

# Ask Joe! Column

## How to Read a Solids Flow Report

by Joseph Marinelli, Solids Handling Technologies, Inc.

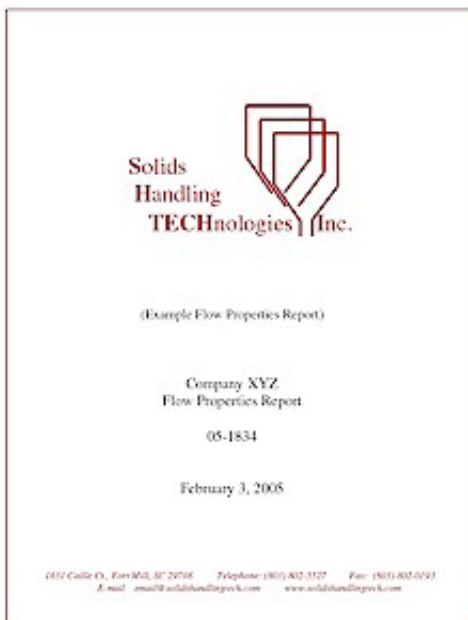


Dangers range from poorly designed storage vessels that sudAs most of my articles have stated, in order to determine if a new bin or silo will work reliably or to be able to make modifications to an existing troublesome bin or silo, you need to know your material's flow properties. In past articles I have discussed the important considerations for reliable flow; namely, cohesive strength and wall friction properties.

Cohesive strength is measured using a bench scale laboratory testing device such as a direct shear tester (Jenike Shear Tester). This device is used to determine a material's "Flow Function" (strength / pressure relationship). The material's cohesive strength is measured as a function of applied consolidation pressure. We can control the sample's moisture content and particle size while the direct shear tester allows us to simulate the effects of temperature and time of storage at rest. This information is then used to determine the opening size required to prevent arching and ratholing in a bin or hopper.

The Jenike Shear Tester is also used to measure wall friction properties. From previous articles, you will remember that friction is developed between a solid and the walls of a bin or hopper. This friction determines whether the solid will slide on the wall (mass flow) or adhere to the wall and preferentially slide on itself (funnel flow).

Once the laboratory tests are completed, the testing laboratory should provide a Flow Report. This report indicates values to be used to design a new bin or modify and existing one. I have provided an Example Flow Report in the attached PDF files for you to open and follow along.



### Page 1: Title Page

The first page is obviously a title page with a description of the project, company, etc.

## Page 2: Introduction and General Comments

This page is a General Comments section and is meant to provide general information regarding the flowability of the particular material being tested. These comments are given without any bin geometry in mind and serve to help explain tabulated data in the following pages and how to interpret it.



Solids Handling Technologies, Inc.

**FLOWABILITY TEST RESULTS**

Bulk Material I	Product
Particle Size	4 mesh
Moisture Content	8.3%

Section 1: Arching and Ratholing Dimensions

**Mass Flow Arching Dimensions**

Time at Rest, hrs	Temp., deg. F.	Mass Flow Bc, ft	Funnel Flow Bf, ft
0	90	1.0	0.5
72	90 to room	2.1	1.0

**Rathole Dimensions**

Time at Rest, hrs	Temp., deg. F.	CP, pct	88.7	126.7	301.5
		124.8	7	16	
		Critical Rathole Dimensions, (D, ft)			
0	90	1.5	1.7	2.7	
72	90 to room	3.4	3.5	6.9	

Bc = Recommended minimum outlet diameter for a conical hopper  
 Bf = Recommended minimum outlet width for a slot in a wedge shaped hopper  
 Bp = Minimum width of a rectangular outlet in a funnel flow bin.  
 CP = Moisture condensation percent.  
 Df = Critical diameter to prevent ratholing.

## Page 3: Flowability Test Results

Section 1 Arching and Ratholing Dimensions of the Flow Report on Page 3, indicates the arching and ratholing dimensions of your material as a function of time at rest, temperature, etc, as follows:

### Arching Dimensions

Time at Rest, hrs---In this case the material was tested to simulate 0 hrs storage (continuous flow) or as if the material was put in a bin and flow initiated immediately. 72 hr storage is indicative of about a week-end of storage at rest, which is typical.

Temp., deg F---The material was tested at 90°F for 0 hrs and at 90° cooling to room temperature after 3 days at rest to simulate actual storage conditions.

**Mass Flow Bc, ft**---“B” is the hopper opening and “c” stands for conical, such that these dimensions are 1.0' for 0 hrs and 2.1' for 3 days. These are the minimum arching dimensions for a conical hopper that is designed for mass flow.

**Mass Flow Bp, ft**---“B” again is the hopper opening, while “p” stands for planar or wedge type hoppers, such that these dimensions are 0.5' for 0 hrs and 1.1' for 3 days. These are the minimum arching dimensions for the width of a slotted opening in a wedge hopper, designed for mass flow. Remember that the slot length should be at least three times the width.

**Funnel Flow Bf, ft**---“B” is the hopper opening and “f” stands for a funnel flow slotted opening, such that these dimensions are 0.5' for 0 hrs and 1.0' for 3 days. These are the arching dimensions for a slotted opening in a funnel flow bin, such as a long slot on a flat bottom bin.

## Ratholing Dimensions

Time at Rest, hrs---Same as above

Temp., deg F---Same as above

s1, psf---This is the major consolidation pressure acting on the material as it remains in a bin. This pressure is simulated in the laboratory tests.

EH, ft---s1 is difficult to comprehend, for example, how much is 331.5 psf? As such, we convert s1 to a value of effective head. The effective head in the example report ranges from 5' to 16'.

Critical Rathole Diameters, Df, ft---“D” is the diameter of the rathole that will form and the opening required to collapse a rathole, while “f” stands for funnel flow. If your effective is 16' after 3 days at rest the rathole dimension is 6.9', meaning that a 6.9' diameter opening is required to collapse a rathole, even at this low head.

## Page 4: Flowability Test Results

Section 2 Bulk Density / Pressure Relationship of the Flow Report on Page 4, indicates the bulk density of your material as a function of consolidation pressure or head of material as follows:

s1, psf---Same as above

EH, ft---Same as above

g, pcf--- g is the Greek symbol used for bulk density. There are a range of bulk densities when dealing with solids, not just loose density and packed density. In this case, g ranges from 67.9 pcf to 84.0 pcf. g is used in opening size and hopper angle calculations along with bin and feeder load calculations.

Section 3 Recommended Hopper Angles for Mass Flow of the Flow Report on Page 4, indicates the conical and wedge hopper angles required to ensure flow along the walls i.e. mass flow, as follows:

Hopper Span, ft---Is usually interpreted as the opening size; however, it could be any span in the hopper, not just the opening.

f' (Phi Prime)---This is the wall friction angle generated during a wall friction on a particular wall surface. It is given in degrees from horizontal.

qc (Theta C)---This is the hopper angle (degrees from vertical) required for mass flow in a conical hopper.

qp (Theta P)---This is the hopper (degrees from vertical) required for mass flow along the sidewall of a wedge type hopper.

As an example of using these dimensions, you could design a mass flow conical hopper with a 2.1' diameter opening (to prevent arching), that would require the following hopper slopes (depending on the wall surface preferred):

**Bulk Material:**  
Packer Size: 4.5"  
Material Content: 4.5%

**Section 2: Bulk Density / Pressure Relationship**

$\theta_{11}$ , psi	45	105	115	403	1213	1913	2103
g, pcf	2.7	6	16	30	59	78	100

**Section 3: Recommended Hopper Angles for Mass Flow**

Material and Wall Friction at 90°F

Hopper Span, ft	Conical Hopper			Wedge Hopper					
	$\theta_c$	$\theta_p$	$\theta_w$	$\theta_c$	$\theta_p$	$\theta_w$			
0.25	28	13	26	19	25	36	23	17	28
0.5	28	13	26	19	25	36	24	18	29
1.0	28	13	26	19	25	36	22	20	31
2.0	28	13	26	19	25	36	21	21	32
4.0	28	13	26	19	25	36	21	21	32
8.0	28	13	26	19	25	36	20	22	33

$\theta_{11}$  = Major consolidation pressure, psi.  
 $\gamma$  = Bulk density, pcf.  
 $\theta_c$  = Conical hopper slope required for mass flow, deg. from vertical.  
 $\theta_p$  = Wedge hopper slope required for mass flow, deg. from vertical.  
\*DINAK 33 is an abrasion resistant ultra high molecular weight polyethylene resin.

<u>Wall Surface</u>	<u>Theta C</u>
Carbon steel	13°
TIVAR 88	25°
2B stainless steel	21°

To summarize, the Flow Report essentially describes the geometry required to ensure reliable flow. It yields opening sizes to prevent arching and ratholing, bulk density values, and hopper angles required for mass flow.

**Contact our author:**

Joe Marinelli  
Solids Handling Technologies, Inc.  
1631 Caille Ct.  
Fort Mill, SC 29708

Phone: 803-802-5527  
Fax: 803-802-0193  
Email: [joe@solidshandlingtech.com](mailto:joe@solidshandlingtech.com)  
Web site: <http://www.solidshandlingtech.com>

+++++

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

For past articles, **Ask Joe!** Archived Articles.

Guest articles for the **Ask Joe!** Column are always welcome, for more information please contact Joe Marinelli directly at his email address: [joe@solidshandlingtech.com](mailto:joe@solidshandlingtech.com).

© Powder and Bulk.com