White Paper

Weighing Is Ideal

for Inventory Control in Tanks or Silos

You can choose from a wide variety of measuring methods for inventory control of solids or liquids in tanks and silos. However, be advised that accurate results can greatly depend on material characteristics and environmental conditions. Non-contact distance and level measurement techniques and almost all flowmeters only provide a volume measurement. In contrast, weighing technology provides a reliable and accurate result for all conditions and for each material.

Conveying, storage and measuring liquids and solids in a tank or silo is a science. Countless publications and presentations at symposia confirm that. Some companies use large testing laboratories to determine the behavior of materials in different situations based on practical trials. The findings are used to develop the ideal materials-handling and storage equipment for individual materials. They are also used for determining the appropriate measurement technology.

Why read this document?

Accurate inventory control inside tanks and silos is important to optimize the management of expensive material. It can also be important for safe hazardous material storage and to detect even the smallest leak. Batching or out-dosing, including small quantities of material, can also require accurate inventory control to ensure product quality.

This white paper discusses weighing compared to other methods to determine the amount of material in a tank or silo. The document also discusses how measurement equipment for inventory control can be integrated into conveying systems leading to tanks and silos.

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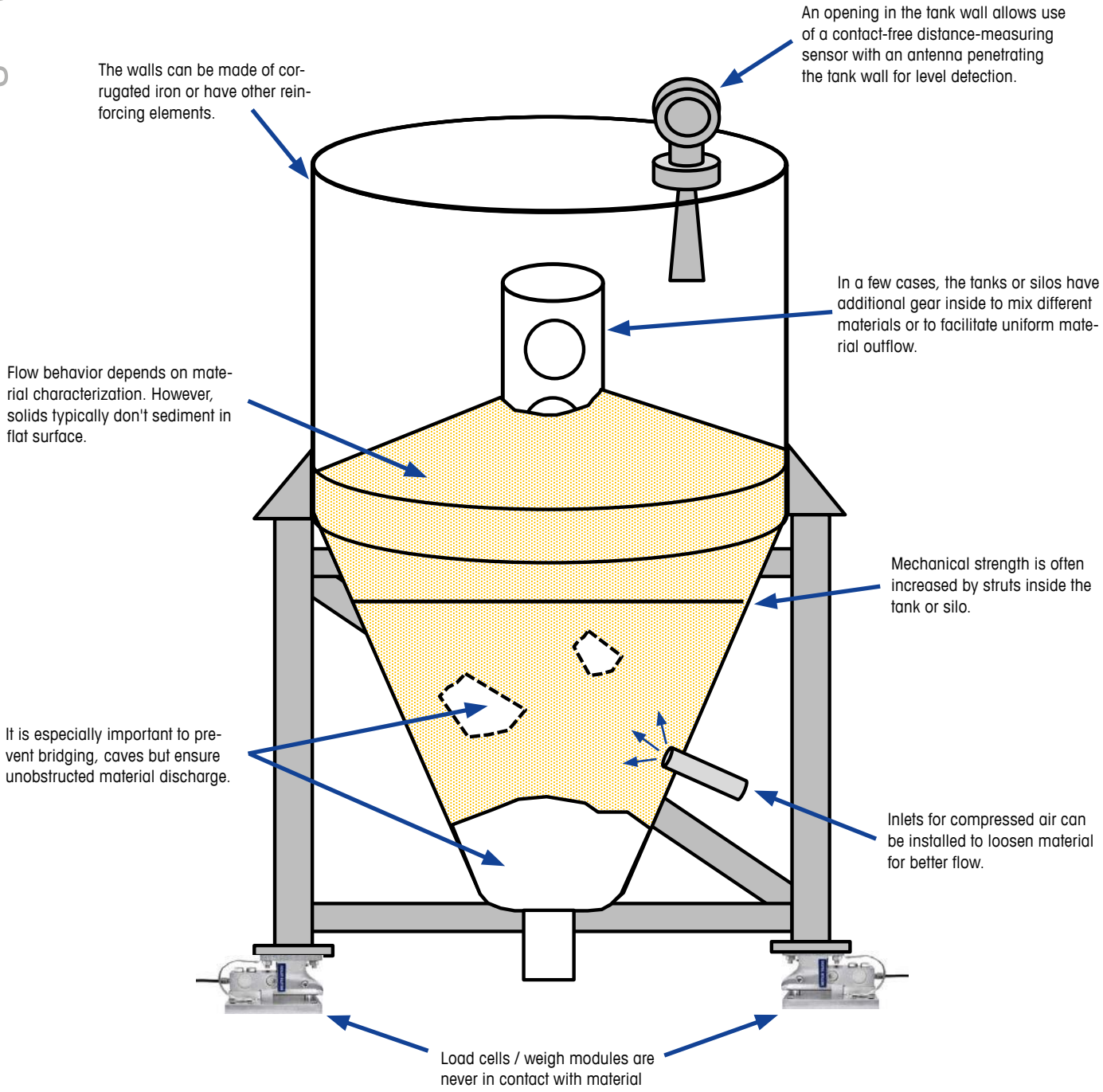
METTLER TOLEDO

1 Introduction

The characteristics of the stored material dictate the design that should be used for tanks or silos. To facilitate material flow, a combination of a cylinder is used for the upper part of the tank or silo and a cone is typically used for the lower part. A nearly perfect cylindrical shape is typically used for storing liquids. The following two chapters address the challenges for storing liquid and solid materials.

2 Tank and Silo Design for Solids

For tanks or silos that store solids, usually a combination of cylinder and funnel shape is chosen. The slope of the funnel is determined, among other parameters, by the material property. Below is an overview of typical situations, challenges and designs.

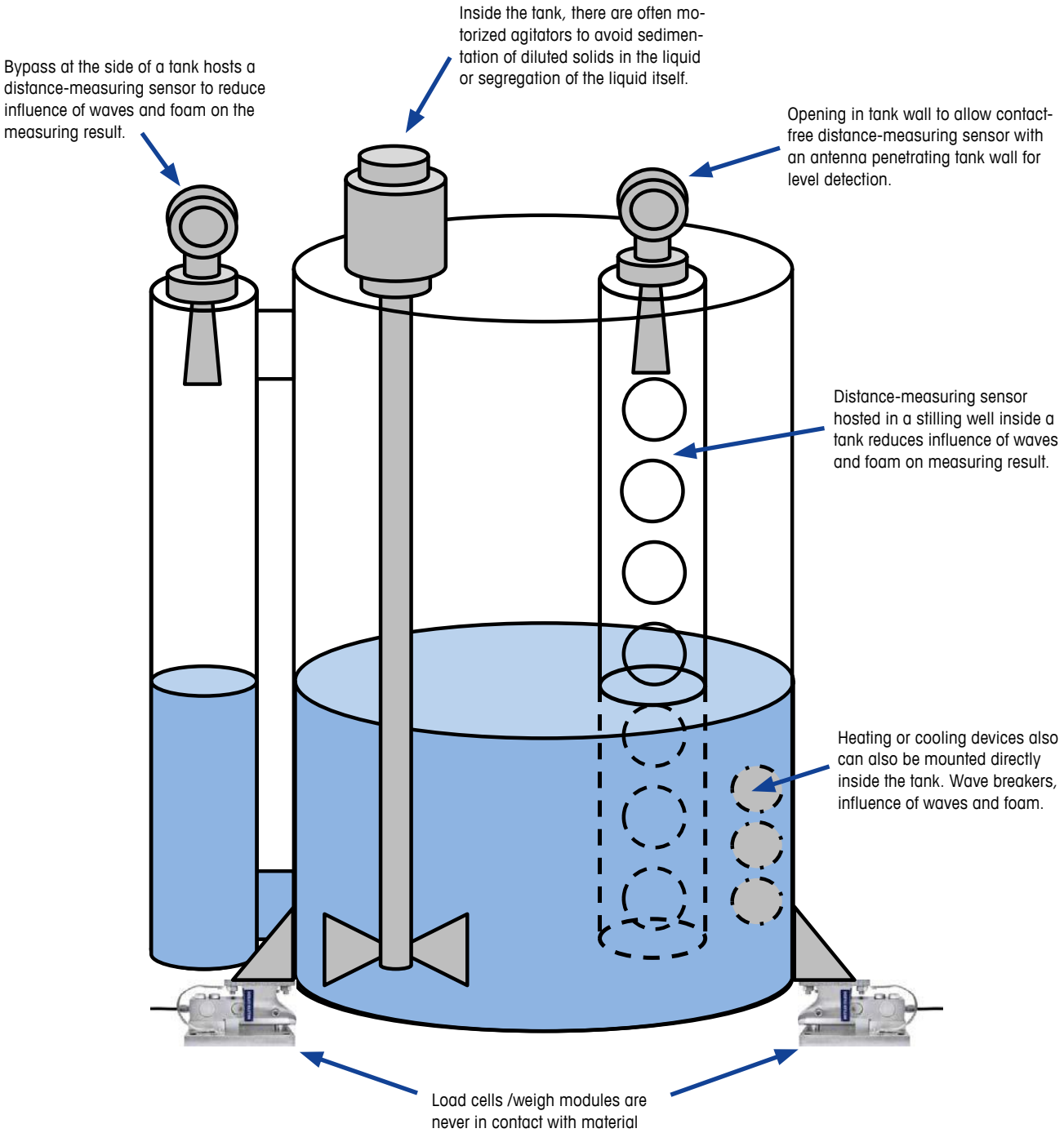


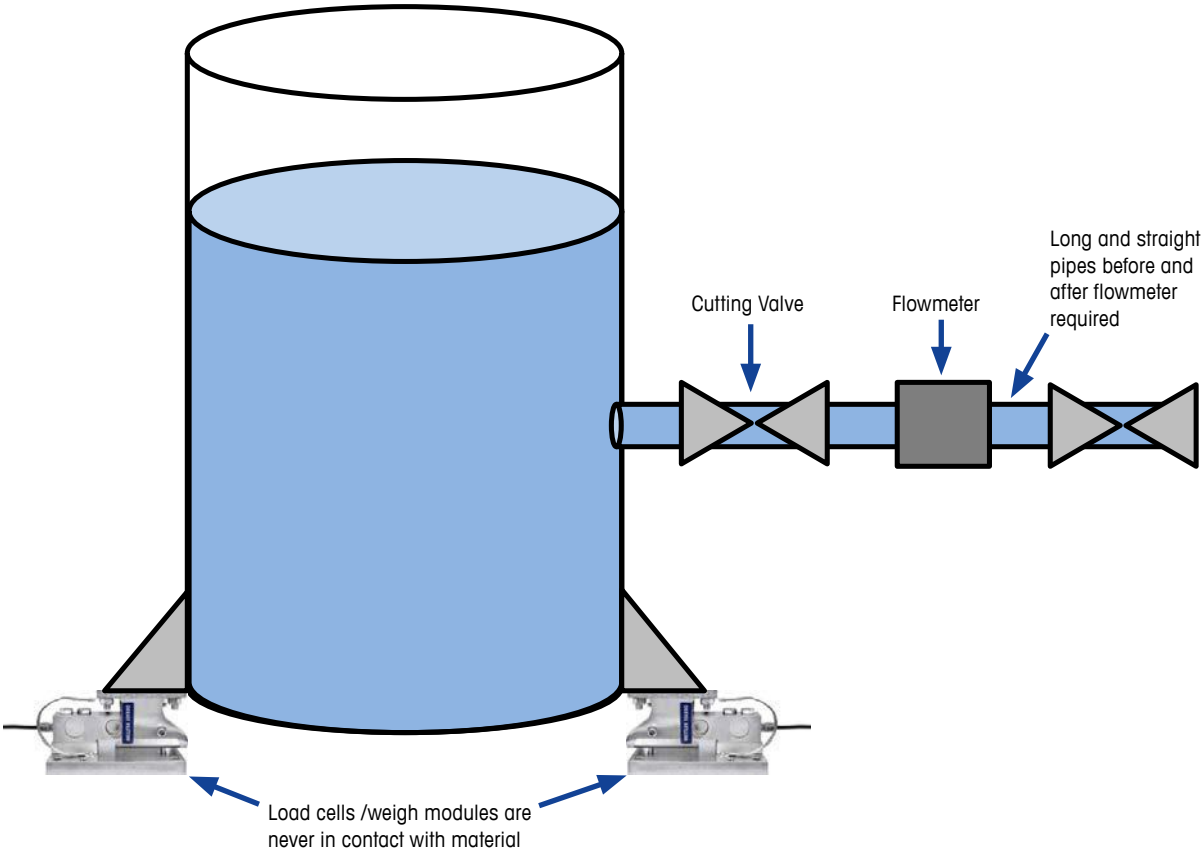
	Advantages	Disadvantages
Weighing	• Highest accuracy achievable • Accuracy of inventory measuring result is independent of tank shape or of any kind of installation inside tank • Accurate regardless of caves, bridges or dust • Doesn't need opening in tank for sensor	• Measures weight, not mass unless installation is correctly calibrated and adjusted • Sensitive to strong vibrations • Load cell is part of tank's under-structure
Level Sensors	• Medium accuracy achievable in case of freely flowing material that doesn't build cones nor leave bridges or caves • Not part of understructure of tank	• Measures volume, which is temperature dependent • Accuracy reduced by inhomogeneous material distribution, such as uneven surfaces, caves and bridges • Accuracy reduced by tank elements, such as mixing pipes, struts, gears and corrugated side walls • Needs opening into tank, which has to be sealed
Flowmeters	• Not common for solids	• Not common for solids

Access to load cell for cleaning, inspection and maintenance is convenient because they are at the bottom of the tank and never in contact with material stored inside tank.

3 Tank or Silo Design for Liquids

For liquids, the nearly cylindrical tank shape is common. A small funnel at the bottom of the tank makes it easier to ensure complete draining of the liquid and prevents the sedimentation of solids, which are diluted in the liquid. Below is an overview of typical situations and designs.





	Advantages	Disadvantages
Weighing	• Accuracy of inventory measuring result is independent of tank shape or of installation inside tank • Accurate despite over-pressure, waves or foam • Doesn't need opening in tank for sensor	• Sensitive to strong vibrations unless stabilizers and electronic filters are in place • Load cell is part of tank under-structure
Level Sensors	• Accurate volume measuring in cylindrical tanks • Sensor is not part of tank's under-structure	• Measures distance that is temperature dependent • Volume has to be calculated if required • Accuracy can be reduced by mixers, heaters, coolers and wave breakers inside tank • Needs opening into tank, which has to be sealed
Flowmeters	• Accurate measuring of in-flow and out-flow • Allows parallel measuring of multitude of in-flow supplies for batching • Not impacted by tank design • Sensor is not part of tank's under-structure • Coriolis technology can determine mass and density regardless of temperature	• No information provided regarding amount inside of tank • Measures volume, regardless of temperature deviations • Accuracy is reduced by density and viscosity variations as well as vibrations, foam, solid particles, gas bubbles and turbulence • Straight tubing required around the sensor

Above is a look into a tank with a mixer for paint manufacturing. Installations, such as mixers, wave breakers or heaters might complicate accurate measuring with level sensors.

4 Challenges Resulting from Material Characteristics

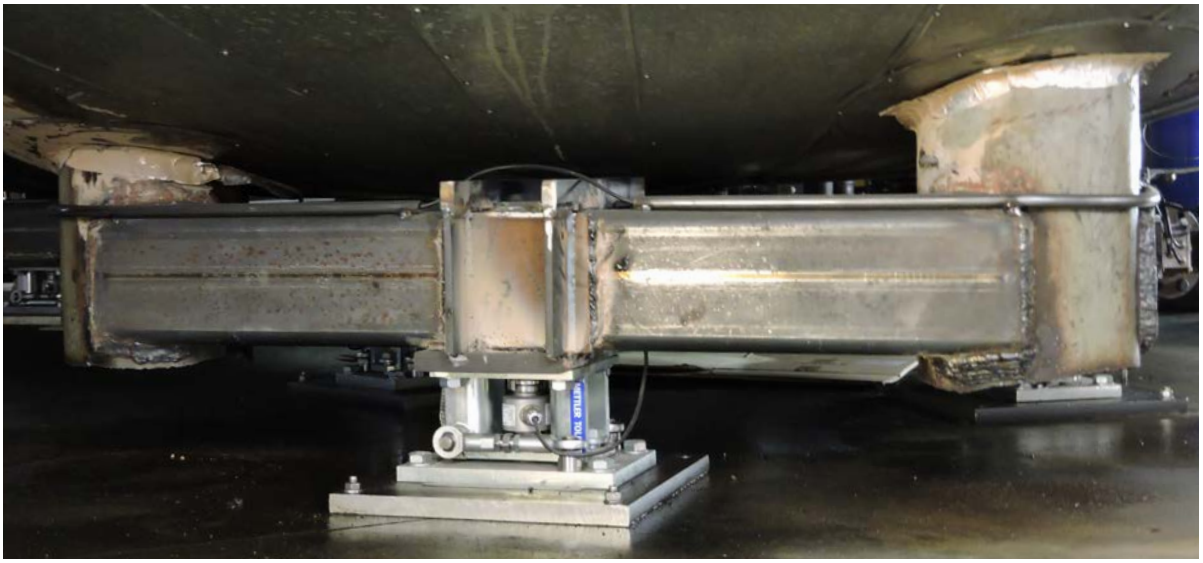
Tanks and silos can host aggressive, flammable, cold or hot material. This requires use of a dedicated material or even a coating for the tank or silo wall or the sensor. Out-gasing material can result in an over-pressure environment inside the tank. The tank requires careful sealing, especially if stored material is flammable or aggressive, or in case it has openings for sensors to penetrate into tanks.

Some technologies measure the temperature-dependent volume. This can lead to significant measurement errors if the material has a high thermal expansion coefficient or variations in density.

For non-contact distance-measuring sensors, the shape, surface, outgassing and moisture of solids can complicate a reliable measurement or make measuring impossible in extreme cases. Thus, critical known materials such as ash, plastic pellets, flour, aerosols and chips have to be subject to practical measuring tests. Otherwise, very inaccurate results are possible.

Each material has different characteristics in flowing capability, shape, temperature behavior, compressibility and Reynolds and Di-Electricity Numbers.

	Advantages	Disadvantages
Weighing	• No direct contact with hot, cold, aggressive or explosive material • Accurate regardless of shape, surface, Di-Electricity, Reynolds Number, viscosity or any other material characteristics • Accurate regardless of density, viscosity and flow behavior of solids as well as from dust, foam and gases	
Level Sensors	• Accurate volume measurement for many free-flowing and non-aggressive materials without high-temperature, extreme viscosity and density deviations • Inflatable balloon can protect level sensor from aggressive material or dust	• Measures volume, which depends on material temperature • Characteristics, such as shape, surface, dust, foam, outgassing, di-electricity, poor flow behavior and moisture of solids can compromise a reliable measurement • Depends on density, which can be higher at the bottom of tank because of compression • Inflatable balloon, including supply of compressed air, is expensive
Flowmeters	• Coriolis measures mass and density independent of temperature and viscosity • Magnetic flow meters are not in contact with material	• In direct contact with hot, cold, aggressive or explosive material • Measures volume, which depends on temperature • Some technologies reduce pressure, suffer from wear, depend on Reynolds Number or Di-Electricity • Accuracy of some technologies is reduced by gas bubbles, muddy liquids and sediments



On this tank a bio lubricant manufacturer modified the tank's legs to integrate weigh modules for replacing flowmeters. This change made it easier for him to achieve high quality goals during filling and formulation. In addition, more reliable and accurate inventory control allows for better management of expensive raw materials.

5 Maintenance and Cleaning for Measuring Equipment

Efficiency and quality of maintenance, including cleaning, depend partly on accessibility of the sensor. Distance-measuring sensors are installed either on the rooftop or on the side wall of the tank or silo. That has the disadvantage that the sensors on mid-size and large tanks or silos are accessible only by ladder. Flowmeters can be located anywhere, but they are typically located where access is easy.

For inspection or replacement, the level sensors must be removed from the opening into the tank or silo through the hole. Flowmeters have to be dismounted from the pipes, depending on what has to be inspected or cleaned. Such activities are expensive if the material is hot, aggressive or under elevated pressure. The tank, silo or pipe may have to be cooled down, emptied and rinsed. In extreme cases, that must be done with a neutral material. Open pipe ends have to be closed during inspection to ensure no material or gas comes out. After inspection or replacement, the openings must be carefully sealed again. Permanently installed gate valves can make disassembly easier and offer protection from hazardous material.

	Advantages	**Disadvantages**
Weighing	• Easy access to load cell for cleaning, visual inspection or replacement • Special features make it easy to jack up and replace load cells • In case one load cell fails, inventory can still be measured with remaining load cells if POWERCELL® weighing technology is used	• Tank has to be jacked up to replace load cell
Level Sensors	• Allows easier replacement or inspection if the gate valve is installed between sensor and tank or if bypass can be closed off from tank	• Vital parts are inside sensor housing and hide from quick visual inspection • Access for staff to the top of tank or silo including transport of spare sensor can be awkward • Precautions required in case sensor is contaminated or hazardous gas exits through opening for sensor • Expensive re-sealing after inspection can be necessary
Flowmeters	• Allows easier replacement or inspection, if gate valves are installed on both ends of flowmeter	• Some flowmeters clog easily • Vital parts are inside sensor housing, making cleaning and inspection difficult • Precautions are required in case sensor is contaminated or hazardous gas or liquid exits through open pipe-ends • Expensive re-sealing after inspection can be necessary

6 Accuracy, Verification and Assurance

Weighing technology enables inventory control for tanks or silos of up to three tons with a reproducible readability according to **International Organization of Legal Metrology (OIML)** guidelines of 30,000 divisions or 0.0033%. Inventory inside tanks or silos from three to several thousand tons can be determined with accuracy between 0.01 and 0.5%. These values are independent of flow behavior, temperature, density, viscosity or any other material characteristics.

A tank of up to three tons can be placed on top of a PFK floor scale with a legal-for-trade approved accuracy of 30,000e, according to OIML.

All level sensors, with the exception of pressure sensors, measure the volume over the distance. In the case of liquids, the value will be inaccurate because it is temperature dependent. For solids, the volume measurement is inaccurate because the material often has a higher density because of compression at the bottom of the tank or silo. It is also common that solids have different densities over time.

Because of those material uncertainties and the usual cone formation of solids and the non-cylindrical shape of the silo, a level sensor can only be calibrated in an unsatisfactory manner by using the material to be stored. Therefore, most level sensors are only calibrated once throughout their lifetime in the factory.

Because of those deficiencies, a manufacturer's calibration is not very meaningful in the long term. At most, the level sensor can be removed and recalibrated in the factory. With those values, a current calibration certificate can be issued. But those certificates don't provide information on the actual volume in the tank or silo at the installation.

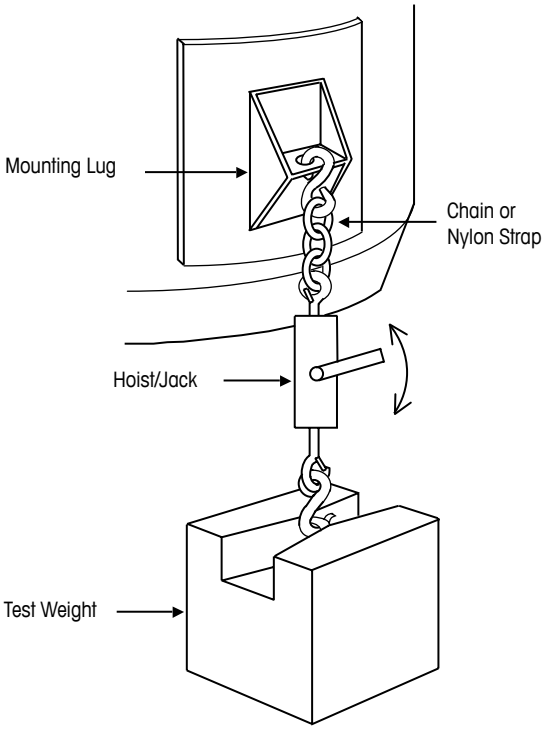
Alternatively, material can be dosed out of the tank or silo in portions on a calibrated scale. The cost for that is significant for medium and large tanks. In addition, that method cannot detect measurement errors due to differences in density and temperature influences. For aggressive, hot or very cold material, the use of that method is difficult.

Weighing technology doesn't leave open points

In contrast, a tank or silo can be calibrated with traceable masses at the place of use. The calibration and adjustment also compensates for deviations due to rigid pipe connections or deflection of the tank or silo's support structure at full load.

The calibration can be executed with traceable weights and a certificate can be obtained by documenting the calibration values to prove performance and traceability to the standard for mass.

A flowmeter usually has to be removed for calibration at the factory or inside mobile calibration stands. Indirect calibration via a weighing device or the installation of a calibration flow meter at a designated location is possible, but expensive.



Calibrating a tank with mass traceable to a standard.

	Advantages	Disadvantages
Weighing	• Typically highest accuracy available for inventory control in tanks or silos from 0.0033 to 0.5 percent • Calibration certificate can be made on site taking into account piping connections or any other deviations resulting from tank structure • Frequent recalibration with physical test weights is common • Legal-for-trade approval is standard feature of most load cells • Using pre-calibrated load cells instead of physical weights facilitates initial calibration where physical weights can't be placed • The substitution method uses a limited weight, such as 1,000 kilograms, and allows accurate calibration of heavy-capacity tanks or silos with some effort required	• Logistic effort is required for moving several tons of physical calibration weights to tank or silo if substitution method is not applied • Suspension on tank or silo required for calibration with physical weights
Level Sensors	• High theoretical accuracy of up to 0.005%	• High theoretical accuracy is limited in practice by deviations resulting from material characteristics • Initial factory calibration doesn't take on-site deviations into account • Frequent on-site recalibration, which is compliant to standards, is not practical • Typically, sensor has to be dismounted for calibration
Flowmeters	• Accuracy of as few as 0.1% available • Legal-for-trade models for most flowmeter technologies available • Initial calibration done at factory • Frequent on-site recalibration possible by using weighing scale • Mobile flowmeter temporarily built into pipes or mobile calibration devices	• Frequent on-site recalibration, which is compliant with standards requires detour via weighing scale or dedicated test stand • Either flowmeter or piping connection has to be dismounted for calibration unless dedicated installations with gate valves are available

7 Conclusion

Distance-measuring sensors and flowmeters can be useful for inventory control in tanks. In fact, those technologies have advantages over weighing for certain applications. But in many cases, weighing is superior because the technology is never in contact with the material and it directly determines the mass of the inventory if correctly calibrated. There are no restrictions with respect to the tank or silo shape or material characteristics. The maintenance and calibration over the entire lifecycle is simple. The expenses related to constructive adjustments for the installation of weighing, as well as high-quality level sensors or flowmeters are similar in most cases, but weighing is typically more accurate.

www.mt.com
For more information

Mettler-Toledo AG
Industrial Division
CH-8606 Nänikon, Switzerland

Local contact: **www.mt.com/contacts**

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