How Much Is in the Silo?

How to meet accuracy expectations for bulk solids storage

V_{red} = ? r^2 H / 3 = (3.14 x 25 x 2) / 3 = 52.3 ft^3 V_{green} = Volume of 1 ft of straight wall = V_{cyl} – V_{orange} V_{cyl} = ? r^2 h = 3.14 x 56.25 x 1 = 176.6 ft^3 V_{orange} = 0.2618 (D^2 + D d + d^2) h = 0.2618 (225 + 150 + 100) 1 = 124.3 ft^3 V_{green} = 176.6 - 124.3 = 52.3 ft^3 V_{green} = Volume of 1 ft of straight wall (V_{cyl}) - V_{orange} V_{cy}l = 176.6 ft^3 V_{orange} = 124.3 ft^3 V_{green} = 176.6 ft^3 - 124.3 ft^3 = 52.3 ft^3 V_{red} = 52.3 ft^3 = V_{green} = 52.3 ft^3 **By Joe Lewis**

A bulk solids level measurement device typically measures the empty space distance between itself and the material surface where it is aimed or directly below where it is mounted. For example, a smart cable-based sensor uses a weight and cable mechanism to lower a plumb bob and cable into the vessel and measure the distance of the cable until it contacts the material surface directly underneath where it is mounted. Likewise, a guided wave radar device will measure the time-of-flight of the reflected radar pulse from the material surface. Once the distance measurement is obtained, the level of the material in the silo is inferred based on the vessel height (the vessel discharge point to the mounting point of the level sensor) and the distance measurement from the sensor. Some level measurement devices, such as ultrasonic devices, do not make a direct measurement from the sensor to the material surface. Ultrasonic sensors measure the time-of-flight of the reflected sound pulse. They are unlike guided wave radar devices that use the wave guide to direct the radar pulse to the material surface and back. The sound energy from ultrasonic sensors scatters when they reflect off the material surface because of the angle of repose of the material. In this situation, the distance measured is typically based off a reflected sound pulse that has bounced around in the vessel, thereby adding slight errors in the basic distance measurement.

Level Measurement Accuracy

The measurement accuracy of a level sensor differs depending on technology and brand. Guided wave radar devices can provide a measurement accuracy of the distance measurement to within 0.8 inch (20

mm) for measurement of bulk solids. Typical smart cable-based sensors are accurate to within 1.5 inch (38 mm) for a 50-foot (15.2 m) measurement. Through-air radar units may be accurate to 0.6 inch (15 mm) but, like ultrasonic units, need to be mounted on a swivel to align their emitted energy as perpendicular to the material surface to minimize error due to multiple reflections. Of course, the choice of technology depends on budget, accuracy and sophistication requirements. However, the overall precision of the calculated volume and weight values is another matter.

Sensor Mounting

The mounting location of the level sensor is usually controllable prior to installation and is important to the overall precision of the calculated volume and weight. The reason it's important to the calculation is due to the angle of repose. The level sensor assumes a flat surface when the calculation of the volume is done. This is not a valid assumption. However, for many applications, there is a simple solution. If the silo is filled and discharged from its center, then the mounting of the level sensor at one-sixth the diameter of the straight wall silo will eliminate the error. Consider the example of a 15-foot-diameter (4.6-m-diameter) silo that is center filled and discharged. The angle of repose will be relatively uniform with a peak at the center during filling. For this example, don't worry about the angle of repose because it will vary with the material. Let's assume it's above the transition point and the angle of repose is positive. The volume of the material in the peak, which is above the level measuring point line, is equal to the volume of the empty space below the line. See the details given in Figure 1 to review the math involved.

Conclusion

Level measurement is a viable method to monitor the amount of bulk solids in a storage vessel. However, many factors contribute to the correct conversion from level to volume and weight. Simply reviewing the accuracy statement of the sensor used is not enough and can be misleading if the sensor's technology and "specsmanship" are not understood fully. Accurate and stable information regarding vessel dimensions and bulk density is extremely important along with the mounting location chosen for the level sensor.
If the silo is not cylindrical or has off-center fill and discharge, it's best to choose a level sensor mounting location where a 1:1 relationship exists between the material above the imaginary level measurement line and the empty space below the line. It's also wise to consult a reputable and knowledgeable manufacturer for assistance.

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