Bulk Solids Conference/Exhibition†.
Jenike & Johanson personnel plan to present the following seminars and workshops:

- Solve Solids Flow Problems in Bins and Hoppers
- How to Select or Troubleshoot Volumetric and Gravimetric Feeders to Ensure Reliable Flow
- Fine Powders: Reliably Handling Bulk Solids That Can Behave Like Fluids
- Blending and Segregation and Their Effects on Product Quality
- Flow Aids: What to Use and When to Use Them
- Retrofit Troublesome Solids Handling Equipment to Improve Flow and Product Quality
- Design of Transfer Chutes to Minimize Buildup, Abrasive Wear, and Dust Generation

Stop by and see us at booth 1626.

May 29-June 1, 2000, Israel
The Third Israeli Conference for Conveying and Handling of Particulate Solids. For more information visit the Conference web site at: http://www.bgu.ac.il/me/bsh/

†To register, contact Reed Exposition Companies, (203) 840-5848.

Hot Off the Press

Gravity Flow Processing Vessels
by Carson, J.W., J.H.Lee, and B.H. Pittenger (Chemical Processing, 8/99, pp. 49-53)

Design Considerations When Silos Are Used as Processing Vessels
by Carson, J.W., K.V. Jacob, J.H. Lee, B.H. Pittenger (International Symposium Reliable Flow of Particulate Solids III Proceedings, 11-13 Aug. 1999, Porsgrunn, Norway, pp. 553-560)

Practical Approaches to Achieving Mass Flow - When "Standard" Design Techniques Fail
by Jacob, K.V. and J.W. Carson (International Symposium Reliable Flow of Particulate Solids III Proceedings, 11-13 Aug. 1999, Porsgrunn, Norway, pp. 537-544)

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Web Site: http://www.jenike.com Email: newsletter@jenike.com

East Coast, USA
Jenike & Johanson, Inc.
One Technology Park Drive
Westford, MA
01886-3189 USA
Voice: (978) 392-0300
Fax: (978) 392-9980

West Coast, USA
Jenike & Johanson, Inc.
3485 Empresa Drive
San Luis Obispo, CA
93401-7328 USA
Voice: (805) 541-0901
Fax: (805) 541-4680

Canada
Jenike & Johanson, Ltd.
400 Carlingview Drive
Etobicoke, Ontario
M9W 5X9 Canada
Voice: (416) 674-8595
Fax: (416) 674-8520

South America
Jenike & Johanson, Chile S.A.
Edificio Arcadia
Arlegui 440 Of. 613
Viña del Mar, Chile
Voice: (+56) 32 690 596
Fax: (+56) 32 690 596

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