What's in My Bin?

Understanding Accuracy in a Bin Level Monitoring System

When it comes to monitoring inventory in bins, tanks and silos, one of the first questions often asked is “How accurate is it?” Unfortunately, that’s a loaded question that can’t be answered easily. Here we discuss why it’s a tough question and what you can and cannot expect from your level monitoring system.

Accuracy of a Single Point Inventory Measuring System

One consideration is the type of device you’re using to measure the material level. Bobs, guided wave radar, open air radar, and ultrasonic level sensors are commonly used devices. What they all have in common is they all measure a single point in the vessel. Although each device has its pros and cons (see our paper on Selecting Continuous Level Sensors), when installed properly they all perform well to their stated or printed measurement accuracy that appears in their literature.

But, what does printed measurement accuracy mean? For a single point measurement device the printed accuracy stated on a web site or in the literature is the distance measured from the sensor on the top of the tank to the material surface. This distance is often referred to as headroom, because it tells you how much space you have left in your bin. So, the printed accuracy is the accuracy of that distance in feet or meters. That one measurement is generally highly accurate within ± 0.25% of the total distance measured. However, this is not the accuracy of the volume or mass of material in the bin; it is simply the accuracy of that one measurement of distance.

Volume

Volume is very different than level. Volume is the amount of three-dimensional space the material takes up. When using the distance measured from the sensor to the material surface to estimate volume, the calculation is based on the internal vessel dimensions and the distance to that one point on the material surface. Therefore, it’s essential to have accurate vessel dimensions as mistakes in geometry will increase the overall error in the volume calculation. Material flow, buildup, or bridging can affect volume calculations. The placement of the sensor and the location of the filling and discharge points also have an impact on the overall accuracy of volume.

Mass

Accuracy can be further impacted when attempting to use a single point measurement device to estimate mass or weight. When converting volume to mass, the bulk density of the material – stated in pounds per cubic foot or $lb./ft.^3$ – can have a significant impact on accuracy. Although there are resources available that provide general information about the bulk density of a particular material, the bulk density of the material that is actually in the bin could be quite different than what’s posted on the Internet.[1]

Attributes such as particle shape, size and moisture content can profoundly impact bulk density. Compaction of material can also cause very different bulk densities of the same material in the top or the bottom of the bin. A cubic foot of material at the top of the bin could weigh less than that same material at the bottom of the bin, where the bulk density is greater due to compaction by the weight of the material above it.

When using bulk density to calculate mass in a bin for a particular material, it is very important to establish an average bulk density based upon the actual material handled at the facility, and not the stated amount given to a material's general name referenced on a table. One way to accomplish this is by taking a measurement before and after a "known-weight" load is put into the bin, and adjusting the bulk density in lb./ft.^{3} to reflect this weight.

What to Expect

When using a single point level measuring system, there will always be an increasing level of error associated as you progress through the conversion of distance to volume and then mass. The measured distance of most single point technologies is quite accurate and will be around ± 0.25% of the distance measured.

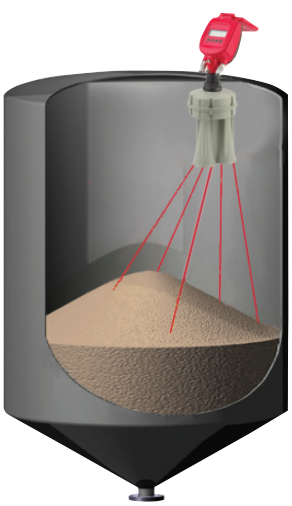
However, when level is used to estimate volume, accuracy will be dependent upon the correctness and completeness of the vessel dimensions, sensor placement, and the location and number of filling and discharge points. A vessel that is center fill, center discharge with material that flows freely and symmetrically will give you the best results when using a single point measuring device.

When converting volume to mass there will always be inherent inaccuracies due to variations in bulk density, regardless of whether you are using a single point or multiple point measuring device. The accuracy of the volume calculation will also impact the accuracy of the mass calculation.

Since there are so many variables, it is very challenging for any manufacturer of single point level measurement devices to pinpoint how accurate the calculated value of the mass will be. With accurate vessel geometry, strategic placement of the sensor, and a good average bulk density, the accuracy of the mass may be around 8% to 15%.

Accuracy of a Multiple-Point Inventory Measuring System

Unlike traditional devices that measure one point and determine a single distance, a 3DLevelscanner takes measurements from multiple points within the silo. These points are used to determine the volume of material in the bin. Measurement points are not averaged to calculate bin volume. Instead, each point is given a "weight" or relevancy rating and a complex algorithm is used to calculate the true volume of material within the bin. This technology takes into account variations that can occur across the topography of the material surface by measuring and mapping the high and low points.



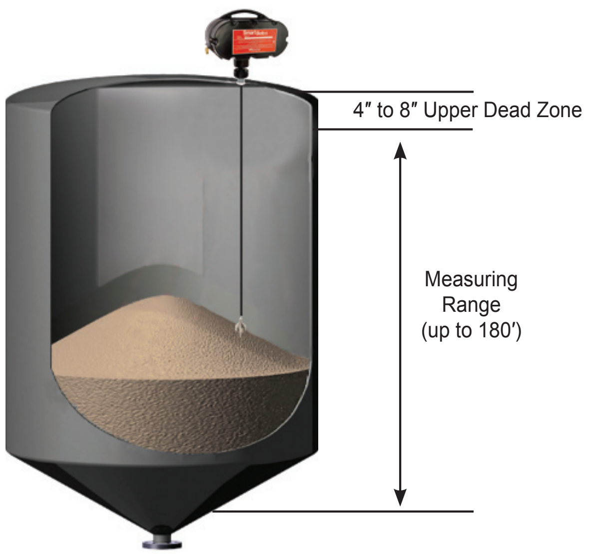
The 3DlevelScanner provides an accurate three-dimensional profile of the top surface within a storage vessel. This is beneficial when there are variations in the material surface due to multiple fill and discharge points, or with materials such as powders that do not fill/discharge symmetrically.

With the 3DLevelScanner as with single point measurement sensor, the volume accuracy is still dependent upon the accuracy of the vessel dimensions and sensor placement. When converting the volume to mass there will still be inherent inaccuracies due to bulk density variables. But, the improved accuracy of the volume calculation will improve the accuracy of mass calculation.

In the case of a 3DLevelScanner, "more is better" with multiple measurement points contributing to a higher degree of accuracy. Given correct vessel geometry and proper sensor placement, you can expect volume accuracy of 3% to 5%. When combined with a good average bulk density, the accuracy of the mass may be around 5-10%.

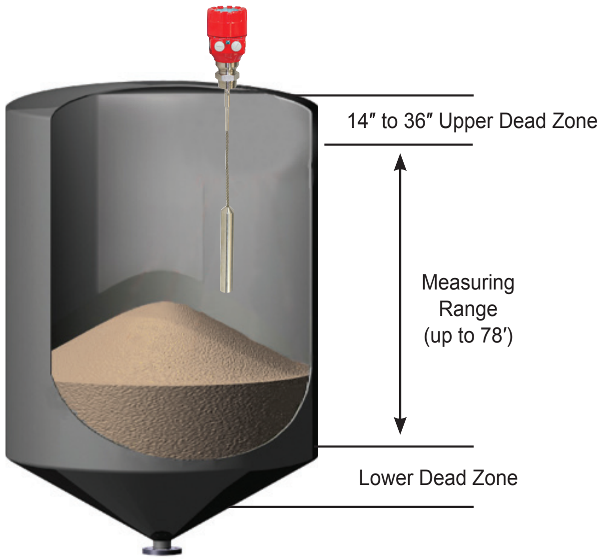
[1] By performing a keyword search for "bulk density table," "bulk density chart," or "bulk density guide," you will come up with a variety of reference charts for bulk density of a variety of materials.

How Continuous Level Sensors Work



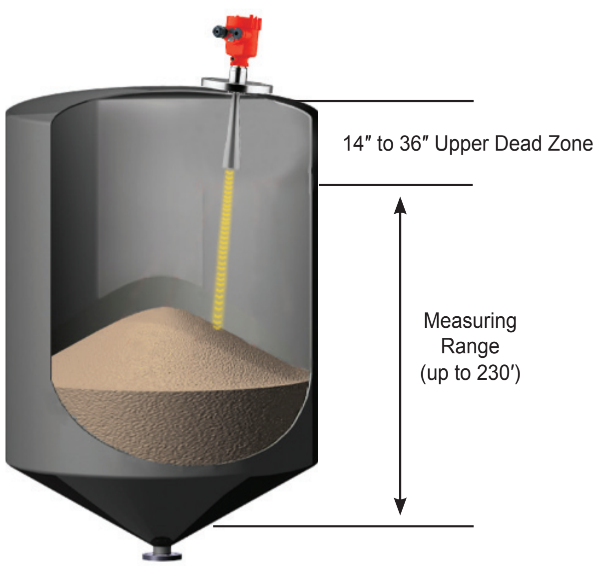
SmartBob 2 and TS1

Measuring range is from the tip of the "Bob" when fully retracted to where the Bob contacts material at the bottom of the vessel. The Smart-Bob measures the level of headroom from a single point on the material surface directly below the sensor's mounting location.



Guided Wave Radar

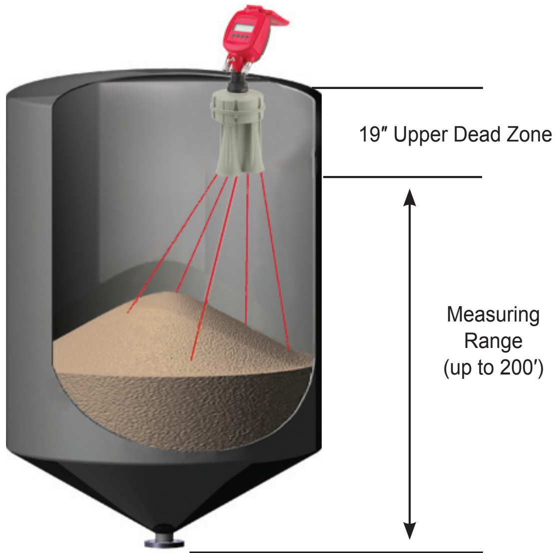
Measuring range is from 14" to 36" below the threads on the process connection (upper dead zone), to 4" above the top of the counterbalance weight (lower dead zone). It measures the level of headroom at a single point where the cable is located in the vessel.



Open Air Radar

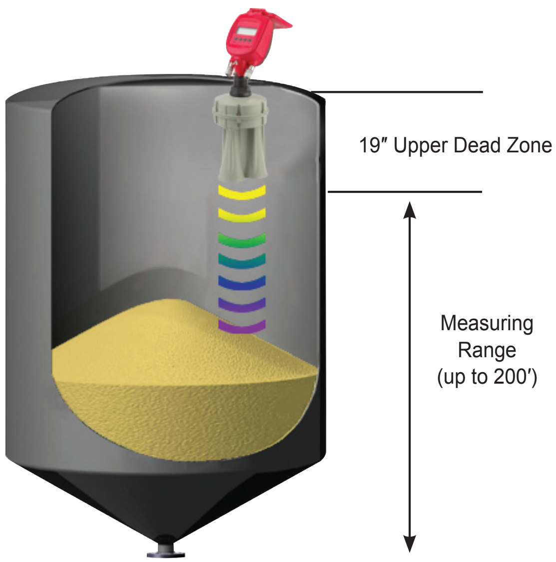
Measuring range is from 14" to 36" below the threads on the process connection (upper dead zone). Open Air Radar measures the level of headroom at a single point on the material surface directly below where the unit is aimed. For liquids it is generally pointed straight down (vertical), and for bulk solids it is aimed at the discharge to prevent the signal from bouncing off an angled hopper bottom causing false reflections.

Dead zones: Radar, Ultrasonic, and 3DLevelScanners have a default blanking distance, or dead zone, typically from the end of the process connection to allow the units to stop transmitting after the transmit pulse is applied and before the receiver circuit is turned on to listen for the return echo. For example, if using a 3DLevelScanner 19" below the threaded process connection would be considered a full tank. Dead zones can be increased if a lower full point is desired. Most manufacturers have the blanking distance pre-set in the controller, based on the unit selected. The SmartBob's dead zone is from the tip of the sensor probe hanging from the cable when the unit is fully retracted.



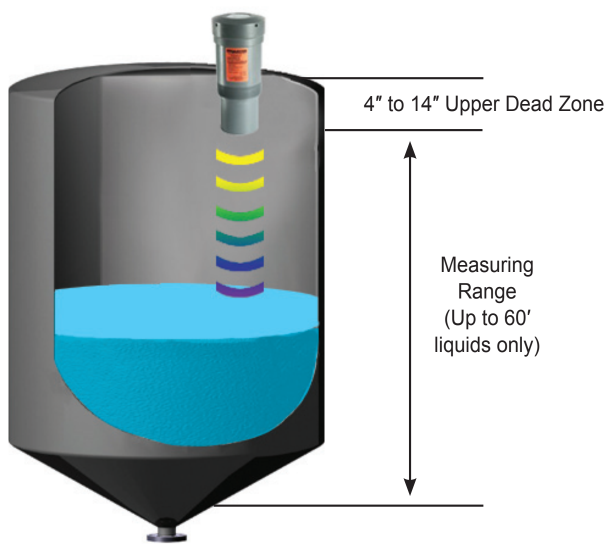
3DLevelScanner
Models S, M, MV, ML & MVL

Measuring range is from 19" below the threads on the process connection (upper dead zone). The 3DLevelscanner takes measurements from multiple points within the silo. These points are used to determine the volume of material in the bin. Measurement points are not simply averaged to calculate bin volume. Instead, an advanced algorithm assigns each point a "weight" to determine the true volume of material in the bin.



RL Acoustic Level Device

Measuring range is from 19" below the threads on the process connection (upper dead zone). The RL measures the level of headroom from a single point on the material surface directly below where RL acoustic level device is mounted.



SmartSonic
Ultrasonic Transmitters

Measuring range is from 4" to 14" below the threads on the process connection (upper dead zone). Ultrasonic measures the level of headroom from a single point on the material surface directly below where the unit is aimed. For liquids it is generally pointed straight down (vertical), and for bulk solids it is aimed at the discharge to prevent the signal from bouncing off an angled hopper bottom causing false reflections.

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BinMaster Level Measurement Systems

Selecting Continuous Level Sensors

SmartBob Weight & Cable Level

PROS

- Not affected by dust or other adverse process conditions
- Not affected by material buildup on sensor
- Can be used in extremely light, signal-absorbing materials
- Measures bins up to 180 feet (SmartBob-TS1 up to 60 feet)
- Not affected by material characteristics such as low dielectric constant or angle of repose
- Remote sensor requires no calibration
- High temperature models available up to 1000°F
- Low purchase cost ($900 to $1,600)
- Very simple setup and installation
- Consistent, repeatable, and accurate measurements
- Minimal contact with stored material
- Leading-edge eBob networkable PC software available
- A variety of digital and analog outputs available
- Cable replacing, wireless interfaces available
- Hazardous location approvals available

CONS

- On-demand system, does not provide an instanta-neous response to change in the material level
- Seasonal maintainence may be required to clean out mechanical cavity in very dusty conditions, if air-purge is not used
- Not recommended in high pressure bins

GWR-1000 Guided Wave Radar Level

PROS

- Continuous level measurement in powders, granules, bulk solids, and liquids
- Performs in vessels prone to dust, humidity, temperature, pressure and bulk density changes
- Suitable for vessels of most any shape or diameter, including narrow tanks
- Can be used on high pressure vessels (232 psi max.)
- High temperature range up to 392°F
- Accuracy of ± 0.2 inches (5 mm)
- Microwave energy is focused and travels along a wave guide, concentrating the radar beam within a small diameter

CONS

- Sensing probe is in constant contact with material
- Minimum dielectric constant of material must be above 2.2
- Maximum range is limited to 78 feet, and may be limited for heavier materials due to tensile load
- Material like large rock may damage probe and be difficult to sense

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SmartWave Open Air Radar Level

PROS

- Continuous level measurement
- Non-intrusive, non-contact design
- Ranges up to 100 feet
- High temperature applications up to 350°F
- In liquid applications, radar is not adversely affected by steam or foam
- Measurement is virtually unaffected by changes in process temperature, pressure, density or gas/vapor composition within the vessel

CONS

- Low dielectric products are difficult to measure. Not enough radar energy can be reflected from the product surface. Requires a minimum dielectric constant of 2.0.
- Susceptible to condensation and product buildup on the antenna. This causes signal attenuation that will adversely affect the performance. The higher the frequency, the more signal attenuation. The higher frequency units have smaller antennas, thus the same level of coating or condensation on a smaller antenna naturally has a greater affect on the performance.
- Cone-bottom vessels can sometimes be problematic when nearing empty. The cone acts as an excellent reflector, throwing energy around the vessel sometimes confusing the transmitter.
- High purchase cost ($2,500)

SmartSonic Level

PROS

- Continuous level measurement
- Non-intrusive, non-contact design
- Ranges up to 90 feet (liquids)
- High temperature applications up to 260°F
- Sanitary models are available with tri-clover fittings
- Low purchase cost ($675 to $1,200)
- Self-cleaning transducer face
- Automatic compensation for temperature changes
- Analog and digital communication options
- PC software used to diagnose and calibrate sensor is free with purchase of SmartSonic unit
- Very easy to install and calibrate
- Available in multiple voltages

CONS

- Performance affected by dusty conditions, pressure fluctuations, turbulence in vessel, and large particulate size
- Not recommended if steam will be present in vessel
- Will measure the surface of the foam, if present
- Maximum pressure of 29 psi

3DLevelScanner Level

PROS

- Continuous level measurement
- Non-intrusive, non-contact design
- Measures uneven powder or solid material surfaces
- Detects cone up, cone down and sidewall buildup
- Provides minimum, maximum and average distances
- Performs in extreme levels of dust
- Calculates highly accurate bin volume due to mapping the surface of the material with multiple measuring points.
- Measuring range up to 200 feet
- Self-cleaning with minimal maintenance
- High temperature applications up to 365°F
- Automatic compensation for temperature changes
- Analog and digital communication options
- Leading-edge 3D MultiVision networkable PC software available for multiple vessel monitoring
- Can generate a 3D image of material surface
- Cable-replacing, wireless interfaces available
- Approved for hazardous locations
- Not affected by material characteristics or low dielectric constants

CONS

- The 3DLevelScanner is an acoustic device and elevated background noise can have an affect on its performance.
- Setup requires care in mounting the sensor in the proper location, and mapping the vessel
- Time required to process multiple pulse echoes limits the sample rate
- Not recommended for liquid applications
- Corrugation on small vessels can cause false echoes
- Not recommended for materials with a bulk density under 11 lb./cu. ft. due to absorbing the acoustic pulse