Level Up! The True Cost of Accuracy

A Varec, Inc. White Paper

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In recent years, European tank gauging manufacturers have focused their marketing efforts on persuading tank farm, terminal, and refinery owners operating within the United States that accurate measurement of bulk liquid receipts, and inventory management require advanced tank gauging technologies. Given various equalities between manufacturers, and parity among products, the answers to these four questions dictate the appropriate technology, accuracy requirements, and associated costs for a tank gauging system within the United States:

1. Why do we use tank gauging? Operations (product delivery, and receipt) between U.S. petroleum facilities, and pipeline companies define if custody transfer or inventory management is the most appropriate use for a tank gauging system.
2. What industry standards govern the use of tank gauging? Standard API 3.1b, recommended by the American Petroleum Institute provides, clear guidelines on the reference, and operational accuracy requirements for inventory management systems.
3. What products, and technologies can we use? Not all technologies are suitable for a given measurement application. Environmental factors, such as liquid properties, in-tank conditions, and tank structure, can affect the accuracy of technologies differently.
4. What is the true cost of ownership? Multiple technologies may give the desired measurement results, but as operational accuracy increases, so do the costs.

Obtaining a level accuracy of ±1 mm is difficult to realize. In trying to achieve this level of accuracy, the investment needed by a facility operator grows exponentially when all requirements are factored into the cost of such a system. This paper will identify the considerations, options, and associated costs of obtaining an inventory tank gauging system vs. a “high-accuracy” tank gauging system.

Within the United States, approximately 68% of all petroleum products are transported via the nation's pipeline infrastructure; this trend drives the tank gauge to be used primarily as an inventory measurement device.

Custody Transfer Requirements

Custody transfer refers to transactions involving the transfer of raw, and refined petroleum products between two companies via tanks, barges, pipelines, rail tankers, trucks, and ships. Within the United States, approximately 68 percent of all petroleum products are transported via the nation's pipeline infrastructure, while 27% is transported via ship or barge, and 5% by truck or rail tanker. During custody transfer, accuracy is of great importance to both the distributor, and the recipient.

Metering at the loading rack

Whenever a transaction is completed at a loading rack (32% of U.S. product shipments), high-accuracy flow meters measure the disbursement. Both parties (distributor, and recipient) have previously agreed upon this method of measurement. Therefore, the tank gauging system is not used as a high-accuracy system to measure the actual transaction, and identify final invoicing. It is used as an inventory measurement for the use of reconciling book versus physical stocks.

Read more at www.tankgauging.com

Once defined as an inventory measurement device, the question should be asked, "What level of accuracy is truly required for inventory management?"

Receipt From a Pipeline

In the United States, a pipeline company provides a final receipt to the terminal company for the amount of product delivered based on measurements from the pipeline company's flow meters. In Europe, and other parts of the world, the distributor's, and receiver's systems are certified after installation, and commissioning. This involves a large capital investment to a third party who tests the system, and provides a custody transfer certification. The two transacting companies can then more readily agree upon the final batch size, with neither company dictating over the other.

In the United States, it has been standard industry practice for many years for the terminal company to account for a discrepancy in the final receipt amount. Terminal operators that are concerned over receipt discrepancies generally use high-accuracy flow meters to measure receipt volumes during receipt, rather than automatic tank gauging, and the tank gauging system is optimized for static measurements. The two systems will each provide different measurements based on the accuracy, repeatability, calibration, and ambient conditions.

In reality, a tank gauging system should be used as a measurement system to manage inventory assets within a facility, not from one party to another. Now that the application of a tank gauging system has been defined as an inventory management system, the next question to ask is "what level of accuracy is truly required for inventory management?" The answer is different for each facility, their operational requirements, and what an operator is willing to pay for.

Throughout the United States, the majority of terminal operators account for product inventory via volume, and not weight. Therefore, the accuracy of a level-based system is one specification that drives purchasing decisions.

What is Tank Gauging?

Tank gauging is the generic name given to the measurement of liquids (product) in bulk storage tanks with the aim of quantifying how much product is in the tank — gauging the contents of a tank. Today, the oil and gas industry generally uses the static measurement of the tank contents to account for product stored, and product moved into, and out of the tank.

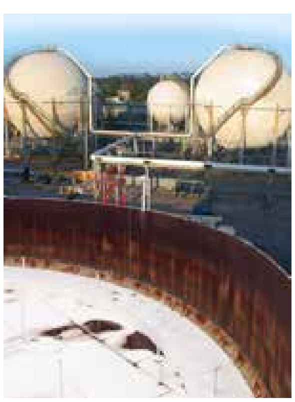
API's Manual of Petroleum Measurement Standards chapter 3 section 6 provides recommendations for custody transfer systems that take into account level, temperature, water, and density in a complete system. Although each of these factors can affect volume, the industry as a whole, and manufacturers look to API 3.1b (which provides the specific level accuracy recommendations) to specify tank gauge devices for inventory control applications. Chapter 3.1b recommends a need for a device to provide ±3 mm (1/8") **reference level accuracy**, and ±25 mm (1") **installed accuracy**.

The issue of cost vs. accuracy must be balanced — do not get side tracked over "nice" features that are not applicable to level accuracy, and technology selection.

Factors for Decision Making

Many factors affect the accuracy, reliability, and repeatability of a tank gauge's ability to obtain highly accurate measurements. Some manufacturers give more weight to "nice" features that a system may offer over a technology's suitability to the measurement task. For example, a company's wireless device capabilities, an instrument's redundancy, or the way it communicates with a system may be marketed as important to the application.

In reality, the primary factors that affect the level measurements of different gauge technologies are the stability of the gauging platform, tank deformations, and surface conditions. Therefore, a gauge's ability to overcome these issues or to minimize their effects in order to meet API 3.1b should be the primary decisive factor in selecting an appropriate system for level accuracy.



The requirement for any form of density measurement adds significant incremental costs to a tank gauging system

Technology as a Factor

In certain cases, the type of measurement may dictate the equipment required. For example, some operators require their tank gauging systems to provide density measurement or density profiles that can then be used to accurately account for their inventories. The additional costs for high-accuracy tank gauges, and ancillary equipment is, therefore, justified because accurate density measurement is dependent on the accuracy of the level measurement.

Density measurement

If spot density or a density profile is required, and the tank does not have an existing pressure transmitter fitted, a servo tank gauging system may be the most appropriate choice. Unlike radar, a servo gauge can provide these measurements without the need for an additional pressure transmitter. Servo systems offer excellent reference level accuracy of at least ±1 mm, the same as the most expensive radar systems.

When continuous density is required, the operator must consider the cost of a pressure transmitter, and its associated life cycle costs, as well as the normal tank gauging system cost. In addition, a software system or tank-side device will also be needed to calculate any inventory measurement.

Continue to use your existing system

If an operator currently uses float-and-tape tank gauges, and is contemplating changing technologies, such as a radar (and pressure) or servo system, to obtain density measurement, then the operator would be wise to maintain the existing float-and-tape gauges in parallel with the new system. The float-and-tape could then be operated as a back-up system in case of a facility-wide power loss.

Product parity throughout tank gauging manufacturers allows a system integrator to mix brands, and select the optimum gauge supplier for the desired measurement application — independent of the wireless technology.

Wireless Communications

For critical measurement applications, the industry still prefers to use hard-wired connections to the control system. However, as wireless networks have become more stable, and secure, their use for standard inventory measurement applications has grown year by year. This growth is mainly due to a cost advantage when compared to updating old, hard-wired systems or running new wiring in hazardous areas.

Today, there are many products from many manufacturers to choose from. Some devices connect directly to the head of the tank gauge, some are mounted on the tank shell with a wired connection to the gauge, some use point-to-point communications, some use multi-point, and some use both types of communications at once.

Marketers use terms such as “matrix” or “self-healing” networks to draw attention to their wireless offerings, and make this a point of difference for their brand selection. In reality, almost all wireless transmitters, and gateway devices use a combination of HART®, and MODBUS communications protocols. Therefore, as long as the tank gauge selected is capable of outputting data via these protocols, the brand of gauge, and brand of wireless device need not be the same. Wireless, which is available from all tank gauging manufacturers, should be considered as an option to the overall solution. It should not influence the decision to select the most appropriate measurement technology for a given application.

"When addressing API Standard 2350, operators must decide how to meet the redundancy and fail-safe requirements, not through the selection of a particular level-measurement technology, but through device I/O and systems capabilities and communications."

Overfill Protection

In the coming months, and years, owners, and operators of United States based petroleum storage facilities will be reacting to the American Petroleum Institute's Standard 2350 for overfill protection. The revised 4th Edition builds on recent industry experiences, and integrates recommendations for tank gauging system compliance within the management system, and overfill prevention process (OPP) of a facility.

API Standard 2350 does not mean an owner or operator needs to re-invest capital in expensive instrumentation, and systems. To address inventory measurement and overfill protection as defined by the Standard, operators must clarify their facilities' operational and overfill response procedures and then agree on these procedures with their transporters. Operators must also identify the tank category, which levels of concern demand alarm automation, and how to meet the measurement, alarm, redundancy, and fail-safe requirements with existing technologies, device I/O, systems software, and logic solver capabilities.

Read more at www.tankgauging.com/api2350.html

Even a high-accuracy radar gauge is more likely to provide an inventory-grade measurement to API 3.1b standards than a measurement that can be compared to a custody transfer approved flow meter.

Radar Gauge Accuracy Reference vs. Real Life

Radar gauges are delicate measurement devices that use radar echoes to measure product level in a bulk storage tank. They are calibrated, and tested in climate-controlled environments before leaving the manufacturing facility to ensure each device is capable of accurate measurement under reference conditions. The test stands (for free space, and stilling wells) are produced to accurate detail in accordance with API recommendations or to the gauge manufacturer's recommendations for optimum performance of the gauge. These test stands do not simulate real-life conditions within a tank, or take into account variations in stilling wells that are likely to be encountered at the tank farm.

Therefore, it is very clear, and freely admitted by all tank gauging manufacturers that the accuracy obtained under test conditions is not what will be achieved when a gauge is installed on a tank. A radar gauge that provides ±1 mm accuracy under reference conditions will, at best, provide ±3 mm in the field and, furthermore, to obtain this level of accuracy, conditions in the tank must be optimized for radar technology. Even a high-accuracy radar gauge is more likely to provide an inventory-grade measurement to API 3.1b standards than a high-accuracy measurement that can be compared to a custody transfer approved flow meter.



In most cases, stilling wells in the field are not optimized for radar measurement.

The Gauging Platform

The tank shape itself can cause errors in level measurement. The weight of the liquid product against the side of the tank wall causes the wall to bow (deform). In turn, this causes the roof to flex. Without a stable gauging platform, free from the effects of tank deformations, an accurate measurement cannot be guaranteed at all levels within the tank. This is the primary reason a stilling well is recommended for high-accuracy radar, and servo tank gauging applications.

Liquid surface turbulence

A second reason to recommended a stilling well is to minimize the effect that product surface conditions, i.e. turbulence, have on radar readings. High-accuracy radars mounted in "free space" are generally not justified for the amount of true accuracy that can be obtained. Turbulence can also present problems for servo tank gauging because it causes horizontal movement of the displacer on the liquid surface. A stilling well overcomes these problems to a degree by providing a relatively quiet product surface, especially during filling, and emptying of the tank.

Stilling well considerations

In most cases, stilling wells in the field are not optimized for radar measurement, or a tank simply does not have an existing well. The three most important factors that make a well unsuitable are:

1. Stability: The well is secured to the tank roof, and not the tank floor. This makes the level reading subject to the effects of tank deformations. The well should be fixed to the tank floor, and should use a vapor seal at the tank roof.
2. Diameter: The well is not a consistent diameter through its entire length, or the years of flexing, and tank movements have caused the well to bend. Inconsistencies cause radar waves to bounce around, and interfere with reception, resulting in decreased gauge accuracy.
3. Slots: The slots in a well are not consistent, smooth or correctly sized, and positioned. The slot pattern or burrs on the edges of the slots cause radar waves to bounce around, and interfere with reception, causing decreased gauge accuracy.

In most cases, to obtain the closest real-life conditions to that of the reference conditions, a stilling well needs to be either modified or a new well needs to be installed.

Calibrating radar to a unique stilling well

In the best case scenario, a radar gauge requires a custom calibration through one or more tank fill-and-empty cycles or it may not provide the desired accuracy; at worst, the gauge will not be able to find the level at all. It is highly recommended to inspect a well before a radar gauge is purchased, let alone installed.

In addition, add to the cost of installation the need to isolate the tank while initial calibrations are conducted. In busy terminals, if the tank cannot be isolated, the expense for the high-accuracy device is almost certainly wasted.

Installing a new stilling well

In most cases, to obtain the closest real-life conditions to that of the reference conditions, a stilling well needs to be either modified or replaced. Either project adds significant cost as it often requires taking the tank out of service. In some cases the tank may need to be emptied, and cleaned to allow personnel to enter the tank to weld the stilling well in place, and create a stable platform. If the application allows, a fiber glass stilling well kit (approx. $3,000 for a 40 ft well) can help reduce costs (compared to the cost of a steel well). If a well needs to be installed, add the cost of renting heavy machinery, such as a crane at approximately $1,000 per day.

A radar operating without a stilling well needs to be installed away from the tank wall, where tank deformations have increased impact on its accuracy.

Do I really need a stilling well for radar?

So you have decided you do not want to invest in the steps needed to modify or install a stilling well, but you would like to use radar for high-accuracy measurement. As previously discussed, there is the issue of turbulence on the surface of the product, that affects the accuracy of measurements at critical times, such as when the tank is being filled close to high levels.

Secondly, the effect of tank deformations is a real problem. All bulk storage tanks heat up, and expand in the midday sun. This expansion causes the roof to buckle, and flex, which in turn causes instability in the gauging platform. For free-space radar applications, this instability is compounded because the gauge needs to be installed away from the tank wall, where roof movements are the greatest. A drop in level-reading accuracy of a few millimeters (mm) may not seem like much, but it is not the consistency, and reliability expected from a high-accuracy measurement device.

In comparison, a float-and-tape gauge that enters the roof through a manhole near the tank wall is far less affected by tank deformations. A large-diameter float traveling on stable guide wires assures consistent inventory measurements even during turbulent conditions. If the tank requires modification for float gauging, it does not need to be emptied or removed from service. A manhole cover can be replaced with a cover that provides the required guide wire tank top anchor points, and a weighted anchor lowered into the tank can provide the required lower anchor points.

I still need to dip my tank

Many tanks in the U.S. do not have adequate tank roof entry points that can be used for gauges. They may have an existing connection for float-and-tape gauges on a manhole cover, but not a flange or stilling well entry, other than the one used for manually dipping the tank. This is not a problem for advanced gauges. A "calibration chamber" can convert an existing entry to allow gauging and hand measurements, but as for a stilling well, the additional cost of converting a cover must be considered. This generally ranges from $1,500-$2,500, depending on the flange size, and the chamber construction materials.

Installing AC/DC-powered roof reading instruments on a standard petroleum tank could easily add $3,000 to $5,000 in conduit costs.

Tank Roof or Tank Side?

In a cost analysis, owners and operators should consider a tank gauging system installed at the side of the tank vs. one that is installed on the tank roof. Operators generally prefer tank-side installation because it allows commissioning, servicing, and reading the unit at ground level without the need to climb the tank, thus saving time, and reducing risk.

The cost of conduit

All advanced gauge technologies — radar, servo, and magnetostrictive — are installed as roof reading units, and require power at the gaugehead. In comparison, float-and-tape tank gauges are installed at the tank-side, and only require power if a transmitter is used.

If an advanced gauge is to be installed on a tank that does not have a power supply to the tank roof, a further cost is incurred. The estimated rate within the United States to install ½" rigid conduit up the side of a tank, and across the roof to the instrument is $50 per foot. This is without the additional cost of equipment, such as a lift needed for the install. It is also considered good practice to run separate conduit for AC power, and communications. Therefore, the additional installation cost on a standard 30 ft cone roof tank could easily grow to $3,000 for DC, and $5,000 for AC instruments. This cost alone forced gauging manufacturers to develop low-powered radar with tank-side communication, and integration units.

Depending on the functionality, the tank-side unit alone may add $2,000 to $4,000 per tank.

Tank-side integration, monitoring, and display

In addition to providing communications to the host system, these tank-side units also act as a configuration unit, tank-side integration device for temperature, and pressure probes, and low-power (DC) power source for the tank top instrument thereby adding more value than just displaying the measurements. However, with this added value comes substantial cost. Depending on the functionality, the tank-side unit alone may add $2,000 to $4,000 (25 to 100 percent of the cost of the gauging instrument) per tank.

Reducing risks - health, and safety

Falls are among the most common causes of serious work-related injuries, and deaths, especially in environments subject to inclement weather, such as snow, ice, rain, or high winds. Whenever an employee climbs a tank to check a gauge — whether it is installation, calibration, or just checking an instrument — employers must work to reduce risk. For a cautious employer, this may mean spending time setting up adequate fall protection systems, such as constructing guardrails, and platforms at the top of the tank, safety ropes, and harness equipment, or scaffolding on the side of the tank. Again, each operation adds cost in manpower and capital.

When all support costs are discovered and calculated — commissioning, annual re-calibration, training, cleaning, and maintenance — misconceptions become apparent.

Complete Life Cycle Costs

It is widely believed that radar gauges require far less maintenance than float-and-tape devices. This is due in part to the way radar manufacturers market their technology as a low-maintenance favorite compared to the perception that mechanical technology needs heavy maintenance, and replacement parts over the life span of the gauge. However, when all support costs are calculated, including commissioning, on-tank verification, re-calibration, training, cleaning, maintenance, and low-cost mechanical spares vs. high-cost electronics, the opposite is true.

Training, and technology acceptance

When considering the different technologies, a company should anticipate requirements for acceptance, understanding, and continued operation by employees that interact with the devices. The average on-site technician is far more willing to perform maintenance work on a float-and-tape gauge. The system is less complex, and any vendor training that is required involves far less time, with employees retaining the knowledge far longer. With this widespread knowledge, float-and-tape gauging system maintenance costs can also easily be managed, and estimated.

There are few terminal companies willing to pay for on-site tank gauging training sessions for their staff. This is especially true for radar systems, either because they realize complex procedures, such as calibration, are difficult for personnel to retain because they are rarely performed, or since they realize employee turn-over is likely to mean the trained individual will no longer be on site or even an employee when the time comes to calibrate the device. Therefore, owners must accept the burden, and cost of having the vendor travel to their site, possibly on an annual basis.

To maintain the high-accuracy measurement of a system, the radar gauge may require regular validation, and on-site re-calibration, a burdened cost from the manufacturer that is difficult to bear.

Commissioning

The majority of terminal operators would prefer an "out-of-the-box working solution", and are reluctant to pay for initial commissioning of a device. However, the initial calibration of radar gauges is critical to the operational accuracy. Therefore, the vendor or integration specialist will probably perform the initial calibration. With an advanced system, you must also account for the configuration of ancillary devices, such as average temperate probes, and tank-side displays. Float-and-tape devices are generally set up in a quarter of the time it takes to set up advanced systems. The United States has a limited number of experts trained to calibrate radar gauges for custody transfer applications, whereas there is an abundance of technicians who can install, and calibrate a float-and-tape gauge. For a custody transfer or high-accuracy radar system, be prepared to accept the burden of a vendor traveling to your site.

Life expectancy

When we compare life expectancy, and the maintenance requirements across instruments, we find float-and-tape gauges have a proven capability to perform for over 20 years in the field with limited maintenance, and still provide accurate measurement. In comparison, terminal operators are more likely to upgrade or replace electronic, and advanced systems after only 10 years of service.

Validation for high-accuracy custody transfer

If an operator decides on a high-accuracy or custody transfer system, it should be checked regularly against a hand measurement, and if needed, re-calibrated, and sealed for custody transfer. Local weights, and measurement regulations dictate how often a system must be validated. The general requirement is once every three years. Most facilities, however, validate a gauge's accuracy at least once every three months, a procedure that requires personnel on the tank, and may interrupt operations.

As shown in the scenarios that follow, validation, and calibration contribute a large portion of the life cycle cost for radar gauges. Frugal operators may wish to ignore this cost, and not check gauge accuracy. By doing so, they may measure inventory with reduced accuracy, and repeatability, which is exactly opposite to the initial justification for their system purchase.

Is the cost of advanced gauge technology justified after life cycle costs and field performance are clearly understood and compared?

Putting it All Together

Throughout the United States, most petroleum product is distributed to bulk storage terminals by pipeline companies. The pipeline company uses high-accuracy flow meters to measure the final receipt of product. The primary functional of a tank gauging system is to serve as an inventory measurement tool that meets relevant API recommendations, and standards.

Operators should avoid the advanced technology hype and not be swayed by a marketer's attempts to promote features not critical to the measurement application, and that, in reality, can be provided by less expensive technology. They should realize the benefits of applying a particular technology to a particular application, and the applicability of operational standards relevant to their geographical region.

Operators of tank farms, and terminals also need to understand the differences in manufacturers' claims on level accuracy based on reference conditions vs. installed conditions in which tank movements, and product turbulence can affect measurement accuracy. It needs to be understood that radar, and servo technologies require stable gauging platforms to provide the high accuracies claimed by their manufacturers. Ensuring the platform is stable for gauging often involves high-cost installations.

Is the cost of the selected level accuracy for inventory tank gauging justified when the entire life cycle costs are clearly understood and compared across technologies? For some, high-capital expenditures for a new system may be justified; for others, ongoing maintenance of the existing system may be a budgeting preference.

Scenario 1

The 40 ft cone roof tank containing gasoline has an existing float-and-tape gauge installed at grade.

- The conduit enters the tank roof through a manhole, and there are two other gauging points (flanges) that are used for hand dipping.
- The gaugehead, tape, float, guide wires, spot temperature bulb, and transmitter need to be overhauled as they are no longer functioning after 20 years of service.
- The operator does not require density or interface measurements, so they have discounted servo gauging.
- Magnetostrictive is not a viable option for this tank height due to cost.
- The tanks existing high-level alarm switches offer adequate overfill protection in accordance with API Standard 2350.
- The tank is currently out of service undergoing an API Standard 653 procedure.

Based on this scenario, the operator is considering three options, the costs of which are estimated below:

1. Replacing the existing gauge with a new unit to provide inventory management level accuracy.
2. Installing a radar gauge offering inventory management level accuracy.
3. Installing a radar gauge offering high-accuracy measurement.

Option 1

Replacing the gauge, and transmitter is the most economical solution that offers a reasonable accuracy of ± 5 to 8 mm. The transmitter will integrate the spot temperature probe, and provide MODBUS communications to the host system.

The service technician on site could perform the installation, but the operator wants the peace of mind, and guaranteed service provided from the manufacturer, Varec. While on site, the Varec service engineer is also contracted to provide service training for the site's four employees so that they can continue to maintain the new gauge, and the other gauges on site.

Table 1: Summary of Costs for Scenario 1 Contact Varec for a full breakdown of the ROM for this estimate	Option 1 Float-and-Tape Technology	Option 2 Radar Inventory Grade Technology	Option 3 Radar High-Accuracy Technology
Tank Gauging Costs (Capital)	$5,000	$8,000	$16,100
Installation Costs (Service)	$750	$3,000	$3,000
Engineering, and Construction Costs	$0	$0	$6,500
Commissioning Costs (Service)	$250	$750	$1,000
Training Costs	$250	$375	$375
10 Year Calibration Costs	$0	$3,000	$5,000
10 Year Maintenance Costs	$2,500	$0	$0
Total Cost of Ownership (10 Years)	**$8,750**	**$15,125**	**$31,975**
System Reference Accuracy	± 4 mm	± 3 mm	± 1 mm
Static "Real" Measurement	± 5-8 mm	± 5-8 mm	± 3-5 mm
Dynamic Measurement	± 8-10 mm	± 8-10 mm	± 5-10 mm

Notes: The costs for each option do not include burdened travel costs for manufacturer's service engineers to the site for initial commissioning or annual service.

Option 2

The hand dip point, and float-and-tape manway cover are too close to the side of the tank for radar gauging to achieve a clear signal. Therefore, the radar gauge needs to be installed on the flange entry furthest from the tank side. The gauge will operate in the free space area of the tank to provide adequate inventory management accuracy of ±5 to 10 mm. A tank-side monitor is required to integrate the spot temperature probe, and provide MODBUS communications to the host system.

As a standard measure, the operator schedules a local contractor to install conduit up the side of the tank to carry the two-wire communications, and low-voltage power cables required on the tank roof for the radar gauge.

The operator requires a factory engineer to calibrate the radar, and monitor, which also means filling, and emptying the tank to ensure correct commissioning. The operator realizes the task of re-calibrating the device every three years will be best performed by a factory engineer, and so they account for this in an annual maintenance budget.

Option 3

To enable high-accuracy measurement, the existing manhole cover must be converted to provide a suitable stilling well, and an average temperature measurement entry point. Heavy lifting equipment is needed to install the stilling wells.

The radar, and temperature device can be multi-dropped so that only one conduit run is needed up the side of the tank for low-power, and communications cables.

The gauge, tank-side monitor, and temperature sensor must be calibrated by the manufacturer, which also means filling, and emptying the tank to ensure correct commissioning. As in option two, the operator also realizes the task of re-calibrating the device every three years will be best performed by a factory engineer, and so they account for this in an annual maintenance budget.

Scenario 2

Ten floating roof tanks (30 ft high) contain crude oil with existing float-and-tape systems operating in a float well.

- There is an operational 10″ stilling well on a stable gauging platform, which is ideal for all gauge types, and does not require modification.
- At the tank base, there is an entry for a 24″ spot temperature element.
- AC power is supplied to the tank side.
- The tank's existing high-level alarm switches offer adequate overfill protection in accordance with API Standard 2350.
- The operator does not require density or interface measurements, so they have discounted servo gauging.
- The operator also has the opinion that magnetostrictive gauges are best used on clean product, and so this has been discounted as an option.
- The tank must remain in service during the tank gauging system install.
- On-site technicians will provide all support after the initial calibration. If a gauge type other than float-and-tape is selected, training will be required.
- They have found they require three times the standard maintenance due to this unique crude product application, but they have the capability to meet these needs on site.
- Finally, they have estimated the costs of disruption to their operations for filling, and emptying during a radar calibration to be at least $500.

Based on this scenario, the operator is considering three options, the costs of which are estimated below:

1. Continue to maintain the float-and-tape gauge system.
2. Installing a radar gauge offering inventory management level accuracy.
3. Installing a radar gauge offering high-accuracy measurement.
4. Combining options 1, and two to provide dual measurements on a redundant system.

Option 1

They believe the existing float-and-tape system will provide another 10 years of service life if well maintained. The only immediate need is to upgrade the existing transmitters. They are content with the current accuracy of ±5 to 8 mm. The service technicians on site could perform the installation, and any continued maintenance.

Option 2

The radar gauge will need to be installed on the 10″ well. To enable continued hand dipping, a calibration chamber will be required. The gauge will provide adequate inventory management accuracy of ±5 to 10 mm. A tank-side monitor will be required to integrate the spot temperature probe, and provide MODBUS communications to the host system.

A factory engineer will be required to calibrate the radar, and monitor, which will also mean filling, and emptying the tank to ensure correct commissioning. The operator realizes the need for two days of on-site service, and calibration training. As a standard measure in the United States, the operator must schedule a local contractor to install conduit up the side of the tank that will carry the I.S. two-wire communications, and low-voltage power cables required on the tank roof for the radar gauge.

Table 2: Summary of Costs for Scenario 2	**Option 1** Float-and-Tape Technology	**Option 2** Radar Inventory Grade Technology	**Option 3** Radar High-Accuracy Technology
Tank Gauging Costs (Capital)	$40,000	$70,000	$156,000
Installation Costs	$0	$30,000	$40,000
Engineering, and Construction Costs	$0	$0	$40,000
Loss of Operations Costs	$0	$12,500	$15,000
Training Costs	$0	$1,000	$1,500
10 Year Calibration Costs	$0	$50,000	$50,000
10 Year Maintenance Costs	$75,000	$0	$0
Total Cost of Ownership (10 Years)	**$115,000**	**$163,500**	**$302,500**
System Reference Accuracy	± 4 mm	± 3 mm	± 1 mm
Static "Real" Measurement	± 5-8 mm	± 5-8 mm	± 3 mm
Dynamic Measurement	± 8-10 mm	± 8-10 mm	± 5-10 mm

Notes: The costs for each option do not include burdened travel costs for manufacturer's service engineers to the site for initial commissioning or annual service. Contact Varec for a full breakdown of the ROM for this estimate.

Option 3

To enable high-accuracy measurement, an average temperature probe must be used with the high-accuracy radar gauge. The existing stilling well needs to be converted to provide space for a 6" radar gauging stilling well, and a 2" thermowell. It is worth noting that API does not recommend the practice of installing one well inside another, even though many operators do this.

To accommodate hand dipping, and both radar, and temperature devices, a custom calibration chamber is needed. Heavy lifting equipment will be required to install the new wells. The gauge, tank-side monitor, and temperature sensor will need to be commissioned by the manufacturer, who will then provide two days of on-site training to give on-site technicians the knowledge to validate, and re-calibrate on an annual basis. The radar, and temperature device can be multi-dropped so that only one conduit will need to be installed up the side of the tank for low-power, and communications cables.

Option 4

Combining a radar gauge, and float-and-tape system for an approximate cost of $278,500 provides a more robust continuous overfill protection system. The operator is able to cross check, and verify the measurement accuracy, and reliability of both systems.

Scenario 3

Five newly-constructed internal floating-roof tanks (50 ft high) contain light product.

- The tank has been designed, and constructed with a gauging platform for advanced gauging. It contains an 8-inch stilling well built to API standards, and a thermowell.
- It also includes a manhole cover to provide access to the internal roof.
- The operator requires a system to measure inventory to API 3.1b standards, spot density measurement, and a separate continuous overfill protection system (wired to a PLC). This tank will be a semi-attended category 2 tank as recommended by API Standard 2350.
- The gauge vendor is required to project manage all mechanical, and electrical installation through commissioning.
- A quick operator training session is expected to be provided after commissioning at no charge.
- This capital expenditure will be expensed over three years.
- Any ongoing maintenance or calibration is to be provided by the vendor in a secondary proposal as it will be considered at a later date in a separate maintenance budget.
- Once operational, out of service costs on all tanks are calculated at $2,500 per day. A tank can be cycled (filled, and emptied) in 36 hours.
- On tank operations for inspection, and maintenance cost $500 plus $250 per hour due to safety requirements.

Based on this scenario, the operator is considering the following options:

1. Use a servo tank gauging system as primary measurement with a radar gauge as overfill protection.
2. Use a servo tank gauging system as primary measurement with a float-and-tape gauge as overfill protection.
3. Use a radar gauge as primary measurement with a float-and-tape gauge as overfill protection.

Option 1

The servo gauge, tank-side monitor, and average temperature will be provided as a primary measurement on the gauging platform. The servo gauge will be able to provide density measurements without the need for a separate pressure transmitter. AC power, and communications conduits are required at the gauging point.

The radar gauge (SIL approved) will measure the tank roof using a roof reflector, and the system will compensate for the difference in level between the roof, and the product. Conduit for DC power (an additional 10 ft) will be needed at the flange entry for the radar gauge. The radar gauge will be wired to the PLC to provide redundancy for overfill protection.

Table 3: Summary of Costs for Scenario 3	**Option 1** Servo & Radar Technology	**Option 2** Servo & Float Technology	**Option 3** Radar & Float Technology
Primary Tank Gauging Costs	$124,750	$124,750	$105,000
Overfill Tank Gauging Costs	$42,500	$36,250	$36,250
Total System Costs (Capital)	**$167,250**	**$161,000**	**$141,250**
Annual Capital Expense (3 years)	***$55,750***	***$53,667***	***$47,083***
Annual Re-calibration Costs	$16,500	$13,250	$20,750
Total 10 Year Re-Calibration Costs	**$165,000**	**$132,500**	**$207,500**

Notes: The costs for taking the tank out of service each year to re-calibrate the radar tank gauging systems add significantly to the overall system costs. When comparing inventory grade systems without the requirements for high-accuracy gauging, the costs of initial capital, and ongoing maintenance become less differentiated. The costs for each option do not include burdened travel costs for manufacturer's service engineers to the site for initial commissioning or annual service. Contact Varec for a full breakdown of the ROM for this estimate.

Option 2

As in Option 1, the servo gauge, tank-side monitor, and average temperature will be provided as primary measurement on the gauging platform. Conduit for DC power will be needed at the manhole entry for the float-and-tape gauge.

The float gauge will measure the tank roof using a float on the roof surface, and the transmitter will compensate for the difference in level between the roof, and the product. The float-and-tape system will be wired to the PLC to provide redundancy for overfill protection. In addition to a continuous measurement, the float-and-tape transmitter will also offer multiple software outputs or limits switches to drive alarms or alerts.

The system will be designed to "level check", and monitor the deviation between both level devices to ensure accuracy, and to alert the operator.

Option 3

An inventory-grade radar gauge with a tank-side monitor, and average temperature will provide primary measurement on the gauging platform. The radar gauge will also need to integrate an additional pressure transmitter to provide density measurements. DC power, and communications conduit will be required at the radar gauging point.

The float-and-tape tank gauge, and system will protect against overfill as described in Option 2.

Tank Gauging Costs Worksheet

Use the worksheet below to estimate the total costs of ownership for your tank gauging system

	Option 1	Option 2
Tank Gauging System		
Tank Gauge		
Tank-Side Monitor/Transmitter		
Temperature Probe		
Additional Sensors (Pressure)		
Total Gauging Cost (Capital)		

	Option 1	Option 2
Physical Installation *(Estimate materials, and $ rate x hours)*		
Tank Gauge		
Tank-side Monitor/Transmitter		
Temperature Probe		
Additional Sensors (Pressure)		
Calibration Chamber/Manhole Cover/Tank Entry Modifications		
Tank Wall/ Roof Wiring, and Rigid Conduit *(Estimate $rate x ft. - AC= $75/ft. DC=$50/ft.)*		
Total Installation Cost (Service)		

	Option 1	Option 2
Tank Construction & Modifications *(Estimate materials, and $ rate x hours for service personnel)*		
Stilling Well Modifications or Replacement		
Thermowell Modifications		
Spot Probe Entry Modifications		
Misc Entry Modifications		
Additional Equipment, such as Scaffold/Crane/Lift		
Total Tank Cost (Engineering & Construction)		

	Option 1	Option 2
System Commissioning *(Estimate materials, and $ rate x hours for instrument engineer)*		
Tank Gauge		
Tank-Side Monitor/Transmitter		
Temperature Probe		
Additional Sensors (Pressure)		
Third Party Custody Transfer System Certification		
Total Commission Cost (Service)		

	Option 1	Option 2
Loss of Operations		
Installation *(e.g. In-service vs. Out of Service Installation)*		
Commissioning *(e.g. Tank Fill, and Empty/Cycle Requirements)*		
Additional Costs		
Total Operations Cost (Ops)		

	Option 1	Option 2
Training *(Estimate rates for 4 personnel)*		
Operator Training		
Maintenance Training		
Calibration Training		
Total Training Costs (Training & Service)		

	Option 1	Option 2
Annual Support *(Estimate materials, ops, and $ rate x hours for support)*		
Annual Maintenance *(Service Technician)*		
Annual Calibration *(Instrument Engineer)*		
Annual Support Total		
System Life Expectancy		
Total Support Costs *(=Annual x Life Expectancy)*		
Total Cost of Ownership		

Notes

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About Varec

Since its founding in 1928, Varec has been a leading innovator in the petroleum, and chemical sectors, delivering automated systems, and professional services for tank farm, terminal, and refinery operators, and owners worldwide. Today, Varec provides completely integrated measurement, control, and automation solutions that are specifically designed to ensure safe storage, and distribution, track product visibility, and provide accurate accounting for the local facility operator to the corporate enterprise. This includes functionality for overfill prevention, facility monitoring, and release detection.

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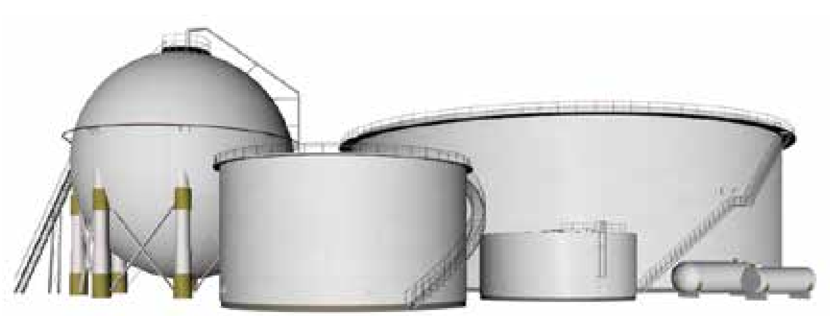

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