Level measurement: General process tank level vs. inventory tank gauging

Determining what type of level instrumentation is required for a specific application can sometimes be perplexing. This is particularly true when we consider process tank level versus inventory tank gauging.

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There are many aspects of level measurement, ranging from point level indication to prevent overfilling a vessel, to extremely accurate measurements providing the kind of precision necessary for custody transfer. The instrumentation required for a specific application will vary depending on the measurement requirement. When we consider process tank level versus inventory tank gauging—which can also include custody transfer tank gauging—the instruments used for each measurement will be different. What is the difference between the two types of measurements and where is each used? This article will unpack those questions and provide some examples of where each is required.

Process tank level

In many applications only general inventory information or process control is required. These are typically applications in process industries where material in storage vessels is transferred on a regular basis (daily, weekly or as needed) from one part of a facility to another, or as a batch process to create a final product. The product is used within one facility and does not change ownership. An example of this would be bulk raw materials that are used to produce a final product. Vessels used for these applications are generally fairly small. Sizes can range from several hundred to 40,000 gallons or more.

Inventory is important for cost considerations and to ensure product is reordered in a timely manner. But, because the product is not changing ownership, the accuracy requirement is less stringent. The amount of product used in the process can be measured by a totalizing flowmeter or calculated from a change in tank level using a level transmitter. Typically, the accuracy requirement for a general inventory control application is plus or minus one inch.

Level	Volume
10%	1000 Gal
15%	2200 Gal
20%	3000
25%	4500
30%	5700
35%	7200
40%	9100
45%	12030
50%	14500
75%	19350
100%	25000

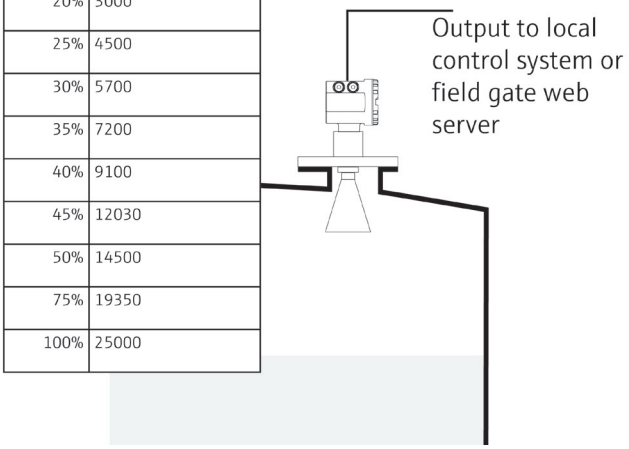

FIGURE 1. Level measurement is linearized to provide volumetric output. This can be adapted as necessary to correct for tanks that are not rectilinear, such as a spherical design or where there are conical sections.

The most common level measurement devices used for general inventory control are standard free-air radar and guided-wave radar instruments. These products can offer accuracies down to several millimeters which is sufficient for general inventory requirements. Outputs from these level transmitters can be linearized (Figure 1) to provide volumetric indication of the vessel's contents. Additional compensation for temperature and density changes is typically not required for general process and control level devices.

Inventory tank gauging

In some applications higher-accuracy measurements are required. These applications are typically for products where the level is not so important but the volume of the material in the vessel needs to be known for inventory purposes. Customers require a system referred to as Automatic Tank Gauging (ATG) in the API (American Petroleum Institute) standards. Common products that require this higher accuracy are oils, fuels, edible oils, alcohols, some solvents and juices. ATG systems will typically use process grade-level instruments but with additional augmentation to increase precision, such as temperature correction (spot or multipoint), along with a system providing built-in density correction tables. Temperature correction adjusts for thermal expansion of the product as this will affect the exact level of a given volume of product.

For example, for a tank diameter of 100 ft, a 1˚C shift in temperature can expand or contract the level of a tank up to 0.1% of its actual level. In a 10m tall tank, 0.1% means a change in level of 10mm, or 78.6 barrels. At today's oil prices of about $80, this represents $6,288.

For inventory tank gauging applications, level, temperature, and sometimes pressure (for density calculations) measurement instruments are employed. Common technologies include radar, guided wave radar and sometimes pressure measurement transmitters. These technologies can provide accuracy of ±2-3 mm and better.

The more accurate the level transmitter is, the better. Using the same tank size noted above, a 2mm error in level is 15.7 barrels. At $80 per barrel, a 2mm error is worth $1,248.00

So if you add the $6,288 for the thermal expansion and the $1,248 for the transmitter accuracy it is possible to have an error in the inventory value of $7,536. For a tank farm with 20 tanks this could be $150,720 of product discrepancy that must be accounted for.

Custody transfer tank gauging

Within this tank gauging segment there are some applications where extremely high accuracy measurements are required and these are characterized as custody transfer tank gaging. These are typically where products are being moved from location to location or changing ownership (custody is transferred from one party to another) and in applications where products are taxed by one or more government entities. Point-of-sale examples include oil and fuel terminals (LNG, NGL, LPG, jet fuel, crude oil, Diesel, etc.), edible oil storage, and alcohol storage vessels. These are typically large diameter tanks that have 40-120 ft. diameters and are 30-65 ft. tall and may contain hundreds of thousands to millions of gallons of product.

For these high accuracy requirements, custody transfer tank gauging systems are required. Standards for inventory tank gauging vs custody transfer tank gauging can be referenced in API chapter 3.1B titled "Tank Gauging - Standard

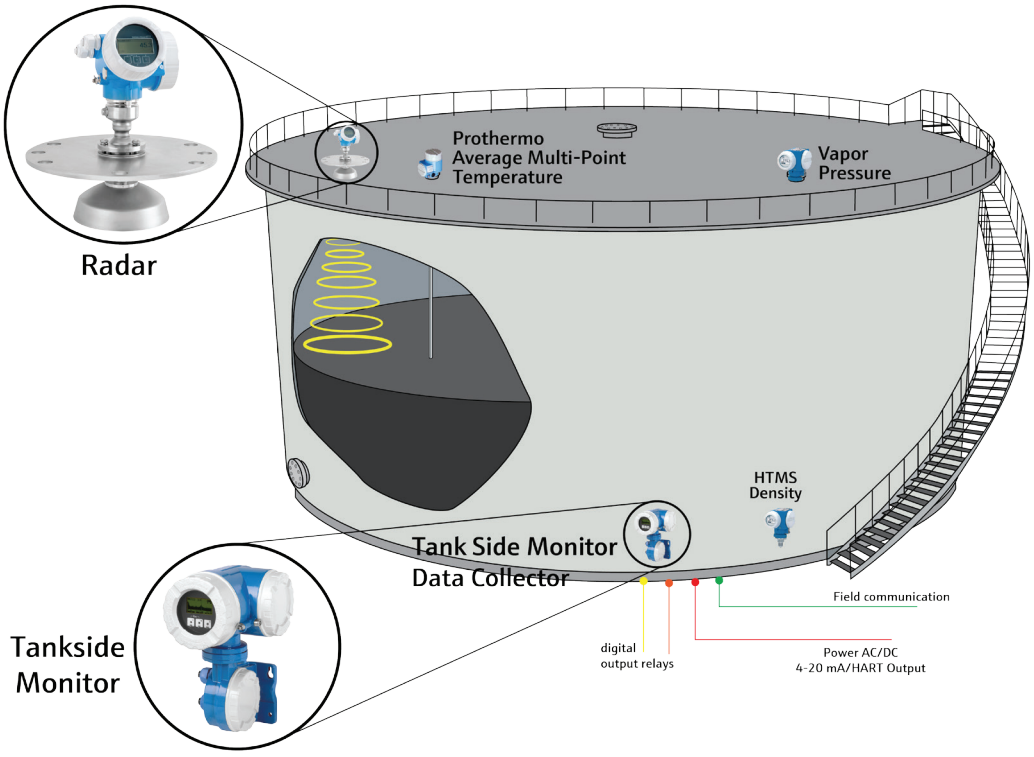

FIGURE 2. A typical inventory tank gauging system with level measurement, pressure and temperature compensation. These technologies, used together, provide for the highest possible degree of precision so that the true mass of the product in the tank can be determined regardless of ambient conditions.

Practice for Level Measurement of Liquid Hydrocarbons in Stationary Tanks by Automatic Tank Gauging." An error of a fraction of an inch can equal thousands of gallons of product and therefore thousands of dollars of inventory.

For custody transfer tank gauging applications the most accurate level, temperature and sometimes pressure (for density) measurement instruments are employed (Figure 2). Technologies include free-space radar and servo measurement transmitters. These technologies can provide accuracy of less than ±1 mm.

In both of the tank gauging applications illustrated above, temperature compensation is required to adjust for level changes to the measured material due to thermal expansion. Depending on the application and required accuracy, the temperature transmitter may be a single point or may be multiple points spanning the range of the level measurement since a large tank may have a broad temperature profile from bottom to top. In some tanks there is stratification as product from different sources being added may not readily mix and it is important that temperature is measured in the different layers. For temperature measurements, API Chapter 7 offers guidance for how to determine the proper spot or average measurement.

Along with accurate level and temperature measurements, some applications require compensation for changes in density. For these applications, a pressure transmitter is included to provide mass measurement of the vessel contents. The level instrument combined with a mass measurement can detect vessel deformation (bulging), characteristic of very large tanks due to hydrostatic pressure exerted on the vessel walls.

In many vessels it is also necessary to measure water accumulated in the bottom of the vessel, called "waterbottom." Most of the accumulation comes from water that

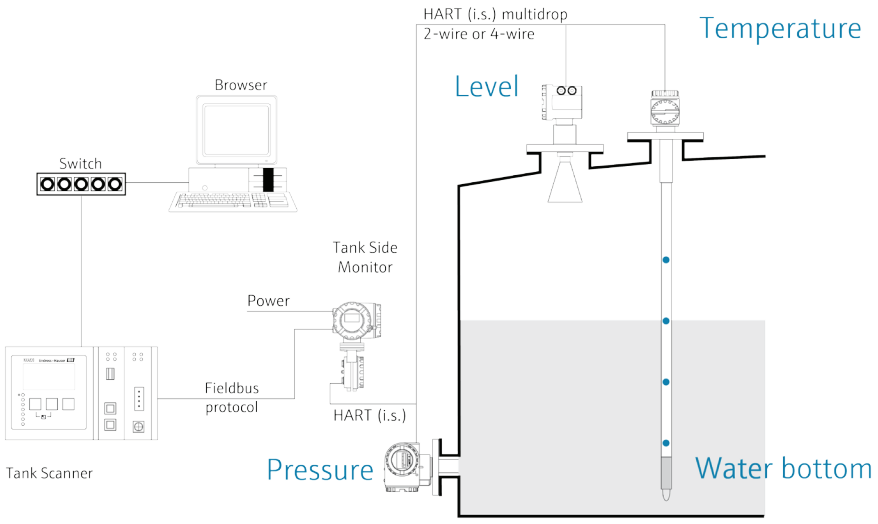

FIGURE 3. A capacitance level transmitter, mounted at the bottom of a temperature probe, can detect waterbottoms.

drops out of petroleum and oil-based liquids, but also water that infiltrates through vents in the vessel and through the gaskets on floating roof tanks. The water separates and sinks to the bottom of the vessel and must be accounted for to reach a Net Standard Volume (NSV) of the product in a vessel. One obvious reason for measuring the waterbottom is so only the desired product is measured and paid for in custody transfers, not water. The waterbottoms are measured to allow deduction of the water from the net standard volume as part of the tank gauging system. Removing the water is also done for maintenance reasons; that is, maintenance departments want to remove water on a regular basis to prevent rust on the tank floor which can lead to leaks and resulting environmental hazards.

Waterbottoms are typically measured using a capacitance level transmitter (Figure 3). A capacitance transmitter uses the electrical differences between the high dielectric and conductive water and the low dielectric and non-conductive hydrocarbon to determine the interface. In most cases, the capacitance sensor is incorporated into the bottom of a temperature sensor or by using a servo gauge.

The data generated by one of these systems can be further utilized by an inventory management system (Figure 4). Along with the various field instruments, a complete inventory management system provides easy access to the data being collected. Outputs from the field devices are interfaced with a tank gauging gateway that does the volume and mass corrections, includes the API correction tables and strapping tables (TCT), and can provide the data to a customer who only needs to use a browser for access.

There are also options for Microsoft Windows-based software, or even to bring the corrected measurements into a PLC or DCS. A gateway or software can provide the calculations to convert the data to volume or mass measurements to meet the requirements for weights and measures approved by agencies such as NMi and PTB. OIML and API make the recommendations on these practices and accuracies. The gateway or software can include a webserver, making data accessible from virtually any location.

As we can see, level measurements vary depending on the requirements of the application. For process tank levels, only a level transmitter is typically required as just the level measurement is utilized. When inventory or custody transfer tank gauging applications are being addressed, additional considerations such as temperature and pressure compensation and a tank gauging gateway or software are required to achieve the desired accuracy. The main difference here is that the mass or volume is required not just the level value. Working with an instrumentation supplier who is knowledgeable in various technologies can suggest the equipment to meet your needs but not exceed your pocketbook. The end result is having the level or volume data your plant requires in the correct format and that will make your task easier.

FIGURE 4. Tank monitoring software, such as this Endress+Hauser Terminal Management package, provides easy access to the data being collected.

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