Weighing accuracy in processing and handling operations has always been vital to controlling product quality and production costs. Now, emerging ISO 9000 quality standards are making weighing accuracy even more important. The standards will apply to every scale in your operation, including in-plant process control scales - like electronic large-capacity hopper or tank scales - that traditionally haven’t required the testing and inspection other scales require. To help you prepare for ISO 9000 quality standards, this article explains what can go wrong with a hopper or tank scale and cause inaccurate weighing, then discusses quick, accurate, and affordable ways to test the scale’s weighing accuracy. Related information discusses how ISO 9000 quality standards will affect your weighing operation.

True or false? Your electronic hopper or tank scale is displaying accurate weight as long as the displayed weight is stable, rather than bouncing around. False. If the scale has three load cells and one has failed or drifted out of tolerance, the displayed weight — however stable — can be off by 33 percent.

Such errors — particularly in a hopper or tank scale with a capacity of several thousand pounds — can be disastrous for quality control, cause production downtime, and cut your profits. And with new ISO 9000 quality standards on the horizon, testing your weighing accuracy is even more important. [Find more information on ISO 9000 quality standards and their impact on weighing operations in the related article, “Competing in a worldwide market: How ISO 9000 will affect your weighing operation.”]

To be sure that your scale is accurate, you need to accurately calibrate the scale when you install it and then regularly test the calibration. Testing the calibration — which checks the weighing accuracy — is legally required at least once a year if your scale is legal for trade. A legal-for-trade scale, for which you must obtain a license, is approved for buy-sell transactions to the public; such scales include truck, railcar, bagging, or drum-filling scales. But no such requirement applies to nonlegal-for-trade, in-plant process control scales (often including large-capacity hopper or tank scales). The lack of testing requirements, combined with the difficulty of testing a typical large-capacity hopper or tank scale with standard test weights, can prevent you from regularly checking the scale’s weighing accuracy.

If these problems are affecting your weighing accuracy, you should know that electronic devices are available to help you easily and accurately test your hopper or tank scale’s weighing accuracy despite its large capacity. Before discussing testing methods and the devices that can help you do the tests, let’s take a look at how an electronic hopper or tank scale works and what can go wrong with the scale.

About electronic hopper or tank scales
A typical electronic hopper or tank scale (Figure 1) includes the hopper or tank, which serves as the weigh vessel or load-receiving element, and a load cell system, which typically consists of three or four load cells, conductor cables, a summing junction box, and a digital indicator (also called a weight processing unit).

Load cell system basics. A load cell (Figure 2) converts mechanical force into an electrical signal. In its simplest form, a load cell is a precision-machined metal element that bends with the force of loading (when weight is applied). Typically, four strain gages are bonded at points on the metal element so the gages form resistors in an electrical circuit called a Wheatstone bridge circuit. Initially, the four gages are balanced; if excitation voltage is applied to the load cell when no load is applied, the output voltage is zero.

When load is applied, the load cell compresses (in a compression-mounted load cell, where the load cell is beneath the load-receiving element) or elongates (in a tension-mounted load cell, where the load-receiving element is suspended from the load cell). The load cell’s compression or elongation causes the metal element to bend and the gages to become unbalanced.
The strain gage resistance changes, and each load cell produces an output voltage proportional to the applied load.

On a hopper or tank scale, each load cell typically weighs its proportional share of both the empty scale's weight (called the dead load weight) and the weight of material inside the weigh vessel (called the live load weight). For instance, in a four-load-cell system, each load cell weighs 25 percent of the total weight; in a three-load-cell system, each load cell weighs 33 percent of the total weight.

**Weighing operation.** As material is loaded into the weigh vessel, the summing junction box, which has a dust- and moisture-tight NEMA 4 or washdown-certified NEMA 4X enclosure, receives a stable excitation voltage (typically about 10 volts DC) from the digital indicator via the conductor cables and distributes the voltage to each load cell via the cables. Each load cell returns a millivolt output signal (typically 2 to 3 mV/V of excitation) to the summing junction box, which sums and averages the signals into one analog millivolt signal. The summing junction box sends the analog millivolt signal to the digital indicator, which converts the signal from analog to digital. The digital indicator displays the digital signal as a numeric weight reading (typically in pounds).

When the scale is controlled by a programmable logic controller (PLC) or personal computer (PC), the digital indicator often reconverts the signal from digital to analog and outputs a 20-milliampere current loop or a 4- to 20-milliampere signal proportional to the applied weight to the PLC or PC.

**Digital offsetting and initial scale calibration.** Because the load cells sense the empty weigh vessel's weight, you need to establish a zero weight (also called zero display or zero-load balance) when the weigh vessel is empty — that is, the scale must display zero, rather than the empty weigh vessel's weight. To establish the zero weight, you need to digitally offset the load cell system's millivolt output signal in the digital indicator. This ensures that when the scale is loaded, the digital indicator's displayed weight indicates only the live load weight, not the dead load weight.

Next, you need to initially calibrate the scale. This involves placing a specific quantity of accurate test weights in the weigh vessel. (The test weights, typically available in 50-pound sizes, are certified by the National Institute of Standards and Technology [NIST].) As the scale weighs the test weights, you input a calibration ratio factor, called a span, into the digital indicator. This causes the digital indicator to interpret a specific amount of millivolt output signal (based on the signal produced by the test weights) as a certain percentage of the scale's weight capacity. The digital indicator then displays this amount as a calibrated weight. For instance, if 20 millivolts is calibrated to equal 50 percent of the scale's 100,000-pound capacity, or spanned load, the digital indicator displays 50,000 pounds.

**What can go wrong with a hopper or tank scale**

Your hopper or tank scale can give inaccurate weight readings in any of several situations: when power flickers or spikes beyond the scale's tolerance, when excitation voltage drifts out of tolerance, when conducting cables are damaged, or when load cells drift out of tolerance or fail.

Power system flickers or spikes can occur during power-usage peaks or storms, interrupting or changing the excitation voltage. Lightning can cause power surges, which can strain the scale electronics rather than burn them up and cause excitation voltage to drift out of tolerance. Old conducting cables become brittle, making them easier to nick, crack, or cut and causing electrical shorts.

Load cell drift can occur when a load cell component drifts out of tolerance in either a positive or negative direction, causing weighing errors. For instance, on a hopper scale with four load cells, if one load cell drifts 5 percent out of tolerance, the scale's averaged overall error would be 1.25 percent.

Load cell failure can cause greater problems. In a hopper scale with a 10-volt excitation voltage and a load cell output of 2 mV/V of excitation (20 millivolts maximum), the digital indicator is calibrated to equate 20 millivolts with 100 percent of the spanned load. Thus, with a 100,000-pound-capacity hop-
per, a 20-millivolt signal is interpreted as 100,000 pounds. If one of four load cell fails, the digital indicator will show a weight of 75,000 rather than 100,000 pounds — a 25 percent error.

Any of these situations can occur in the blink of an eye, so you may not be aware when a problem has occurred and, instead, assume the scale is providing accurate weight readings. This is why frequently testing your scale’s weighing accuracy is important to your operation’s quality control.

**Testing your scale’s weighing accuracy**
Standard industrial practice outlines the following procedure for testing an electronic scale’s weighing accuracy using test weights:

- Empty the weigh vessel and verify that the scale’s digital indicator displays zero. If the digital indicator doesn’t display zero, then adjust it so it does.
- Check the high weight display by loading the weigh vessel with NIST-certified test weights to about 80 percent of the scale capacity.
- Check whether the displayed weight equals the weight of the applied test weights and, if necessary, adjust the digital indicator’s span so the actual applied weight is displayed.
- If the previous steps indicate the weight displayed is inaccurate, you need to isolate the problem’s source, which could be in the load cells, the digital indicator, or both. (An electronics technician usually uses test equipment to perform this fairly complex procedure.)

Although this method is effective for checking small-capacity scales, it’s difficult to use for large-capacity hopper and tank scales. Why? Filling a 80,000- or 100,000-pound-capacity hopper or tank scale to 70 to 100 percent capacity with test weights is impractical and time-consuming.

Other variations of the same method are more efficient, but can still create problems. One method is to use accurately delivered (or transferred) measured weights, in which a quantity of bulk material is first weighed on a legal-for-trade scale, then loaded into the hopper or tank scale. For instance, to check the weighing accuracy of a hopper scale in a cement plant, a truck load of material is first weighed on a legal-for-trade scale, then loaded into the hopper or tank scale. The cement is carefully unloaded from the truck into the hopper and the hopper scale’s display is checked to ensure it reads 52,000 pounds. The cement is carefully unloaded from the truck into the hopper and the hopper scale’s display is checked to ensure it reads 52,000 pounds. Problems with this method include ensuring that the truck scale itself is accurate (its components can fail suddenly, too), completely emptying the truck load of material into the hopper scale, and taking the time to both empty the truck and fill the large-capacity hopper scale.

**Using scale verifiers and calibration test kits to check weighing accuracy**
You can use one of two electronic devices — a scale verifier or a calibration test kit — to quickly test your hopper or tank scale’s accuracy and avoid the problems of using the test weight method.

**Scale verifier.** A scale verifier is an accurate, inexpensive device (typically under $200) that tests the scale components to check the scale’s calibration, but doesn’t calibrate the scale. Because the scale verifier is used before each new batch, it can check a large-capacity scale’s calibration in less than 5 seconds. Two scale verifier types are common: one checks the calibration of each load cell, and the other checks the digital indicator’s calibration.

The first type is a passive device — a digital volt meter — that tests the calibration accuracy of each load cell by verifying the load cell’s analog signal. To use the scale verifier, an operator typically has to manually disconnect all load cells but the one being tested and then connect the scale verifier to that load cell. Because the scale verifier’s signal reads out in millivolts, rather than a digital weight reading, the operator must convert the signal to a weight reading. Disconnecting the load cells not being tested is time-consuming, and reconnecting the load cells can cause problems with faulty contacts later.

The second type of scale verifier, called an R-cal (resistance calibration) unit, is an active device that tests the calibration accuracy of the digital indicator by substituting an induced load signal for the load cell signals. (The unit tests the digital indicator as part of a matched set with the load cells, but doesn’t test the load cells.) Most R-cal units are manually operated. With a manual unit, the operator activates the unit immediately after verifying that the scale’s weigh vessel is empty (or at heel weight, the weight of residual material constantly left in the weigh vessel before each batch) and ready to start a new batch. Activating the unit induces a precise, simulated resistance load into the scale’s electronic circuit in graduated steps and causes the digital indicator to display and record a test (or calibration) number.

The recorded calibration number serves as a base reference number, so that the R-cal unit’s induced resistance load will return to this recorded calibration number. If the induced resistance load produces the same calibration number when the weigh vessel is empty, then the load cells and digital indicator as a matched set are probably still accurately calibrated. If the recorded calibration number doesn’t repeat, then the operator must isolate each load cell and the digital indicator to determine the problem’s source.

With a remotely operated R-cal unit on a PLC- or PC-controlled scale, the PLC or PC activates the R-cal unit’s induced resistance load immediately after verifying that the scale’s weigh vessel is empty (or at heel weight) and ready to start a new batch. The PLC or PC then compares the induced signal (a 4- to 20-milliampere output to the PLC or PC, rather than a displayed weight on the digital indicator) with its recorded calibration number. If the numbers match, the PLC or PC starts the weighing process. Immediately before each batch is weighed, the PLC or PC sends the recorded data (called the quality audit trail), showing that the scale was tested and found accurate, for review by quality assurance or other staff. Linking the R-cal unit to a PLC or PC makes the unit suitable for applications requiring real-time quality control documentation, especially under an ISO 9000 program.

A scale verifier that incorporates both functions — checking the calibration accuracy of both the digital indicator and the load cells — is also available. The unit uses an induced resistance load to check the digital indicator’s accuracy and also automatically switches individual load cells on and off to check their accuracy, which eliminates the problems of time-consuming manual disconnects and faulty contacts.

**Calibration test kit.** A calibration test kit accurately measures applied load to the scale rather than simply checking scale com-
ponents. The kit precisely measures dead load and live load weights and can test weighing accuracy during a batch, unlike a scale verifier, which can test only between batches. A calibration test kit is much more expensive than a scale verifier (around $11,000 to $30,000).

The two most common types of calibration test kits use factory-calibrated, precision load cells and a digital indicator as secondary metrology standards. In operation, both types of kits are used simultaneously with the scale’s load cells (the load cells permanently mounted under the weigh vessel, called the static load cells) and the scale’s digital indicator (called the static digital indicator).

The first type, called a hydraulic calibrator, is similar to an R-cal scale verifier, because it uses a false load rather than the scale’s actual load. The hydraulic calibrator applies a hydraulic load to both the calibrator load cell and the static load cell and displays the true weight on the calibrator’s digital indicator. The static digital indicator’s displayed weight is then checked against the calibrator’s true weight. The calibrator gives a good idea of the scale’s accuracy, but isn’t suitable for testing legal-for-trade scales because it ignores some problems that can affect scale accuracy, such as the bending of a supporting I-beam beneath a fully loaded, large-capacity hopper scale. A bending I-beam can redistribute the load on the scale’s balanced load cells as the hopper fills, causing some load cells to sense more or less than their proportion of the total weight, creating weighing errors.

The second type of calibration test kit, called a dead-weight calibrator, uses the actual dead load weight and live load weight within the weigh vessel as a calibrated test weight. The kit consists of a complete load cell system (load cells, conducting cables, summing junction box, and digital indicator) and works by using fixation: inserting each calibrator load cell into the vertical load string (in vertical alignment with a static load cell and the weigh vessel). The calibrator load cells are linked to the rest of the kit components.

In operation, the operator uses a keyboard tare feature on the calibrator’s digital indicator to subtract the weigh vessel’s pre-recorded dead load weight. This way, the calibrator system and prepared for any weight loaded into the weigh vessel. The dead-weight calibrator is accurate under conditions such as I-beam bending and, because the calibrator measures the actual load, can serve as a backup weighing system when the hopper or tank scale fails or is down for repairs (for instance, due to a lightning strike).

References
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