The measure of success

‹Author›, Gauging Systems Inc., USA, compares conventional and modern tank guaging technologies and outlines how to obtain the data requitrd for accurate accounting and tank integrity monitoring.

Gone are the days when a simple level indicator and temperature probe provided adequate information to manage tank farm operations and inventory. Regulatory requirements, product quality concerns, loss mitigation, and improved accounting have combined to require more accurate and expansive data monitoring capability.

Similarly, these same enhanced requirements need more sophisticated tank gauging software systems than conventional local tank gauge indicators and display systems provide. Comprehensive operational data (on both product and tanks) must be provided to all interested parties in a timely fashion, regardless of location. Systems must be more capable of collecting, processing, and sharing data over a broader range of communication networks and platforms than ever before.

Critical data requirements

When selecting an appropriate tank gauging technology, users must consider all the relevant data that is needed to operate their facilities safely and efficiently.

For example, tank calibration (strapping) tables need to be accurate. New tank calibration tables need to be created after the installation of new equipment or structural modifications within a tank (i.e. mixers, gauge wells, floor modifications, etc.).

Level and temperature data are paramount, and there are a variety of technologies that provide very accurate level data; however, accurate temperature data is just as important. Single point resistance temperature detectors (RTDs) have given way to multi-point temperature monitoring in many cases, but a gauge must also be able to provide volume-weighted averaging rather than simply wetted sensor averaging for best accuracy.

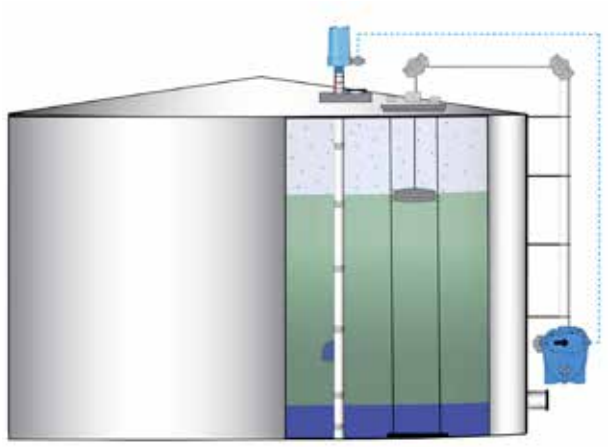

Figure 1. A conventional float and tape gauge combined with a multi-point temperature probe to provide level, multiple point temperatures, and volume-weighted average product temperature.

Figure 2. Advanced hydrostatic gauge with multiple pressure and temperature sensors installed in a single 2 in. tank penetration. Also shown is an independent high level alarm switch for overfill protection.

Water measurement is also important for accurate inventory accounting. However, most conventional technologies are only able to measure free water bottoms. Entrained, emulsified, and total water in a tank are just as important as settled water because they can also affect both product quality and inventory.

Product density is necessary for accurate inventory calculation and is generally determined by manual sampling and laboratory analysis. However, this is labour intensive, time consuming and does not always produce accurate results, especially when the product in a tank is stratified. Even if the sampling process manages to avoid any mixing at each sampled height, and laboratory equipment provides an ideal accuracy, there is still a possibility that the results will be incorrectly averaged. The practice of arithmetical averaging of the samples may lead to a significant average density miscalculation because it relies on the assumption of a strictly linear density distribution in a tank, which is rarely the case. Ideally, a gauge should be able to continuously monitor multiple density measurements throughout a tank to detect and alert product stratification issues and provide an accurate average density.

Tank integrity factors such as bottom movement, floating roof loading (e.g. snow and rain), and bulging can all affect inventory.

Vapour pressure monitoring can be used to prevent tank ruptures from over-pressuring or vacuum, and to confirm proper operation of pressure relief vents and gas blanketing systems.

Leak detection technology can be utilised to provide more reliable detection of small leaks than simply monitoring level or volume changes.

Preventing overfills

Besides complete and accurate data monitoring of product inventory and quality, and the tank integrity factors already mentioned, users should also ensure that their tank gauging systems and procedures adhere to the API/ANSI standard 2350 requirements regarding overfill prevention.

The key requirement is that the sensors and alarm detection equipment used for high-high tank level or any part of an overfill protection system (OPS) must be independent of any sensors or systems used for routine tank filling operations.

This commonly leads to the use of a point level detector for overfill protection and a continuous level sensor for tank gauging. However, it is possible (and preferable) to utilise two independent continuous level sensors if they are adequately independent and diverse in their design, installation, and monitoring.

Basic tank gauging technology alternatives

Float and tape, radar, servo, magnetostrictive, hydrostatic, and capacitance are the most popular tank gauging technologies. Each has its own strengths and limitations, but none inherently provide multi-point temperature monitoring and volume-weighted temperature averaging.

Float and tape technology performs simple level monitoring by measuring shaft rotations while a float moves up and down as level changes. Temperature monitoring requires single or multiple external temperature sensors. Accuracy is generally adequate for inventory, but not always for custody transfer. All parameters other than level require additional instrumentation (Figure 1).

Servo gauges use a displacer rather than a float and force on a servo motor system to measure level. Servo gauges can be designed to measure interface (water) and density in addition to product level; however, these are not mutually continuous measurements. Level measurement is suspended while water or density is being measured.

Density accuracy with a servo mechanism is low while emulsions are not detectable. All other parameters such as temperature require additional instrumentation.

Radar gauges utilise radar to measure ullage. Accuracy is generally adequate for both inventory and custody transfer (assuming a stable reference point and a slotted stilling well are available). As with float and tape technology, all parameters other than level require additional instrumentation.

Magnetostrictive technology utilises one or more floats containing a magnet to activate a magnetostrictive membrane within a tube for level monitoring. By using multiple floats and displacers, this technology can also measure water bottoms and overall density within a relatively narrow range. Density accuracy with a magnetostrictive technology is low while emulsions are not detectable and water bottom measurement is generally only suitable for measuring clear water. The technology is also limited to clear product applications. As with Servo gauges, all other parameters such as temperature require additional instrumentation.

Hydrostatic tank gauging (HTG) utilises three pressure sensors mounted on the side of a tank to compute product mass. Tank geometry and mass are used to compute level and average density. Accuracy is generally adequate for inventory but not always for custody transfer. All other parameters require additional instrumentation.

Conventional capacitance tank gauging is based on the capacitance change of a capacitor where the tank wall and probe form a capacitor and the product in the tank is a dielectric which changes the capacitance as the product level changes. Most capacitance probes have a single sensor and require additional instrumentation for any parameters other than level. It is suitable for use in non-conductive liquids such as petroleum-based products and gasses. Accuracy is generally adequate for inventory but not always for custody transfer.

Advanced tank gauging technology alternatives

Capacitance and hydrostatic technologies are attractive because they have no moving parts, generally do not require stilling wells, and are essentially maintenance free. By utilising multiple, compound sensors in a single probe, these technologies can be enhanced to provide much greater capabilities and advantages over conventional capacitance and hydrostatic gauges, and indeed any other basic tank gauging technology.

Advanced hydrostatic technology involves the use of multiple pressure sensors, each coupled with an RTD for temperature measurement, within a single probe (Figure 2). Since this technology includes multiple pressure and temperature sensors, it has the inherent ability to provide all of the following data parameters without any external instrumentation:

- Product level, mass, and volume.
- Multiple individual temperatures as well as volume-weighted average temperature.
- Multiple individual densities as well as overall average density and product stratification.

Figure 3. Multi-section advanced capacitance gauges with multiple capacitance and temperature sensors installed in a battery of horizontal tanks.

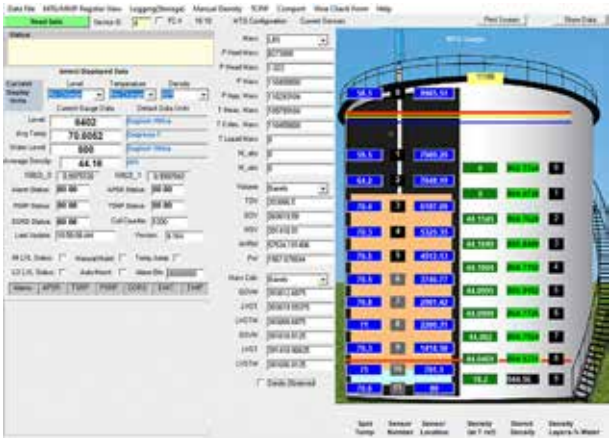

Figure 4. A tank detail screen from an advanced tank gauging software system showing data from an advanced hydrostatic gauge including a visual presentation of the product and water levels and the temperature and density profiles. Also includes mass and volume, product quality and system diagnostic information.

- Water bottom measurement as well as entrained, emulsified, and total water measurement.
- Vapour pressure, temperature, and density.
- Atmospheric pressure and ambient temperature.

Advanced HTG can provide all the previously listed critical data parameters for accurate tank inventory and custody transfer operations. Since the technology is based upon a tank-top mounted intrinsically safe transmitter and a bottom-referenced probe, it is also able to detect tank bottom movements.

By using a dual-transmitter head with complete physical and electrical independence, and each monitoring a separate set of sensors within the probe, advanced HTG is able to meet the overfill protection requirements of API/ANSI 2350 by providing total redundancy and continuous monitoring of both level and alarms. Tanks should be at least 6 ft. tall but can be over 200 ft. tall.

Advanced capacitive technology

Advanced capacitive technology involves the use of multiple capacitance sensors that can be coupled with an RTD for temperature measurement within a single probe (Figure 3). Unlike the traditional technologies, advanced capacitive technology can handle both conductive and nonconductive liquids and determine the interface between the two at any height. It can therefore be used for product water interface with high and low water bottoms. Advanced capacitance technology enables a gauge to inherently provide the following data parameters within a single instrument and without any external instrumentation:

- Product level, volume, and mass (with an additional density sensor).
- Multiple individual temperatures as well as volume-weighted average temperature.
- Water bottom measurement.
- Vapour pressure and temperature.

Advanced capacitive technology can provide most of the previously listed critical data parameters for accurate tank inventory and custody transfer operations within a single instrument and a single tank penetration. This technology can also meet the overfill protection requirements of API/ANSI 2350 by utilising independent probes within a single tank penetration to provide continuous monitoring of both level and alarms.

This technology is generally best suited for relatively small tanks (under 20 ft in height) and product with good dielectric characteristics (i.e. relatively clean petroleum products and liquefied gasses).

Advanced tank gauging software

Advanced tank gauging software can take advantage of the inherent capabilities of advanced hydrostatic and advanced capacitance technologies in a manner that conventional tank gauging software packages cannot (Figure 4).

In addition to local display indicators, an advanced tank gauging software system can use modern technologies such as ethernet networks, cloud storage, and a variety of communication technologies such as email, SMS, GPRS, etc. Data viewing via local and remote browser access on a computer or hand-held device eliminates reliance on dedicated, hard-wired monitors as the sole means of data presentation. Furthermore, data sharing can be provided over MQTT, AWS, IFTT, OPC and other protocols.

The enhanced data parameters achieved by advanced hydrostatic and advanced capacitance gauges, coupled with software specifically designed to monitor, store, and analyse the data, enable advanced tank gauging software to provide the following capabilities:

- Graphic displays illustrating density layers and stratification, water content (water bottoms, entrained water, emulsified water, total water, and percentage of water), and product and vapour pressure distributions in addition to the typical tank gauging parameters found on most systems.
- Product quality analysis based on temperature gradients, density stratification, and water content.
- Leak detection data analysis and reporting.
- Sensor and tank integrity data analysis and diagnostics, including the ability to schedule maintenance based on predictive analysis of gauge performance.
- Overfill and rupture protection analysis.

Conclusion

Several modern tank gauging technologies can help to obtain suitable product level accuracy for inventory and custody transfer. However, most require the addition of multiple external devices to obtain all the relevant data required to provide accurate accounting and adequate tank integrity monitoring. Advanced hydrostatic (for large storage tanks and virtually any petroleum product) and advanced capacitive (for horizontal tanks and small vertical tanks with liquid gas or light petroleum products) can accomplish all the relevant data within a single instrument, utilising a single tank entry.

While conventional tank gauging software systems can obtain and display data from advanced capacitance and advanced hydrostatic gauges, an advanced tank gauging software system is required to utilise these advanced technologies to their fullest potential. T&T