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Clamp Down on Clumping

First understand what’s really causing the problem.

By Tom Blackwood, Healthsite Associates

POOR FLOW is one of the most common problems encountered in handling or storing solids. With liquids you open the valve and (hopefully) material runs out. With solids you often have to pray before opening the valve. Wouldn’t it be nice to have an inexpensive well-established test method or procedure that would allow you to predict whether a fine powder will flow after a given time interval?

Often test methods take too long and generate results that are qualitative and very subjective. Also, material may be limited and quantitative test procedures are very expensive. If your plant has been working with solids you’re probably familiar with this scenario. The basic issue is a balance of cost versus usable results. Clumping is a complicated issue that’s difficult to quantify; so it’s no surprise that finding a meaningful test is difficult. In most cases, clumping is unpredictable. However, a generalized procedure can be used to solve a clumping problem after it has occurred.

By clumping we really mean unintended agglomeration. While some types of agglomeration are desirable, e.g., to reduce dustiness or make a material easier to handle, most clumping isn’t appreciated. The last thing you need in a pharmaceutical plant is for a bulk bag of acetaminophen to come in as a solid block (as has happened). Clumping is such a tricky issue due to its many causes. Before you can select a test method or procedure, you need to determine the root cause of clumping. Sometimes that can identify a solution without further testing.

CAUSES OF CLUMPING

The 10 most common sources of agglomeration in bulk solids are:

1. Simple dissolution followed by drying of solids without any chemical reaction. This is the fundamental problem with a lot of storage systems. Bags aren’t sealed well enough or a solvent gets into the transport line. Several of the following causes also involve this process but in a roundabout way.

2. Chemical reaction between particles and gases in voids in the bulk solid. Most common is formation of hydrates, which changes particle density or creates bridges between particles. Oxidation or reduction of particles is less common but can release gases or yield condensable products that form a sticky film on the solids. Diffusion of soluble gases such as carbon dioxide can soften particles and make them susceptible to shear. In addition, particles can interact with wall material through abrasion, which can act as a catalyst to reduce the potential energy needed for a reaction to occur.

3. Change of phase. This is the most difficult problem to diagnose but often is easiest to prevent. Many people don’t realize that a polymorph could be present. About one-third of all organics have at least one polymorph [1]; lots of pharmaceuticals rely on chemicals that aren’t in their most stable form. While transformation upon storage may take years a small amount of change can result in a big effect on flowability. For crystalline solids the problem usually starts with a very small amount of excess solvent and a temperature change. The unstable form dissolves and then recrystallizes into the stable form with solvent release. The process will repeat as solvent moves from particle to particle. A similar process can occur with amorphous organics because the crystalline form is at a lower potential energy.

4. Recrystallization of solids during storage. Often particles can pick up excess energy prior to storage though handling or milling operations. The latter is a very common culprit because attrition raises the surface potential energy of the solids and creates very fine solids, which have a much higher charge-to-mass ratio. It’s rare for solid-state transformation to occur but it only takes a small amount of solvent to aid the crystallization process, similar to a polymorphic transformation.

5. Viscous films on particles. Interstitial solvent can prompt formation of such films. Heating or cool-
ing solids can cause solvent to migrate and collect in one location. As the solvent partially evaporates, it leaves behind a sticky surface on the particle that can lead to bridging.

6. Impurities in solids. These can induce stresses in the particles, which can hasten chemical reaction, phase changes and recrystallization. Impurities can act as catalysts in a reaction or interact with wall materials to initiate one of the causes previously cited. Localized change in density due to an impurity can prevent normal transfer of shear force from particle to particle and put more stress on an individual particle, resulting in breakage. Location of the impurity — whether on the surface or interior of the particle — may even be critical and cause some batches of solids to behave much differently than others.

7. Particle size and width of the particle size distribution (PSD). These attributes often can’t be changed but contribute to clumping. Finer particles have higher specific surface area and more particle/particle contact, resulting in higher shear forces. In addition, the van der Waals’ forces increase rapidly with finer particles. The wider the PSD, the more likely voids around larger particles will fill in with fine particles and boost cohesion. While this is a major factor in clumping, it’s very easy to identify in advance of a problem.

8. Attrition. This is more of a contributing factor for the previously mentioned sources of clumping. Breakage of particles releases energy that’s confined to the solids’ surface. In addition, finer solids will have poorer flowability and higher

STOP SOLVENT SNAGS
Solvents — gases as well as liquids — cause many clumping problems; so understanding the nature of the solvent can play a critical role in coming up with a solution. The solvent in bulk solids falls in four major categories (with the relevant one often related to how solids are dried):

1. Free or surface. These are easily removed by drying. However, in a production facility time may be limited or heat not uniformly distributed to solids. Most dryers are run based on contact time or exit temperature. While a longer time will give a dryer product that extra time may alter product color, taste or effectiveness.

2. Bound. Cohesive or electrostatic forces can cause physical or chemical adsorption of solvent onto particles. Some types of dryers are better at removing bound solvent but this can a difficult source to quantify.

3. Inherent. Solvent molecules trapped inside crevices of crystals or micropores of amorphous powders come into play when particles break. These molecules usually can’t be removed by drying but you can minimize their effect, especially after a milling process. Solvents of hydration or crystallization are part of this group — but they’re a stable form of the chemical that only would be released by a phase change or chemical reaction.

4. Interstitial. Vapor that fills voids in bulk material may total only a very small amount of solvent but can play an important role in caking mechanisms. When this source is identified as part of the problem it’s fairly easy to fix by purging or fluidizing with dry gas.

Total solvent is the sum of all of the above.

In evaluating clumping it’s important to know where solvent comes from so you can understand the clumping and propose the correct solution to the problem. There are eight common methods for determining the solvent in a particle solid. Some are specific to the most common solvent, water. Each one can give a slightly different result because of the technique. The methods are:

1. Karl Fischer — for free and bound moisture (note other chemicals can be used to titrate solid for presence of other solvents);

2. Loss on drying (LOD) — for free or surface solvent and a major portion of bound solvent (for moisture, the test usually takes place at 90°C for 6 hours);

3. Infrared — for surface moisture, which is a close approximation to free moisture;

4. Radio frequency — for inherent (sometimes), bound and free moisture;

5. Microwave — for total and interstitial moisture (using different wavelengths);

6. Loss on ignition — for total solvent (can be done following LOD to get solvent of crystallization). Often this test is carried out in temperature steps to observe crystallization solvent as well as other volatile components or decomposition;

7. Thermo-gravimetric analysis — for total solvent loss with time (differential thermal analysis is more precise for solvent flux and can be combined with gas chromatography/mass spectroscopy to identify chemicals in a multi-component solvent system); and

8. DSC — for heat flow with time (which is especially useful in multi-component solvent systems).
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electrostatic charge. The increase in fines makes the PSD wider and solids easier to bridge.

9. Mechanical deformation of solids. This usually isn’t the primary cause of agglomeration. The normal stresses in a bulk bag or fiber drum are fairly low. However, the ultimate formation of agglomerates often appears as a mechanical failure. Because a solid is defined as something that can support its own weight, most failures stem from shear forces that exceed the solid’s strength. Many of the previous sources of clumping induce a failure that allows for compression of solids to form agglomerate.

10. Vibration. This often is overlooked as a cause of finer solids sift ing into voids and increasing compression of bulk solids. When combined with temperature changes, vibration can make solids soften or plasticize, resulting in physical deformation and clumping. However, sometimes vibration can help to prevent mechanical deformation during transport.

As the above highlights, one major factor that repeatedly enters the equation is the presence of excess solvent or solvent vapor. If either afflicts solids, you must focus attention on the solvent source. Water is the most common solvent; moisture causes many clumping problems reported in the chemical and pharmaceutical industries. Four major types of solvent in bulk solids contribute to clumping (see sidebar). No single test can detect all four; methods for determining the amount of solvent may not give a clear indication of the type.

**USEFUL TESTS**

Chemical Processing has published many articles on ways to test the strength of bulk solids and how they gain strength on storage. The majority of these tests focus on setting parameters for design of a bin or chute to keep product moving or to induce flow. Clumping is an afterthought of these methods. The tests can show how a material gains strength

<table>
<thead>
<tr>
<th>Degree of Flowability</th>
<th>Flowability Index</th>
<th>Compressibility %</th>
<th>Cohesion Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Good</td>
<td>91–100</td>
<td>&lt;5 25</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>6–9 24</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>10 22.5</td>
<td></td>
</tr>
<tr>
<td>Fairly Good</td>
<td>81–90</td>
<td>11 22</td>
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<td></td>
<td></td>
<td>12–14 21</td>
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<td></td>
<td></td>
<td>15 20</td>
<td></td>
</tr>
<tr>
<td>Good</td>
<td>71–80</td>
<td>16 19.5</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>17–19 18</td>
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<td></td>
<td></td>
<td>20 17.5</td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>61–70</td>
<td>21 17</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>22–24 16</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>25 15</td>
<td>&lt;6 15</td>
</tr>
<tr>
<td>Not Good</td>
<td>41–60</td>
<td>26 14.5</td>
<td>6–9 14.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>27–30 12</td>
<td>10–29 12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>31 10</td>
<td>30 10</td>
</tr>
<tr>
<td>Bad</td>
<td>21–40</td>
<td>32 9.5</td>
<td>31 9.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>33–36 7</td>
<td>32–54 7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>37 5</td>
<td>55 5</td>
</tr>
<tr>
<td>Very Bad</td>
<td>0–20</td>
<td>38 4.5</td>
<td>56 4.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>39–45 2</td>
<td>57–79 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;45 0</td>
<td>&gt;79 0</td>
</tr>
</tbody>
</table>

*Note: There are three conditions when the cohesion test should not be used:
1. Mean density (i.e., the average of tapped and aerated density from the Carr bulk density tests) is below 0.4 g/cm³ and particles are greater than 150 μm;
2. Mean density is between 0.4 and 0.9 g/cm³ and particles are greater than 75 μm; and
3. Mean density is above 0.9 g/cm³ and particles are greater than 45 μm.*

Table 1 - Carr Index of Flowability (adapted for clumping)
upon storage but can’t predict outside of testing conditions (time or temperature) future increase in strength. In many cases the rise may be limited, at least to a solid block of solids. In addition, most methods require specialized and costly equipment, which is the major reason plants don’t conduct such tests prior to experiencing a problem. However, these tests, by determining the time-dependent unconfined yield strength, are some of the best ways to determine when there’ll be a problem.

The three major contenders for test equipment for this property are the Schultze (ASTM D6773) and Jenike (ASTM D6128) shear cells and the Johanson Indicizer. In addition, other devices have been developed for specialized industries, such as the Humboldt Tri-axial Tester for geotechnical assessment. Some of these methods can use samples as small as 20 g — but several runs may be needed to account for product variability. These tests’ major limitation is that, to be assured that material won’t exceed a given strength in the future, trials must cover a wide range of temperature and humidity over the expected storage time. This may not be practical for solids kept in a bag or drum for many months and for replicating shipping conditions.

Carr [2-4] developed several tests in an attempt to determine the flowability and compressibility of bulk solids. His methods give indices that have had mixed reviews over the last 40 years. Many companies have devised their own internal methods and have published these for others to use — but they’re often subjective and depend on the operator’s scrutiny. Examples are observation of flow though different orifice sizes, lumping and compression as well as frangibility and friability tests.

Here’s a highspotting of the pros and cons of the most common qualitative tests for evaluating clumping potential:

1. **Carr Flowability Index** (ASTM-D6393) [5] — is quick and easy to do (simple equipment) and used extensively, gives a relative indication of how much a powder will compact and the strength of cohesive material, but can’t provide quantitative results and isn’t useful for time and temperature effects on solids;

2. **BASF lumping and compression tests** (BASF Bulletin TPU 0402) [6] — uses small amount of material (10–15 g) to get qualitative results, but provides limited ability to study the effect of storage time and temperature on flow;

3. **Flow through an orifice or down a surface** — offers qualitative results on how big an orifice

---

**Table 2 - Ten Solutions To Clumping**

<table>
<thead>
<tr>
<th>CAUSE</th>
<th>POTENTIAL SOLUTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Simple dissolution</td>
<td>Shrink-wrapping pallets of bags can help. Choosing the correct liner or using multi-liner bags is another solution. Ensure that convey lines are dry and operators know how to properly store the material (i.e., good education on the product). Clamp down on procedures.</td>
</tr>
<tr>
<td>2 Chemical reaction</td>
<td>The material safety data sheet should provide an indication of potential reactivity of the solids. If not, this needs to be spelled out in the specification for the material. Consider potential chemical reactions before selecting a packaging method or container. If the material forms a hydrate, purge particles with dry gas prior to packaging. Also, don’t package solids hot as this can speed up a reaction.</td>
</tr>
<tr>
<td>3 Change of phase</td>
<td>Know if the material has polymorphs. Molecular models can suggest and a DSC can verify that the material is the most stable form. Ensure there’s no free solvent. In some cases a desiccant can be put into the container to pick up excess solvent. When an unstable material has to be packaged, use conditioned transport to minimize temperature changes.</td>
</tr>
<tr>
<td>4 Recrystallization</td>
<td>Avoid packing freshly milled solids unless there are no polymorphs — or minimize the intensity of the milling (i.e., use multiple millings rather than a single pass).</td>
</tr>
<tr>
<td>5 Viscous films</td>
<td>Avoid packaging solids when hot as this can drive solvent to voids in the top of the container where they can condense. Also, control humidity in the packaging area.</td>
</tr>
<tr>
<td>6 Impurities</td>
<td>These can be critical in promoting chemical reaction. They aren’t a common source of clumping but can cause problems. When an impurity doesn’t affect end use, improve product purity to remove it.</td>
</tr>
<tr>
<td>7 Particle size</td>
<td>This is the most difficult problem. When the customer wants a fine particle or a wide distribution, a problem is likely. Maybe a different specification can be used to make the particle larger and the distribution narrower.</td>
</tr>
<tr>
<td>8 Attraction</td>
<td>Design filling and handling equipment properly to limit attrition. Use an extended chute to minimize dropping distance. If the material is sensitive to attrition, use dense-phase conveyors.</td>
</tr>
<tr>
<td>9 Mechanical deformation</td>
<td>Consider not stacking bags or limiting the depth in a drum (use separators or sleeves). If a material has a poor initial strength, it’s likely to deform and then clump. Design packages to limit the amount of compression by restricting the height of solids or inducing motion during transport.</td>
</tr>
<tr>
<td>10 Vibration</td>
<td>Vibration can work for or against clumping. Use specialized containers that limit transmission of motion to minimize the effect — or air-ride shipping methods.</td>
</tr>
</tbody>
</table>
needs to be for 50% of solids to flow out of a container (commercial instruments are available (Figure 1); however, many companies have constructed their own devices) or the necessary angle of slide (specific to wall material), but can’t give the effect of storage time on flow; and
• Frangibility (sometimes called friability) tests — indicate relative strength of agglomerates, can be used to estimate crushing strength or how easily a clump can be broken, which may eliminate the need to solve a clumping problem, but use non-standard equipment (large balls are placed on the upper screen of a sieve stack and vibrated; amount of solids that pass to the pan is compared to the amount that goes to the pan without the balls).

In general, these tests will give an indication of the potential for clumping to occur upon storage when starting particulate solids are cohesive or flow poorly, i.e., Carr flowability index of less than 50 (see Table 1). However, initial good flowability doesn’t predict lack of clumping upon storage. So, when facing a problem, it’s important to look at the 10 most common sources of agglomeration to ascertain the likely culprit(s). In that respect the following techniques are useful in determining potential for phase change and can identify chemical components that are the cause of the problem:
• Raman spectroscopy — can determine polymorphs;
• Differential Scanning Calorimetry (DSC) — can identify changes in structure and presence of unstable chemical forms or polymorphs;
• Scanning Electron Microscopy — can see formation of bridges (this can be combined with a probe to look at specific elements);
• Transmission electron microscopy — can detect bridge composition and impurities (but has limited application unless sample is very strong because it must be thin); and
• Atomic force microscopy — can observe real-time agglomeration (this technique is evolving rapidly and eventually may be able to see atomic-level changes).

CLUMPING SOLUTIONS
Is it possible to predict cohesion? Probably not. No one test is appropriate but many qualitative tests can help define the potential. So, what do you do to minimize clumping?

The solution to many prospective causes of clumping centers on minimizing solvent contact with solids, controlling particle size, limiting attrition sources and avoiding putting excess energy into solids, especially prior to packaging. Table 2 gives some specific suggestions for the ten common causes of clumping. For each there’s often a first line of defense. However, many of the solutions can treat other related causes. For example, filling a drum from an excessive height can increase attrition, mechanical deformation and solvent vapor trapped (by boosting the amount of voids). Also, packaging a hot material can promote chemical reaction, phase change, recrystallization and formation of viscous films. As a last resort you can modify solids through agglomeration or addition of flow aids such as silica. But that’s another subject.

TOM BLACKWOOD is director of technology for Healthsite Associates, St. Louis. E-mail him at trblac@att.net.

REFERENCES
Mixing Solutions and Slurries

Effectively, Economically and Safely.

By Dan Haugh, Hapman Product Managers

THE OLD CHALLENGE:
One of the perpetual challenges in the chemical industry has been finding an ideal way to effectively mix solids and liquids to create optimal slurry – and at the same time, utilizing the least amount of floor space, energy and human resources.

The most common method for combining powders and liquids is to introduce the powder into an agitated tank that has been filled with the liquid component. The typical process for this is to have an operator manually open the tank hatch, lift the bag of powdered product, slit it open, and then dump the dry contents into the tank. The mixture is then blended through the agitation process. The disadvantages of this method are that it produces substantial dusting, creates inefficient liquid-to-solids contact, and is labor intensive.

Dusting creates significant housekeeping issues, and can potentially affect a company’s Certified Good Manufacturing Practices, (CGMP). Another critical element of dusting is that many applications use caustic and/or hazardous chemicals, raising exposure issues. This concern increases when human operators are involved in the handling and dumping of powder bags into the mixing process. In addition to the risk of exposure, is the physical risks of climbing a ladder while carrying bulk bags to a raised platform, or lifting bulk bags of dry product where the weight inside the bag can shift unexpectedly and cause operator injury.

In addition, the process of dumping a large mass of dry product into a liquid can cause an undesirable exothermic reaction. This chemical heat-producing situation has the potential to create inconsistent or poor quality end product. Other possible issues with this standard agitation mixing process include the insufficient wetting of powder, and the potential to create a major process bottleneck when uniform blending requires substantially more time.

THE NEW RESOLUTION:
The good news for process design engineers is there are now more effective methods to mixing solutions and slurries. Strategies for an optimal slurry mixing process are best done on an individual basis working collaboratively with a custom design equipment manufacturer who understands the particular challenges of the chemicals being mixed, and how to efficiently address them. Some basic process design concepts are described within this article, with the understanding that many system variables are unique to a plant or to a process. For this reason, a standard equipment purchase may not produce the best results when processing more challenging components.

AN OPTIMIZED APPROACH:
The basis of effective dry and liquid mixing includes a wetting cone and eductor working in combination with a powder feeder.

The process begins with a solution that is metered, using a wetting cone to ensure good contact between the powder and the liquid. The eductor uses the
flow of liquid through an orifice to create a vacuum through a calculated pressure drop. The vacuum then draws the powder and wetting solution through the eductor. The wetting stream, which is roughly 10% of the total flow before the eductor, is introduced tangentially to produce a vortex effect. The vortex allows the powder and liquid to pre-mix prior to flowing through an eductor.

The amount of turbulence created by the vortex effectively completes the blending process as the mixture passes through the eductor. For applications with powders that are difficult to wet, or where the powder handling can be hazardous, the best practice design uses a self-contained system for adding one or more powders with the mixing solution. This mixing method works exceptionally well in a variety of chemical processing applications. It also solves many of the common mixing challenges in the food, pharmaceutical, water treatment, and oil and gas industries.

A CUSTOMIZABLE SOLUTION:
From this core mixing design, various configurations can be developed based on specific application requirements. One example is slurry, or a solution system, using multi-powder, loss-and-weight feeders coupled with a hoist-assisted bag unloader and bag dump station. The operator simply loads the bulk powder using a hoist or bag dump station. This system can be designed to deliver slurry in measured batches, or by continuous flow.

Another option uses a helix or tubular drag conveyor to deliver the powder to the feeder, eliminating
the need for manual dumping and decreasing human risk. The combination of a weight-and-loss auger style feeder, or volumetric auger style feeder, allows for the accurate mixing of solutions and slurries with, or without, a known concentration. Other engineered configurations are easily conceivable through design collaboration to address specific challenges presented by the chemical properties of the products being processed. (See figures 2, 3, and 5).

When designing a new or upgraded slurry mixing system, there are several important design elements to consider. First, the viscosity of the resulting slurry or solution must not exceed the requirements of the eductor. When the viscosity is too high, a standard eductor will fail to create a vacuum, resulting in poor or no mixing. Special eductors can be used in applications where the viscosity exceeds the capacity of the standard version. Process design engineers should be prepared to work closely with equipment design engineers to ensure accurate eductor sizing.

The second consideration is taking into account that the maximum allowable back-pressure is 15 psig, which can limit the vertical discharge lift height. The use of a loss-in-weight feeder, or a more cost effective volumetric feed system, permits a controlled and accurate feed for a slurry or solution. This enables virtually instantaneous mixing at any required concentration. To verify the final slurry or solution, use a Coriolis meter to detect the density, total solids, and flow rate.

**CASE STUDY – OPTIMAL MIXING FOR DIATOMACEOUS EARTH**

EP Minerals, located in Reno, Nevada, is a major producer of diatomaceous earth, cellulose and perlite filter aids, coatings, absorbents, and soil additives. The company enlisted Hapman to help develop an optimized manufacturing process for diatomaceous earth slurry to meet their customer’s specifications for coating paper products. The solution had to precisely add dry diatomaceous earth at an accuracy of ±2%, and a concentration of 7.15% by weight. Because the diatomaceous earth was delivered in super sacks (bulk bags), a system featuring a combination bulk bag unloader with a feeder, and an eductor with a wetting cone was recommended, (see Figure 4 on previous page).

Based on the above specifications, the flexibility of an eductor system proved beneficial for several reasons. An eductor type mixing system can be used on a batch or continuous basis. A continuous process can control the concentration based on outside requirements, such as pH, conductivity, flow, pressure, temperature, and rate of reaction. A batch system can also be adjusted from one batch to another varying the concentration of the solution or slurry.

The bulk bag unloader was included in the system and put on load cells to correctly measure how much material was delivered over time. To help EP Minerals design an optimal system for their application, Hapman first established a materials rate

<table>
<thead>
<tr>
<th>ft³/hr</th>
<th>5 PSIG, gpm</th>
<th>10 PSIG, gpm</th>
<th>15 PSIG, gpm</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td></td>
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</tr>
<tr>
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<td>8</td>
<td>7.1</td>
<td>7.9</td>
<td>9.3</td>
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<td>9</td>
<td>7.25</td>
<td>8.25</td>
<td>9.5</td>
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<td>7.4</td>
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<tr>
<td>11</td>
<td>7.5</td>
<td>8.7</td>
<td>9.95</td>
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<tr>
<td>12</td>
<td>7.6</td>
<td>8.8</td>
<td>10.2</td>
</tr>
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<td>7.75</td>
<td>9.1</td>
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<td>7.9</td>
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<td>8.2</td>
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<td>10.9</td>
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<td>10</td>
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<tr>
<td>23</td>
<td>10.75</td>
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<td></td>
</tr>
<tr>
<td>24</td>
<td>11.5</td>
<td></td>
<td></td>
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</tbody>
</table>

Table 1
to determine the most efficient size for the feeder and the eductor. The bulk density of the diatomaceous earth was stated as 16 lbs/ft³. The rate was determined to 22 ft³/hr to successfully achieve a concentration of 7.15%. The following steps were used to determine feeder and eductor size:

Determine the feed rate required (22 ft³/hr) and select the feed rate, (see Table 1).

Select the maximum discharge pressure required (5 psig). Using the standard educator, the maximum pressure drop allowed is 5 psig.

If the feed rate is in excess of 24 ft³/hr, or the maximum discharge pressure is not acceptable, then find the appropriate multiplier and divide that multiplier by the actual rate, (see Table 2).

Use the multiplier to find the required liquid flow rate.

The data from the EP Minerals application is shown in tables 1-3. The selected eductor is 1”, to meet a feed rate of 10 gpm, with a not-to-exceed 5 psig back pressure on the discharge of the eductor. Because of the abrasiveness of diatomaceous earth, stainless steel construction was selected for the system.

Next, the auger size of the feeder was determined, based on feed/dosing rate, (see Table 3). An appropriate nozzle was then selected to match the screw.

The final step was to determine if the system should be controlled by volume or by weight. Because of the application’s need for accuracy, a weight-based system was selected. Though more expensive and complex than standard volumetric controls, a weight-based system allows for ± 0.5% accuracy.

A volumetric control has an accuracy margin of between ± 2% to 5%, and would not have worked with this application’s process specifications.

**SUMMARY**

This case study demonstrates how an eductor-based mixing system can effectively handle a wide range of materials, and how overall process optimization can be achieved. In addition, the eductor mixing system offers increased efficiencies over a conventional system of mixing by allowing solutions and slurries to be made on demand – as opposed to pre-mixed in large holding tanks.

---

**Table 2**

<table>
<thead>
<tr>
<th>Size Screw, Outside Diameter, Inches</th>
<th>Screw diameter, Solid Center diameter</th>
<th>Dosing Rate ft³/hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>⅜”</td>
<td>⅛”</td>
<td>0.03 to 0.42</td>
</tr>
<tr>
<td>⅜”</td>
<td>⅝”</td>
<td>0.07 to 1.06</td>
</tr>
<tr>
<td>⅜”</td>
<td>⅜”</td>
<td>0.11 to 1.58</td>
</tr>
<tr>
<td>1 ⅛”</td>
<td>½”</td>
<td>0.25 to 3.7</td>
</tr>
<tr>
<td>1 ⅛”</td>
<td>⅝”</td>
<td>0.88 to 14.12</td>
</tr>
<tr>
<td>2”</td>
<td>⅛”</td>
<td>1.5 to 24</td>
</tr>
<tr>
<td>3”</td>
<td>¾”</td>
<td>5.3 to 88</td>
</tr>
<tr>
<td>4”</td>
<td>1”</td>
<td>14 to 230</td>
</tr>
<tr>
<td>5”</td>
<td>1”</td>
<td>30 to 475</td>
</tr>
<tr>
<td>6”</td>
<td>1”</td>
<td>58 to 918</td>
</tr>
</tbody>
</table>

* This is an abbreviated table and does not represent all available auger sizes.

**Table 3**

<table>
<thead>
<tr>
<th>Relative Size</th>
<th>Capacity Ratios</th>
</tr>
</thead>
<tbody>
<tr>
<td>⅜”</td>
<td>0.64</td>
</tr>
<tr>
<td>1”</td>
<td>1</td>
</tr>
<tr>
<td>1 ½”</td>
<td>2.89</td>
</tr>
<tr>
<td>2”</td>
<td>4</td>
</tr>
<tr>
<td>2 ½”</td>
<td>6.25</td>
</tr>
<tr>
<td>3”</td>
<td>9</td>
</tr>
</tbody>
</table>

---

Another important benefit is the system limits exposure to operators, and mitigates issues of delivering solid material in a large vapor space.

The design flexibility of an educator-based mixing system offers a high level of customized configurations. This allows process design engineers the opportunity to efficiently and effectively meet the demands of a facility’s many different raw material handling needs.

For more information on this study, or for addressing other mixing challenges, call Hapman at (800) 427-6260. Or, visit www.Hapman.com.

**DAN HAUGH** earned a Bachelor of Chemical Engineering degree from Georgia Institute of Technology, with a concentration in polymer science, and graduate work in biochemical engineering. He also studied electrical engineering at the University of Houston, and worked in the pharmaceutical, chemical, food, packaging, energy, and manufacturing industries. E-mail him at dan.haugh@hapman.com.
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Good Vibrations in Storage Vessels

Vibrating rod level sensors for point level detection in challenging powders

By Jenny Nielsen Christensen, MBA, Director of Marketing, BinMaster Level Controls

THE PROBLEM WITH POWDERS
What makes powders so challenging to detect with a level measurement device? One attribute is the variable composition of the powdered substance; it can be light and fluffy or extremely heavy and dense. The characteristics of the material stored in the vessel can vary due to factors such as moisture content or particulate size. Powders can be very fine – almost like a dust – or of a larger particle size, which will behave differently. Often in chemical processing plants, different types of material can be stored in the same tank over time, so it is more convenient to install a point level device that works in various types of materials.

If you are charged with managing a production facility, measuring the level of powders in bins, tanks, silos and other vessels is nothing to sneeze at. There are many types of level detection devices to choose from and undoubtedly, there will be performance and budgetary parameters that need to be met. A point level sensor is a device that sends an alert when the material in a vessel reaches a desired height, such as indicating if the vessel is nearly empty or full. Point level indicators are often the most affordable, reliable, and longest lasting solution for a chemical processing facility. When mounted in various strategic locations in the vessel, such as at near the top, at a critical replenishment midpoint, and near the bottom of the vessel, you can easily know when a bin is full, is ready for more material, or about empty. A rotary paddle switch, tilt switch, pressure switch or capacitance probe can be applied in a variety of powders with success. However, when dealing with challenging powders, a vibrating rod level sensor may be your best remedy.

TOUGH, YET SENSITIVE
The vibrating level sensor or vibrating rod is a piezoelectric driven vibration type level switch that is used for point level detection in bins, silos, hoppers and other vessels filled with powders or dry bulk solid materials. One of the technical advantages of a vibrating rod compared to other point level devices is its high sensitivity. A vibrating level
sensor can detect extremely light, fluffy materials as light as 1.25 lb./ft.\(^3\), such as aerated powders or flakes as well as heavier, coarse materials of larger particle size.

Vibrating level sensors are known for high performance and reliability and since the sensitivity is located at the tip of the sensor, material clinging to the vessel wall does not influence the function of a vibrating level sensor. Plus, a combination of low energy and tip sensitivity reduces the risk of false alarms due to building hollow spacing around an active sensor. As a vibrating level sensor is piezoelectric, it can be used to overcome difficulties in some applications associated with changes in dielectric constant, humidity, temperature, or material density.

A vibrating rod is a rugged sensor that is highly durable and virtually wear and maintenance free. For chemical processing applications where materials are harsh, the vibrating rod selected should feature stainless steel construction of all components that are in contact with the material or the vessel.

WO’N’T BUILD BRIDGES
A vibrating rod features a single rod element that prevents material from bridging, unlike a tuning fork that has two probes where material can lodge in between and result in a false signal. With a tuning fork, bridging can occur even in low level alarm applications where the pressure from material piled above the device can press material in between the two probes. When the material level drops below the level where the tuning fork is installed, the fork will still indicate “full” status, because the material bridged in between the probes doesn’t fall away and continues to dampen the vibration. False full signals can interrupt a production process or shut down operations until the material in the vessel is replenished.

Particularly in powders, a single rod with a sword-shaped design overcomes the problem associated with tuning forks where material lodges between the two probes of the fork, builds a bridge and sends a false “full” signal. Some single rod

---

**SWOR D-SHAPED ROD MAXIMIZES VIBRATING ROD PERFORMANCE**

BinMaster’s family of vibrating rods can detect the level of powders materials in bins, tanks, silos and other vessels.
- Suitable for high, mid & low level indication, or plugged chute detection
- Unique single rod, sword-shaped probe design resists false alerts
- Detects extremely light powdered materials with bulk density as low as 1.25 lb./ft.\(^3\)
- Standard insertion length of 7.37”, up to 19’ extensions for top mounted applications
- Durable, stainless steel construction of all components in contact with material
- Hazardous location options for volatile environments
- LED status indicator light alerts to device status
- Three sensitivity settings, no calibration required
- Easy to install, convenient dual conduit entries
- Switch selectable high/low fail-safe
- High temperature and remote electronics models available
designs feature a round probe that may not be optimal for use in powders as material might adhere to it. A sword-shaped, single rod design is optimal for use in powders as its sharp edges encourage material to flow around the rod and reduce the risk of material sticking to it. The functionality of a vibrating rod improves when there is less surface area for material to cling to.

**A TIP FOR EXCELLENT SERVICE**

The tip of the sensor rod is what drives the sensitivity and correctness of the device status. The rod vibrates when there is no material covering the active rod. When the rod becomes covered with material as the vessel is filled, the vibration is dampened and an electronic circuit causes a relay to switch and sends an alert that the device is covered. Conversely, when the rod becomes uncovered, the vibration resumes and the relay will switch back indicating that the material level is now below the device.

With advancements in product design, most vibrating rods do not require calibration and easily adjust to the desired sensitivity level. Dust does not prevent the rod from vibrating, which ensures the device reacts properly when dust clouds or agitation are present. Environmental changes in the bin – such as temperature, humidity or pressure – do not require recalibration or impact performance. For process-critical applications, some models of vibrating rods offer a fail-safe alert that provides notification when power to the device is interrupted. This valuable feature helps to avoid overfills and empty tank situations that could shut down operations.

**WHAT’S THE POINT?**

Vibrating level sensors offer a great deal of flexibility utilized as a high, mid or low level alert mounted on the vessel wall. They can also be mounted on the top of the tank as a high level detector or in the bottom cone of a tank to sense when the tank is nearly empty. A vibrating rod mounted on the top of the tank can be extended down into the tank using a rigid or flexible extension. A top mounted, rigid extension can be installed anywhere on the vessel roof, as long as it is not in the fill stream. The rigid extension can be made of galvanized or stainless steel and is manufactured to a customer’s specification, so the vibrating rod can detect material when it reaches the desired headroom height. A flexible extension made of steel rope reinforced cable withstands the rigors of material falling into the bin.

Some manufacturers may offer the option of mounting the electronics remotely from the sensing rod to protect the electronics from excessive conditions such as heat or vibration. In some chemical processing facilities, high temperature vibrating rods – some of which can withstand temperatures of almost 500°F – may be mounted directly on the vessel or using remote electronics.
BIN LEVELS without climbing!

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- Non-contact 3DLevel-Scanner with optional 3D mapping for dusty environments
- SmartBob sensors & eBob PC software for monitoring multiple bins

Affordable. Reliable. Safe.

BinMaster inventory management systems and bin level indicators eliminate guesswork and keep employees safe

SmartBob and eBob Software

For bins, tanks, silos and chutes

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800-278-4241 or info@binmaster.com
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Explosibility Testing
Stuart Johnson, Fike Combustion Testing Services

IT TAKES less time than you may realize to start an explosion. Dust and gas explosions are deadly and commercially devastating. Unfortunately, many of them occur at facilities without a prior explosion incident, providing a false sense of security. Leading insurance firms estimate the direct costs of an explosion typically run in excess of one million dollars, with many unprotected explosions leveling plants and/or closing businesses. The reality is that many facilities have inherent risks that should be addressed to prevent an inevitable catastrophe.

When it comes to safety and protection in dealing with dust explosions, there is little margin for error -- effective testing, product analysis and explosion risk management are critical. The first step in hazard analysis is to effectively determine the material’s combustible or explosive nature. To assure proper execution and interpretation of the results, tests must also be conducted in accordance with ASTM and CEN standards. Some material tests available include:

DUST EXPLOSIVITY SCREENING OF A DUST CLOUD
Prior to performing more specific tests to determine explosibility parameters such as KST and PMAX, a series of tests can be performed to determine whether the sample in question can produce a dust deflagration at all. The latest version of ASTM E1226 “Standard Test Method for Explosibility of Dust Clouds” includes a procedure for performing a simple explosivity screening test. Tests are conducted at a few dust concentrations covering a wide range, exposing the resulting dust clouds to a sufficiently strong ignition source. Analysis of data is performed to determine whether any test conducted produced sufficient pressure to meet the qualification for ignition.
MAXIMUM DEFLAGRATION PRESSURE (PMAX) AND KST OF A DUST CLOUD
Tests are conducted in accordance with ASTM Standard E1226 “Standard Test Method for Exposibility of Dust Clouds”. Dust samples are pneumatically suspended and ignited using a sufficiently strong ignition source. The maximum rate of pressure rise measured is used to calculate the KST value -- an internationally recognized index used to classify dust explosibility. This test measures the potential explosion severity of a dust/air mixture, and is used to assist in the design of explosion protection systems.

MINIMUM DUST CLOUD IGNITION TEMPERATURE OR AUTO IGNITION TEMPERATURE (MAIT)
The minimum temperature at which a dust cloud will ignite when exposed to air heated in a furnace, in accordance with ASTM E1491 “Standard Test Method for Minimum Autoignition Temperature of Dust Clouds”. The minimum ignition temperature is the lowest furnace temperature that results in propagation of flames. The MAIT is used in the analysis and design of explosion prevention and protection systems. In addition, the MAIT of a dust, along with the samples minimum ignition energy (MIE) and its minimum explosible concentration (MEC) is used to calculate the ignition sensitivity (I.S.) of the dust sample.

MINIMUM DUST CLOUD IGNITION ENERGY (MIE)
Determines the lowest spark energy required to initiate a dust explosion. Small quantities of dust are pneumatically thrown into suspension and ignited with an electric spark within a test vessel. This test assesses relative sensitivity of the sample to ignition by electrical sparks using the test procedures specified in ASTM E2019 “Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air”. The MIE of a dust, along with the samples minimum explosible concentration (MEC) and its minimum dust cloud ignition temperature (MAIT) is used to calculate the ignition sensitivity (I.S.) of the dust sample.

AUTO-IGNITION TEMPERATURE OF VAPORS
Tests are conducted in a temperature controlled 1-L vessel per ASTM E659 “Standard Test Method for Autoignition Temperature of Liquid Chemicals”.

Tests are conducted at varying sample concentration to determine the lowest temperature for the development of a hot-flame ignition.

**MINIMUM EXPLOSIVE CONCENTRATION OF DUSTS (MEC)**
The minimum explosible concentration (MEC) of a dust is the lowest airborne concentration of dust particles that can result in a deflagration. Tests are conducted in accordance with ASTM E1515 “Standard Test Method for Minimum Explosible Concentration of Combustible Dusts”. The data from this test can be used to design explosion prevention systems per applicable NFPA standards. In addition, the MEC of a dust, along with the samples minimum ignition energy (MIE) and its minimum dust cloud ignition temperature (MAIT) is used to calculate the ignition sensitivity (I.S.) of the dust sample.

**LIMITING OXYGEN CONCENTRATION FOR DUSTS (LOC)**
This test determines the lowest oxygen (oxidant) concentration at which a dust deflagration hazard exists for a given dust. Tests are conducted in accordance with the ASTM draft standard “Standard Test Method for Limiting Oxygen (Oxidant) Concentration of Combustible Dust Clouds”. It is used in the design of explosion prevention systems, specifically inerting systems, per applicable NFPA standards.

**MINIMUM DUST LAYER IGNITION TEMPERATURE**
Determines the minimum temperature at which a dust layer will ignite when exposed to a heated surface. Tests are conducted in accordance with ASTM E2021 “Standard Test Method for Hot-Surface Ignition Temperature of Dust Layers”. This data is used to analyze and design fire / explosion prevention and protection systems.

**LIMITS OF FLAMMABILITY (LIQUIDS / GASES)**
Determines upper flammable limit (UFL) and lower flammable limit (LFL) of liquid or gaseous chemicals in the air at ambient pressure per ASTM E681 “Standard Test Method for Concentration Limits of Flammability of Chemicals (Vapors and Gases). This test is used in the design of safe operating limits and process operations. Information is suitable for publication in Material Safety Data Sheets.

**LIMITS OF FLAMMABILITY (ELEVATED PRESSURE AND TEMPERATURE)**
Determines upper flammable limit (UFL) and lower flammable limit (LFL) of liquid or gaseous chemicals at elevated pressure and/or temperature per ASTM E918 “Standard Practice for Determining Limits of Flammability of Chemicals at Elevated Temperature and Pressure”. Tests can be performed at conditions as high as 300°C, 300 psig. This test is used in the design of safe operating limits and process operations.

Material explosibility testing provides a basis for safe plant design, safe operating parameters, and safe handling procedures. It is important to find a testing lab that not only has the correct testing facilities, but is staffed with highly trained technicians, engineers, and combustion scientists.
Fike can help you make the right decisions.

Proper explosion protection is essential for a safe facility. But it may be hard to get your hands around all the changing regulations, codes, and legislation in the U.S. Fike has been providing explosion protection solutions for nearly 40 years. We have the expertise to help you make good decisions to improve the safety of your facility and comply with regulations. Without spending a fortune.

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1-866-758-6004
When Powders Are Too Cohesive

Robert G. McGregor General Manager - Global Marketing and High-End Lab

FLOW PROBLEMS
Arching and ratholing are two of the common problems that accompany powders that have cohesive flow behavior. Cohesiveness is the physical phenomenon where powder particles bind together. Arching is the capacity of flowing powder to build a bridge, or structural blockage, across the opening of a hopper, thereby limiting or totally preventing discharge from the bin. (See Figure 1a) Ratholing is similar in nature in that the powder builds sufficient structural strength to create an annular ring inside the bin, which does not move. (See Figure 1b) In both cases, someone on the production floor has to take action to eliminate the flow restriction.

Lost productivity and the potential for negative impact on product quality are the immediate consequences of these flow problems. Worker safety may also be compromised, depending on the corrective action taken to remove the arch or the rathole. “Hopper bashing”, a common practice, requires someone to bang the bin with a hammer in an attempt to dislodge the powder arch. Sending a man inside the vessel is the most drastic step that might be taken to collapse the rathole. Personal injury can result in either case.

TYPES OF FLOW BEHAVIOR
Mass flow and core flow are the two patterns that occur when powders discharge from a bin. Gravity is the driving force which causes the powder particles to flow. The combined weight of the powder in the bin pushes the powder particles
through the hopper section toward the opening at the bottom. Frictional forces between the powder particles and frictional forces between hopper wall and powder particles provide resistance to flow.

Mass flow is characterized by uniform downward movement of the particles in the bin. (See Figure 2a) “First in, first out” correctly describes what is happening. Note that the hopper walls are relatively steep relative to the vertical. Formulations that are a mixture of different powders benefit from this type of flow because there is limited tendency for desegregation.

Core flow is characterized by movement through the central channel of the vessel. (See Figure 2b) Powder particles at the top of the bin cascade toward the middle and move down through the core of the bin. “First in, last out” describes the flow behavior. Desegregation of mixtures is one of the undesirable consequences.

Most hoppers operate in core flow. The primary reason is that the hopper half angle (the angle of the hopper wall relative to vertical) is not steep enough to permit mass flow. Hoppers are traditionally designed for angles of 30°, 45° and 60° or variations thereon. Mass flow oftentimes requires much smaller angles relative to vertical. A combination of design practice and space limitations in the plant preclude hoppers from having the necessary dimensions to achieve mass flow.

METHODS FOR PREDICTING FLOW

Popular methods used to predict flow behavior in gravity discharge from bins include the Flodex Cup, the Angle of Repose measurement, and the Tap Test. They have been in use for many years, are easy to perform, and can be inexpensive to purchase.
Figure 3 shows the Flodex Cup which is similar to the many types of flow cups used to measure liquid viscosity. There is a hole in the bottom with a specific diameter opening. Note that the bottom of the cup is relatively flat, so the shape of the cup does not simulate the V-shaped structure of the hopper. The powder is poured into the cup and flowability is determined by whether anything comes out the bottom. In short, it’s a “Go” or “No Go” situation.

The Flodex Cup comes with a selection of discs that have holes of varying diameter. The operator can experiment by changing discs in order to find one that will allow the powder to flow. This determination may then be correlated with a target value for the opening dimension of the hopper.

Angle of Repose is a measurement technique that measures the angle of a pile of powder relative to horizontal. The correlation of this angle with the necessary size for hopper opening is an empirical process. Results are generally less than satisfactory as most operators report that it seems to be a guessing game at best.

The Tap Test involves filling a cylinder with powder, tapping it a defined number of times to cause settling, and measuring the reduction in volume. This method gives a clear indication of the change in density that might be expected as a powder settles. The unanswered question is how fast the powder will settle. This, of course, affects the cohesive flow behavior that may result.

Figure 4
Shear Cell Components – Trough and Vane Lid

Figure 5
Brookfield Powder Flow Tester with Sample in Trough

CONSOLIDATION
What’s missing in these commonly-practiced test methods is the physical process of consolidation that
a powder experiences when placed in a bin. Gravity is always at work. Therefore, the self-weight of the powder will gradually cause settling. This process expels the air trapped in the powder and brings the particles closer to each other. Increased proximity causes the sliding friction between particles during movement to experience greater resistance to flow. Herein lies the key to coming up with a test method that can simulate what is actually happening to the powder.

SHEAR CELL METHODOLOGY
The Shear Cell was designed decades ago in the minerals industry and has since become the most effective method for predicting powder flow behavior in gravity discharge from vessels of any shape or size. One design that has become popular is the annular ring. (See Figure 4) The powder sample is placed in the outer ring of the Trough. The Vane Lid and Trough are placed on the instrument shown in Figure 5. The Vane Lid comes down on top of the sample, compresses it to a specified pressure, and then shears the powder. The particles in the trough slide against the particles in the lid and the frictional resistance prior to the start of movement is measured. Essentially, the yield stress of the powder, or the amount of strength that it has, is quantified by this technique. This measurement process is repeated at increasing levels of compressive pressure applied by the Vane Lid which simulates, in effect, higher fill levels of powder in a bin.

THE FLOW FUNCTION
Industrial experts in the science of powder flow have agreed on the Shear Cell test method for characterizing flow behavior. The graphical description of the data that results is called the Flow Function which plots “failure strength” against “consolidation stress”. (See Figure 6) Note that various regimes of flow behavior are described as one of the following:

- Free Flowing
- Easy Flowing
- Cohesive
- Very Cohesive
- Non Flowing

The material in Figure 6 is “Very Cohesive” at low consolidation stress and transitions to
“Cohesive” behavior as consolidation stress increases. Many powders exhibit a similar pattern which means that flow behavior may actually improve as the fill level in the bin goes higher.

**DENSITY**

Shear cell methodology requires that the density of the powder be measured at each consolidation stress. Figure 7 shows how the density increases from its lowest value at the initial “loose fill” volume condition when the powder is poured into the trough, to a much higher value at the highest consolidation stress. Somewhere on this curve is a point of equivalency that will correlate with the Tap Test described earlier.

Compressibility of the powder is a characteristic that can be correlated with cohesive behavior: the more compressible the powder, the more likely that it will exhibit cohesive behavior. A general rule of thumb is that powders, which increase in density by over 50% relative to the loose fill condition, will have cohesive to highly cohesive flow behavior.

**WALL FRICTION**

The test procedure for measuring the effect of the powder sliding against the hopper wall is similar to the flow function test. In this case, the lid is a flat surface made of material similar to the hopper wall. Examples might include a mild steel, stainless steel, or plastic material. The powder sample is compressed by the Wall Friction Lid which then shears the material in order to measure the amount of frictional resistance that builds up prior to movement of the lid surface against the powder. The data from the test is shown in Figure 8a. The angle which the data curve makes with the x-axis (consolidation stress) is equivalent to the chute angle. This simulates taking a powder sample, placing it on a horizontal plate, and inclining the plate to an angle where the powder starts to flow down the surface. (See Figure 8b)

**DATA ANALYSIS FROM THE SHEAR CELL TEST**

When using the shear cell, flow behavior for the powder is clearly characterized in terms of the friction between particles and the friction between powder and hopper wall. The density data gives a picture of the compressibility of the powder. With this data it is now possible to calculate the potential for cohesive arching when the powder is in mass flow.

![Figure 8a](wall_fric_test_data.png)

**Figure 8a**
Wall Friction Test Data

![Figure 8b](chute_angle_determines_whether_powder_will_flow.png)

**Figure 8b**
Chute Angle Determines Whether Powder Will Flow
and ratholing when the powder is in core flow.

Software provided by shear cell manufacturers automatically performs this data analysis. Note that the values for the arching dimension, which equates with the minimum hopper outlet opening, and the rathole diameter are conservative estimates for what may be needed in hopper design. Figure 9 shows the type of graphs that result. In addition, it is possible to calculate the hopper half angle required to achieve mass flow. For cohesive powders the hopper half angle may be < 30°, and perhaps even close to 0°, which implies that it is not practical to have a mass flow condition because the hopper would be extraordinarily tall in height.

CONCLUSION
Processors that handle cohesive powders know only too well the types of throughput problems that come up on a recurring basis. The ability to predict flow issues beforehand is the new capability offered by shear cell methodology. The ability to take corrective action through the use of flow aids or the redesign of hopper/bin dimensions is the solution that derives from the analytical calculations on shear cell data.

It is now possible to evaluate the effect of various concentrations of flow aid, because the shift in the flow function position is directly correlated with the amount of additive in the powder. Obviously, if less additive can be used, 1% for example instead of 2%, the savings goes directly to a reduced cost to manufacture.

There are many reasons to investigate what a shear cell can do for your plant. Reasonable purchase price, simple ease of use by anyone in the lab, and rapid test time per sample are all trademarks of today’s conventional shear cell. Why not take the opportunity to check it out and see if the shear cell can make a difference for your operation, especially if your powders are
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