How to Prepare Storage Tanks for Automatic Tank Gauging Systems

Best practices for vessel design and equipment installation

EMERSON

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Introduction

Accurate and reliable tank gauging is essential. It ensures precise measurements for inventory and custody transfer purposes while protecting financial integrity and avoiding costly discrepancies. It also sustains safety by preventing overfills, leaks and spills. Enabling tanks to be filled closer to capacity improves efficiency. Reliable tank gauging supports regulatory and environmental compliance by meeting strict reporting and safety standards. Modern radar-based systems reduce maintenance and downtime, lowering total lifecycle costs.

The accuracy and reliability of an automatic tank gauging system can be maximized by following the guidelines outlined in the API Manual of Petroleum Measurement Standards (MPMS) chapters 3.1B, 3.3, 3.6, and 7.3, as well as the ISO 4266 series and API 2350. These international standards cover the measurement of level and temperature in petroleum and liquid petroleum product storage tanks by automatic methods. For a comprehensive explanation of what tank gauging entails, the technologies involved, and the relevant engineering standards and approvals, refer to Emerson's The Engineer's Guide to Tank Gauging, 2021 Edition.

Good storage tank design and proper installation practices are critical in helping to achieve accurate and reliable tank gauging. Even the most advanced automatic tank gauging systems can deliver suboptimal results if tanks are not designed and equipped to support them. This handbook describes industry best practices and provides practical design guidelines for the construction of new storage tanks. It is a guide to help ensure compliance with both the API and ISO standards. The handbook offers valuable recommendations for alterations that can be made during tank shutdowns and API 653 overhauls. It is useful in helping you to maintain industry compliance, enhance reliability and boost operational efficiency with your automatic tank gauging system. Even if you are not installing an automatic tank gauging system now, this guidance will help you to prepare your tank so that it can accommodate a system in future.

Measurement requirements

Monitoring the volume of liquid in a storage tank is essential to support effective inventory management, custody transfer, safety and overall operational control. Calculating the volume or mass requires several key measurements. In addition to gauges for measuring liquid level and temperature, tanks need dedicated instruments for overfill prevention. This is also true for measuring water cut and liquid density.

Level

The primary parameter to measure is the liquid level. When combined with the tank's strapping table, the liquid level enables the observed gross volume to be calculated. Several technologies are available to provide level measurement, but in large storage tanks, the preferred modern solution is radar-based gauging. Radar level gauges are mounted on the tank roof, with the installation opening determined by the type of antenna selected. The choice of antenna depends largely on the tank design and operating conditions.

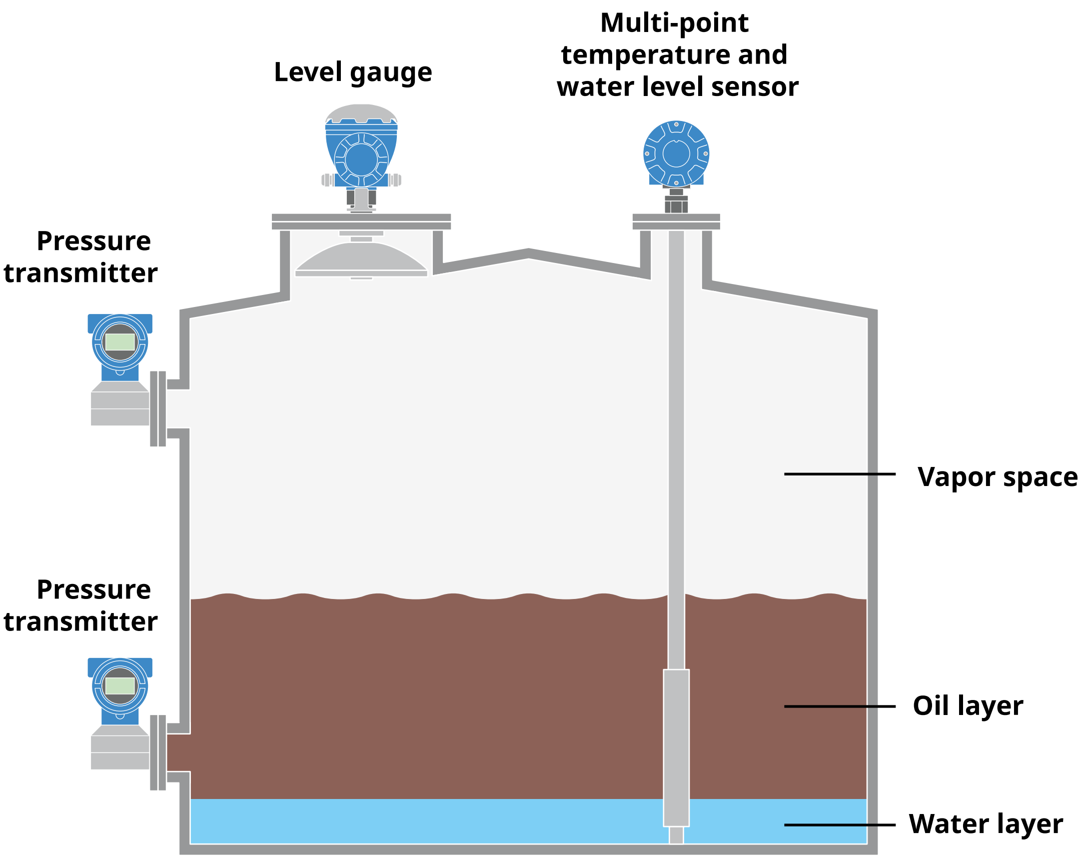


Figure 1: A fixed roof tank equipped with an automatic tank gauge, two pressure sensors for density measurement, and a multiple-point temperature sensor with an integrated water level sensor.

Temperature and water cut

To calculate net volume, temperature compensation is required. This takes into account the expansion or contraction of the liquid due to changes in its temperature. In smaller tanks, this can usually be achieved by measuring the temperature at a single point in the liquid. In larger tanks, temperature must be measured at multiple levels throughout the tank height. In larger tanks, the liquid can stratify and exhibit different temperature in different layers. In addition to temperature, it is often necessary to measure water cut (i.e., the amount of water that has separated and settled at the bottom of the tank beneath the product). Determining the water cut is essential for accurately calculating the net volume of useable product.

API MPMS chapter 7.3 provides guidance on the number of temperature measurement points required, depending on tank type and size. A common solution is a multiple-point temperature probe installed from the top of the tank. Some probes also incorporate a built-in water sensor at the lower end. This provides continuous information on any free water layer. These probes are typically designed to fit into a 50mm (2") opening.

Liquid density

Density measurement is an essential part of API volume calculations. Traditionally, it is obtained through manual sampling and laboratory analysis. The resulting values are entered manually into the tank gauging software. Alternatively, density can be measured in real time using a pressure transmitter installed at the bottom of the tank as part of the tank gauging system. This approach typically uses one or two pressure sensors and requires a tank nozzle between 50mm and 100mm (2" to 4") in diameter. It is described in API MPMS chapter 3.6.

Overfill prevention

Overfill prevention solutions are essential for reducing the risk of tank overfills and spills. API 2350 provides a comprehensive standard and guideline for overfill prevention and mitigation, covering many topics around tank farm operations and the equipment required. Advanced overfill prevention systems can be designed to meet the requirements of the IEC 61511 functional safety standard, with level detection instruments that are fully SIL-compliant and safety certified by an independent third party.

The automatic tank gauging system itself forms the first layer of overfill protection. It provides alerts and alarms when predefined tank levels are reached. In many installations, a second layer of protection, referred to as the safety layer, is added. This is illustrated in the yellow-highlighted area in figure 2.

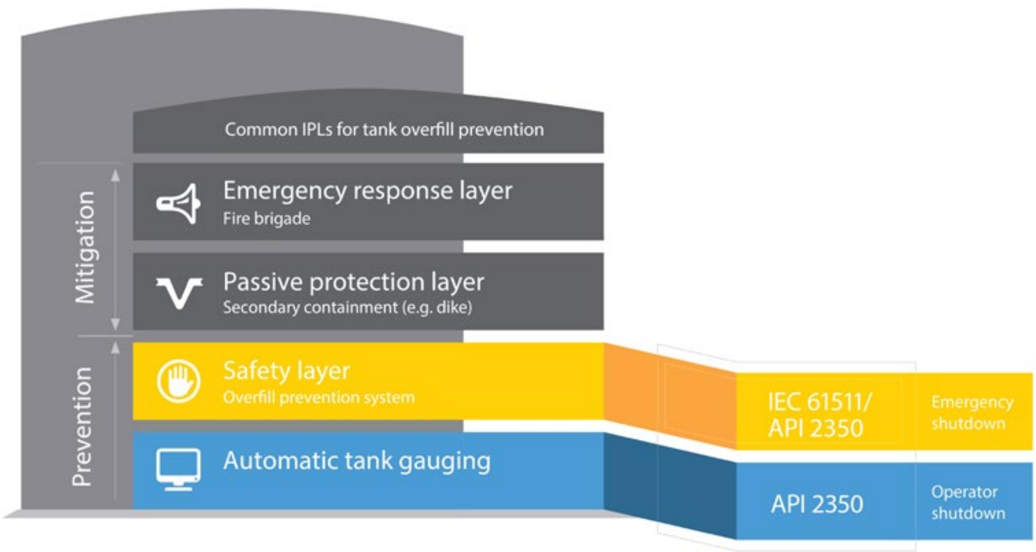


Figure 2: The different layers of overfill prevention and mitigation.

The safety layer is often implemented using a level switch connected to an alarm system or an automatic shutdown function. While level switches are simple and cost-effective, a safer and more versatile alternative is a continuous measurement device, such as a radar level gauge. Radar-based solutions provide several advantages such as remote proof-testing without climbing the tank, and easy adaptation to changes in tank design or operating conditions.

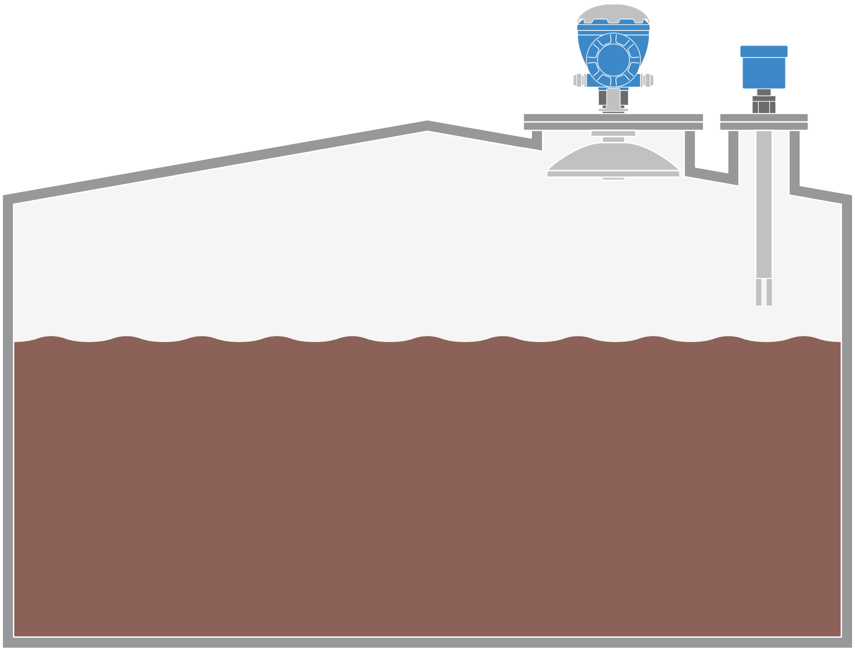


Figure 3: Tank gauging and overfill prevention using a level switch.

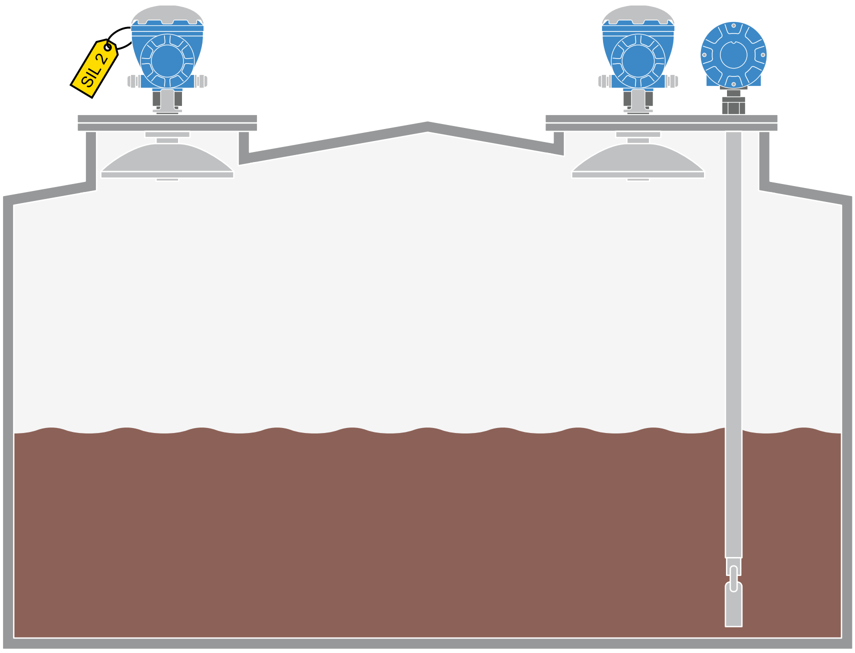
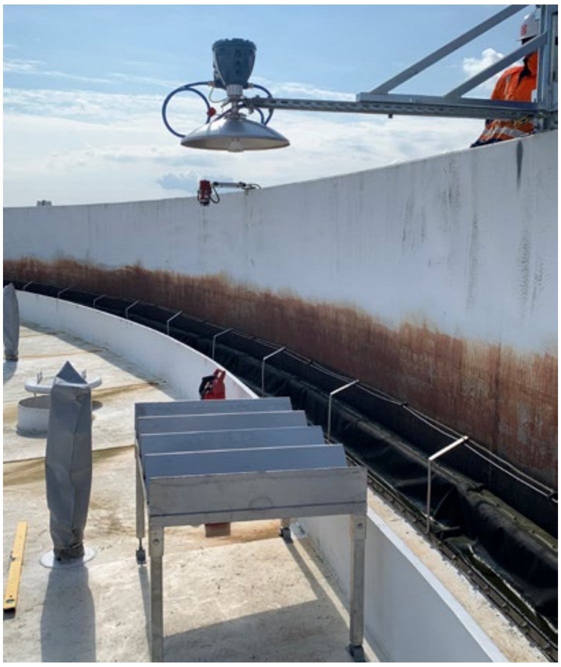


Figure 4: A tank gauging and overfill prevention system using continuous measurements from radar level gauges.

There are several equipment options for overfill prevention. Typical installation requires a nozzle on the tank roof. In some floating roof tanks, the position of the roof can be monitored using a radar. This serves as a high-level or floating roof monitoring device. In this case, the roof acts as the radar target. If necessary, a target plate can be installed as illustrated in the image opposite on page 7, to ensure proper signal reflection.



Floating roof monitoring with a target plate ensuring proper signal reflection from the radar level gauge.

Another convenient solution is a 2-in-1 radar level gauge. This combines tank gauging and separate overfill prevention in a single unit, requiring only one tank opening. These two functions are fully independent, compliant with API 2350, and carry full SIL certification in accordance with IEC 61511.

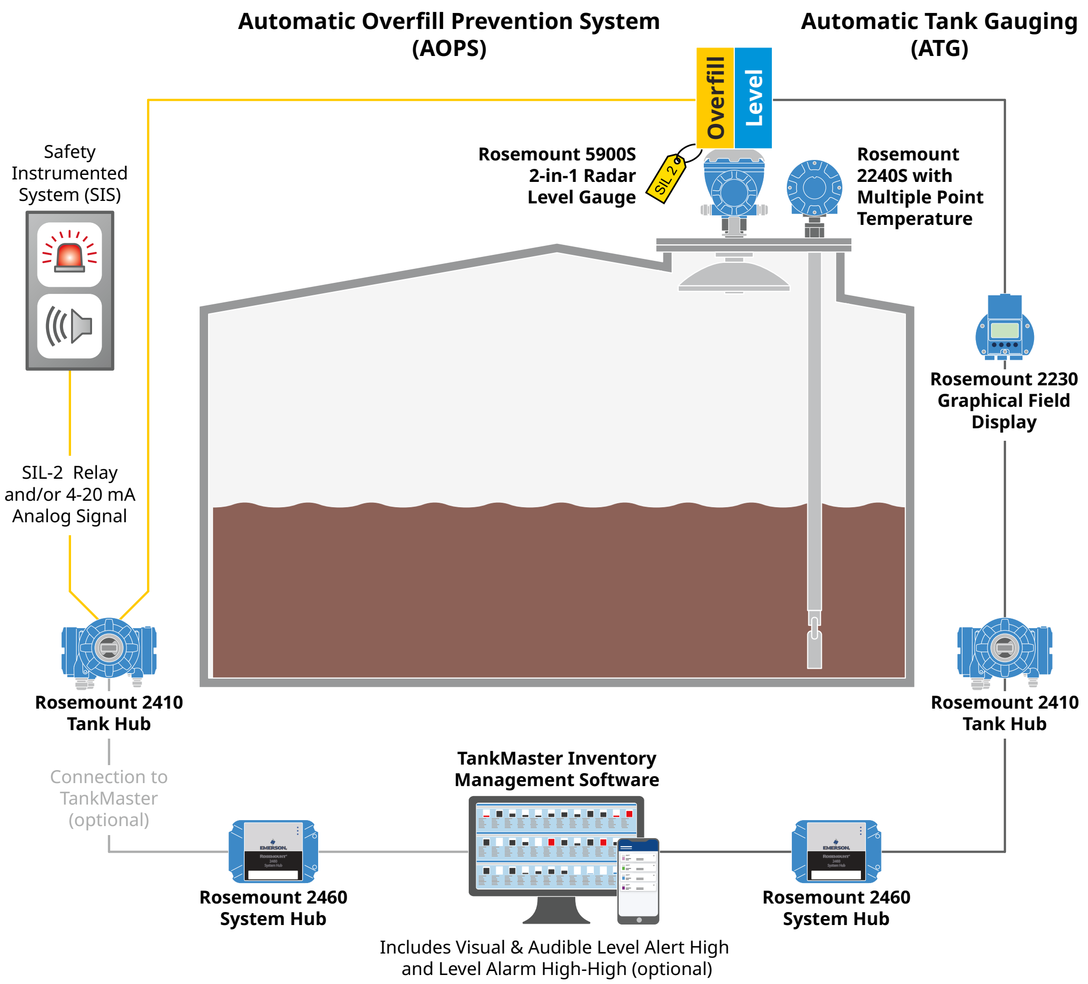


Figure 5: A tank gauging and overfill prevention solution incorporating a 2-in-1 radar level gauge.

Recommendations for installing instrumentation and infrastructure

Floating roof tanks

Floating roof tanks are generally classified into two main types: tanks with an external floating roof and tanks with an internal floating roof. The choice between these designs depends on factors such as stored product characteristics, safety considerations and environmental requirements.

Best practice

Ideally, a floating roof tank should be equipped with three still pipes – one for manual gauging, one for automatic gauging and one for average temperature measurement. This is illustrated in figure 6.
A still pipe (also called a still well or gauge well) is a vertical pipe installed inside the tank that provides a controlled environment for measurement devices, ensuring accurate readings by shielding them from turbulence, roof movement and surface disturbances.

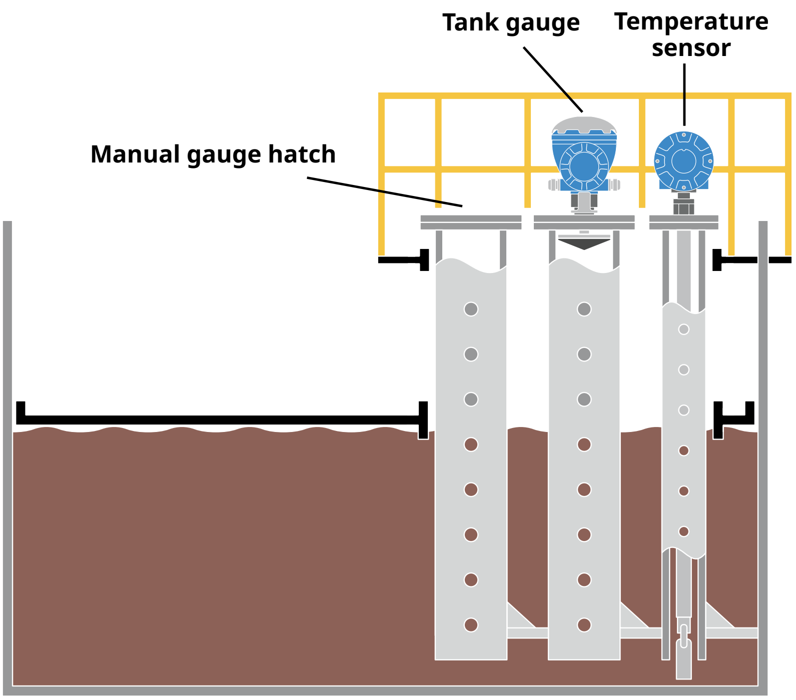


Figure 6: The ideal still pipe arrangement.

To ensure accurate level gauging, a still pipe should be fixed at the lower end to the tank shell. This provides the most stable reference point. At the upper end, the pipe should be connected with a sliding or flexible fitting, so that the roof or platform can move vertically without affecting the pipe. This is illustrated in figure 7. This arrangement prevents tank wall bulging from interfering with level measurements.

Manual and automatic gauge still pipes should be installed within 1m (3ft) of each other to allow easy comparison of measurements.

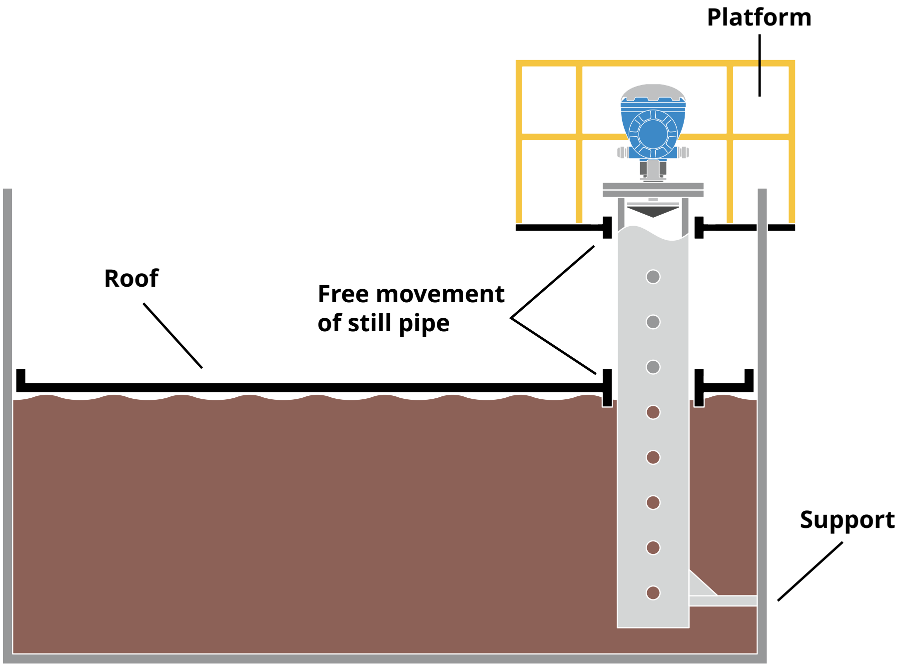


Figure 7: Still pipe connected with a sliding or flexible fitting.

Temperature still pipes can range from 50mm to 200mm (2" to 8"), with 100mm (4") being the most common size. The temperature still pipe should be positioned at least 1m (3ft) from the tank shell to avoid heat influence from the wall. If manual temperature verification is required, the temperature still pipe should be positioned within 1m (3ft) of the manual gauge still pipe. Where water measurement is needed, the temperature still pipe should be installed directly above the sump. Temperature probes can also be equipped with water sensors at their lower end for this purpose.

Still pipes for level gauging are typically 200mm (8") in diameter. Proper placement of the still pipes is important. Still pipes should be designed and fabricated in accordance with API MPMS 3.1A annex B5, with smooth internal surfaces (free from burs and welds), a vent hole at the top, and two rows of holes along the length of the pipe. The vent hole prevents air pockets from forming at high liquid levels. The total hole area must comply with the specifications of the level gauge manufacturer.

In some jurisdictions, emission controls are required for slotted still pipes. Local regulations should be checked. Emission-reducing still pipe designs are available and remain fully compatible with radar level gauges.

A deflection plate should be installed directly below the automatic gauging still pipe to disperse the radar beam. A 75mm (3") angle iron is sufficient, making sure that its sides do not face any obstructions that could reflect the signal back into the pipe.

Alternative approach

In some cases, it is not technically feasible to retrofit an existing tank with three still pipes. Often, only a single still pipe is available that is typically used for manual gauging. In such situations, this pipe can be adapted to serve multiple functions, including automatic tank gauging, manual gauging and sampling. Some automatic tank gauges are designed with easily accessible upper fittings that allow manual gauging and sampling through the same pipe, as illustrated below. A separate installation point for the temperature sensor is still required in this case.

If only one pipe is available but a separate location for a temperature sensor can be found, an openable automatic tank gauge solution is useful. When opened, the pipe becomes fully accessible for manual gauging and sampling.

An openable tank gauge provides full access to the still pipe.

Another option is a pipe-in-pipe solution, where the automatic tank gauge, manual gauging and temperature measurements are all accommodated within the same still pipe (as shown below).

For floating roof tanks, temperature sensors may also be installed through a support structure and opening in the floating roof, if no additional still pipe is available.

Fixed roof tanks

Fixed roof tanks are typically equipped with manways and roof nozzles that can be used to install both automatic tank gauges and average temperature sensors (as shown below).

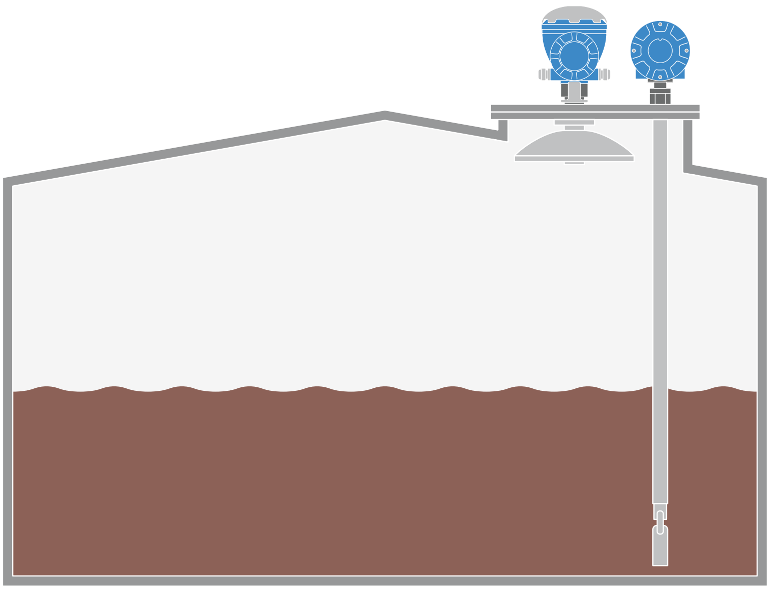


Figure 8: Manways and roof nozzles can be used to install both automatic tank gauges and average temperature sensors.

Best practice

Best practice for fixed roof tanks without internal floating roofs is to use a 600mm (24") manway (minimum 500mm (20")) positioned at least 1m (3ft) from the tank wall. Locations near the tank center should be avoided, since roof flexing is typically greater further from the shell.

When a 600mm (24") manway is available, both the level gauge and the temperature probe can be mounted on the manway cover. In this set-up, the manway cover should be fitted with a 100mm (4") hole near the center and a 100mm (4") nozzle, 300mm (12") tall, near the inner edge. The temperature probe is installed vertically so it will not interfere with the level gauge.

If only a 500mm (20") manway is available, the temperature sensor should be installed in a separate 50-200mm (2" to 8") nozzle located at least 1m (3ft) from the tank wall. Another option is to install a 200mm (8") nozzle at least 1.5m (5ft) from the tank wall for automatic level gauging. This is often the preferred solution for tanks without a suitable manway cover. In most cases, the level and temperature nozzles should be placed within 1m (3ft) of each other to allow accurate manual verification of both parameters.

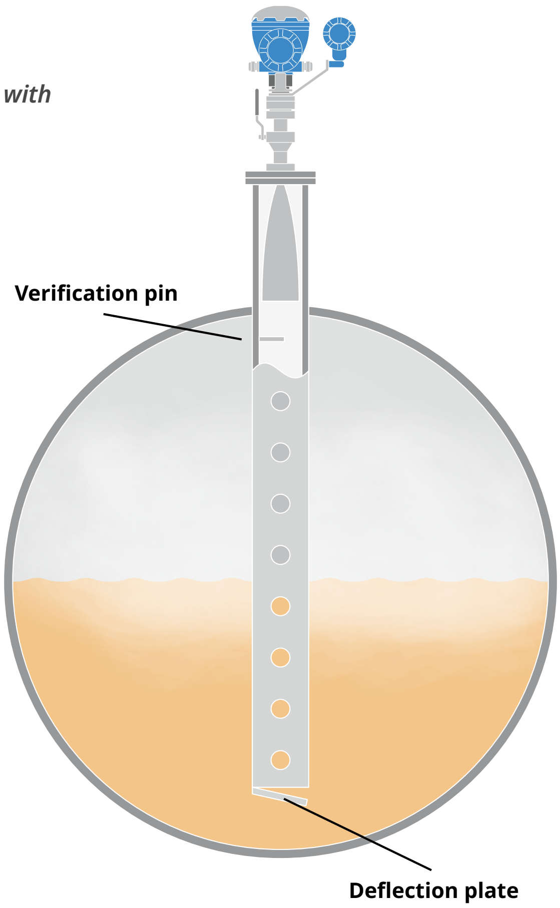
Pressurized tanks

Pressurized tanks are typically constructed as either spheres or horizontal bullets. Manual measurement with dip tapes is not possible in these designs and the use of an automatic tank gauging system is essential. Guidance on automatic tank gauging for pressurized tanks is provided in API MPMS chapter 3.3.

Best practice

For pressurized sphere or bullet tanks, radar level measurement requires a 100mm (4") still pipe with a 150mm (6") flange, fabricated to specific standards. The still pipe should be constructed of stainless steel and be fitted with holes, rather than slots, on only one side of the pipe (as illustrated in figure 9).

Figure 9: Pressurized sphere tank with stainless steel still pipe.



In accordance with API MPMS 3.3, the still pipe must also include one or more verification pins mounted inside the pipe. This enables in-tank gauge level verification during normal pressurized operations. A deflection plate should be installed at the lower end of the pipe to eliminate false echoes (i.e., spurious radar reflections caused by strong signals bouncing off the tank bottom or other internal structures). These can interfere with accurate level measurement. Temperature measurement in these pressurized tanks is typically achieved using a single-point sensor installed in a short thermowell located at the bottom of the tank.

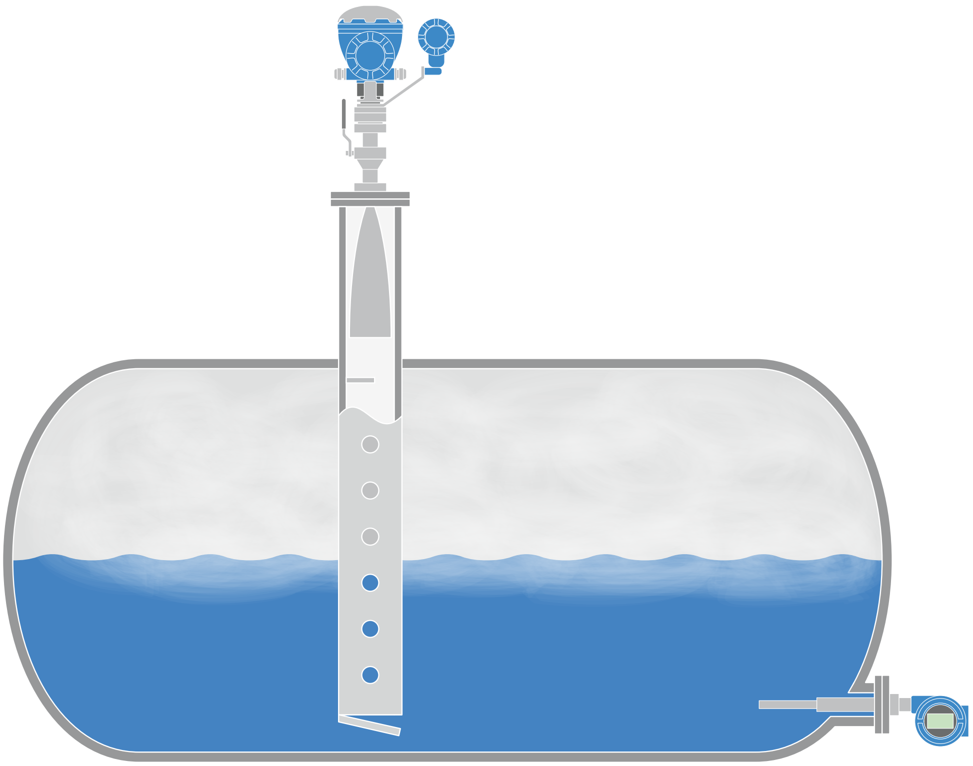


Figure 10: A bullet tank with a radar gauge and a single-spot sensor.

Summary

Accurate tank gauging is essential for maintaining operational efficiency, regulatory compliance and safe storage. By diligently adhering to industry standards, installation guidelines and best practices, operators can ensure the reliability and precision of their gauging systems. The combination of automatic gauging with robust overfill prevention solutions minimizes risks, optimizes tank management, and creates safer working conditions, ultimately enhancing both operational performance and facility safety.

Checklists

Floating roof tanks

- ☐ A floating roof tank should be equipped with still pipes for automatic gauging, manual gauging and average temperature measurement, where feasible.
- ☐ Each still pipe should maintain the same internal diameter throughout its entire length.
- ☐ The still pipe should be supported and fixed at the lower end to the tank shell, the most stable point of the tank.
- ☐ The upper fitting should allow for vertical movement between the still pipe and the floating roof or platform.
- ☐ The still pipe should include two rows of overlapping holes along its length, from the maximum liquid level to the bottom.
- ☐ The standard still pipe diameter is 200mm (8"). Other sizes may be used but not less than 150mm (6") in diameter.
- ☐ The top of the still pipe should be fitted with a standard flange.
- ☐ The temperature sensor should be installed through a separate still pipe at the tank top, allowing free insertion through the floating roof.
- ☐ Temperature still pipes should be 50–200mm (2"–8") in diameter, most commonly 100mm (4").
- ☐ Manual and automatic gauging still pipes should be placed within 1m (3ft) of each other to allow comparison of measurements.
- ☐ The temperature still pipe should be positioned at least 1m (3ft) from the tank wall.
- ☐ If manual verification of temperature is required, the temperature still pipe should be within 1m (3ft) of the manual gauging still pipe.
- ☐ If water measurement is required, position the temperature still pipe directly above the sump, and use a temperature probe with an integrated water sensor.
- ☐ Still pipes must be designed and fabricated in accordance with API MPMS 3.1A annex B5, with no burs or welds inside the pipe, a vent hole at the top to prevent air pockets, and correctly-sized perforations as specified by the level gauge manufacturer.
- ☐ In jurisdictions requiring emissions control for slotted still pipes, confirm compliance and use compatible low-emission designs that support radar gauging.
- ☐ Install a deflection plate (e.g., a 75mm/3" angle iron) below the automatic tank gauge still pipe to disperse the radar beam.

Fixed roof tanks

- ☐ Use a 600mm (24") manway or nozzle near the tank wall, positioned at least 1m (3ft) from the tank wall. Avoid positions near the tank center, where roof flexing is greater.
- ☐ When using a 600mm manway, both the automatic tank gauge and the temperature probe can be mounted on the manway cover. For this configuration, provide a 100mm (4") hole near the center of the manway cover, and a 100mm (4") nozzle, 300mm (12") tall, near the inner edge.
- ☐ If the manway is 500mm (20"), install the temperature sensor in a separate 50–200mm (2"–8") nozzle at least 1m (3ft) from the tank wall.
- ☐ As an alternative, a 200mm (8") nozzle located at least 1.5m (5ft) from the wall can be used for automatic tank gauge installation.
- ☐ The automatic tank gauge and temperature sensor nozzles should generally be located within 1m (3ft) of each other to allow accurate manual verification of both level and temperature.

Pressurized tanks

- ☐ Provide a 150mm (6") flange at the tank top to accommodate the still pipe.
- ☐ Install a 100mm (4") schedule 10 stainless steel still pipe for radar level gauging.
- ☐ The still pipe should have one row of 20mm (¾") holes along its entire length, spaced at 500mm (20") intervals, located on only one side of the pipe.
- ☐ Incorporate one or more verification pins inside the still pipe, in accordance with API MPMS 3.3, to enable level verification during pressurized operation.
- ☐ Fit a deflection plate at the bottom of the still pipe to eliminate tank bottom reflections.
- ☐ Temperature should normally be measured using one or more single-point sensors installed in a short thermowell at the bottom of the tank.
- ☐ Ensure all materials and construction details follow the special fabrication requirements for pressurized tanks.

Pressure sensors for online density gauging

- ☐ Provide a 100mm (4") flanged nozzle with a shut-off valve located approximately 1m (3ft) above the tank bottom for installation of the primary pressure sensor.
- ☐ For non-vented tanks, or tanks with significant vapor pressure, install a second pressure sensor connection at the tank top to enable differential measurement.
- ☐ Ensure all fittings and valves are rated for the tank's operating pressure and compatible with the stored product.

Glossary

2-in-1 radar level gauge
A device combining two independent radar level gauges in one housing, enabling tank gauging and high-level detection through a single tank opening.

API
American Petroleum Institute.

API MPMS
Manual of Petroleum Measurement Standards published by API, covering methods and requirements for accurate measurement of petroleum and petroleum products.

API 650
An engineering standard for the design and construction of welded, non-pressurized, vertical cylindrical storage tanks for oil and petroleum products.

API 653
A standard covering the inspection, repair, alteration and reconstruction of storage tanks.

API 2350
A standard covering overfill prevention for petroleum storage tanks, providing requirements and guidance for safe operation.

Automatic tank gauging
The automated measurement of liquid level and temperature in large storage tanks to determine the volume and mass of the product stored in the tanks. See API MPMS chapter 3.1B and 7.3.

Average temperature sensor
A long, vapor-tight, flexible probe containing multiple temperature sensing elements distributed along its length. Its measurements determine average liquid temperature.

Bullet tank
A horizontal cylindrical pressurized tank, commonly used for the storage of liquefied gases.

Deflection plate
An angular metal plate installed at the bottom of a still pipe to prevent strong radar echoes from the tank bottom.

Fixed roof tank
A storage tank with a permanently fixed outer roof. It may be equipped with or without an internal floating roof.

Floating roof tank
A storage tank where the liquid surface is covered by a floating metallic roof, designed to reduce vapor emissions from the stored liquid.

Free water
A separate layer of water that can accumulate at the bottom of a petroleum storage tank.

Free water sensor
A sensor, often integrated at the bottom of an average temperature probe, designed to detect and measure the free water layer up to about 1m (3ft) from the tank bottom.

Hybrid tank gauging
A tank gauging method combining a radar level gauge with one or more pressure sensors to provide online density measurement and mass calculations. See API MPMS chapter 3.6.

IEC 61511
An international technical standard defining practices for functional safety in process industries through the use of instrumentation, including the design of overfill prevention systems for storage tanks.

ISO 4266
An international series of standards covering automatic methods for level and temperature measurement in storage tanks.

Level switch (point switch)
A mechanical or electronic device that detects when the liquid reaches a specific level, triggering an alarm or control action.

Manway
A tank access opening, normally 500–600mm (20"–24") in diameter, fitted with a cover and providing manual entry to the tank. Manways can be used for installation of automatic tank gauging equipment.

Sphere tank
A spherical pressurized tank used for the storage of liquefied gases.

Still pipe (still well, gauge well)
A vertical steel pipe installed inside a storage tank, extending from the bottom to the top. It provides a controlled environment for manual or automatic level gauging and may end with a gauge hatch or a flange.

Thermowell (temperature pipe)
A pipe design to house a temperature sensor, protecting it from direct contact with the liquid and enabling safe insertion and removal.

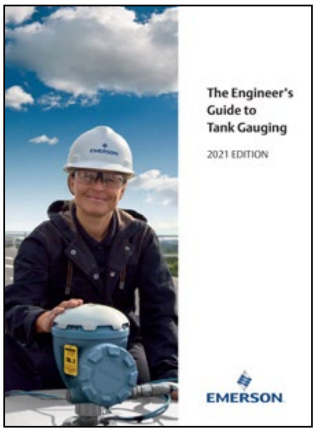
Verification pin
A fixed reference point inside a still pipe of a pressurized tank, used to verify radar level measurements where manual gauging is not possible. See API MPMS chapter 3.3.

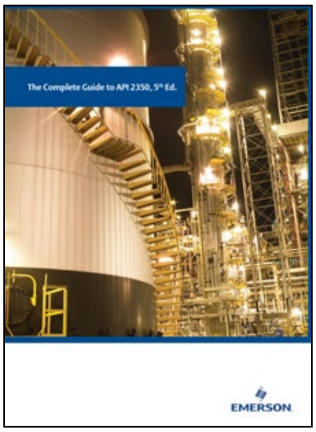
Vibrating fork
A type of point level switch that uses the principle of a tuning fork, with vibration changes indicating the presence of liquid.

Water cut
The amount of water that has separated and settled at the bottom of the tank beneath the product.

Literature references

- API Standard 650, Welded Tanks for Oil Storage
- API Standard 653, Tank Inspection, Repair, Alteration, and Reconstruction
- API Standard 2350, 5th Edition, Overfill Prevention for Storage Tanks in Petroleum Facilities
- EN 14015 Specification for the design and manufacture of site built, vertical, cylindrical, flat-bottomed, above ground, welded, steel tanks for the storage of liquids at ambient temperature and above
- EEMUA 159, Above ground flat bottomed storage tanks – a guide to inspection, maintenance and repair, Edition 6
- IEC 61511 Functional safety – Safety instrumented systems for the process industry sector
- ISO 4266 Petroleum and liquid petroleum products – Measurement of level and temperature in storage tanks by automatic methods





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