

New tank gauging technologies reduce cost for improving terminal efficiency and safety

Recently developed technology for tank gauging can help bulk liquid storage plants to handle the ever-increasing demands on efficiency, safety and accuracy.

An open system architecture makes it easy to install the devices needed today and add or replace units in the future. This flexibility protects users' investments so that refineries and tank farms more easily can become and stay efficient. Additional benefits include lower installation costs, high accuracy and built-in safety functions.

One feature with substantial potential to save cost is wireless transmission of measurement values. This enables high precision tank gauging data to be made available anywhere on the plant at a much smaller cost than before.



Caption: Tank gauging requires integrated high performance level, pressure and temperature measurement [file: emerson_illustration_1_highres_8-bit_v15.jpg]

Operational requirements

A modern Automatic Tank Gauging (ATG) system is an integrated high performance measuring and calculation system. It normally includes sensors for measurement of following storage tank data:

- Level
- Average Product Temperature
- Pressure (if on-line density and mass is required)
- Free Water Level (if required)

These data are in most cases used for three main processes handled via a Human-Machine Interface (HMI):

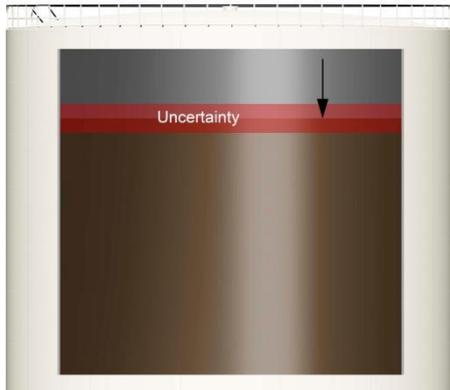
- Tank terminal operations monitoring including overfill prevention
- Inventory management to calculate storage tanks net volumes
- Custody transfer to buy and sell bulk liquids

Each process has specific requirements. As for terminal operations they are getting more demanding as the owners of the bulk liquids want to reduce capital cost by faster turnaround. When several storage tanks are operated at the same time, reliable alarm functionality plus a good operator overview is essential from a safety and efficiency point of view. In addition, historical data trends and printed reports should be provided for follow up and documentation.



Caption: **Graphic product movement indication for each tank gives quick summary of tank activity.** [file: Tankmaster_045_v02.jpg]

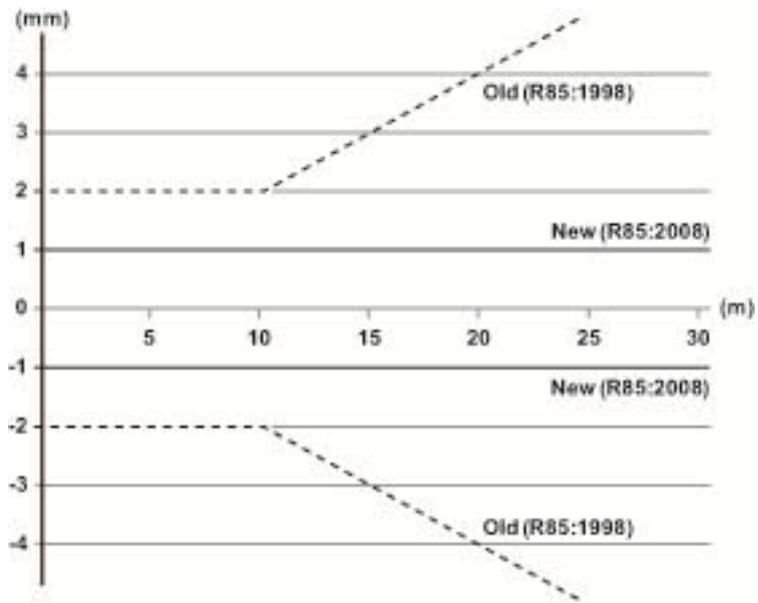
For inventory and custody transfer purposes, errors and uncertainty in volume measurement can obviously have large economic implications. A 5 mm level measurement error plus a temperature error of 0,6° C in a large crude oil tank corresponds to around 32 m³ of liquid. Considering the amount of transfers this can add up to a value of several tens of thousands of US Dollars for one tank during one year of operation.



Caption: **Reduction of net volume measurement uncertainty can correspond to large annual values.** [file: Produkttank Inventory Uncertainty v02.jpg]

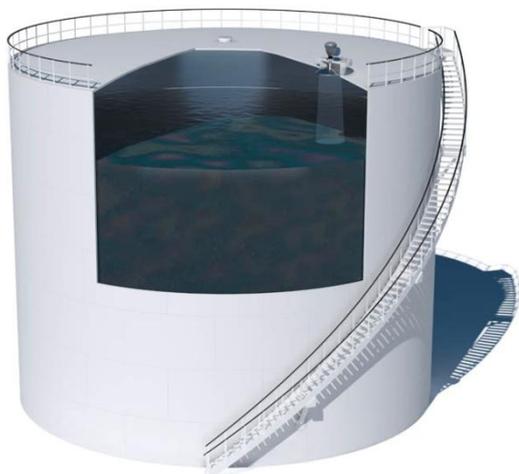
A precise calculation of net volumes is consequently the key for useful inventory data required for both internal accounting purposes and external taxation.

Custody transfer based on automatic tank gauging requires in addition very accurate volume measurement of product transfer batches. Many countries have metrological authorities approving gauging systems for legal custody transfer. Most of these authorities accept gauges that are approved and tested by an accredited laboratory according to the OIML requirements (OIML = Organisation International Metrologie Legal). The performance requirement of the OIML standard is approximately 1 mm level accuracy under reference conditions and 2 mm installed accuracy.



Caption: **Latest OIML (R85:2008) level accuracy requirement under reference conditions** [file: OIML_graph_generic.eps]

Radar level gauging for reduced downtime



Caption: **Free propagation radar with parabolic antenna.** [file: emerson_raptor_ill3_v05(3).tif]

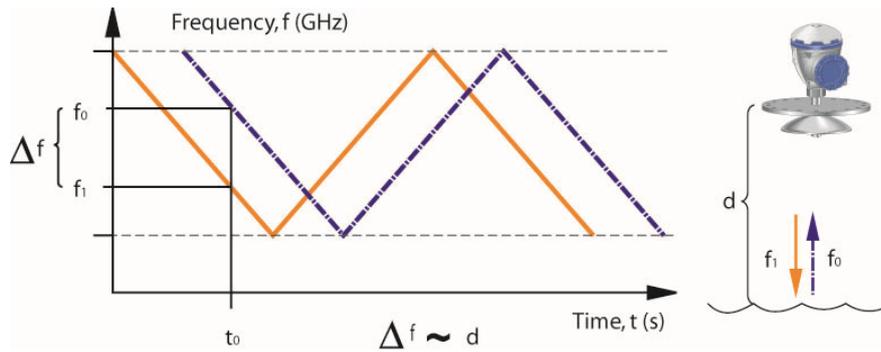
Since radar level gauges provide high reliability with no moving parts, and only the antenna/probe is inside the tank, they have become widely used both for high accuracy tank gauging and process level measurement. The radar level gauge/transmitter measures the distance to the surface of the product. Using tank distances stored locally in the memory of the gauge, it calculates the level of the liquid's surface. The radar gauge/transmitter consists of a transmitter head and an antenna. The transmitter head can be combined with any antenna type in the same gauge series, minimizing spare parts requirements. No matching of transmitter head and antenna is required, which means the transmitter head can easily be replaced without opening the tank.

For radar level measurement, there are mainly two modulation techniques used today:

- Pulse method
- Frequency Modulated Continuous Wave, FMCW.

Using the pulse method means that the radar transmitter measures the time it takes for a pulse to travel to the surface and back. The time difference is converted to a distance, from which the level is calculated. The Time Domain Reflectometry (TDR) technology is a special case, when a low power nano-second pulse is guided down a probe towards the process media surface, where it is reflected back.

The FMCW method is used by high performance radar level gauges to enable real custody transfer accuracy. The radar gauge transmits microwaves towards the surface of the liquid. The microwave signal has a linear frequency variation. When the signal has travelled down to the liquid surface and back to the antenna, it is mixed with the signal that is being transmitted at that moment. The reflection from the liquid surface has a slightly different frequency compared with the signal transmitted from the antenna when the reflection is received. The difference in frequency is measured, and it is directly proportional to the distance to the liquid surface. This technology can provide a measured value with high accuracy.



Caption: **FMCW measuring method.** [file: FMCW_ver2.eps]

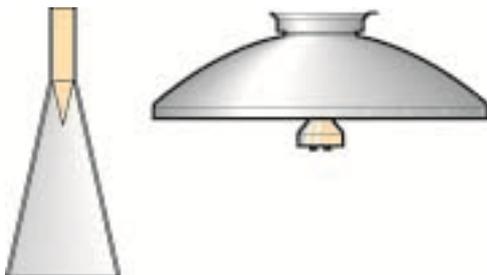
The gauges in a high end tank gauging system must also be suitable for all climate zones with a wide ambient temperature range. To enhance accuracy further under varying temperature conditions it is possible to use the following features:

Digital reference

An FMCW radar gauge needs an internal reference to make the radar sweep linear. Each deviation from the linearity produces a corresponding inaccuracy. To achieve highest precision, the gauge should have an on-line adjustment of transmitter frequency.

Drip-off means less condensation

An antenna with an inclined polished PTFE surface where microwaves are emitted will be less susceptible to condensed water or product. The amount of condensation coating the active part of the antenna will be reduced, resulting in a performance increase.



Caption: **Drip-off antennas** [file: DRIP-OFF.eps]

Open and scalable architecture

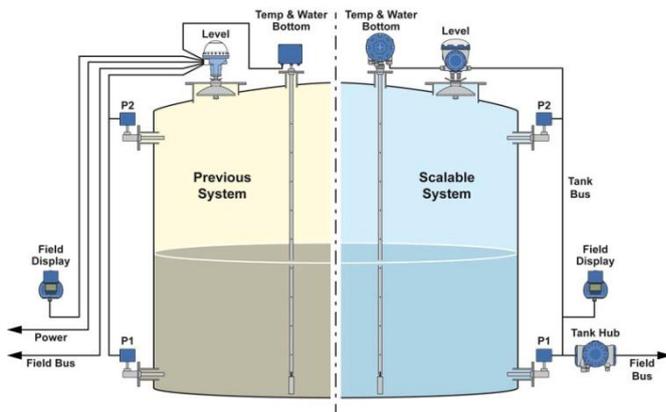
One way to implement a flexible system architecture is to build the system around a Tankbus connecting all measuring devices on the tank to a "tank hub", normally located at the tank foot. From the tank hub, a fieldbus, often Modbus based, is used to transmit data to the control room.

If the Tankbus is based on an open industry standard, FOUNDATION™ fieldbus, it will allow integration of any device supporting this communication protocol. By making the devices self-configuring startup will be easy requiring no special knowledge of FOUNDATION™ fieldbus. One system can include a wide range of components to build a small or large customized tank gauging system.

Because of the modular design, a system can later easily be expanded/upgraded and suited to different requirements on accuracy/performance, functionality, or system output.

The system should be designed to minimize power consumption, to enable the use of 2-wire intrinsically safe technology for the connected devices. These devices can then be powered by the Tankbus. This solution has several advantages as:

- It is safer both at system start-up, and in operation
- Installation costs less, is quicker and easier due to less cabling
- No expensive cable conduits are required



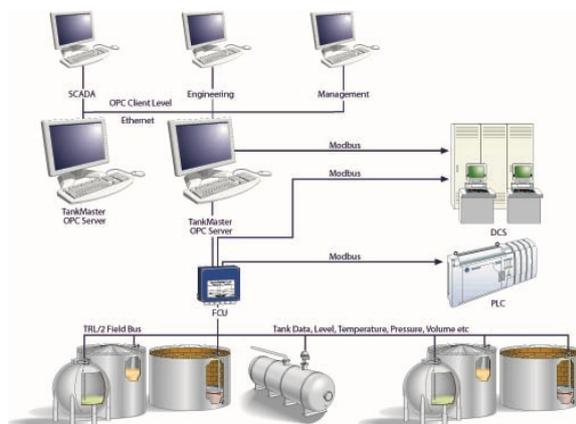
Caption: **New bus powered scalable 2-wire system means less cabling** [file: cable-spare_hwedit1_ver2.ai]

Networking and remote access

Interoperability and remote access of tank data is necessary for efficient tank farm management. The tank gauging system should be able to connect to all major suppliers of DCS, SCADA systems, plant host computers or terminal automation systems.

The advantage of connecting host computers to a tank gauging system HMI software is that not only the measured values, but also the calculated inventory data can be communicated. Communication to office environment computers and Scada/DCS systems can be made via OPC server or via Modbus.

To utilize redundant functionality it is also possible to build a network of several server and client PCs with tank gauging HMI software.



Caption: **The HMI software distributes essential inventory tank gauging data.** [file: NYSYSTEM_ed3 [Converted].ai]

Overfill prevention

All refineries, tank farms and fuel depots have a responsibility to ensure that overfill incidents do not occur. Depending on the requirements, the tank gauging devices should be certified for overfill protection according to IEC 61508-2 and 61508-3. This type of system provides High-High level alarm functionality, based on a separate SIL 2- or SIL 3-rated relay functions. The alarm loop triggers the safety relay output to the Emergency Shutdown System (ESD).

The inclusion of two electronics packages integrated into one transmitter head, a 2-in-1 solution, makes it possible to install a level gauge, and get one primary plus one backup unit, or one primary level gauge plus an independent radar based High-High level alarm. Compared to having two separate gauges, the 2-in-1 solution makes mechanical and electrical installation easier.



Caption: Two radar gauges in one housing. [file: 900_4000x4000_new_cutaway_utan_kablar_v01.tif]

Smart wireless tank gauging

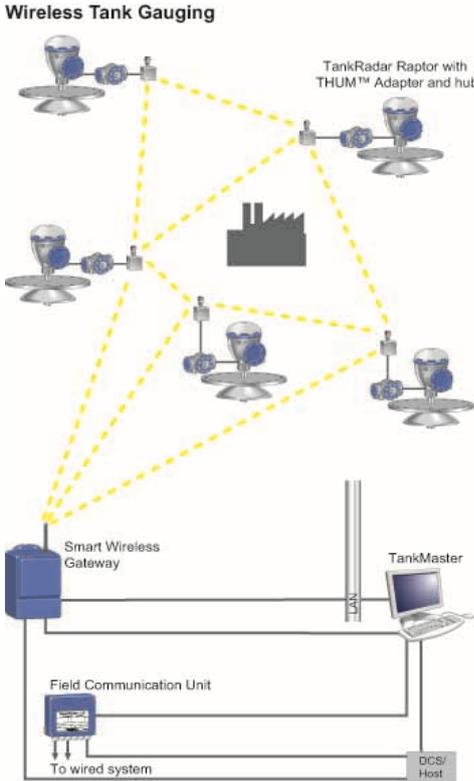
Many tank storage facilities that would benefit from modern, non-contacting gauging have obsolete or non-existing signal wiring from the tank storage area. Retrofit of the gauging system in such plants is normally expensive and time consuming as the distance between storage tanks and the control room can be more than one kilometer requiring extensive trenching and cabling.

As a result of budget restrictions, some plants therefore continue to experience maintenance problems by keeping low performing mechanical tank gauges. Now, with innovative wireless technology, installation of a new radar based tank gauging system can be done without any new long distance signal wiring. This will radically reduce material and labor cost as well as engineering and project execution time.

By connecting a wireless adapter to the tank gauging system, complete tank inventory data can be sent to the control room via WirelessHART™ communication.

The self organizing mesh network ensures uninterrupted data communication also in an environment with large mechanical obstacles such as storage tanks. Every wireless adapter serves as a network connector and backup so there is no single point of failure. All data transfer is protected by 128-bit encryption for best-in-class-security. Data are received by a wireless gateway in the control room area and fed into the inventory management software package or DCS system. In addition to level data, all relevant data from multi point temperature transmitters, pressure sensors and water bottom level sensors are transmitted.

Wireless tank gauging also means that precise inventory data for remotely located tanks that was previously out of reach can be made available. For those plants already using a wireless network, installation of the first gauging units will be even easier as they can use mesh nodes from other equipment.



Caption: **Tank gauges work as mesh nodes securing data transfer in spite of mechanical obstacles** [file: wireless-tg-raptor_ver2.eps]

Antennas for all storage tank types

To get high precision, radar antennas for level gauges need to have optimized design for various storage tank designs:

Parabolic Antenna for fixed roof tanks

This is the optimal antenna design for installation on tanks with fixed roofs without still-pipes. The design of the parabolic antenna gives extreme tolerance against sticky and heavily condensing products, such as bitumen and asphalt. The parabolic antenna has a high antenna gain and a high signal to noise ratio. The large antenna diameter gives a narrow radar beam, which means the gauge can be installed close to a tank wall. The parabolic antenna can be installed on existing manhole covers. A typical parabolic reflector diameter is 440 mm (17 in.) which fits a standard 500 mm (20-inch) manway. Installation is normally made with the tank in service.



[file: 5900S_Parabolic_128_Montage_A_Label.jpg]

Horn Antenna for fixed roof tanks

The horn antenna is designed for easy installation on fixed roofs tanks, with 200 mm (8-in.) or larger nozzles. It measures on a variety of oil products and chemicals except asphalt or similar for which the parabolic antenna is recommended.



[file: 5900S_Horn_107_Label.jpg]

Still-pipe Array Antenna for floating roof tanks

The small-sized array antenna has a drip-off design, with an inclined surface, and it is made for installation on new or existing still-pipes. Typical applications are crude oil tanks with floating roofs and gasoline/product tanks with or without inner floating roofs. To get highest accuracy the antenna uses advanced technology to transmit radar waves in the pipe center. This virtually eliminates signal and accuracy degradation due to rust and product deposits inside the pipe. The still-pipe array antenna is made in versions suitable for installation on 5-, 6-, 8-, 10- and 12-in. pipes. It is available in a version enabling full pipe size product sampling or verification hand-dips. Installation is normally made with the tank in service.



[file: 5900S_Array_140_Label.jpg]

LPG/LNG Antenna

The LPG/LNG antenna is designed for level measurements on pressurized or cryogenic liquefied gas, such as LPG or LNG. Radar signals are transmitted inside the still-pipe which enables the gauge to have a sufficiently strong echo even under surface boiling conditions. The pressure seal is equipped with a double-block function, consisting of a quartz/ceramic window and a fire-proof ball valve. A pressure sensor enables volume correction due to vapor for best measurement performance. A reference device function enables measurement verification with the tank in service.



[file: 5900S_LPG_LNG_020_Label.jpg]

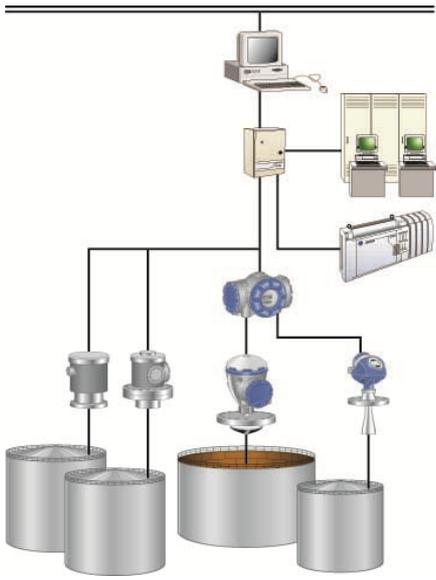
Emulation for step by step upgrades

In order to modernize existing tank gauging system step by step, the new tank gauging system must be compatible with other major tank gauging vendors.

With this compatibility, it is possible to replace old mechanical or servo gauges with modern radar level gauges using the existing tank openings, field cabling, and control system. The gauge is normally installed with the tank in operation. No hot work is required. A gauge seamlessly replaces another device, independent of measurement technology. Data from the integrated radar gauge is displayed as before on the existing inventory management system. By replacing old servo gauges, you can avoid re-calibration and the expenses associated with spare parts and maintenance.

It is also possible to seamlessly replace other tank management systems with a new tank gauging HMI software solution. Data from different types of units is then collected and displayed.

This solution provides system connectivity with existing field devices, often with a better update rate than before.



Caption: Gauge emulation [file: emulering_generic.eps]