SHAPA TECHNICAL PAPER 3

TEN KEY STEPS
FOR
ACHIEVING RELIABLE FLOW FROM HOPPERS

Ten Key Steps for Achieving Reliable Flow from Hoppers

Lyn Bates, Ajax Equipment Limited, Bolton
Mike Bradley, The Wolfson Centre, University of Greenwich

1. Choose your flow pattern – mass flow or core flow:

In the first instance, decide what flow pattern you want in the bin – do you need mass flow, or will core flow be adequate?

a) If you have a material which is free flowing and contains a wide range of particle sizes or blend components, this will segregate easily. If that segregation would create a problem to your customers or downstream processes, then you need mass flow.

b) If you have a material which is highly time-dependent - for example it goes off, goes hard, cakes or ferments in long term storage - then you need mass flow **unless** you empty the bin right out sufficiently often to prevent spoilage in the material near the bottom (in a core flow bin, the first material put in never moves until the bin is emptied right out).

c) If you need very accurately controlled discharge rate through a precision feeder, you need mass flow to give a consistent bulk density.

d) If you have a material which is very finely divided and can retain air and stay in a fluid-like condition for a long time – like cement powder for example – then you need mass flow to avoid “flushing” (uncontrollable flow of aerated material from the top of the inventory, down through the central flow channel).

e) If you have a material which is very cohesive – makes a “snowball” in the hand – then mass flow might be a good idea as you won’t need such a big outlet for reliable discharge, as if you had a core flow bin. Especially if you need to go down to a small outlet, use mass flow for the lower section – known as an ‘Expanded Flow’ construction.

If none of the above a to e apply, i.e. the material is free flowing, always remains so, does not spoil or harden with time, does not segregate (or segregation does not matter to you), is not very fine and you don’t need highly accurate control of feed rate, then go for core flow, it will make for a cheaper construction which requires less headroom. If any one of the above a to e applies, then you had better choose mass flow to avoid trouble.

Do not leave this issue to chance, it is the single most important decision to make when sourcing a hopper or silo, and make sure the supplier understands which flow pattern you need and why. If you don’t understand mass flow and core flow, then find out about it. (Reference 1, or other texts on materials handling).

2. Obtain a good sample of the material:

Make sure that you know the full range of conditions of the material to be stored. Secure an officially verified, ‘fully representative’, sample and check that it is of consistent supply, from an homogeneous stock and stable in time and under the relevant operating conditions - or know the reason why. If the material is at all variable, then get a range of samples covering the full range of material conditions, and make sure you identify and design around the worst.

3. Measure the friction between material and hopper wall, and determine the necessary hopper wall angle:

Measure wall friction every time. If possible use several options of the wall contact material (hopper inner surfacing material) – note that the surface finish, as well as the material, must be strictly representative of that to be used in the hopper. Record the measurement for both design and reference. There is no ubiquitous 'Low Friction' lining material, it all depends upon both the product and the contact surface – hence the advantage in testing several different surface options to find the best. Use the wall friction value to determine what the hopper slope should be, either to obtain mass flow, or to ensure self-draining in core flow. Note that selection of the right hopper angle depends almost entirely on wall friction. It is much easier to do something about breaking an arch over an outlet which is too small, than it is to generate wall slip if the slope of the hopper wall is inadequately steep – hence the key role of measuring wall friction and getting the right hopper angle.

4. For a cohesive material, determine its arching dimension, then select appropriate bin outlet size and feeder size:

If the material is significantly cohesive, i.e. forms a snowball when pressed in the hand, then if possible measure the internal flow properties ("Jenike flow function") in addition to wall friction, and use this to determine how wide the outlet needs to be for reliable discharge. Select a feeder larger than this determined outlet size, even if this means the feeder is bigger than what you would need to just cover the maximum discharge rate needed. For further details see reference 1.

Establish, and allow for, any extended periods of storage. Not just in normal use, but for reasons of production campaigns, holidays, breakdowns, or irregular stoppages. These will require a larger outlet size for flow to re-initiate reliably after the shut-down, and can be allowed for in determination of the Jenike flow function.

5. Check on changes in operating conditions:

Check whether the ambient conditions alter according to production conditions, weather, season or events such as site wash-downs – and allow for the effects of these on the material being stored. Severe local vibrations will strengthen the material, so allow a larger outlet size.

6. Ensure correct detailing:

Ensure by design and fabrication that there are no surface impediments to smooth surface slip. Weld spatter or weld runs across the contact wall surface, offset flange joints, protruding gaskets, recessed ports and projecting intrusions near the outlet are highly effective at opposing the slip of material on the wall contact surfaces.

7. Allow for future changes:

For preference, allow a flanged joint well above the outlet, and a little spare headroom so that access is available, then in the event of major flow difficulties caused perhaps by a change in the material, a new outlet section can be retrofitted with little site work.

8. Outlet valve:

Consider fitting a valve of a larger size than the final outlet, and completing the convergence below this valve, to assist the commencement of flow. Materials, once moving, will flow through a smaller opening than that required to commence flow from a static condition, particularly if hopper contents are consolidated as a result of time in static storage. If using this approach then make sure the shutdown sequence causes the valve to close, then the material to be cleared from underneath it, before the feeder stops.

9. Choose flow assistance devices with care:

Be aware that circular bins 'ring' like a bell when vibrated. They have inactive nodes at 45° to the initiating point. If fitting two vibrators, install them at 45° horizontal spacing, as near as practical to the outlet and activate them alternately, preferably only when flow is required and not occurring. Do not be bashful about considering flow assisting devices.

If storing a finely divided powder, then the application of a little air injection on the converging section will be desirable.

10. Consider vee versus conical designs:

The most vital region for flow is the geometry of the outlet zone. Vee-shaped hoppers are twice as effective for outlet size than conical flow, and do not need to be so steep to make the material slip on the walls (i.e. to give mass flow). For reliable flow with variable materials, with highly frictional materials, or when the final outlet size is limited, use a vee-shaped hopper, preferably with 'Sigma Two' relief (For an explanation of Sigma Two relief, and details of how to use inserts to improve flow, see Reference 2)

Reference 1 – Handbook "Design of Hoppers and Silos for Strength and Flow", Wolfson Centre, University of Greenwich, Wellington Street, Woolwich, London, tel 020-8331-8646

Reference 2 – Technical article by Lyn Bates, Ajax Engineering Ltd, Mule Street, Bolton, Lancs, tel 01204 386723

Too late? - If you have to bang the hopper to get the material to flow, it is not properly designed.
Fix it before it gets worse, as it will.