White Paper

How to select a Continuous Level Sensor

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Using a continuous level sensor to monitor the material level in your storage vessels can help your operation maintain efficiency – preventing costly process interruptions and keeping you up-to-date on your inventory level. This whitepaper is intended to help operations choose a continuous level sensor without having to wade through volumes of technical data. It will briefly describe the sensor types available, address the pros and cons of each type, and explain what information you need to gather before working with a sensor supplier.

A continuous level sensor measures the amount of material in a storage vessel on a continual basis, rather than just indicating whether the material is above or below a certain point, as point level sensors do. This makes a continuous level sensor ideal for monitoring material inventory in your vessels to prevent downtime. Depending on the sensor type and supplier, the continuous level sensor can output data to a console or panel, send information to a PLC, HMI, or PC, or send information via SMS text or to the Internet for anywhere, anytime access. An advanced system using multiple sensors can report data from multiple vessels at your site or from vessels at multiple sites, making it easy to monitor your entire operation's inventory status.

However, choosing the right continuous level sensor for your application can seem like ordering off a menu when you don't speak the language. An overwhelming amount of information is available about the different types of sensors and the technologies they use. And a level sensor is just one of the many

pieces of equipment you need to worry about. Knowing some basics about how different sensor types work and their pros and cons can help you determine which sensor you need.

Before getting into these basics it's important to understand that a continuous level sensor, which is typically mounted on the top of a vessel, has a default dead zone (or blanking distance) that it cannot measure. The dead zone is the area between the highest point the sensor can measure and the vessel's top. When the material reaches the bottom of the dead zone, the sensor will indicate that the vessel is full.

Dead-zone height varies by sensor type but can range from about 4 inches to about 36 inches. Most suppliers preset the dead-zone height in the sensor controller based on the sensor type, but a dead zone's height can be increased if the application requires a lower full point.

Sensor Types

Types of continuous level sensors include weight-and-cable, 3D scanners, guided-wave radar, open-air radar, laser, and ultrasonic. Each type operates differently and has its pros and cons.

Weight-and-Cable

A weight-and-cable (or plumb bob) sensor works like an automatic measuring tape: The sensor lowers a cable with a weight (also called a bob or probe) attached to its end into the vessel. The sensor determines the material's level by measuring how much cable has been let out when the weight reaches the material's surface; then the sensor retracts the cable and returns the weight to the vessel's top. Not strictly a continuous sensor, the weight-and- cable sensor is programmed to take measurements at predetermined intervals, such as every 30 minutes, once an hour, every 6 or 8 hours, or once a day.

The weight-and-cable sensor measures a single vessel distance or point directly below its mounting location and is highly accurate and reliable. The weight-and-cable sensor's measuring range can be up to about 150 feet (approx. 46 meter) , and the dead zone is minimal, just 4 to 8 inches (approx. 102 to 204 mm) measured from the sensor's mounting location to the weight's tip when the cable is fully retracted.

Pros

The weight-and-cable sensor:

- Isn't affected by dust or other adverse process conditions
- Has minimal contact with the stored material
- Can be used in vessels up to about 150 feet (approx. 46 meter) tall
- Is available in models that can handle temperatures up to 1,000°F (approx. 540°C)
- Isn't affected by material buildup
- Isn't affected by material characteristics, such as angle of repose or low dielectric constant
- Can measure extremely light, signal-absorbing materials
- Is approved for use in hazardous, high-dust locations
- Can be equipped with an air purge to keep the mechanical components clean in very dusty conditions
- Is simple to install and set up
- Requires no calibration
- Provides consistent, repeatable, and accurate measurements
- Has a low purchase cost compared to the other sensors

Cons

The weight-and-cable sensor:

- Doesn't instantaneously respond to material-level changes
- Measures a single vessel location distance or point
- Isn't recommended for use in high-pressure vessels
- May require periodic maintenance

Guided-wave Radar

A guided-wave radar sensor uses time-domain reflectometry to measure the distance from the sensor to the material. For this sensing method, a low-power microwave signal is sent along a sensing probe (a cable with a counterbalance weight at its end) that acts as a wave guide, concentrating the radar signal within a small diameter around the probe. The sensor calculates the material level based on the signal's flight time. The sensor's cable diameter and length vary depending on the material's characteristics and the vessel size.

The guided-wave radar sensor typically is for vessels up to 100 feet (approx. 30.5 meter) tall and can be used in powders, granules, pellets and other bulk solids. Dependent on the model, it can be used in materials with a dielectric as low as

1.3. The sensor measures the material level at a single point in the vessel (along the cable) between the bottom of the upper dead zone and the top of the lower dead zone. Guided wave radar works in high dust or humidity and is immune to condensation.

Pros

The guided-wave radar sensor:

- Provides continuous level measurement
- Provides highly accurate measurements
- Is suitable for almost any vessel shape or diameter including narrow silos
- Is available in high-temperature models up to about 800°F (approx. 430°C)
- Performs well in vessels prone to changes in dust level, humidity, condensation, temperature, pressure, and material bulk density
- Can be used in high-pressure vessels
- Is relatively easy to install and set up
- Virtually maintenance free

Cons

The guided-wave radar sensor:

- Has a sensing probe that is in constant contact with the material
- Measures a single point along the cable
- Typically has a maximum cable length of less than 100 feet (approx. 30.5 meter) , limiting the measuring range
- Not all models perform well in materials with a very low dielectric constant
- May not be suitable for use with heavy or abrasive materials, such as large rocks, which are difficult to measure and can impose a high tensile load on the cable and damage it
- Upper and lower dead zones vary by manufacturer and model
- Has a relatively high purchase cost (but typically lower than open-air radar or 3D scanners)

Open-air Radar

An open-air radar sensor transmits a radio-frequency signal to the material surface, which reflects a small portion of the signal back to the sensor's antenna. The sensor processes this returned signal to determine the material's level. The sensor's antenna is typically aimed at the vessel's discharge to prevent the signal

from reflecting off the angled bottom when the vessel is nearly empty, which could cause false measurements.

Sensor models are available with different antenna types and operating frequencies (typically ranging from 6 GHz to 80 GHz). Which model will perform successfully in an application depends on the vessel height, the material being measured, the presence or absence of dust, and the sensor's operating frequency.

The sensor's measuring range varies depending on the operating frequency. Sensors with frequencies of 26 GHz or less can measure up to about 100 feet (approx. 30.5 meter) , while a 80 GHz sensor can measure almost 400 feet (approx. 122 meter). A 26 GHz radar measures in a 10° beam angle, while a 80 GHz radar measures in a very focused 4° beam angle that is ideal for precise targeting. All open-air radar sensors measure the material level at a single point where the sensor is aimed.

Pros

The open-air radar sensor:

- Provides continuous level measurement
- Is nonintrusive and doesn't contact the material
- Can – with high frequency (80GHz) models – be used in vessels up to 393 feet (approx. 120 meter) tall
- Can – with high frequency (80 GHz) models – be precisely targeted to avoid structures
- Updates quickly for accurate tracking of filling or emptying activity
- Is versatile for use in solids, liquids, and slurries
- Is not affected by corrugation
- Is virtually unaffected by changes in process temperature, pressure, or material bulk density

Cons

The open-air radar sensor:

Measures a single location
Must be carefully located and pointed to desired measurement location
May require air purging in lower frequency models potentially requiring a supply of compressed air be run to the sensor

May not perform reliably in very dusty environments with lower frequency models. The high frequency 80 GHz radar has a flush lens antenna highly resistant to product buildup, eliminating the need for air purge and making it suitable for use in dust.

Accuracy of a Single Point Inventory Measuring System

1. Printed Measured Accuracy: The "printed accuracy stated" of any single point level device is the measured distance from the sensor to the material surface. This is not the accuracy of the conversion from a measure of distance to volume or mass.

2. Volume: When converting measured distance from the sensor to the material surface to volume, the calculation is based on the internal vessel dimensions and the measured level of material at a point on the material surface. Inaccurate vessel geometry will increase the overall error in the volume calculation. The placement of the sensor and the location of the fill inlet and discharge outlet will also have an impact on the overall accuracy of volume.

3. Mass: When converting volume to mass (weight), the bulk density will have a large impact on the accuracy when converting volume to mass. There are several considerations involved to obtain an accurate assessment of the bulk density.

- First, it should be stressed that a material's general name (e. g. polyethylene or cement) provides little about its bulk density. A "ballpark" number associated with a name may be off by 50% or more depending on the specific circumstances.
- The material's bulk density will vary based on the specific grade (composition), the particle size distribution, and moisture or volatile content. Tendencies towards segregation during handling should also be considered.
- A material's density will vary based on the extent it is fluidized or compacted. When calculating bulk density, it is very important to use an average – not the stated amount given to the materials general name. One way to accomplish this is by taking a measurement before and after a known weight load is placed in the vessel and adjusting the bulk density to match this weight.

There will always be error associated with the conversion of distance/volume/mass when using a single point level measuring system. The measured distance of most single point technologies will be around ± 0.25% of the distance measured.

The calculated volume accuracy will be dependent upon the accuracy of the vessel dimensions, sensor placement, and location and number of fill/discharge points. A vessel with center fill/center discharge with material that flows symmetrically will give the best results when using a single point measuring device.

It is very challenging for any manufacture of single point level measurement devices to accurately pinpoint the exact calculated value of mass. With accurate vessel geometry, strategic placement of the sensor, and a good average bulk density, the accuracy of mass may be figured around ±8-15%.

Ultrasonic

An ultrasonic sensor transmits an ultrasonic pulse of pressurized air to the material's surface. The pulse reflects off the material as an echo and is received by a microphone in the sensor. The sensor is generally aimed at the vessel discharge to prevent the signal from bouncing off a nearly empty vessel's angled hopper bottom and causing false measurements.

The ultrasonic sensor's dead zone is typically 4 to 14 inches (approx 102 to 355 mm), and its measuring range is typically limited to about 40 feet (approx. 12.2 meter), but can be higher in some low frequency models. The sensor measures the material level at a single point on the material's surface. Ultrasonic performs best in liquids and is commonly used for continuous level measurement in tank inventory management.

Pros

The ultrasonic sensor:

- Provides continuous level measurement
- Is nonintrusive and doesn't contact the material
- Performs well in liquid applications
- Is available in high-temperature models up to about 300°F (approx 150°C)
- Requires minimal maintenance
- Is easy to install and calibrate
- Has a relatively low purchase cost compared to the other sensors

Cons

The ultrasonic sensor:

- Measures a single vessel location
- Typically measures only up to about 40 feet (approx. 12.2 meter)
- Is not generally recommended for powders or solids
- Doesn't perform well in dusty conditions or with pressure fluctuations, vessel turbulence, or large particle sizes
- Isn't recommended for vessels containing steam
- May not perform well in high-pressure vessels

Laser

A laser sensor is mounted on top of the silo using an adjustable 10° mounting flange for aiming the laser beam to the desired output location. Minimum and maximum measuring distances are set using 4 and 20 inputs configured on the sensor. The sensor sends timed laser pulses to the material surface. Distance is calculated using complex algorithms that convert the laser pulses to a data output. A compensation for "slant range" is made based upon the angle of the beam to ensure accurate level measurement.

Laser is for low or no dust environments, as it does not perform reliably in high dust. It is ideal for level control in narrow vessels containing solids or plugged chute detection. It can also be used in restrictive chutes and hoppers where precise targeting is needed. Another use is to monitor buildup when installed above or pointed to the sidewall. Laser sensors may be applied in opaque liquids in vessels where the beam must be precisely targeted to avoid walls or structure.

Pros

The laser sensor:

- Has a narrow beam that can be directed to avoid obstructions
- Is easily configured in the field using a USB port
- Can be configuration without filling or emptying the vessel
- Features a fast update rate of 8 times per second
- Has integrated dust protection for minimal maintenance
- Can also be used in opaque liquids

Cons

The laser sensor:

- Does not measure reliably in dusty environments
- Only measures a single point on the material surface
- Is subject to interference from falling materials
- May need an air purge option to keep lenses free of dust for reliable performance
- Is not recommended for liquids with excessive vapor that is too opaque for the laser to "see through"

3D Scanners

Unlike any other continuous level sensor, the acoustics-based 3D scanner sensor takes measurements at multiple points within the vessel. The sensor uses three independent transducers, which convert electric energy into acoustic sound pulses. The sound pulses bounce off the material in multiple locations on the material surface, and the sensor measures the time it takes for the pulses to return (or echo) back to the transducer. The multiple measuring points take into account the material's irregular surface topography.

The 3D scanner has a measuring range of up to about 200 feet (approx. 61 meter) and a 19-inch (approx. 480 mm) dead zone. The sensor uses an advanced algorithm that assigns each measuring point a weight to precisely determine the material volume and produce a 3D image of the material level.

Pros

The 3D scanner sensor:

- Provides continuous level measurement
- Is nonintrusive and doesn't contact the material
- Measures multiple vessel points to create a 3D map of the material's surface and accurately calculate the material volume
- Can measure uneven material surfaces, including sidewall buildup and cone-up or cone-down formation
- Can report minimum, maximum, and average material levels
- Offers a 3D visualization of the vessel topography
- Can be used in vessels up to about 200 feet (approx. 61 meter meter) tall
- Is available in high-temperature models up to about 350°F (approx. 176°C)
- Isn't affected by material characteristics
- Works in very dusty conditions
- Is approved for use in hazardous locations
- Self-cleans and requires minimal maintenance

Cons

The 3D scanner sensor:

- Requires time to process multiple sound pulse echoes, limiting its sample rate
- May not perform well in an environment with a lot of background noise
- Isn't recommended for measuring a material with a bulk density less than 12 lb/ft3 (approx. 192 kg/m3) because such a material will absorb the sound

pulse
- Must be carefully located and mounted to accurately map the material surface
- May not perform well in small vessels with corrugated walls, which can create false echoes
- Has a high purchase cost compared to other sensors

Accuracy of a Multi-Point Inventory Measuring System
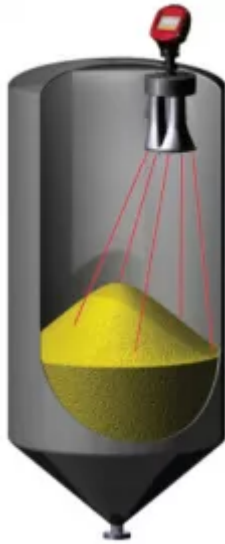
Unlike standard devices that measure one point and determine a single distance, the 3DLevelscanner takes measurements from multiple points within the silo. These points are used to determine the volume of material in the bin. Measurement points are not averaged to calculate bin volume. Instead, each point is given a "weight" or strength of accuracy rating assigned by an algorithm to determine the true volume of material within the bin. This technology takes into account variations that can occur on material surfaces by mapping the high and low points.

The 3DlevelScanner provides an accurate 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 that do not fill/discharge symmetrically.

With the 3DLevelScanner 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 determining the correct mass calculation.

Given correct vessel geometry and proper sensor placement, you can expect a volume accuracy of ±3-5%. With a good average bulk density, the accuracy of the mass may be around ±5-10%

Evaluating your Level Measurement Needs

Before you contact a supplier to determine which level sensor is best for your application, you should know some basic information about your material, your vessel, and your operation. This preliminary information will help you quickly rule out sensor types that won't work for your application or budget.

Your material:

- What is the material?
- What is its bulk density in pounds per cubic foot?
- Is it sticky?
- Does it tend to create buildup?
- Is it corrosive?
- What's the material's moisture content?
- Does the material create dust, steam, or vapor?

Your vessel:

- What are the vessel's dimensions?
- Are there limitations to where the sensor can be mounted?
- What's the temperature in the vessel?
- What's the pressure in the vessel?
- Is there excessive noise or vibration in the vessel?

Your operation:

- How often do you need to measure the material level or access the data?
- How many people need access to the data, and how will it be shared?
- Is monitoring the material level in one vessel at a time okay, or do you need to monitor levels in multiple vessels simultaneously?
- Do you need a notification or alert if the level reaches a certain high or low point?
- How accurate do you need the measurements to be?
- What is your budget?

Most sensor suppliers offer an online application worksheet addressing many of these questions to help evaluate your application. Completing the worksheet is great preparation for working with a supplier to select the right continuous level sensor for your needs.