

Improving dry bulk inventory management with pressed-in and bolted-on strain-gauge weighing systems

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This article describes the operation of a weighing system that uses pressed-in or bolted-on strain-gauge sensors, then explains how you can determine if the system is a good choice for keeping track of the bulk solids inventory in your storage vessel.

In the world of inventory monitoring in dry bulk storage bins, steel tanks, and other vessels, weight-measuring systems offer a big plus: Unlike level-measurement systems, which *calculate* the material weight in a vessel by converting a distance or level measurement to volume and then to weight, weight-measuring systems *directly measure* the material weight. This eliminates conversion errors that often occur in indirect weight measurement using level-measurement sensors. As a result, weight-measuring systems have an advantage — and are often required — in applications where high-accuracy material measurements are essential.

However, a drawback to directly weighing material in a vessel is the difficulty and expense of retrofitting an existing vessel with conventional weighing sensors (load cells). Strain-gauge sensors that can be pressed in or bolted onto the vessel's support structure simplify this task and reduce its cost. Unlike conventional stationary load cells, which are typically mounted under a vessel's legs or other support members while the vessel is lifted by a crane or other equipment, pressed-in and bolted-on strain-gauge sensors are simply attached to the vessel's legs or other support members. This eliminates a need to lift the vessel and may even allow it to remain in use during sensor installation.

In the following information, we'll explain how weighing systems with pressed-in or bolted-on strain-gauge sensors work, provide details about their installation and calibration, and discuss their pros and cons for measuring material in vessels. [***Editor's note:*** Using a weighing system with strain-gauge sensors doesn't eliminate the need for installing other level-control devices in a vessel, particularly high-level detection sensors that can shut down the vessel-filling process to prevent costly and dangerous overfilling. For more information on level-detection sensors, see "For further reading."]

How a strain-gauge weighing system works

A strain-gauge weighing system includes multiple pressed-in or bolted-on strain-gauge sensors, cables, typically one (and sometimes more than one) junction box, and a remote controller-display device.

More about the components. *Pressed-in sensors* are attached by being inserted or pressed into a hole drilled into the vessel's leg, frame, or other support member. *Bolted-on sensors* are simply bolted onto the member.

One junction box is typically located just before the controller-display; cables from each sensor lead into this box, and another cable connects the box to the controller-display. On a large vessel, a junction box (in this case called a *terminal box*) may also be located near each sensor simply to connect the sensor's short prewired cable (if so equipped) to an additional cable (up to 50 feet long) that runs to the remote controller-display.

How the system works. In operation, as material is added to or removed from the vessel, the vessel's support members deform. The strain-gauge sensors mounted on the members measure this deformation as strain. Each sensor sends an electrical output signal (in millivolts DC) that's proportional to the increasing or decreasing strain to the controller-display via the terminal boxes (if so equipped) and junction box. The junction box typically averages the signals from all sensors before sending one averaged output signal to the controller-display. The controller-display converts this signal into a weight measurement in pounds, tons, or other appropriate units and displays it for the operator. The controller-display also provides operating power to the sensors via the junction box, performs calibration functions, and provides an interface that allows the operator to not only read the material weight in the vessel but set up and adjust the controller-display and the weighing system.

Sensor number and location

How many pressed-in or bolted-on strain-gauge sensors an application requires and where the sensors are attached will depend on the vessel size, the support structure's configuration, and the specified weighing accuracy. For instance, a vessel supported by legs typically requires one sensor per leg. To recommend the correct number of sensors and their locations, the weighing system supplier will need accurate information about the vessel dimensions, support structure configuration, and required weighing accuracy.

Calibration and weighing accuracy

Once the strain-gauge sensors, cables, junction boxes, and controller-display have been installed, the sensors must be tested and the entire weighing system must be calibrated to ensure that the system delivers the expected weighing accuracy before it's put into use. Many calibration methods exist, and the weighing system supplier typically provides training and instructions for plant operators on how to calibrate the equipment.

Given the expense of the weighing system's hardware, installation, and setup, it's best to calibrate the system for the highest possible accuracy. This requires zeroing out the weighing system (that is, setting a zero point to establish a zero reference value) with the vessel completely empty and then adding a known quantity of material to the vessel in the highest amount possible, such as a truckload of material for which a weight ticket has been generated on a legal-for-trade scale. So, for instance, if the sensor's output signal is at 10 millivolts when the vessel is empty (at zero weight), and then after adding 40,000 pounds of material to the vessel the sensor's output signal increases to 14 millivolts, we can assume that 4 millivolts equals 40,000 pounds. This means that every time the sensor output signal changes by 4 millivolts, up or down, we'll see a 40,000-pound addition or subtraction in the controller-display's readout. The weighing system typically requires recalibration *only* if its weighing accuracy varies beyond the application's specified accuracy as the system is operated over time.

Properly calibrated, a strain-gauge weighing system can typically provide a weighing accuracy between 2 and 5 percent. In general, the system isn't as accurate as a weighing system with stationary load cells but is slightly more accurate than many properly installed level-detection systems. Depending on the model, each strain-gauge sensor in the system is capable of detecting up to about 30,000 psi.

Cost

The equipment cost for a strain-gauge weighing system with either pressed-in or bolted-on sensors runs about $6,000 to $9,000 total. This is about half — or less than half — the cost of a typical weighing system with stationary load cells, which ranges from $13,000 to $25,000 or more depending on the application. Installing and calibrating the strain-gauge weighing system involves additional costs, which vary depending on the application, with the average between $2,000 and $4,000. Installation and calibration costs for a stationary load cell weighing system are at least double that because of the heavier vessel weight involved and the site work required for a new installation or extra work (including lifting and modifying the vessel) required for a retrofit application.

Analyzing the pros and cons

Does a weighing system with pressed-in or bolted-on strain-gauge sensors make sense for your application? Consider these pros and cons to help you decide.

Pros. The strain-gauge weighing system:

- Can provide higher-accuracy weight measurements than a level-detection system that must convert a level reading to a volume measurement and then to a weight measurement.
- Works well and delivers accurate weight readings despite material flow problems, which can lead to false level-detection readings. (For instance, the strain-gauge weighing system isn't affected by an asymmetrical flow pattern, ratholes, or peaks in the material surface resulting from the material's high angle of repose.)
- Is external to the vessel so it can't be affected by material buildup or the vessel's internal environment, including dust and high temperatures.
- Isn't affected by material characteristics because it doesn't contact the material in the vessel, making the system ideal for sanitary applications and applications han-

Courtesy of Thermo Fisher Scientific, Minneapolis, Minn. (www.thermoscientific.com).

This pressed-in strain-gauge sensor (foreground) is part of a weighing system that also includes a remote controller-display, which is available in various types (three are shown here) to fit the application.

dling corrosive, abrasive, toxic, carcinogenic, and other difficult materials.

- Is safe for handling hazardous materials because the sensor can be certified as intrinsically safe in a hazardous application by an appropriate testing organization and because none of the system components is installed inside the vessel, an environment that can often be classified as hazardous by the National Electrical Code and other local codes. (For more information on using the strain-gauge weighing system in hazardous applications, consult the weighing system supplier.)
- Has a lower installed cost and is easier to install than a weighing system with stationary load cells.
- Is ideal for retrofit applications that require weight measurements.
- Is cost-effective for applications that don't require the higher weighing accuracy of a weighing system with stationary load cells.
- Can measure a wide range of material weight, typically up to about 30,000 psi per sensor.

Cons. The strain-gauge weighing system:

- Costs more to purchase and install than a level-detection system.
- Requires correct sensor location and calibration by supplier-trained workers to achieve accurate weight measurement and top performance.
- Provides weight-measurement accuracy between 2 and 5 percent.
- Can have accuracy limitations if the material load is very small compared with the vessel weight.
- Can have accuracy problems if another structure is attached to the vessel.

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For further reading

Find more information on topics discussed here in articles listed under "Weighing and batching" and "Level measurement" in *Powder and Bulk Engineering*'s comprehensive article index (in the December 2011 issue and at *PBE*'s website, www.powderbulk.com) and in Joe Lewis's book *Solids Level Measurement and Detection Handbook* (Momentum Press, LCC, 2012). You can also purchase copies of past *PBE* articles at www.powderbulk.com.

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