# What's new in smart weight-and-cable bin level sensors

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**This article covers the latest generation of smart weight-and-cable bin level sensors. After explaining how the smart sensors work and how they overcome a conventional sensor's limitations, the article describes new smart sensor features that provide more reliable measurement performance and reduce the sensor's maintenance requirements.**

Conventional weight-and-cable bin level sensors — also called *plumb bobs* and *yo-yos* — have been used for many decades to monitor material levels in storage vessels. The sensor lowers a weight (also called a *bob* or *probe*) on a cable to the material surface in a storage vessel and then raises the weight as the distance it travels is measured and related to the material level. Plastics processors, food manufacturers, concrete producers, and many other bulk solids processors use the sensor to improve their raw material inventory management, production efficiency, and plant safety.

While the conventional weight-and-cable sensor is relatively accurate and provides an economical alternative to other level measurement sensors and direct weight measurement devices, it does have a reputation for high maintenance. With the myriad of other level measurement technologies available today, how does the weight-and-cable sensor continue to find a place in level measurement applications? The answer is in the development of the smart weight-and-cable sensor.

## How the smart weight-and-cable sensor works

The smart weight-and-cable sensor, as shown in Figure 1a, combines the conventional unit's weight-and-cable operation with state-of-the-art electronics. The sensor's housing is installed on the storage vessel's roof, as shown in Figure 1b, and has two sections: electronics and mechanical.

***Electronics section.*** The electronics section houses a microcontroller with firmware (that is, programming instructions stored in read-only memory) for controlling the weight and cable movement. This section also houses optics, including optical sensors, that are part of an optical measuring system. In some sensors the optics are enclosed in a sealed compartment within the housing for dust protection. The drive motor for lowering and raising the weight and cable is also located in the electronics section, and the motor's drive shaft extends into the housing's mechanical section.

***Mechanical section.*** The mechanical section houses the cable, which is wound on a storage hub rotated by the drive shaft, and a measuring wheel that's part of the optical measuring system. The cable is usually high-strength stainless steel, sometimes jacketed with nylon or polyester, and provides a pull strength of about 270 pounds (123 kilograms); some smart sensors use cable made of polyester cord, which has far lower pull strength. The cable runs across the measuring wheel and then down through a vertical standpipe, below the mechanical section, that is mounted to the vessel roof. The standpipe includes a *cable-wiping mechanism,* typically a brush-like device with a center hole that fits around the cable, which wipes material residue off the cable before it returns to the housing after a measurement cycle. The weight at the cable's end seats against a flange at the standpipe's bottom. (Together, the weight and cable form what's called the *weight-and-cable assembly*.) The standard cast-aluminum weight (Figure 1a) is suited to about 80 to 90 percent of applications; other specialized weight designs are also available to suit other applications, such as measuring materials with extremely low densities (from 20 lb/ft$^3$ [320 kg/m$^3$] down to 5 lb/ft$^3$ [80 kg/m$^3$]) or corrosive properties.

***Sensor operation.*** The microcontroller initiates a measurement cycle at intervals determined by an operator interface or by presetting the sensor. For each cycle, the drive motor lowers the cable until the weight reaches the material surface in the vessel and then raises the cable. The cable travel is stopped when the weight contacts the material surface and becomes buoyant against the surface's density. Some smart sensors use a braking mechanism to stop cable from continuing to unreel after the weight contacts the material surface. Others control the cable travel speed and use the sensor's firmware and optics to ensure that cable travel is stopped and reversed when the weight reaches the material surface.

As the weight is lowered, the cable turns the measuring wheel, which generates optical pulses that are detected by the optical sensors. The optical measuring system is typically an optical encoder mechanism, and recent versions can provide up to 100 counts per foot for a measurement resolution of 0.01 foot (3 millimeters). The microcontroller evaluates the pulses and converts them to a distance measurement, and the microcontroller and electronics then convert the distance measurement to an output that's sent to a PLC- or PC-based control system or other receiver, depending on the user's needs.

**Figure 1**

**Smart weight-and-cable bin level sensor**

**a. Sensor components**


**b. Sensor installed on storage vessel roof**

### How the smart sensor overcomes a conventional sensor's limitations

One limitation with a conventional weight-and-cable bin level sensor is the difficulty of keeping the cable taut as it travels up and down to ensure that the sensor operates correctly and takes reliable level measurements. If the cable becomes slack, it can cause "cable jump," in which the cable hops off the rollers guiding its normal travel path, prematurely stopping the cable travel. This can result in a buried cable — that is, the weight can become buried in a large amount of material, stopping the sensor's operation. Trying to control cable slack with a conventional sensor requires frequent preventive maintenance and adjustments of the sensor's mechanical components, but these steps typically can't prevent the problem.

*If the sensor isn't operating as it should, the microcontroller sends an appropriate error message to the user.*

Most smart weight-and-cable sensors eliminate cable slack and the resulting cable jump and buried cable problems by using a swing-arm mechanism. This mechanism, located in the housing's mechanical section just below the cable storage hub, consists of an arm-like bar with two springs attached to one end and a roller attached to the other, as shown in Figure 2. The cable runs around the roller and, with the aid of the springs, the swing arm floats up or down, depending on the cable tension. This action keeps the cable uniformly taut and prevents slack.

Another limitation for a conventional weight-and-cable sensor is that the sensor has no self-diagnostic capability, which means it can't diagnose operating problems during a level measurement and alert the user to take corrective action. The smart sensor's microcontroller overcomes this limitation by checking the weight-and-cable assembly's operation, diagnosing any problems, and sending this information to the user. The smart sensor monitors the cable travel during the level measurement and measures the travel distance both from the standpipe flange to the material surface and from the flange back to the housing to verify input from the optical measuring system. The microcontroller evaluates this input based on what should be happening and determines if the sensor is operating correctly. If the sensor isn't operating as it should, the microcontroller sends an appropriate error message to the user.

### The latest advances in smart sensors

The latest smart weight-and-cable sensors are more capable than ever, thanks to recent technology advances. These include using mechanical and other means for preventing a stuck weight, using an easy-to-replace cable-wiping mechanism, monitoring weight and cable travel with Hall-effect sensors, and functioning as a standalone analog transmitter. [***Editor's note:*** Not every feature described here is available from all smart weight-and-cable sensor suppliers; in the following information, the supplier is identified when only one supplier offers a given feature.]

***Preventing a stuck weight.*** Freezing condensation or material buildup on the standpipe flange can cause the weight to stick to the flange's underside as the measurement cycle begins, creating what's commonly called a *stuck bob*. Two smart sensors are available with features to help ensure that the weight drops rather than sticks to this flange.

One smart sensor can be equipped with a mechanical impact mechanism, as shown in Figure 3, that consists of a Teflon cap located above the weight on the cable and three Teflon balls that are crimped to the cable.[1] Two balls are above the cap and one is between the cap and the weight. If the cap sticks to the standpipe flange when the cycle begins, the weight will begin to descend, and the descending weight's full force will cause the ball above the cap to drop and strike the cap, breaking it free from the flange. The top ball also protects the cable when the weight is retracted into the housing.

Another smart sensor has a freeze-resistant standpipe flange with a small surface area that reduces the mating contact area between the weight and the flange.[2] This means that any freezing or material buildup on the flange's underside has limited contact with the weight, which prevents the weight from sticking when the measurement cycle begins.

***Using an easy-to-replace cable-wiping mechanism.*** One preventive maintenance step required to keep a smart sen-

**Figure 2**

**Swing-arm mechanism**

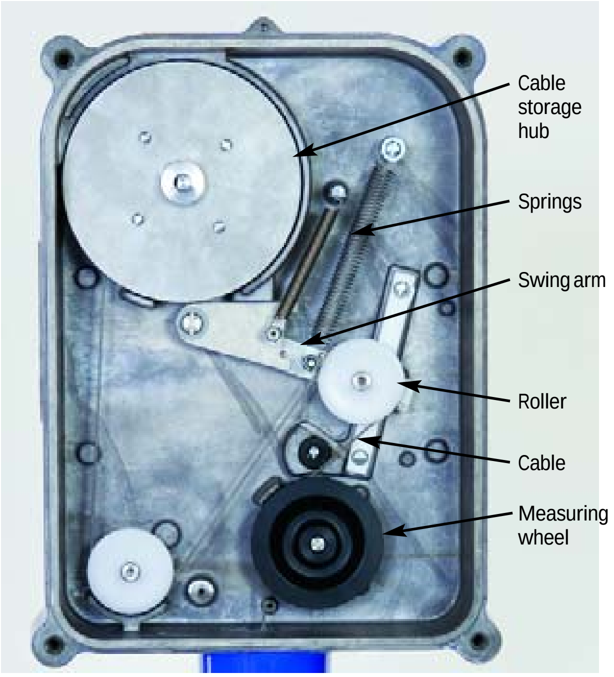



**Figure 3**

**Mechanical impact mechanism**


Courtesy of BinMaster, Lincoln, Nebr.

sor working correctly is to inspect the cable-wiping mechanism in the standpipe. For most smart sensors, if the inspection reveals that this mechanism is worn, the weight and cable must be disconnected so that the mechanism can be replaced. Some smart sensors are now available with an easily replaceable cable-wiping mechanism, as shown in Figure 4. Fitted into the standpipe behind a removable cover, the mechanism is designed so that it can be replaced without disconnecting the weight and cable, reducing downtime and maintenance costs.

***Monitoring weight and cable travel with Hall-effect sensors.*** One smart sensor can be equipped with an array of analog sensors based on the Hall effect to detect the swing-arm mechanism's position while the sensor's optical measuring system monitors the weight and cable travel distance and direction.[3]

Simply put, the Hall effect is the development of a transverse electric field in a current-carrying conductor placed in a magnetic field. Applying the Hall effect in a smart weight-and-cable sensor requires installing a circuit board with an array of Hall-effect sensors in the electronics section, directly behind the swing arm, as shown in Figure 5a, and attaching a neodymium nickel-plated magnet to the back of the swing arm in the housing's mechanical section, as shown in Figure 5b. The magnetic field produced by the magnet is strong enough to extend into the electronics sec-

**Figure 4**

**Easy-to-replace cable-wiping mechanism**

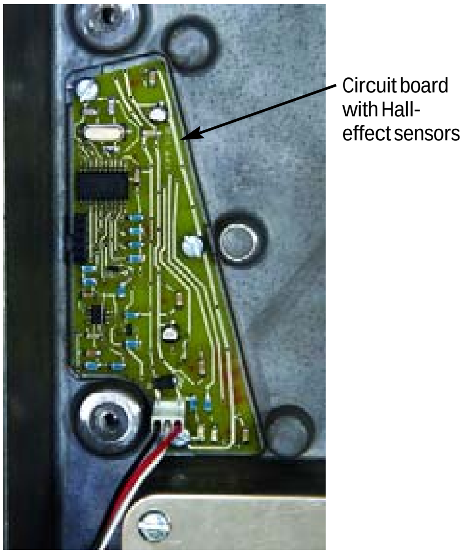
a. Removable cover over cable-wiping mechanism


b. Cable-wiping mechanism

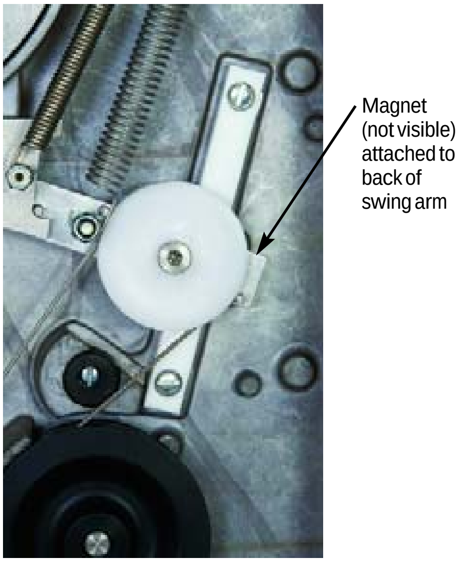
**Figure 5**

**Hall-effect swing-arm sensing system**

a. Circuit board with Hall-effect sensors mounted in housing's electronics section




b. Magnet in housing's mechanical section



# Some pros and cons for smart weight-and-cable sensors

A smart weight-and-cable sensor is just one of many available bin level sensors. A quick look at the following advantages and disadvantages for the smart weight-and-cable sensor can help you determine if this instrument is right for measuring your material level. [***Editor's note:*** For information on other bin level sensors, see the author's white paper "Technology Review — Continuous Level Measurement of Bulk Solids and Powders" on bin level measurement technologies (at www.monitortech.com) and articles listed under "Level detection" and "Storage" in *Powder and Bulk Engineering*'s comprehensive article index (at www.powderbulk.com and in the December 2005 issue).]

**Pros**

- The smart weight-and-cable sensor isn't affected by your process conditions or material properties and thus requires no calibration.
- The sensor's distance measurement for a standard range of 150 feet (45 meters) isn't affected by your material's angle of repose.
- The sensor has a relatively low purchase cost (typically about $1,300 or more, depending on what auxiliary equipment your application requires) compared with other level measurement sensors.
- The sensor is easy to install and set up.
- You can repair the sensor in the field.
- The sensor's latest designs are very durable in difficult applications.
- You can use the sensor with dusty powders.
- You can use the sensor with signal-absorbing materials, such as powders with extremely low bulk densities.
- The sensor is unaffected by your material's dielectric constant (a measure of the material's ability to resist the formation of an electric field within it).
- You can use the sensor in high-temperature applications (up to 500°F [250°C]).
- You can use some smart sensors in hazardous locations, such as those with potentially explosive conditions.
- The sensor provides good accuracy (±0.25 percent to ±0.50 percent) for ranges up to 30 feet (9 meters).
- Wireless interface is available for the sensor.
- Advanced PC software, including simple supplier-managed inventory software, is available for the sensor.
- The sensor can provide any of multiple outputs to suit your application.

**Cons**

- The smart weight-and-cable sensor doesn't respond instantaneously to changes in material level.
- The sensor is momentarily intrusive during the measurement cycle, which can affect a vessel-filling operation.
- In an extremely dusty application, the sensor may require periodic preventive maintenance.
- Some materials can abrade the sensor's mechanical parts.
- The sensor operates best in low-pressure vessels (at 30 psi [2 bar] or less).
- The sensor provides acceptable accuracy at ranges greater than 30 feet (9 meters).

***—J. Lewis***

***For decades, bulk solids processors have used weight-and-cable level sensors to monitor material levels in storage vessels.***

tion to the Hall-effect sensors, and the sensing circuit created by the sensors produces a voltage that varies with the magnetic field's strength. As the swing arm moves, causing the magnet to swing from one sensor toward the next, the magnetic force on the first sensor decreases, while the force on the second sensor increases. The sensor's microcontroller uses the voltage input from the sensing circuit to calculate the swing arm's position between the sensor locations and produces an output signal relating to the swing arm's position through its full range of motion.

Understanding the swing arm's position during a measurement cycle while the optic measuring system monitors the weight and cable travel allows the smart sensor to start and stop the motor and adjust the cable travel direction, broadening the sensor's use and improving its measurement reliability. For example, if the signals generated from the Hall-effect sensors and the optical measuring system indicate that the weight and cable are descending, there is cable slack, and no optical pulses are being generated, the smart sensor will take these actions: stop the motor, attempt weight retrieval, and indicate an error. In this case, the problem's source could be a stuck weight or broken cable. In another example, if the signals indicate that the weight and cable are ascending, the cable has maximum tautness, and no pulses are being generated, the smart sensor will take these actions: attempt weight retrieval and indicate an error. The problem could be a stuck weight or material accumulated on the weight.

*Some of today's smart sensors now function as standalone level transmitters that can generate output independent of additional hardware or a remote operator interface.*

***Functioning as a standalone analog level transmitter.*** While all smart weight-and-cable sensors can provide an analog output, many need outside input to initiate a measurement cycle, and this requires additional hardware or a remote operator interface. Some of today's smart sensors now function as standalone level transmitters that can generate output independent of additional hardware or a remote operator interface. These sensors can automatically initiate measurement cycles when they're set up by an operator via a built-in display. The sensors also have a relay output that can be programmed to change state when the material in the vessel reaches a predetermined level, if a sensor error exists, or to indicate that a measurement cycle is in progress.

## Some final advice

The new features available on the latest generation of smart weight-and-cable sensors make them more attractive than ever for bin level measurement. To determine whether the sensor is a good fit for your application, consult a level measurement sensor supplier or independent solids handling consultant for advice. For more helpful information, see the related sidebar "Some pros and cons for smart weight-and-cable sensors" and the following "For further reading" section. **PBE**

## References


1. SureDrop Cable Release System for SmartBob II smart weight-and-cable sensor, available from BinMaster, Lincoln, Nebr. (www.binmaster.com).
2. Freeze-Resistant Flange for SiloPatrol SE smart weight-and-cable sensor, available from Monitor Technologies LLC, Elburn, Ill. (www.monitortech.com).
3. Swing Arm Sensing System with Hall-Effect Sensors (patent pending) for SiloPatrol SE smart weight-and-cable sensor, available from Monitor Technologies LLC, Elburn, Ill. (www.monitortech.com).


## For further reading

Find more information on bin level sensors in articles listed under "Level detection" and "Storage" in *Powder and Bulk Engineering*'s comprehensive article index at www.powderbulk.com and in the December 2005 issue.

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