For many bulk solids manufacturing operations, feeding accuracy is critical to product performance. This article focuses on feeding methods for both continuous and batch operations and provides an overview of how to select the optimal feeding method for your application.

Bulk solids manufacturers are always looking for ways to cut manufacturing and ingredient costs, minimize downtimes during product changeovers, and, in many industries, optimize product and process safety. For both batch and continuous processes, using automated feeders to accurately control ingredient dosing can help to achieve many of these goals. Using the most appropriate feeding system for your application can reduce your raw material consumption and waste, improve your overall product yield, ensure that your final product meets technical and quality specifications, improve system reliability, and reduce costly, unscheduled downtime.

It’s important to work with a feeder supplier when choosing a feeding method. The supplier should be able to provide an extensive outline of the choices available and have comprehensive expertise in handling a wide range of materials. This will ensure that you’re aware of the most accurate, economical, versatile, and efficient feeding options for your application. Before discussing those options, however, it’s important to know some basics about batch and continuous processes and the different feeder types available. [Editor’s note: For more detailed information on the processes and feeder types discussed in this article, see the “For further reading” section at the end of this article.]

Batch versus continuous processing

The decision of whether to manufacture a product using batch or continuous processing typically depends on the demand for the product, cost factors, and scale factors. During batch processing, each ingredient must be added, in the right amount (and often in the right order), following a recipe. Products are manufactured in discrete batches, one batch at a time, and the equipment components related to the required unit operations (the basic steps in the manufacturing process) function discretely as well.

Many bulk solid chemical, pharmaceutical, specialty food, beverage, and paint and pigment products are produced using batch processing. Pharmaceutical and biopharmaceutical manufacturers, for example, have historically relied heavily on batch processing because of the final products’ high value and potentially limited market size and because of complex and rigorous regulations that often require batch validation, product pedigree, and traceability. In recent years, however, semi-continuous and continuous production of solid-form pharmaceuticals is also gaining popularity.

In a continuous process, each ingredient must also be fed into the process in the right amount and at the right time in accordance with a governing recipe, but, unlike in a batch process, the equipment components related to the required unit operations function as a single system and are designed to operate 24 hours per day, 7 days per week (except for required maintenance periods). During continuous processing, ingredients must be fed into the
process continuously, and the final product is produced in a continuous stream, rather than in discrete batches.

In most cases, the increased equipment utilization and economics of scale associated with continuous processing create cost savings and operational efficiencies compared to batch processing. Many chemicals, petrochemicals, plastics, and mass-market products are produced using continuous processing.

Volumetric versus gravimetric feeding
As previously stated, both batch and continuous processes depend on ingredients being added in the right amount, and at the right time. To achieve this, bulk solids feeders are designed to either volumetrically or gravimetrically control (or meter) the rate at which they feed material into a process.

Volumetric feeders. As the name implies, a volumetric feeder discharges a known volume of material per unit time into a process. While simple and relatively inexpensive, a volumetric feeder isn’t able to capture or consider the material’s weight during discharge.

Gravimetric feeders. A gravimetric feeder discharges a known mass of material per unit time into a process. Compared to a volumetric feeder, a gravimetric feeder gives the operator more control over the feeding process and can discharge bulk solid materials with higher accuracy and precision.

Feeder configurations
Whether a process is operated in batch or continuous mode, volumetric and gravimetric feeders can be configured with a variety of feeder-discharge mechanisms. Selecting the proper configuration depends on the desired feedrate, the material’s flow behavior and physical and chemical properties, and how each material responds to atmospheric and loading conditions. The most common configurations are:

Single-screw feeder. A single-screw feeder uses a motor-driven, rotating screw inside a feed tube to draw material from a hopper and discharge it into a process. Single-screw feeders can be designed to operate either volumetrically or gravimetrically and tend to be best suited for granular or free-flowing powders, pellets, and flakes, such as salt, sugar, plastic pellets, and polyvinylchloride resins. Specific screw designs (such as constant- or variable-pitch), diameters, and profiles are available, and the screw can often be changed out between production runs, allowing a single feeder to handle multiple materials with different flow properties.

Twin-screw feeder. A twin-screw feeder is similar to a single-screw feeder but uses two screws (either intermeshed in a single feed tube or in two separate feed tubes). A twin-screw feeder with intermeshed screws is well suited to cohesive, sticky, or floodable materials, because the intermeshed screws keep floodable materials (such as carbon black, titanium dioxide, and iron oxide) from running through the feeder. The twin-screw feeder’s intermeshed screws are also self-wiping, which helps to keep sticky materials flowing.

Rotary feeder. A rotary feeder uses a motor-driven rotor with several blades (or vanes) enclosed in a metal housing. As the rotor turns, material flows into the spaces between the blades and is discharged into the process. Rotary feeders can be either top-fed or side-fed and are typically designed for very fine, free-flowing, or floodable powders.

Vibratory tray feeder. As its name suggests, a vibratory tray feeder uses a rapid vibration to feed material along a feed tray and into a process. Adjusting the vibration controls the material feedrate. Vibratory tray feeders are suitable for abrasive, friable, or fibrous materials that could damage or be damaged by other feeder types. In some cases, vibratory-tray feeders can also be used for very sticky materials, which tend to coat and plug screw-feeder configurations.

Weighbelt feeder. A weighbelt feeder operates by continuously weighing a moving bed of material on a defined length of conveyor belt. Using a control algorithm, the feeder’s controller continuously compares the material’s actual weight with a preprogrammed setpoint and automatically adjusts the belt speed to maintain the desired feedrate at the belt’s discharge point. A weighbelt feeder is typically best suited for relatively free-flowing materials that don’t require dust containment and fragile materials that could be damaged by other feeder types. These include many food and animal-food products, detergents, and plastic pellets.

Optimizing feeding accuracy in batch processes
A batching system’s operational efficiency depends on several factors, including the resolution and accuracy of the weighing device and batching method, the time required to produce a batch, and the space available for the equipment. The two basic batching methods are gain-in-weight (GIW) batching and loss-in-weight (LIW) batching. Each method has inherent advantages and limitations. In order to choose the most efficient method, it’s important to review your application’s requirements with respect to batch time, accuracy, changeover and cleaning time, and overall cost.

Gain-in-weight batching. GIW batching systems sequentially feed multiple ingredients into a collection hopper mounted on load cells (also called a scale hopper or weigh hopper), as shown in Figure 1. The load cells indicate when the correct amount of each ingredient has been added, and when the batch is complete, a valve at the
hopper’s bottom opens and discharges the material into the process below.

A GIW system’s accuracy depends largely on whether the system uses valves, such as wafer or slide-gate valves, or volumetric feeders to load ingredients into the scale hopper. Valves are generally more cost effective but can limit your control over the material flow into the feeder’s hopper and cause flow problems if the material isn’t free flowing. Scale hoppers that use valves can typically achieve weighing accuracies of ±0.5 percent of the scale hopper’s full-scale capacity (the capacity including the weight of the material, hopper, and discharge valve) making them suitable for high-volume or major-ingredient applications, where precise ingredient measurement isn’t critical.

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Wafer valves are also commonly used with pneumatic conveying systems. To optimize such a system, make sure the material flows freely without building up in the conveying line, the discharge valve, or the hopper below and operate the system free of internal moisture.

A pneumonic conveying system receiving vessel suspended on load cells can also be used as a batching scale hopper. This is ideal for loading blenders and mixers but is best suited for major ingredients, as the load cells may not be able to measure minor ingredients accurately.

A more accurate GIW method uses volumetric feeders, such as screw feeders, rather than wafer or slide-gate valves to load the scale hopper. Each feeder delivers approximately 90 percent of the ingredient weight at high speed, then slows down for the last 10 percent to ensure higher batch accuracy than can typically be achieved with a simple valve and scale hopper combination. The system’s GIW controller monitors the weight of each ingredient and signals the volumetric feeder to start, increase or reduce speed, or stop accordingly. Because each feeder operates sequentially, GIW batching allows feeding devices to be used for multiple ingredients, but this sequential operation also results in a longer overall batching time if the number of ingredients is high.

Loss-in-weight batching. In LIW batching, gravimetric feeders operating in batch mode simultaneously feed multiple ingredients into a collection hopper, as shown in Figure 2. Each feeder is on load cells or a scale to monitor the material lost from the feeder. The system’s LIW controllers turn the feeders on and off and adjust the feedrates. Since all of the ingredients are delivered at the same time, overall batch times are greatly reduced. In addition, highly accurate load cells specifically sized for the individual ingredient batch weights greatly increase this type of system’s accuracy. This method is often used for more expensive micro-ingredients because of the increased accuracy. However, this method can also be more costly, because each feeder requires a weighing device and feeders can’t be used for multiple ingredients.

Combination GIW-LIW batching. Many times, to make the overall batching operation more cost effective, a combination of GIW and LIW batching is used. GIW batching methods handle the major ingredients, and
separate LIW feeders handle the minor ingredients, whose batch weights may be too small to be detected by the GIW scale hopper.

Once you’ve determined the optimal batching method for your application, you can also integrate other design options into your batching system to further improve efficiency. These include easy-access and easy-clean support devices and frames, quick-disconnect systems, and even wash-in-place features to allow for quick product changeover and cleaning. It’s important to discuss all of these options with the batching system supplier to ensure that your operation is as efficient as possible.

**Optimizing feeding accuracy in continuous operations**

You can use either volumetric or gravimetric feeders to deliver bulk solids into a continuous process, depending on the materials and application.

Volumetric feeders are simpler in design and typically more cost effective than gravimetric feeders, but a volumetric feeder is essentially an open-loop device, meaning that the feedrate is solely a function of feeder speed and isn’t governed by any ongoing data feedback from the operation. Since a material’s bulk density can vary over time, the actual amount of material delivered to the process (the mass flow) can vary as well. Also, it’s possible for a volumetric feeder to have little or no material discharging while the feeder is running with no way of detecting the error. Even using level sensors in the feed hopper may not alert the process of this condition in a timely fashion, and off-spec product may result for a period of time. This makes volumetric feeders inappropriate for many continuous processes that have rigorous accuracy requirements. Volumetric feeders are best suited for applications handling materials whose bulk density doesn’t vary significantly and processes for which high feeder accuracy isn’t critical and direct measurement of the discharged material isn’t required.

For continuous processes where the ingredient amounts are critical to product quality — producing a continuous blend in a pharmaceutical tableting process, for example — gravimetric feeding is the best method. Gravimetric feeders continuously measure the material’s mass flow and adjust the feedrate to maintain the desired setpoint. The two leading gravimetric feeding methods used in continuous processes are LIW feeding and weighbelt feeding.

**Continuous LIW feeding.** LIW feeders are highly accurate, directly measure and control a wide range of material feedrates, and can fully contain the material and dust within the confines of the feeder. For continuous LIW feeding, the way material is refilled in the feeder can be almost as critical as the feeder type itself. The objective is to refill the feeder as quickly as possible to avoid interrupting the feeding process, so pneumatic receivers, which operate under a dilute-phase, vacuum-transfer principle, are often used as refill devices in a process called vacuum sequencing.

In vacuum sequencing, the pneumatic conveying system uses vacuum to fill a vacuum receiver that’s separately mounted and supported above the feeder’s hopper. The receiver fills to a set material level monitored by level-sensing devices and then holds this material charge until the feeder’s control system requests a refill. Then the receiver’s discharge valve opens, and the material is discharged into the feeder hopper. While the receiver is discharging, the system’s pulse-jet cleaning system cycles to release any material buildup on receiver’s filter.

Immediately after dumping the material into the feeder hopper, the receiver’s discharge valve closes and the fill cycle begins again so the receiver is ready for the next refill request. The vacuum sequencing process must be coordinated to avoid interfering with the LIW feeder’s accurate material delivery to the process.

**Continuous weighbelt feeding.** A weighbelt feeder is useful for continuous applications that require a gravimetric feeder but don’t have adequate headspace to support a traditional hopper and LIW feeder system. Similarly, a weighbelt feeder can provide greater operational flexibility, because the feedrate can be adjusted by altering the existing material-bed geometry or belt speed. By comparison, most continuous LIW feeding systems require an increase in physical size to accommodate increased flow rates.

This feeder has intermeshed twin screws and is mounted on a scale for loss-in-weight operation.
For further reading

Find more information on feeding methods in articles listed under “Feeders” in Powder and Bulk Engineering’s article index in this issue or the Article Archive on PBE’s website, www.powderbulk.com. Find more information on pneumatic conveying systems and components in articles listed under “Pneumatic conveying.” (All articles listed in the archive are available for free download to registered users.)

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