JENIKE®
& JOHANSON
SCIENCE ENGINEERING DESIGN

Engineer Product Flow, Dry Products & Ingredient Handling

2023 California Grain & Feed Industry Conference

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Jenike.com

Outline

- The cost of getting it wrong
- Bulk solids flowability
- Bulk solids flow properties
- What to consider during projects to improve to avoid handling problems

Who is Jenike & Johanson?

A specialized engineering firm focused on providing clients solutions to material handling applications

- 55+ years experience, all industries
- 13,000+ materials tested, 8,000+ projects
- 650+ accumulated years of solids experience
- Offices in Australia, Brazil, Canada, Chile, USA (Massachusetts, Texas, California)

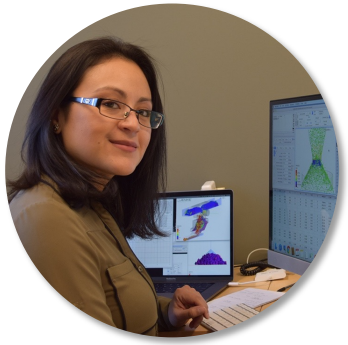
Jenike & Johanson – Our Approach

Scientific approach – based on your materials

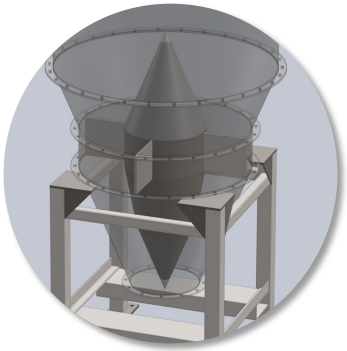
Not a trial-and-error approach

On-site Assessments & Inspections

Testing & Physical Modeling



Technology, Computer Simulations



Conceptual Engineering, Flowability Review, Detailed Design, Equipment Supply

All Industries Globally

Bulk Solids Handling (BSH)
a.k.a. the weakest link in the chain

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FAMILIAR?

Safety Side of Flow Problems

TODAY'S TOPIC: GRAIN ENGULFMENT

Identify potential engulfment hazards from outside the storage unit e.g. grain built-up against wall, potential bridge conditions (history of where grain is drawn off), atmosphere conditions, lighting arrangement and deteriorated grain.

OSHA HAZARD ALERT: GRAIN ENGULFMENT

Engulfment can occur when a worker: **Stands on moving/flowing grain.** The moving grain acts like "quicksand" and buries the worker in seconds.

UNIV. OF ARKANSAS: GRAIN BIN SUFFOCATION HAZARDS

Engulfment can occur when a worker: **Stands on or below a "bridging" condition.** "Bridging" occurs when grain clumps together, because of moisture or mold and forms a crust over the surface, creating an empty space beneath. "Bridged" grain can unexpectedly collapse under the worker's weight, burying the worker.

OSHA PUBLICATION: GRAIN BIN ENTRY WALLET CARD

Engulfment can occur when a worker: **Stands next to an accumulated pile of grain on the side of the bin**. The grain pile can collapse onto the worker unexpectedly or when the worker attempts to dislodge it.

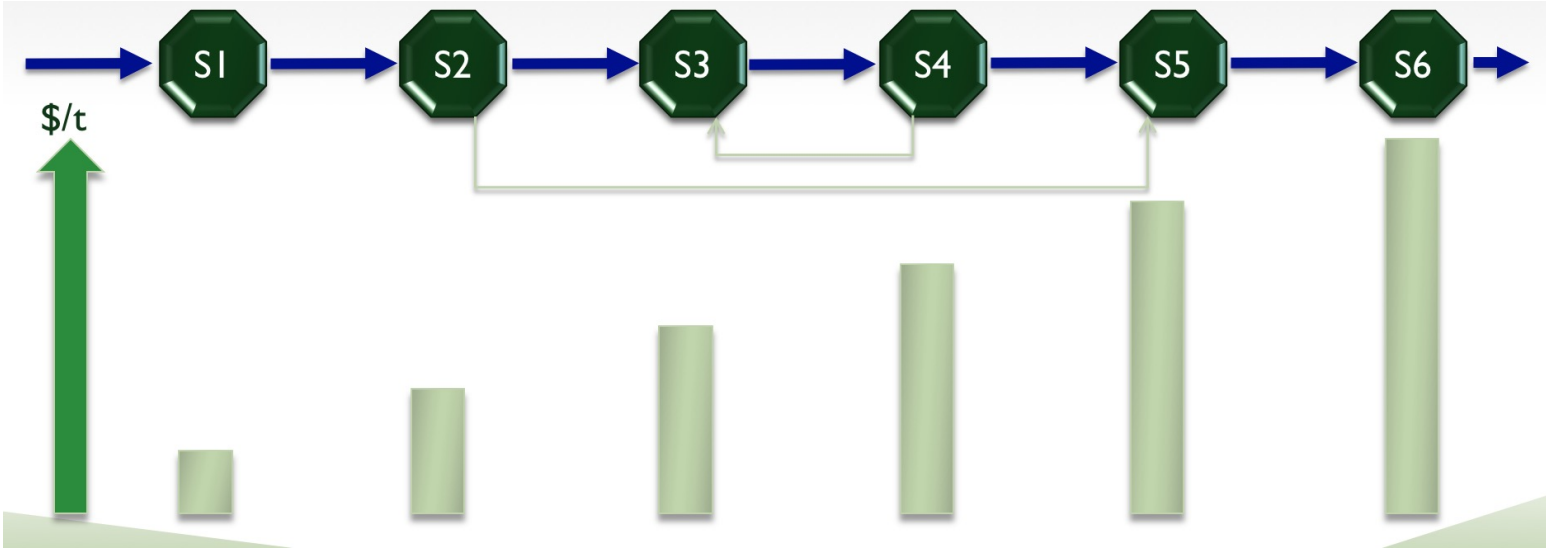
NGFA SAFETY TIP SHEET: PREPARING BINS FOR HARVEST

TABLE 1. The number of nonfatal and fatal incidents related to grain entrapment in the United States (adapted from Issa and Field, 2015)

Year	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
Nonfatal	15	17	22	26	19	11	20	21	10	161
Fatal	16	17	19	31	11	8	13	17	14	146
Total	31	34	41	57	30	19	33	38	24	307
(Fatal/Total)	51.6%	50.0%	46.3%	54.4%	36.7%	42.1%	39.4%	44.7%	58.3%	47.6%

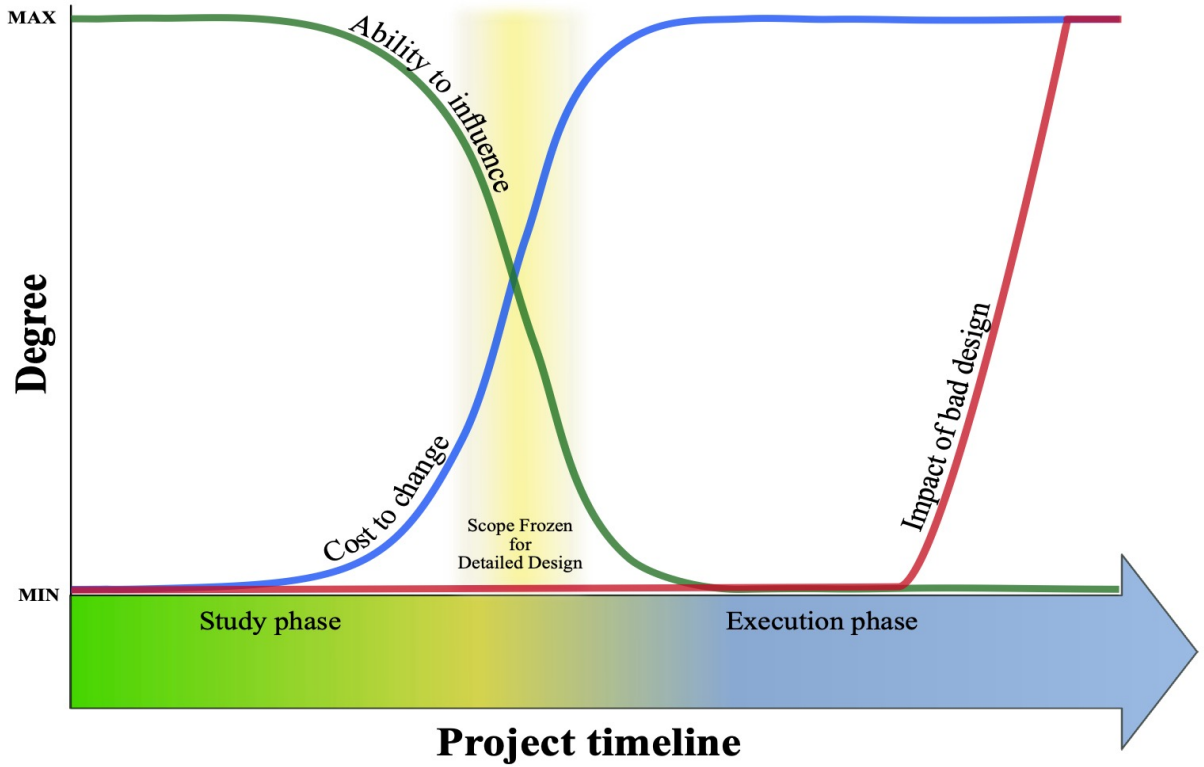
NGFA and OSHA – "Stand-Up for Grain Engulfment Prevention Awareness Week" April 9-13, 2018
https://www.uaex.edu/publications/pdf/FSA-1010.pdf
Issa, S., Y. Cheng and B. Field. 2015 Summary of U.S. Agricultural Confined Space-Related Injuries and Fatalities.

The Basic Nuts and Bolts of Why We Do What We Do In Making Feed

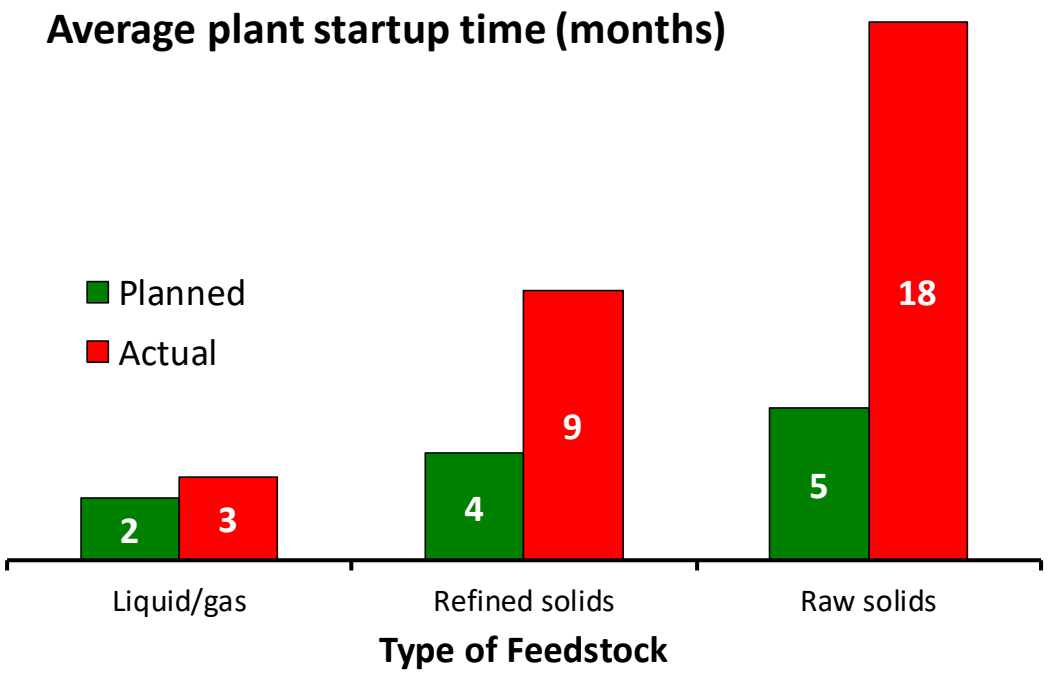


But what if your material doesn't FLOW through the process?

Ability to Influence and Cost of Modification



RAND Study



Rand Study: Sample of 40 plants in US and Canada over a 6 year duration. Merrow, E., "Problems and progress in particle processing", Chemical Innovation, Jan. 2000 & Chemical Engineering; Oct. 1988, Vol. 95, Issue 15

Conclusions

- 80% experienced solids handling problems
- Average startup time 18 months vs. 3 months for liquids
- Typical performance 40 to 50% of design
- Problems related to "physics and mechanics of processes rather than to chemistry"

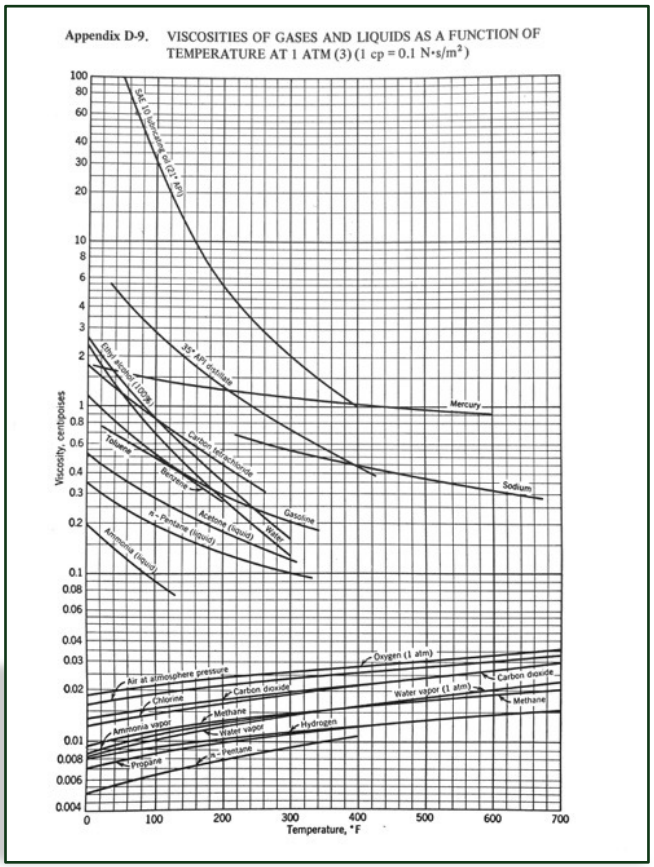
Common Reasons Issues get “Baked” into a Plant Design

- Failure to measure flow properties to be handled to inform design basis.
- Borrowing data from library values to try and save cost of physical testing
- Not testing representative samples or the range of anticipated materials.
- Lack of awareness and training on the science of bulk solids handling
- Fast tracking a project
- Copy and paste designs

Liquids vs. Bulk Solids

Liquids

- No internal friction
- Cannot form piles
- Not sensitive to pressure
- Incompressible
- Flow behavior dependent on viscosity – look up table based on temperature



Bulk Solids vs. Biomass

Bulk solids

- Internal friction
- Can form piles
- Sensitive to pressure
- Compressible

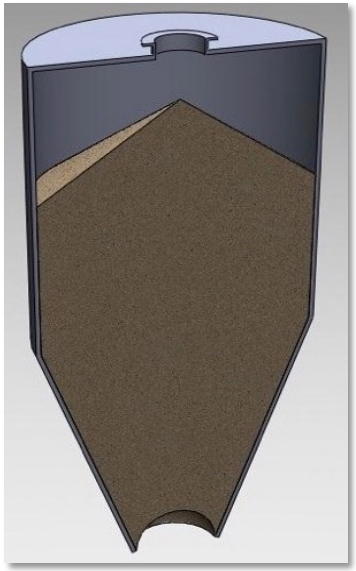
In addition →

Biomass

- Can be springy
- Have a high aspect ratio
- Particles can align
- Shear plane may not be the same as a bulk solid

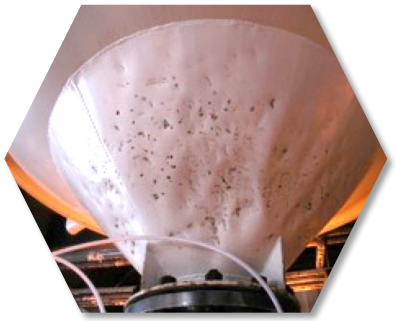
Common Flow Problems

No Flow / Erratic Flow



Arching / Bridging

Ratholing

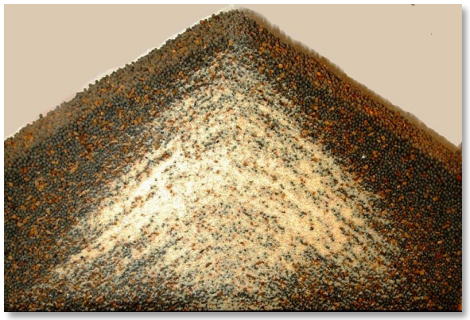


Common Flow Problems

No Flow / Erratic Flow

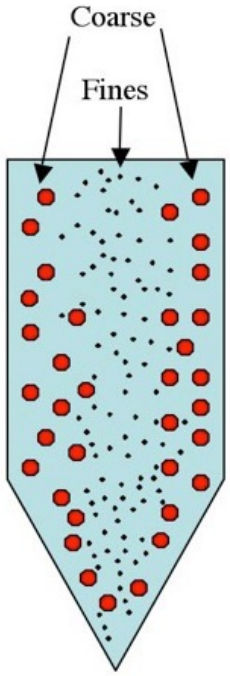
Common Flow Problems

Segregation



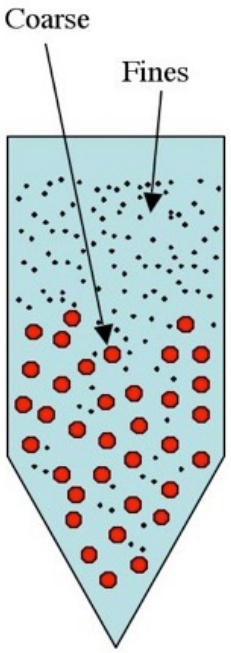
Coarse Fines Coarse

Sifting



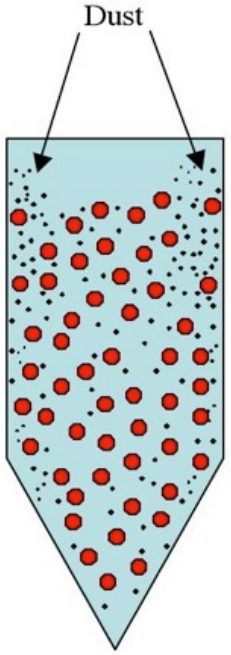
Side-to-Side

Fluidization

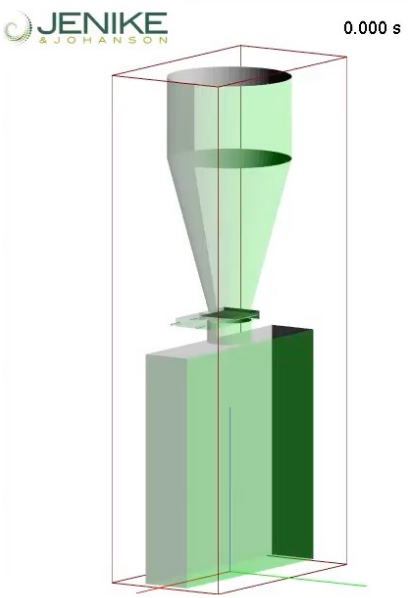


Top-to-Bottom

Dusting



Side-to-Side & Top-to-Bottom



Common Flow Problems

Uncontrolled Flow - Flooding

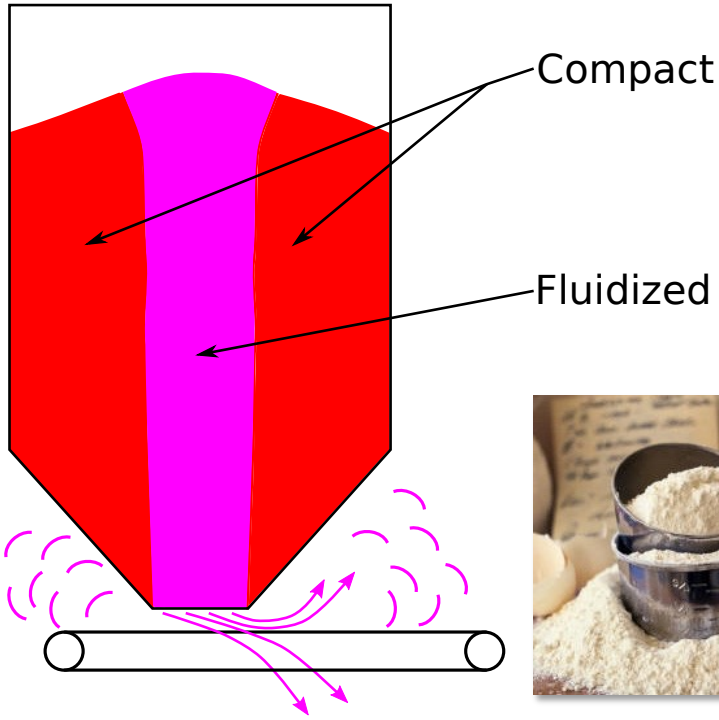
Fluidization

- Fine powders, average size <150um

Result

- Flooding

Fly ash



Common Flow Problems

Attrition

Before pneumatic conveying After pneumatic conveying

Common Flow Problems

Caking and Spoilage

“Flowability”

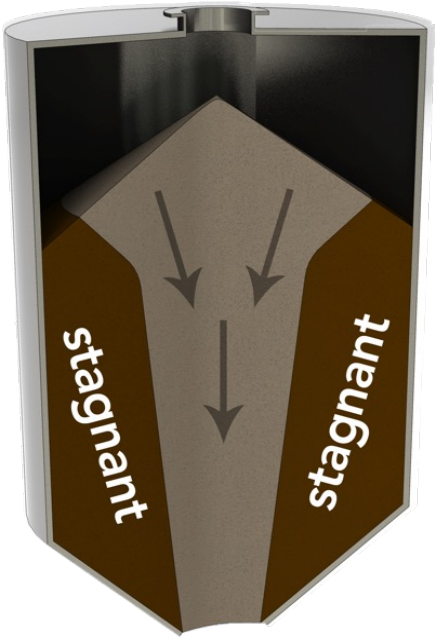
Flowability is a function of the material AND the equipment

- “Poor flowing” material can be handled easily in properly designed equipment
- “Easy flowing” material can present flow problems in poorly designed equipment

Funnel Flow

Issues

- Some material is stagnant
- Caking, product degradation, spoilage
- Arching, ratholing, and erratic flow can occur
- Limited live capacity
- Varying bulk density



Features

- Low headroom
- First-in, last-out
- Ratholes may develop
- Fine powders will flood
- Sifting segregation issues exacerbated

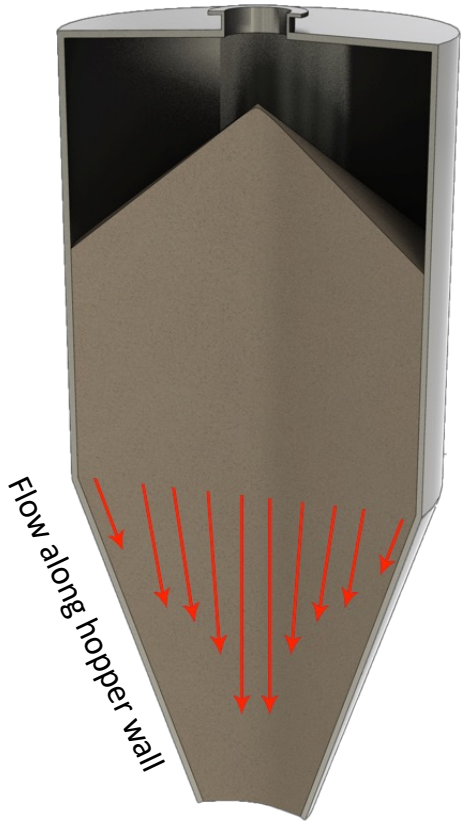
Mass Flow

Features

- Smooth, steep hopper
- First-in, first-out
- Ratholes cannot form
- Fine powders deaerate
- Sifting segregation minimized
- Uniform feed

Suitable for

- Cohesive materials
- Fine powders
- Degradable material
- Materials that segregate by sifting



Required for material that is

- Cohesive
- Fine
- Degrading over time
- Sifting by segregation and that is a concern

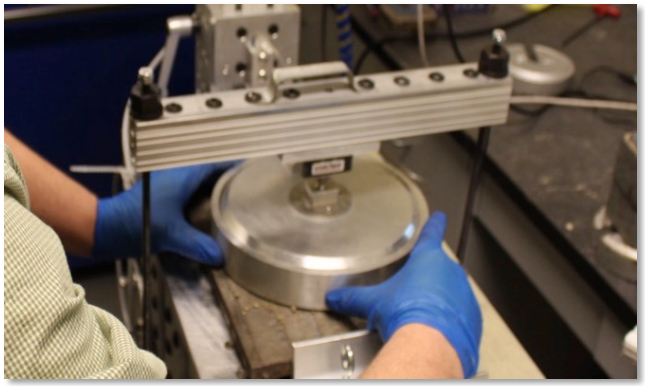
Achieving mass flow requires

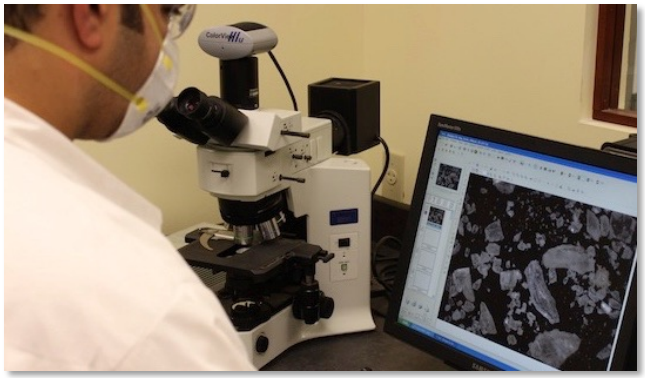
- Flow along hopper walls
- Outlet large enough to prevent arching
- Correct feeder design

Bulk Material Testing

Typical tests

- Cohesive strength
- Wall friction
- Bulk density/compressibility
- Particle density
- Permeability
- Segregation potential
- Pneumatic conveying
- Fluidization
- Sorption/desorption
- Particle size distribution





What Affects Flowability?

- Particle size and distribution
- Moisture
- Time at rest
- Temperature
- Relative humidity
- Particle shape
- Chemical composition

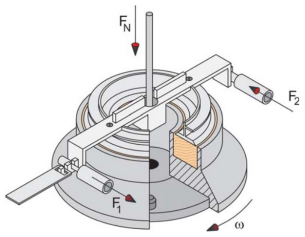
Example: Types of sugar

It's critical to match your process conditions!

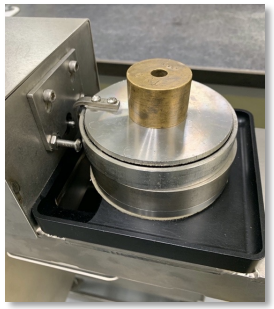
Flowability Testing

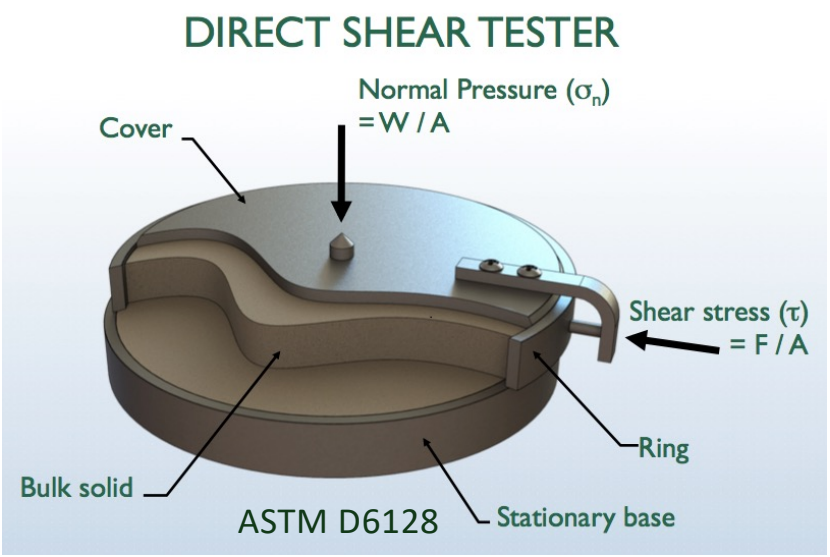
Cohesive Strength

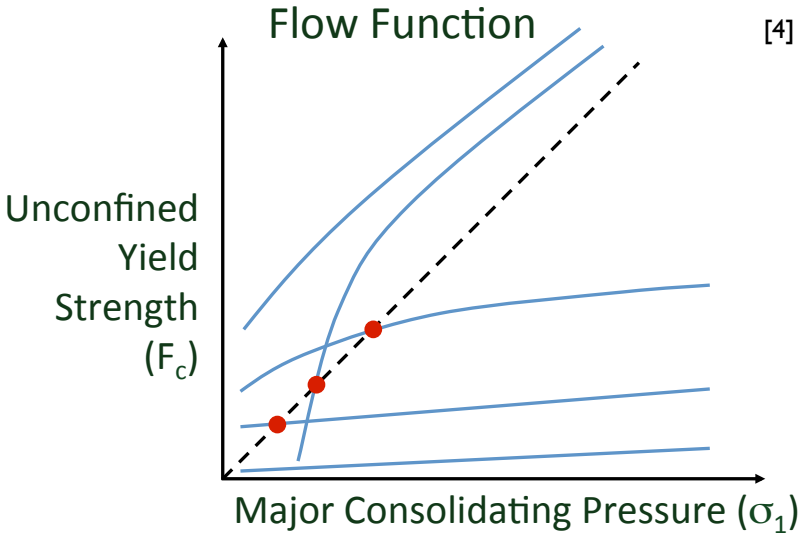
Ring Shear Tester
ASTM D6773



Jenike Shear Tester
ASTM D6128





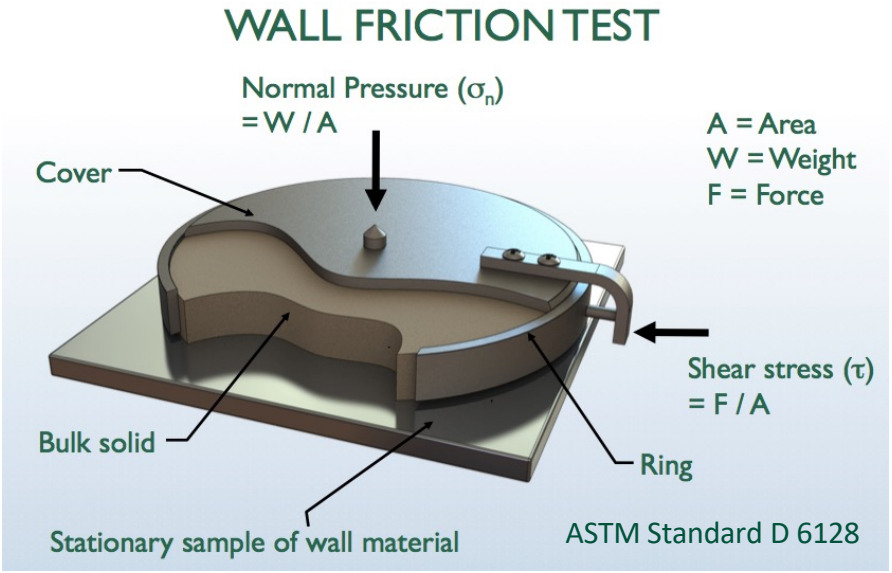


Recommended Hopper Outlet

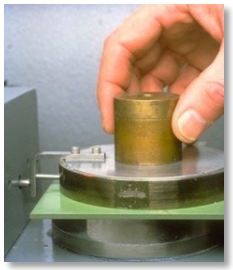
[4]Jenike, A.W., Storage and Flow of Solids, Bulletin 123, University of Utah Engineering Station, 1964 (revised, 1976).

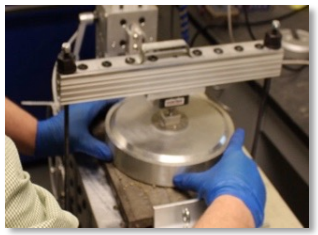
Flowability Testing

Wall Friction

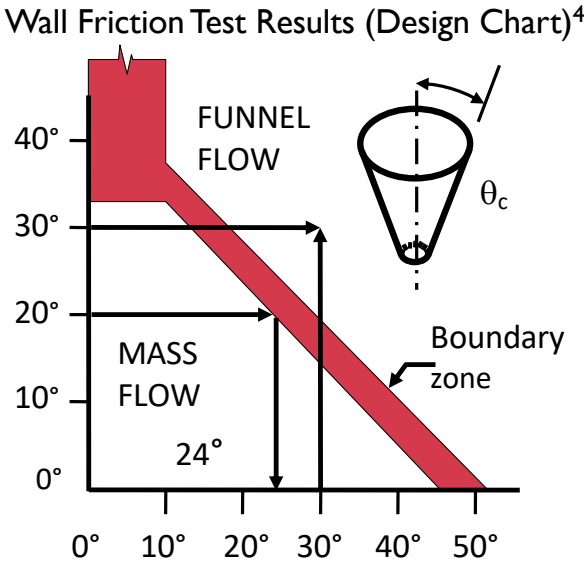


ASTM D6128





ϕ': Wall friction angle



Note: There is no magic angle!

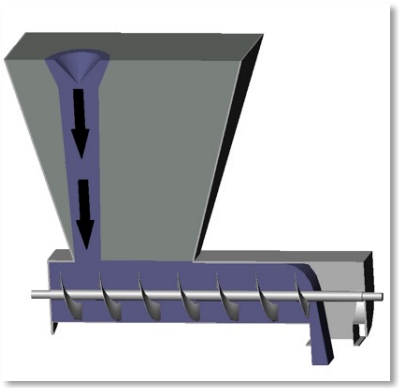
Recommended Mass Flow Hopper Wall Angle

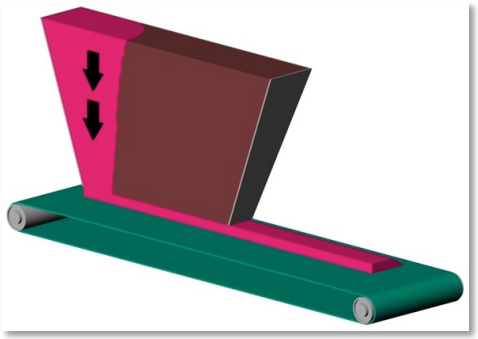
[4]Jenike, A.W., Storage and Flow of Solids, Bulletin 123, University of Utah Engineering Station, 1964 (revised, 1976).

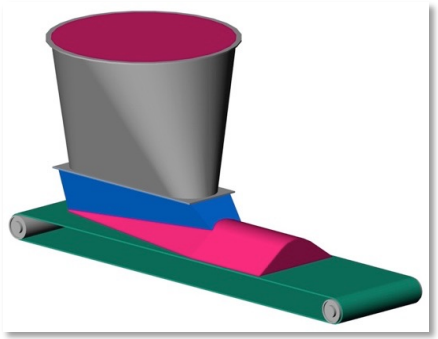
Pay Attention to the Feeder

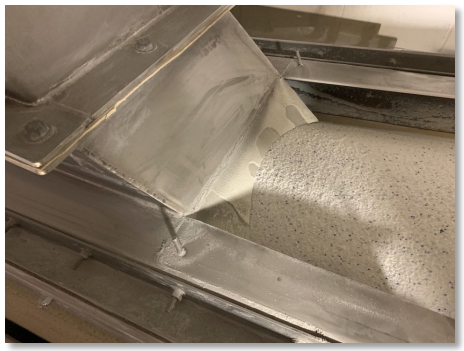
Feeder should

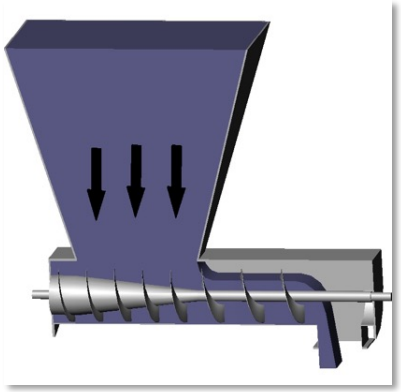
- Provide reliable flow of material
- Control discharge rates
- <u>Withdraw material from the entire hopper outlet</u>



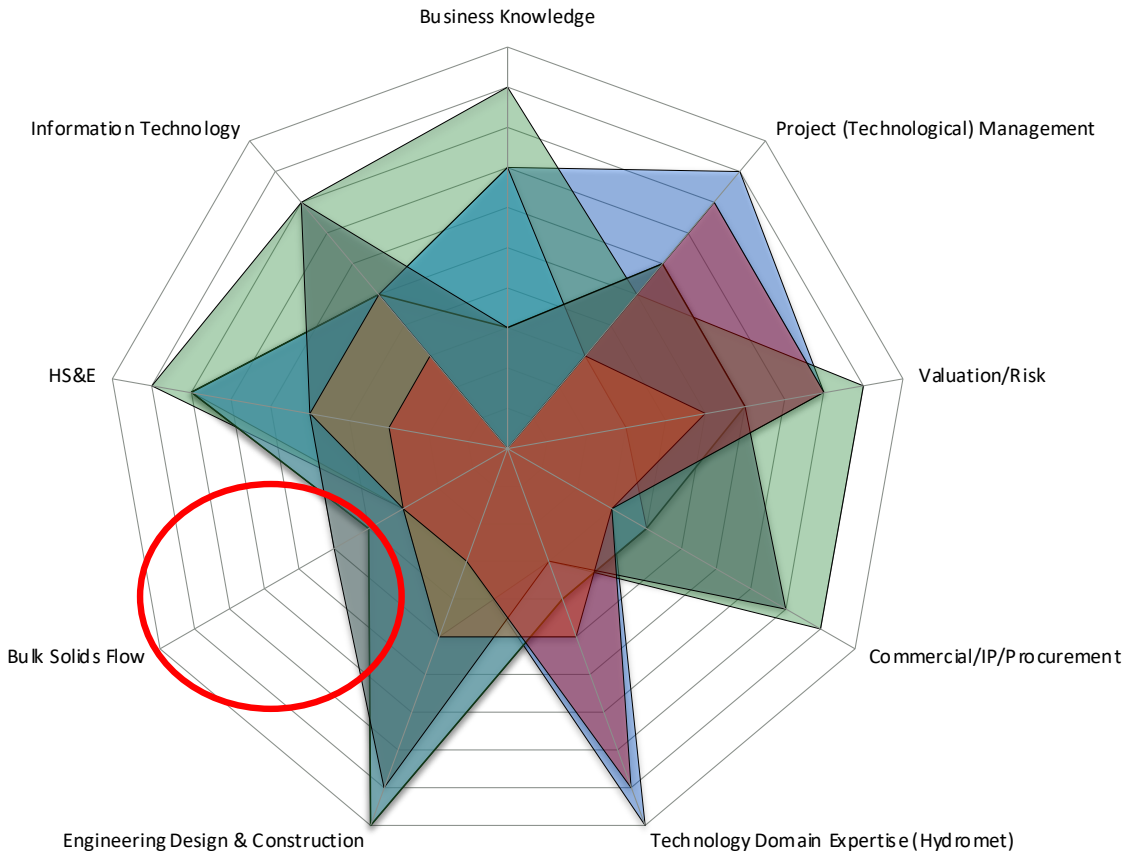






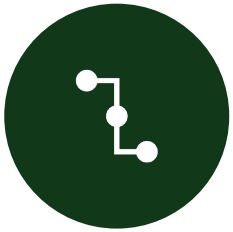


Capability Map



- Company Technology
- Corporate Functions
- Host Site
- EPCM #1
- EPCM #2
- Suppliers
- Special Matter Experts

Conclusion



Flowability testing is key in providing inputs to the design basis

Testing must be performed on representative samples and at anticipated process conditions

Without flowability test data, it is a guessing game → increases project risk

The science has been around for over 60 years – tried and true

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