

# **Bin Level Indication Applications in Grain Elevators**

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## Introduction



Figure 1: First grain elevator in western Canada circa 1879

Grain elevators are facilities used for storage of a wide variety of grains. As a part of the distribution system for whole grains from the farm to processors of grain these storage facilities perform a vital role. The initial introduction of grain elevators is said to have been in Buffalo, NY in 1842. It was Joseph Dart who first invented a steam-powered mechanism called a “marine leg” that was used to scoop grain from barges and ships

and load the grain into storage silos. Eventually the modern bucket elevator emerged for lifting grain up to the top of the storage silos for filling purposes.

Early on in the history of grain elevators they were constructed from wood, and were prone to fire. Since the early part of the twentieth century concrete was introduced as a building material and corrugated steel is also used. In farming communities each town had one or more grain elevators and many still do. However, in more recent times improved transportation centralized grain storage and much larger grain elevators now serve multiple communities and farms.



Figure 2: 1928 Burrus Elevator (slip form concrete steel reinforced) in Lubbock, TX just before demolition in 2004 contains 123 silos.

An interesting problem that old grain elevators had was that of silo explosions. Grain dust can be very explosive in enclosed areas. Electrical area classification is typically Class II, Division 1 where explosive dust exists continuously. Fine powder from the millions of grain particles passing through the facility would mix with the oxygen in the air. Even the slightest spark could cause an explosion as a spark spreads from one tiny dust particle to another with a resulting chain reaction that can be devastating to the facility and a killer of personnel. While it is not as prevalent, this hazard and problem still exists today. For this reason all electrical devices must be properly certified, installed and operated. Ventilation has been improved and many components, such as bearings within the bucket elevators, are constantly monitored for excess heat and friction.

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## Bin Level Indicator Usage

Two primary applications exist for level indicators. The first is a critical application to ensure that each silo is not overfilled. Bin level indicators are used to detect a high level condition within each silo chamber. In addition to indicating a “full” condition in the silo, this device also prevents overfilling. The second application of bin level indicators is for inventory monitoring purposes. In this situation a bin level indicator device is used to measure the level of the grain in each silo. However, these devices for inventory monitoring are much more expensive than high level detectors and therefore fewer grain elevators have employed inventory monitors within each silo.

High Level Detectors: This application monitors the presence and absence of material at a predetermined “high” point within each silo structure. The output is typically a relay contact closure or electrical switch closure to indicate material high level. However, the reverse can also be used (switch/contact opening upon high level detection).

The technology best suited for these applications is the Tilt Switch and the Rotary Paddle bin level indicator. A summary follows.

*The Tilt Switch* is suspended by a cable to a point where the high level detection is required. An electrical cable is also extended between the switch and the control point (remote control unit or plant-wide control system). The tilt switch must not be suspended by the electrical cable. A Tilt Switch suitable for hazardous locations by being intrinsically safe must be used. This may require the use of a remote control unit with the appropriate intrinsically safe power source and input circuitry or the same from your control system.

Tilt Switch units are actuated by a tilt sensor within the switch probe. There are three types of tilt sensor technologies in use. The first is mechanical activation. In this case a steel ball depresses an electrical switch when the Tilt Switch probe is suspended and in a plumb position. When material comes up to the location of the Tilt Switch and begins to tilt the probe, the ball will fall off the electrical switch when the probe is tilted between 15-17 degrees. This opens the electrical switch contact. When the grain falls away, the Tilt Switch probe will go back to the plumb position and the ball will seat back over the electrical switch and close its contact again.

The second method of actuation is the use of a mercury switch encapsulated within the Tilt Switch probe. The mercury switch contact state changes when the probe is tilted by the presence of the material 15 degrees from plumb. The mercury switch contact will revert back to its normal state when the grain falls away and the Tilt Switch probe reverts to its normal plumb position.

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The third actuation method uses mercury-free tilt sensors, optical or other type, or accelerometers. These sensor types of Tilt Switches offer the same simple principle of operation while eliminating the mechanical or mercury-laden type sensor. The mercury-free sensor is still encapsulated for protection and uses a cable to connect with its remote control unit. Output from the control units in each case are potentially the same.

Table 1: Comparison of Tilt Switch sensor techniques Advantages and Disadvantages

Tilt Switch Sensor Type	Advantages	Disadvantages
Mechanical	<ul style="list-style-type: none"> <li>✓ Simple design</li> <li>✓ Lowest cost</li> <li>✓ No toxic mercury</li> </ul>	<ul style="list-style-type: none"> <li>✓ Mechanical, moving parts</li> <li>✓ Not suitable for hazardous explosive dust environments</li> <li>✓ Typically bare metal probes</li> <li>✓ No remote control unit available</li> </ul>
Mercury Switch	<ul style="list-style-type: none"> <li>✓ Industry standard for many years</li> <li>✓ Has remote control unit or can be directly wired to control system</li> </ul>	<ul style="list-style-type: none"> <li>✓ Mercury is toxic material</li> <li>✓ Higher cost than mechanical switches</li> </ul>
Solidstate (mercury-free) Switch	<ul style="list-style-type: none"> <li>✓ Solidstate</li> <li>✓ No toxic mercury</li> </ul>	<ul style="list-style-type: none"> <li>✓ Higher cost</li> <li>✓ Do not currently work without their remote control unit</li> </ul>

*Rotary Paddle bin level indicators* are also used for high level detection in grain elevators. In this case an assembly including the Rotary Paddle power pack, flexible coupling, extension shaft, extension guard and paddle are used. The Rotary Paddle assembly is top mounted on the silo. The extension shaft extends the monitoring point (the paddle) into the silo to the desired high level detection point. The flexible shaft coupling helps protect the power pack output drive shaft from damage due to side loading from flowing and shifting material. The shaft guard protects the extension shaft from bending and also protects the output drive shaft from damage.

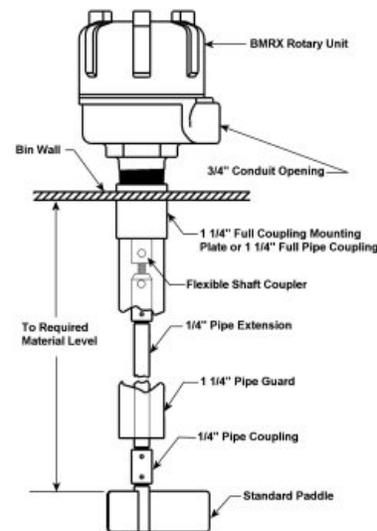


Figure 3: Rotary Paddle bin level indicator assembly for top mounting and high level detection

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The Rotary Paddle bin level indicator consists of a small synchronous motor which turns at 1 rpm. With material absent at the high level detection point, the shaft rotates the paddle freely in air. When the silo fills and grain reaches up to the paddle, the weight of the grain will resist the paddle rotation and stop it from turning. The drive motor inside the Rotary Paddle bin level indicator will rotate on its mounting plate and activate the units' control output. Subsequently, another switch will be activated that will turn power off to the drive motor. The drive motor mounting plate is spring loaded and when the grain in the elevator silo falls away or recedes from the high level detection point at the paddle, the drive motor will rotate back to its normal point and reactivate the switch that turns power on to the drive motor and also reactivate the other switch that reverses the control/alarm output state.

For further information about Rotary Paddle bin level indicators, Tilt Switches and other point level monitoring technologies refer to the White Paper titled "Application Considerations for Point Level Monitoring of Powder and Bulk Solids".

Inventory Monitoring in Grain Elevators: Grain inventory monitoring (determining the amount of material) is usually based on measuring the level of grain in each silo. Often this is not done because of the expense of installing a level sensor of \$1300-3000 in each silo. This is a sizeable expense when you have 50, 70, 100 or more silos in the grain elevator facility. Many facilities will fill each silo until the high level point is reached and weigh out the amount of material when discharging. When real-time inventory monitoring is employed a level sensor is used that will measure the empty space distance between the sensor and the material surface and relate this distance to the overall height of the silo to obtain the relative level of grain in the silo. Calculations can then be made to estimate the amount of grain in bushels, pounds or tons.

The sensors most commonly used for grain silo inventory monitoring is the weight & cable, ultrasonic and even the open-air radar type of devices. However, the weight & cable system (a.k.a. smart plumb-bob, yo-yo, and bin-bob) is usually the most effective as it is a good balance between cost and measurement performance. Refer to Table 2 for a quick comparison of the technologies. Also, refer to the White Paper titled "Application Considerations for Continuous Level Monitoring of Powder and Bulk Solids".

All three technologies can be tied directly into the elevator control system for monitoring of silo inventory. The smart weight & cable systems can also be provided with their own standalone operator interface that can be either a wall mounted alphanumeric display or PC software.

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Smart weight & cable devices are capable of calculating volumes and weights for cylindrical and rectangular silos. They even include a capable weight table fit that can allow you to customize the conversion from level to weight by setting up a linearization table, sometimes with up to 100 data pairs.

Table 2: Comparison of top inventory monitoring technologies for grain elevator application

Continuous Level Technology	Advantages	Disadvantages
Weight & Cable	<ul style="list-style-type: none"> <li>✓ Moderate cost (\$1300+)</li> <li>✓ Mostly solid-state with modern versions</li> <li>✓ Rugged enough for grain silo applications</li> <li>✓ Can measure up to 150 feet even with dust</li> <li>✓ Standalone or with their own operator interface</li> </ul>	<ul style="list-style-type: none"> <li>✓ Not non-contact</li> <li>✓ Not typically used for measuring during filling</li> <li>✓ Not true continuous, more intermittent measurement (sample rate can be set to within ever few minutes)</li> </ul>
Ultrasonic	<ul style="list-style-type: none"> <li>✓ Non-contact</li> <li>✓ Moderate cost (\$1600+)</li> </ul>	<ul style="list-style-type: none"> <li>✓ Not reliable with heavy dust</li> <li>✓ Not reliable for long range measuring devices for 100+ feet</li> <li>✓ Must be tied into elevator control system for operator interface</li> </ul>
Radar (open-air)	<ul style="list-style-type: none"> <li>✓ Non-contact</li> <li>✓ Good in dust laden air</li> <li>✓ Better reliability than ultrasonic</li> </ul>	<ul style="list-style-type: none"> <li>✓ Range may be limited to 80-100 feet</li> <li>✓ Most expensive of three technologies, e.g. \$2500+</li> </ul>

*Weight & Cable* devices measure the distance of cable as it is lowered into the silo until it contacts the material surface. The distance measurement is also made as the motor reverses and retracts the weight & cable. The measured distance is reported to the control system or operator interface via a RS-485 digital communication connection. Cables are typically 3/16" diameter stainless steel with a plastic jacket. Smart motor control, optical sensing for distance measurement and smart weight & cable control aspects of the modern weight & cable sensor.

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*Ultrasonic* continuous level sensors measure the distance by determining the time-of-flight of sound energy emitted from the sensor and reflected off the material surface. As such, it is never in contact with the material, however, sound energy can be easily absorbed by internal silo dust and the energy dissipates as the range gets longer and longer, as in an empty or near empty silo.

*Open-Air Radar* continuous level sensors measure distance by determining the time-of-flight of radar energy reflecting off the material surface. Radar techniques are more tolerant of dust in the silo atmosphere, but they are expensive and may be limited in measuring range to 80-100 feet at the most.

## **Conclusion**

Bin level indicators are an integral part of the operation of grain elevators and have been for decades. Whether protecting against silo overfilling, controlling filling operations or monitoring inventory in silos, they are an important part of the grain elevator operation. Tilt Switch, Rotary Paddle, Weight & Cable, Ultrasonic or Radar technologies are what are typically employed in grain elevators for these important bin level applications.