Reap the Benefits of Accurate Weighing Systems

Proper load cell installation saves material costs and time

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Accurate weight measurements are critical for inventory management, optimizing production and quality control in any bulk manufacturing facility. Load cells are the heart of any modern weighing system, so selecting and installing the load cells properly are the first steps to ensuring many years of accurate measurement. This article discusses common industrial weighing applications, load cells types and proper load cell selection as well as how load cell installation can affect scale accuracy.

INDUSTRIAL USES OF WEIGH MEASUREMENTS

The three most common uses for industrial scales are inventory control, process control and custody transfer. Accurate inventory measurements allow proper production scheduling and proper ordering of raw materials and may help to keep company finances under control. Weigh measurement also allows accurate process control, reducing scrap or the need to reprocess material. Finally, in an industrial environment, weight measurement may be used for custody transfer, a method to determine the value of bulk goods to bill customers properly.

INDUSTRIAL WEIGHING APPLICATIONS

Industrial weighing applications can be classified in three categories: nonautomatic scales, automatic scales and continuous scales. Although each type of application may have specific requirements for installation and maintenance, the basic requirements for load cell use will remain the same.

Nonautomatic scales. These scales required an operator's intervention during the weighing process. This intervention could be as simple as reading the weigh measurement. Some examples of nonautomatic scales are platform scales and bin weighing systems.

Platform scales use a platform mounted to one or more load cells. An object is placed on the platform, and the weight measurement is taken. Bin weighing systems use load cells under a tank, hopper or small bin. The vessel's weight is calibrated out, and the amount of product in the vessel can be determined by the weight measurement.

Automatic scales. These scales do not require an operator's intervention during the weighing process, which is carried out following a predetermined process. Examples of automatic scale include filling scales, batching scales and checkweighers.

Filling scales measure material as it is put in a container. The container is moved onto a platform scale, and the container's weight is measured as material is put into the container. When the target weight is reached, scale electronics stop the filling process, the container is moved off the platform, and a new container is moved onto the scale. The entire process is carried out in an automated system.

Batching scales use load cells on a mixing tank. The weighing system determines when the correct amount of material has been moved into the mixing tank and turns the filling process off. This is repeated with each component of the batch.

With both filling and batching scales, the goal is to reach the setpoint as quickly as possible and stop the material flow as closely to the setpoint as possible. To do this, these types of weighing systems have built-in functionality to monitor the amount of material that is put into the vessel. As the setpoint is approached, the flow rate is switched to a slower fill stream so that the fill can be turned off with little difference between the desired setpoint and the amount of material delivered.

Checkweighing systems measure the weight of individual items as they are transferred across a belt or roller conveyor. Checkweighing systems with belt conveyors use a short conveyor designed specifically for the checkweighing system. A platform supports a section of the carrying side of the belt and is mounted to one or more load cells.

Checkweighing systems on roller conveyors use a section of the roller conveyor supported by load cells. In both cases, the scale will use a peak measurement or a photoelectric sensor to determine when the item being weighed is completely on the conveyor's weighing portion.

Continuous scales. These scales measure the weight of bulk material as it is transferred in a continuous process. These scales typically have two outputs: the instantaneous rate and an accumulated total. Types include belt scales, solids flow meters and loss-in-weight feeders.

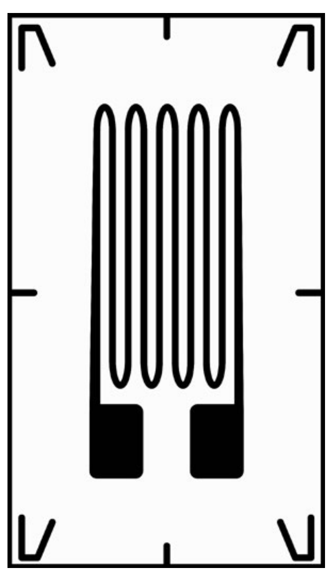
Belt scales measure bulk material as it is transferred on a belt conveyor. They use load cells placed under one or more of the idlers that support the belt. A speed measurement also is made. These measurements are used to determine the amount of material being transferred across the conveyor.

Solids flow meters measure dry powder or granular material that is flowing through a pipe. One type of solids flow meter directs the material flow across a plate, and the force when the material strikes the plate is measured to determine the amount of material flowing through the flow meter.

Loss-in-weight feeders are designed to control the feed rate of a dry material in a process. Loss-in-weight feeders most often are used to control the flow rate of dry solids as they are blended in a continuous process. They use a small hopper with a screw conveyor discharge. The hopper and screw conveyor are mounted on load cells. As the screw conveyor draws material out of the hopper, the load cells measure the rate at which the material is removed. A control loop controls the rate of discharge by increasing and decreasing the screw conveyor's speed.

THEORY OF LOAD CELLS

Regardless of the application, the load cell is a critical component of most modern weighing systems. The strain gauge load cell is the most common type. It uses a strain gauge bonded to a load cell body to measure force. Strain gauges use the principal that resistance is a function of the cross-sectional area and length of the conductor.

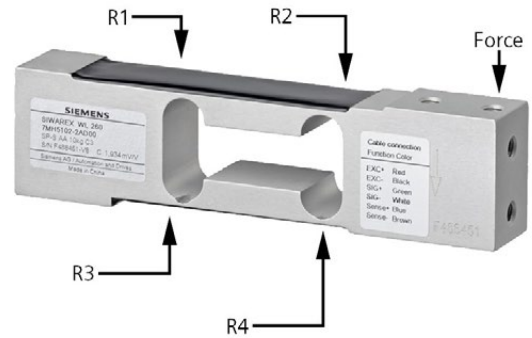


TYPICAL STRAIN GAUGE

Figure 1. The conductor will stretch in several locations as the pad is stretched.

It can be thought of like this: If a piece of wire is stretched, the wire's diameter will decrease and its length will increase. In a linear relationship, the wire's resistance will go up. This change in resistance is very small, so to increase this effect a strain gauge, as shown in Figure 1, will use a pad with the conductor arranged so that as the pad is stretched, the conductor will stretch in multiple locations.

The load cell body is designed to deflect a slight amount, less than 1 mm, in specific locations as a force is applied. The load cell shown in Figure 2 is designed to deflect in locations R1, R2, R3 and R4 as force is applied. A strain gauge is bonded to the load cell body in each of these locations. As a force is applied, strain gauges in positions R1 and R4 are stretched, and the strain gauges in positions R2 and R3 are compressed.



TYPICAL SINGLE-POINT LOAD CELL
Figure 2. Applied force results in strain gauges in positions R1 and R4 being stretched, while strain gauges in positions R2 and R3 are compressed.

The strain gauges are configured in a Wheatstone bridge with the strain gauges in compression on opposite legs of the bridge and the strain gauges in tension on opposite legs of the bridge. A DC voltage is applied to the Wheatstone bridge, and it will output a millivolt signal proportional to the load applied to the load cell. The output of a load cell under full load normally is specified as the load cell's characteristic value, which will be in millivolts of output per volt of excitation (mv/V). A common load cell characteristic value is 2 mv/V, and a typical load cell excitation voltage is 10 V, so the output of the load cell under full load will be 2 mv x 10 V, or 20 mv.

SELECTING THE PROPER LOAD CELL

When selecting the proper load cell, several factors should be considered. Response time, creep, hysteresis and nonlinearity can affect a weighing system's accuracy. The importance of these specifications depends on the application. An example of when response time is an important consideration is in high-speed applications such as filling machines and checkweighers, but creep may not be an issue in these applications. Conversely, speed of response usually is not an issue on a bin weighing system used for inventory management, but creep could be. Consult your load cell supplier to determine which factors are most important in your application.

The four general types of load cells are compression, S-type, beam and single point. Selecting the proper load cell type and capacity also can affect a weighing system's performance. Table 1 shows examples of each type of load cell.

Compression load cells. These vertical cylinders have a load bearing point in the top-center of the cylinder. They can handle very high loads, in some cases up to 500 tons per load cell. Because of their high

Compression load cell	S-type load cell	Beam load cell	Single-point load cell
			

LOAD CELL TYPES
Table 1. This table shows the four general load cell types.

capacity, they often are used for bin weighing systems or vehicle scales.

S-type load cells. These load cells have an S-shaped frame. They are most accurate when used in tension, so they often are used in hanging-type scales. These load cells are mounted or suspended from the top of the load cell, and the load is attached to the bottom of the load cell.

Beam load cells. These cuboid or horizontal cylinders usually are mounted rigidly on one end, and the load is applied to the other end. Double-ended beam load cells are horizontal cylinders or cuboids that are supported on both ends and the load is applied to the center of the beam. Single-ended beam load cells typically have capacities up to approximately 35 tons. They can be used in such applications as smaller bin weighing systems or larger platform scales.

Single-point load cells. Like beam load cells, they are cuboid-shaped and mounted rigidly on one end. Single-point load cells are designed for small platform scales, usually up to approximately 36 in. sq. These cells normally are used in weighing systems in which only one load cell is needed to support the platform and typically would not be used in scale systems in which three or more load cells are used in a single weighing application.

Each type of load cell has a variety of different load cell capacities. The live load, deadload, safety factor and the number of support points should be used to determine the proper load cell capacity.

Live load is the temporary weight that will be applied to the load cell. It will be what is being weighed. *Dead load* is any permanent weight that will be applied to the load cells. This is anything to support the item or items being weighed. For example, on a platform scale, the dead load is the weight of the scale's top plate, known as the load carrier, and any hardware required to attach the

Anything that restricts the load carrier's vertical movement will cause errors in the weighing system.

plate to the load cell. The live load and dead load are added to determine the total load.

A *safety factor* in a weighing system, usually expressed in a percent of total load, is additional load cell capacity that may be required in the application for environmental influences. For example, if a bin weighing system is located in an area that may have wind loading or forces from seismic activity, an appropriate safety factor should be applied to allow for these forces.

There sometimes is a tendency to oversize the load cell significantly to account for these external influences, but that also can have a negative impact on the scale's accuracy. If too large of a safety factor is used, the weighing system's resolution may not allow accurate measurements. To be certain the load cells are sized properly for your application, consult your load cell supplier to determine the proper safety factor for your application.

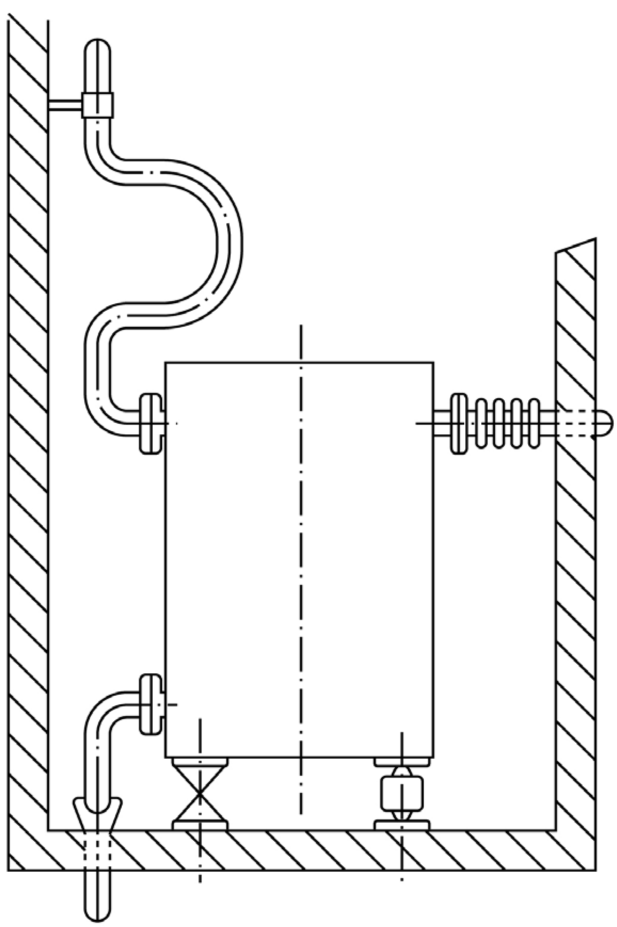
After determining the proper safety factor, the load cell capacity can be calculated by dividing the total load by the number of *support points* and multiplying it by the safety factor plus 1, and the next larger size load cell is selected. For example, if the total load on a bin weighing system is 24T, the bin has three support legs and requires a safety factor of 20%, the minimum load cell capacity would be calculated as 24/3 x (1 + 0.2), or 9.6T. If a 9.6T load cell is not available, the next larger size load cell would be used. Most load cell manufactures have a 10T load cell in their portfolios.

LOAD-BEARING SYSTEMS

A weight-measuring system will bear the load's weight in specific locations called bearing points. Load cells are installed at each bearing point. The most common bearing systems have one, three or four bearing points. The load should be centered on the load cell and applied straight down without any rotational or leverage forces. Any forces other than a direct force downward or any off-center loading can cause errors in the weighing system.

To allow the load to be applied equally across each load cell, all bearing points should be level and rigid enough to support the load without deflection. If the load cell mounting base is not level, the load will not be applied straight down. Similarly, if the mounting base for the load cell deflects under the load, the load no longer will be applied straight down, causing errors in the weighing system and possibly causing structural damage to the load carrier.

All the bearing points also should be at the same level. On weighing systems with four or more bearing points, if one bearing point is higher than others, the load cell under the higher bearing point will carry more of the load. To be certain all the bearing points are on the same level, after the load cells have been installed, each load cell's output should be checked before the live load is applied. Each load cell's output should be within 20% of the others. If one or more of the load cells has a greater difference, shim plates should be used to level the load cells until the all outputs are all within 20% of each other.



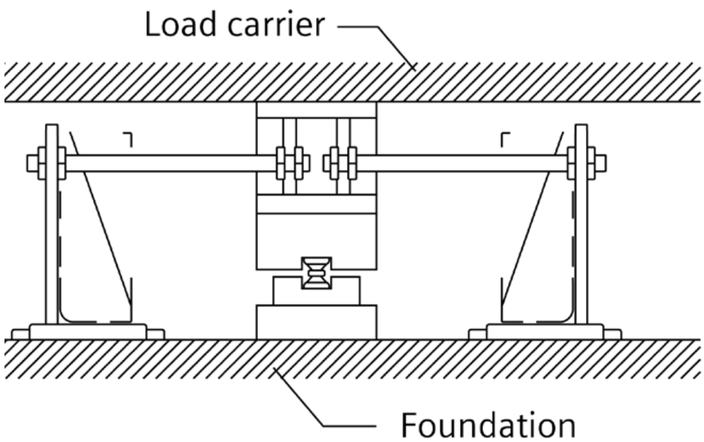
SOFT COUPLINGS FOR PROPER VERTICAL DISPLACEMENT
Figure 3. "C" bends can prevent restriction in downward movement.

INSTALLATION REQUIREMENTS

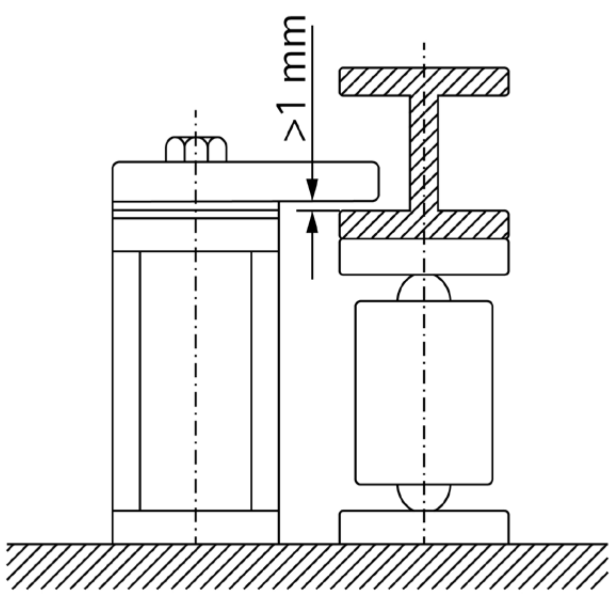
As already mentioned, load cells must deflect slightly to operate properly. Anything that restricts the load carrier's vertical movement will cause errors in the weighing system. Whether it is a conveyor belt scale or a bin weighing system, one of the more common sources of error is the restriction of vertical movement.

To allow the proper vertical displacement, anything connected to the load carrier must be able to flex. For example, on a bin weighing system, any fill pipes, vents and discharge piping should allow the bin to move down slightly. Any restriction in downward movement will cause errors in the weighing system. This can be done using soft couplings. In some cases, "C" bends in the pipe as shown in Figure 3 can allow for this deflection.

Additionally, scales using beam or compression load cells require the load carrier to "float" on the top of



STAY RODS TO PREVENT LATERAL MOVEMENT
Figure 4. Well-sized and placed stay rods help to prevent improper lateral movement.



LIFTOFF PROTECTION
Figure 5. Properly placed and mounted structural steel can help to prevent liftoff.

the load cells. Because the load carrier is "floating" on top of the load cells, the load carrier must be protected from slipping off the load cells. Stay rods, as shown in Figure 4, typically are used to prevent lateral movement of the load carrier. A structural engineer should determine the proper size and placement of stay rods for your application.

In addition to stay rods, liftoff protection should be provided to prevent the load carrier from lifting off the load cell. It should be designed so the load carrier cannot be lifted more than 1 mm above the load cells. This can be done with a piece of structural steel firmly mounted to the foundation and fixed 1 mm above the load carrier. On bin weighing systems, there often is an I-beam between each leg of the bin. If this is the case, the structural steel can be fixed between the horizontal sections of the I-beam as shown in Figure 5.

CONCLUSION

Load cell weighing systems are common in industry. Proper equipment selection and installation will enable the weighing system to provide very accurate weight measurements in a range of conditions. A proper installation requires taking steps to ensure the load is applied directly to the load cell and the load cells vertical deflection is not restricted. ●

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