Mass flow where stuff wants to stick:

FIFO technology to completely empty bins and silos

by John Koorn

Feed manufacturers are using more by-products and co-products of other industries than ever before. These ingredients can be very economical sources of protein, energy, fiber and other nutrients, but some can be a nuisance to handle, too. Often the feed mill's conventional bulk handling systems have trouble with protein meals, bakery by-products and "spent" grain products. These materials may bridge, clog or cross contaminate.

Cross contamination in bulk handling systems used to be a major concern mostly with medicated feeds, which required careful product sequencing, equipment cleanout, clean grain flushing and other control procedures. Recently, however, feed manufacturers have been asked to exercise similar controls to protect ruminant feeds if they are using mammalian protein ingredients in the same plant. This is part of new federal regulation to prevent an outbreak of bovine pongiform encephalopathy (BSE). For example, now meat and bone meal has to be kept out of cattle feeds. In many plants, this may mean doing a better job of getting bins and silos completely empty.

Figure 1. Funnel flow versus mass flow: Funnel flow occurs as stored materials cling to the wall of the silo, resulting in "first-in-last-out" (FILO) discharge; mass flow occurs when allthe material is discharged, resulting in "first-in-first-out" (FIFO) discharge.

For dry bulk materials in feed milling, the ideal form of discharge from a silo is "mass flow" (Figure 1, left). Mass flow discharge causes the uniform settling of the material without "funnel flow", "rat-holing" or bridging of the material (Figure 2, next page). Feed manufacturers typically think of mass flow as a passive design feature of special concrete or steel hopper or cone bottom silos.

Unfortunately, passive design mass flow silos cannot easily handle a wide range of ingredients. This is because each material has its own "angle of repose" at which it settles in a pile on a flat surface. This angle indicates the flowability of the material and is a major factor in developing the correct hopper design to promote mass flow.

To make matters worse, the angle of repose of a single type of ingredient—for example, poultry meal—may vary according to particle size, texture, density, temperature and moisture content. Ironically, the by-product and co-product ingredients that attract the nutritionist or formulator of least cost rations often cause headaches for the plant manager who must handle and process them.

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What is really needed: Inventory control

The plant manager may desire "mass flow" — but what he really needs is "first-in-first-out" (FIFO) inventory control. He wants the first pound of material loaded into the silo to be the first pound of material discharged. With FIFO material handling, the inventory of raw materials is moving constantly, which has many advantages, including:

- Better inventory records and management, because bin level sensors and other volumetric instruments give more accurate readings;
- Less pest infestation, because along with sufficient moisture and temperature, insects and others pests require enough time to reproduce and multiply, which is less likely in feedstuffs in motion; and
- Less deterioration or degradation of ingredient quality, again because no material is stuck in the bin too long, but also because there is less material surface area exposed to ambient air.

Caked and compacted oat hulls forming a "rat hole"

A well-designed passive mass flow silo can provide most of these benefits so long as the ingredient characteristics match the silo's mass flow requirements. But what about those low-cost-but-troublesome materials, bought by the feed mill's purchasing agent on the advice of a distant nutritionist?

The stickiest stuff

For really sticky materials, passive mass flow is not enough to achieve FIFO control. Moreover, when vibrators are employed in such situations, the plug or bridge can set like concrete. Worse still, when fixed auger or conveyor "live bottom" silos are used, the bridge often forms in the hopper itself, compacted by the weight of material above it.

Such a bridge of old material is seldom wide enough to be broken up by vibration. Rather, vibration usually makes the bridge stronger. Whenhammering proves useless, the plant manager calls for the remote-control grinder. Or, he sends a worker down into the silo—a dangerous job that nobody likes.

Yet it is still possible to achieve a kind of mass flow of sticky material. More importantly, FIFO inventory control is possible. Using the right silo discharge technique can produce mass flow of the stored materials.

"Hammer tracks" show this hopper has chronic—maybe terminal— bridging problems.

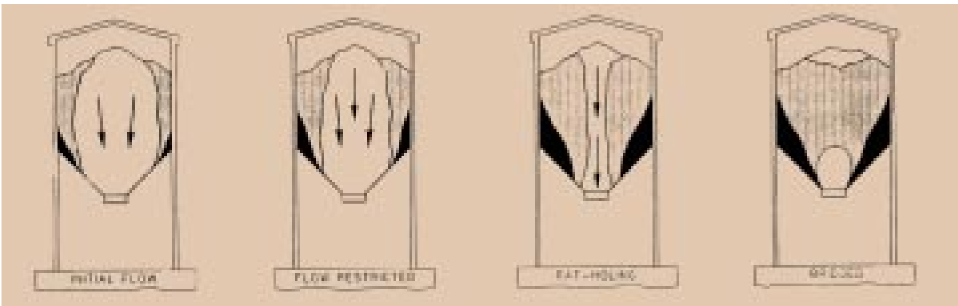

Figure 2. Progressive stages of the silo bridging process.

One design, for example, consists of a screw-type auger at the bottom of the hopper or the center of the flat-bottom silo near the discharge opening (Figures 3 and 4, below). As the auger revolves it also rotates, traversing or "sweeping" around the perimeter of the hopper or flat-bottom silo. The "sweep auger" thus undercuts the stored material, allowing the material to flow down in a flood formation which resembles mass flow. This technique results in "active", not passive, mass flow. And it permits FIFO inventory control—what the plant manager wanted all along.

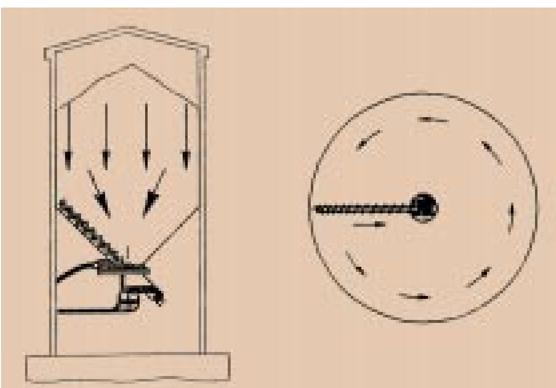

Figure 3. Material flow characteristics during discharge by means of a sweep auger discharge system.

It is important to note that a sweep auger discharge system is not simply a "live bottom" silo. A live bottom silo typically consists of a row of augers or screws at the bottom of a widened hopper. But "live bottom" is a misnomer, because with sticky ingredients the bottom may only be "live" for the beginning of discharge. This is because the bank of screws is not totally undercutting the mass, only cutting out a section of the material which may soon bridge above the screws.

The sweep auger discharge system can work as a retro-fit in a 60° hopper-bottom silo. However, installation of the system is much simpler in a 45° hopper or in a flat-bottom silo. Also, usually there is a much wider range of silo sizes for 45° and flat-bottom units. Silos with 60° hopper bottoms are less efficient designs in terms of space required and storage capacity. For new installations, 45° hopper-bottom or flat-bottom silos are the best alternatives.

Worst cases

One of the surprising things is that even common ingredients can be very sticky under certain conditions. For example, soybean meal—at 12% moisture and hot summer temperatures—can be very difficult to flow. Another typical but potentially problematic material is canola meal. "Worst cases" include: Meat and one meal, feather and poultry meals, blood meal, corn gluten feed and brewers grains.

Even wheat midds can be trouble. If you put the material in a silo and compact it, it will not flow without some sort of excavation device. Problems are compounded with high starch materials if there is any condensation along the silo walls.

Two examples stand out as the worst cases I have seen. The first involved a bakery by-product. When it was put in a "sweaty" or condensation-prone 24 x 80-foot silo in any significant amount, it compacted, becoming like concrete.

The solution for FIFO discharge of this product was a flat-bottom silo with sweep auger and rack-driven FIFO dome positioned in the center of the silo. Because of the horizontal mixing action of this machine, the discharged product was of higher quality than obtained previously. The moister bakery by-product along the silo wall had been commingled by the sweep auger with drier product toward the center. Yet the mixing action was horizontal, not vertical, and thus maintained the FIFO status of the product.

In the second example, a plant had a cluster of 10 silos with vibratory hopper bottoms used to store soybean meal. The company required a special crew to fight this material out of the silos every day, using compressed air lances and hammers. The soybean meal was bridging across the vibratory hopper bottoms and the vibrators mostly were moving air.

The solution had to be rather drastic. The vibratory hopper-bottoms of the silos were removed and a single 26-foot silo discharger was installed in each silo. Each discharger included a high-power sweep auger in the silo and a twin-screw discharge feeder to transport the product to the loadout system.

At 26 x 138 feet each, the geometry of the silos still was not ideal—it was more than 1:5 (width-to-height), when it should have been 1:3. Also, the soybean meal moisture content sometimes exceeded 13%. However, today the unloading crew is gone, the silos can be fully loaded, and the operator simply pushes a button to discharge each silo.

Sweep auger discharge systems

A sweep auger discharge system does require some extra engineering of the silo. By creating mass flow, the moving material puts additional pressures on the silo walls, which may have to be reinforced in a conventional silo not designed for mass flow.

All maintenance work on a sweep auger discharge system takes place outside the product zone except for work on the screw. In some designs for flat bottom systems, provision is made to stop the product flow for access to most of the moving parts inside the silo. In this way, the maintenance worker does not have to enter a confined space with the product present.

Sweep augers are highly effective in discharging the majority of meal-type feedstuffs from flat-bottom silos. For soybean meal discharge at the rate of 20-30 tons per hour, the flat-bottom sweep augers tend to be more expensive to maintain than hopper-bottom sweep augers. In terms of installation costs, for silos of diameters of 20 feet or less, costs are roughly equivalent for flat or hopper types. Above 20 feet in diameter, the flat-bottom type is more expensive, but silo capacity can be much greater.

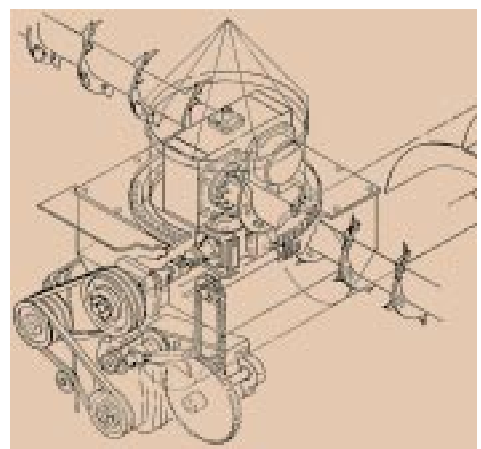

Figure 4. Details of one design of sweep auger discharge system, including twinscrew discharge feeder.

In determining particular requirements for sweep auger systems, a few details about the product are key: Product particle size, moisture content, bulk density, incoming and ambient temperature, and duration of storage. **FM**