# Gain-in-weight batching: Choosing system components for maximum accuracy

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**The scale isn't the only contributor to your gain-in-weight batching system's batching accuracy. The feeders, and the control system that governs them, also make major contributions to batching accuracy by controlling the feedrate during the batch and stopping the ingredient flow when the batch setpoint is reached. This article details an example application to explain how batching time, batch container and feeder size, batching controls, dust collection, and batch container emptying can affect a gain-in-weight batching system's accuracy. Calculations are included to help you choose system components based on your batching requirements.**

Selecting the right components for your batching system is crucial to achieving your desired batching accuracy. In this article, we'll focus on how components in a gain-in-weight (also called *add-weigh*) batching system affect the system's accuracy. Unlike a *loss-in-weight* batching system, which controls batching by sensing weight loss in a gravimetric feeder, in a gain-in-weight system each ingredient is dispensed by a volumetric feeder into a batch container on a scale (also called a *weigh hopper*), and the batching process is controlled by sensing the weight *added* to the batch container.

A simple gain-in-weight batching system is shown in Figure 1. Each ingredient is supplied from a bulk storage bin to the supply hopper of a volumetric feeder, which is typically a screw feeder or vibratory tray feeder.[1] (In this system, only one feeder is shown, although several feeders — one per ingredient — are typically included.) The feeder's discharge is located above a batch container on an automatic scale that can consist of either one load cell (as shown) or three loads cells and a summing box. The batch container's discharge is located above a process vessel (such as a mixer) or a transfer conveyor leading to a downstream process. A control system (not shown) links each feeder via cables to the batch container scale, and includes a signal amplifier and a controller with readout (typically in a control room some distance from the batching system and linked by cables to the rest of the control system). Before the batch is run, an operator enters the batch recipe and the batch setpoint for each ingredient into the controller.

In operation, the controller signals the feeder to begin dispensing the first ingredient at a coarse (fast) feedrate to the batch container. The load cell (or load cells) senses the weight. Because the analog load cell weight signal is weak, the signal amplifier amplifies (strengthens) it, digitizes it, and sends it to the controller. The controller receives this weight signal and uses it to compare the weight of the ingredient added to the batch container to the batch setpoint for that ingredient. When the ingredient weight nears the batch setpoint, the controller signals the feeder to slow down to a fine (slow or dribble) feedrate, called the *final dispensing rate,* until the weight reaches the setpoint. Throughout the process, the controller readout displays the ingredient weight in the batch container. The process is repeated for each ingredient in the batch until all ingredients have been added. The batch container is then emptied into the process vessel or transfer conveyor. (Find more details about these steps in the later section "Batching controls.")

To select components for a gain-in-weight batching system, you need the following information about your batch:

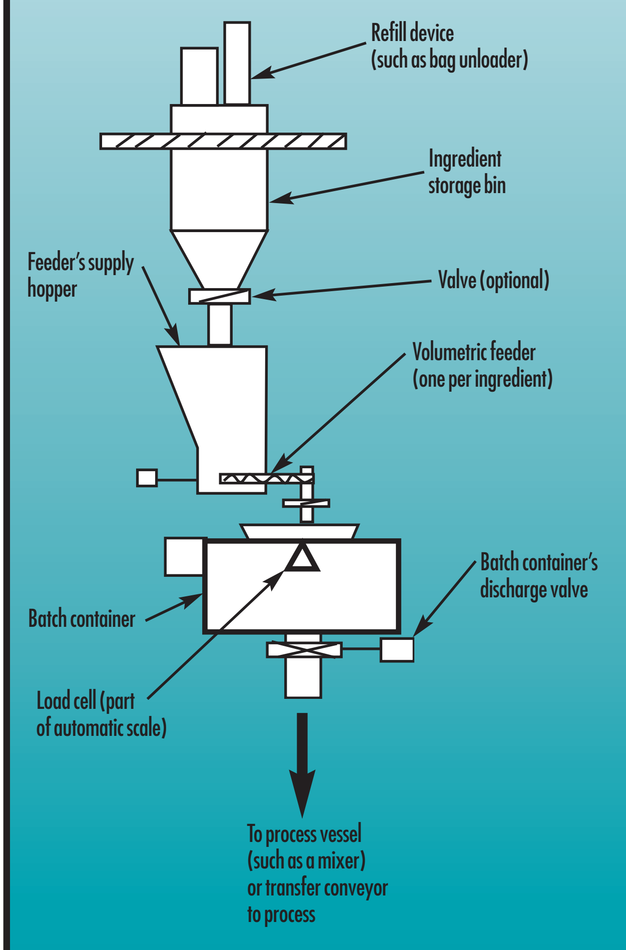
- ***Ingredient bulk density.*** This is the bulk density, expressed in pounds per cubic foot or kilogram per liter, of each ingredient in your batch.

- ***Ingredient batch weight.*** This is the quantity of an ingredient, expressed in pounds or kilograms, that must be added to the batch to meet the batch recipe requirement.

- ***Batch time.*** You need to know two times: *batch dispense time,* which is the time available in your process for the entire batch to be emptied from the batch container into the downstream process, and *time between batches,* which determines how much time is available for dispensing all ingredients for a batch into the batch container. Both times depend on your downstream process, such as how long your mixer takes to mix a previous batch and discharge it before the mixer is ready to accept a new batch.

**Figure 1**

**Simple gain-in-weight batching system**




- ***Desired batch accuracy per ingredient.*** This accuracy, typically expressed as pounds or kilograms within a certain tolerance (such as 10 pounds ±0.05 pounds), will help you make calculations for selecting and sizing the batching system components.

Once you know this information, you're ready to choose and size the equipment that makes up your gain-in-weight batching system. To illustrate how to use the information, the following sections provide calculations for selecting and sizing components in a simple example batching application.

### Sizing batch container, scale, and feeders based on batch time

In this simple example, the batching system batches only two ingredients and dispenses the batch to a mixer. The ingredients are sugar at 40-lb/ft$^3$ bulk density and flour at 30-lb/ft$^3$ bulk density. The sugar's batch weight is 10 pounds, and the flour's is 15 pounds. The maximum batch dispense time to the mixer is 10 seconds, and the minimum time between batches is 60 seconds.

From this information, we can make the following calculations to size the batch container, its scale, and the ingredient feeders:

***For the batch container volume:***

Batch container volume = batch volume of sugar + batch volume of flour

$$= \frac{10 \text{ pounds}}{40 \text{ lb/ft}^3} + \frac{15 \text{ pounds}}{30 \text{ lb/ft}^3}$$

$$= 0.75 \text{ cubic foot}$$

Note that the batch container outlet also needs to be large enough to discharge 0.75 cubic foot of material in 10 seconds.

***For batch container scale capacity:***

Ingredient batch weight = sum of largest ingredient batch weights in largest recipe

= batch weight of sugar + batch weight of flour

= 25 pounds

Batch container weight = weight of container's materials of construction

= 30 pounds (Type 304 stainless steel container for this example)

25 pounds + 30 pounds = 55 pounds

Thus the batch container scale has to handle at least 55 pounds (for more scale capacity information, see the later section "Expected batch accuracy").

***For dispensing feeders' size:***

$$\text{Feedrate for each ingredient} = \frac{\text{ingredient batch volume}}{\text{time between batches/ number of ingredients}}$$

$$\text{Feedrate for sugar} = \frac{(10/40) \times 3{,}600 \text{ seconds/hour (s/h)}}{60 \text{ seconds/2 ingredients}}$$

$$= 30 \text{ ft}^3\text{/h}$$

$$\text{Feedrate for flour} = \frac{(15/30) \times 3{,}600 \text{ s/h}}{60 \text{ seconds/2 ingredients}}$$

$$= 60 \text{ ft}^3\text{/h}$$

This feedrate calculation assumes that the feedrate will be constant during the batch dispense time. But this isn't a typical situation, because dispensing the material at the end of the batch at the lowest possible rate (the *final dispensing rate*) achieves the highest batching accuracy. In fact, this fine-feed time is often a minimum of 10 seconds and is typically set at 10 percent of the coarse feedrate. The result is that the average sugar feedrate may be 30 ft$^3$/h, but the batch will actually be dispensed at a coarse feedrate for 20 seconds and a fine feedrate for 10 seconds.

Thus, we need to recalculate the coarse feedrate as follows:

Let the coarse feedrate = Z ft$^3$/h

$$\text{Let the fine feedrate} = \frac{Z}{10} (\text{ft}^3\text{/h})$$

For sugar:

$$Z \times 20 \text{ seconds} + \frac{Z \times 10 \text{ seconds}}{10} = \frac{10 \text{ pounds}}{40 \text{ lb/ft}^3} \times 3{,}600 \text{ s/h}$$

$$20Z + (10Z/10) = (10/40) \times 3{,}600$$

$$21Z = 900$$

$$Z \text{ (coarse feedrate)} = 42.86 \text{ ft}^3\text{/h}$$

For flour:

$$Z \times 20 \text{ seconds} + \frac{Z \times 10 \text{ seconds}}{10} = \frac{15 \text{ pounds}}{30 \text{ lb/ft}^3} \times 3{,}600 \text{ s/h}$$

$$20Z + (10Z/10) = (15/30) \times 3{,}600$$

$$21Z = 1{,}800$$

$$Z \text{ (coarse feedrate)} = 85.71 \text{ ft}^3\text{/h}$$

As a result, the feeder for sugar must be large enough to feed at 42.86 ft$^3$/h and the feeder for flour at 85.71 ft$^3$/h, both 43 percent higher than calculated without considering the fine and coarse feedrates.

*Note:* To simplify this example, the batch time for each ingredient (that is, the time it takes to dispense each ingredient to the batch container) is the same: 30 seconds. But batch times for all ingredients in one batch don't have to be the same. To achieve the highest accuracy, it's also best if no ingredient's batch time is less than 30 seconds.

### Calculating the expected batch accuracy

Now that we've sized the main batching system components — the batch container, including its scale, and the ingredient feeders — we can begin to calculate the system's expected batch accuracy.

***Understanding batch accuracy.*** It's important to understand two ways of looking at the expected batch accuracy: as a percent of setpoint and on a check scale as a percent of the batch controller readout.

- *Batch accuracy as a percent of setpoint:* In this example, the sugar batch setpoint is 10 pounds. Of course, it's desirable to achieve a sugar batch of precisely 10 pounds. But tolerances are built into the batching system controller to control the batching process, which means that slightly more or less than the batch setpoint for an ingredient may actually be dispensed into the batch. When the ingredient batch is completed, the batch controller readout will show the actual weight of the ingredient dispensed from the feeder. For this example, let's assume the batch controller readout shows that 9.98 pounds of sugar was dispensed into the batch container.

- *Batch accuracy on a check scale as a percent of the batch controller readout:* The batching system uses its own load-cell-based batch container scale, which may be somewhat inaccurate. Periodically checking the scale's accuracy can minimize this problem. Batch-to-batch accuracy during production is checked by using the actual batch weight as shown on the batch controller readout. The weight of each dispensed ingredient can be check-weighed on a calibrated check-weigh scale. Such a scale typically has a resolution (also called *sensitivity*) higher — by up to factor of 10 — than that of the batch container scale as shown on the controller readout. For our example, let's say that when the 9.98 pounds of dispensed sugar is check-weighed, the check weight is 9.973 pounds. This represents a -0.07 percent difference, which for many batch applications is insignificant. However, we must still try to understand why the weights are different to improve the batching system's accuracy.

***Expected batch accuracy.*** Now let's determine the expected batch accuracy for our example.

A scale's resolution is the smallest weight increment that it can sense, that the batch controller can use, and that the controller readout can display. This resolution (which can be considered the *usable* scale resolution because it reflects the actual load cell signal after it's converted to digital, amplified, and sent to the controller) can be expressed as 1:1,000, 1:10,000, or even 1:1,000,000. The batch container scale's weight resolution in pounds (that is, the weight resolution after the weight signal is conditioned) can be calculated as follows:

Scale weight resolution (pounds) = scale capacity (maximum load) × usable scale resolution

In our example, the total maximum batch weight is 25 pounds (10 pounds of sugar and 15 pounds of flour), and the batch container itself weighs 30 pounds, giving a total batch weight of 55 pounds. To handle this batch weight, we could select a scale with a 75-pound capacity (which will hold the total batch container weight and allow a generous safety margin for loading forces and overloads) and a scale and control system that, in a production environment, can achieve a resolution of 1:10,000. This gives:

Scale weight resolution (pounds) = ±75 pounds × 1/10,000
= ±0.0075 pounds

To check that this scale weight resolution is high enough, we will use the desired batch accuracy we determined when we began designing this batching system. For this example, let's assume that we determined a desired batch accuracy of ±0.05 pounds per ingredient. Since the batch container scale is 0.05/0.0075 — that, is 6.7 — times more accurate than our desired batch accuracy, this resolution is acceptable. Based on this scale weight resolution, we know that when we dispense a batch, the batch weighment per ingredient will be well within our desired batch accuracy.

Now, let's take a look at how three factors — batching controls, dust collection, and batch container emptying — can affect the system's accuracy.

### Batching controls

Knowing more about how the batching system controller controls the batching process can help you ensure that the system achieves your desired accuracy. A typical set of batching steps for a dry ingredient is:

1. The batching process is manually or automatically initiated.
2. The controller tares the scale.
3. The controller starts the ingredient feeder at a coarse feedrate.
4. At a preset point (as sensed by the scale and controller), the controller switches the feeder to a fine feedrate.
5. At a preset weight below the ingredient's batch setpoint weight — called *preact* or *in-flight compensation* (for ingredient still "in flight" before it reaches the batch container) — the controller stops the feeder.
6. Once the scale is stable, the controller determines the ingredient's actual dispensed weight and displays this batch weight.

Step 5 is critical: The controller stops the feeder before the scale has determined the final dispensed batch weight for the ingredient. If the feeder is stopped after the scale determines the weight, the batch weight will be higher than the setpoint. The major purpose for this weighing delay is that when the feeder stops, some ingredient is still falling from the feeder — in flight — and isn't yet in contact with the batch container, so it can't be weighed. The delay's less obvious purpose is to allow the scale to become stable before it determines the batch weight. During ingredient dispensing, the scale must sense a dynamic, or constantly changing, weight in the batch container. This means that the scale can't instantly process the weight signal but must allow a little time delay to filter out vertical forces (like vibration) from the weight before processing it. The ingredient also needs a little time to settle in the batch container before the scale can make a final batch weight reading.

However, we need to understand how the preact — that is, the point at which the controller stops the feeder before the weight reaches the setpoint — affects the batch accuracy. Thus, the preact for sugar is at 9.9 pounds — 99 percent of 10 pounds (0.99 × 10), and the preact's 1 percent difference from the batch setpoint is 0.1 pound. The final batch accuracy will be determined both by the repeatability of this 0.1 pound and the closeness of this 9.9-pound preact to the batch setpoint.

During the sugar's fine feeding, the feedrate is 10 percent of the coarse feedrate, or 4.3 $ft^3/h$. Thus, based on the sugar's 40-$lb/ft^3$ bulk density, the 0.1 pound represents a dispensing time of 2.09 seconds at the fine feedrate. The fine feedrate must be very repeatable to achieve high batching accuracy. One way to ensure that the feedrate is repeatable is to ensure that the ingredient flows reliably from the feeder. For instance, a screw feeder whose hopper is equipped with agitating paddles can condition the ingredient for reliable flow, as shown in Figure 2.

### Dust collection

Dust collection is an important part of any batching system because dry ingredients falling through the air and displacing air in the batch container cause an airflow that in turn entrains dust particles. Typically, a dust capture hood is located above the batch container and airflow is drawn through the hood into the dust collection system by a fan or blower. While the capture hood doesn't affect the ingredient weight in the batch container, the airflow can affect the scale. As a result, the airflow velocity at the hood's inlet should be just high enough to collect the dust-laden air displaced from the batch container. The capture hood should also be installed in a way that keeps it from contacting the batch container scale and affecting the scale's sensed weight.

### Emptying the batch container

Completely emptying the batch container between batches directly affects the batching system's accuracy because any residue left in the container doesn't get used in the downstream process and can affect the next batch weight's accuracy. Choose a batch container that can be quickly and completely emptied. Some batch containers are designed to assist complete emptying rather than discharge through a typical container's converging hopper bottom and discharge valve. One example is a tilting bowl that discharges by tilting to one side to empty ingredients from its open top, as shown in Figure 3.

**Figure 2**

**Screw feeder hopper with agitating paddles**

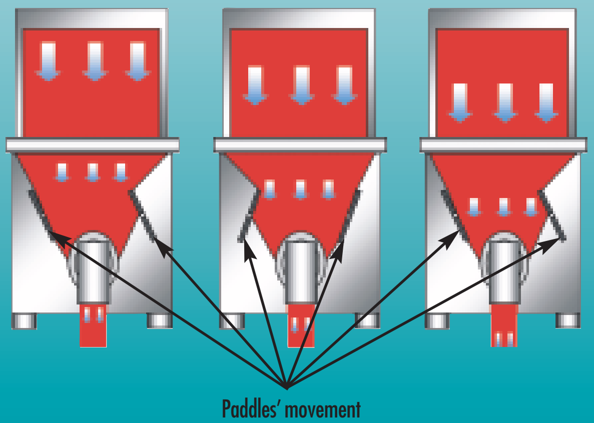



**Figure 3**

**Tilting batch container for complete emptying**

### Some advice

Although we've used a simple example with just two ingredients to explain how several factors affect a gain-in-weight batching system's accuracy, most batching systems handle many more ingredients. To help you design a more complex system that achieves the batching accuracy you need, follow these tips:

- Calculate each ingredient feeder's feedrate based on the feeder's coarse and fine feedrates and times.
- Choose a batch container scale with a resolution several times more accurate than your desired batch accuracy for the ingredient with the smallest batch weight setpoint.
- Select a batch time for each ingredient that's long enough (for best results, 30 seconds or longer) to ensure that the preact can stop the feeder at a point that leaves a very small percent of the batch weight in flight.
- Choose ingredient feeders with a repeatable feedrate; if the feeders are screw feeders, they should also have a reliable ingredient agitation mechanism.
- Make sure that the dust collection system uses minimal airflow, and don't allow the dust capture hood to touch the batch container scale.
- Choose a batch container that will empty completely.

**PBE**

### Reference

1. How to select volumetric feeders for your batch ingredients is beyond this article's scope. For more information, see articles listed under "Feeders" in *Powder and Bulk Engineering*'s comprehensive "Index to articles" (at www.powderbulk.com and in the December 2002 issue).

### For further reading

Find more information on batching in articles listed under "Weighing and batching" in *Powder and Bulk Engineering*'s comprehensive "Index to articles" (at www.powderbulk.com and in the December 2002 issue).

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