



RADAR GAUGING

Hans Westerlind, Emerson,
Sweden, discusses the use of radar
to gauge LNG tank levels.

Radar based tank gauging has in recent years become widely used for level measurement and overfill prevention in LNG storage tanks. This non-contact method with no moving parts offers advantages in terms of accuracy, reliability and less maintenance. Radar is considered particularly suitable in applications like LNG where in-tank maintenance is only possible at scheduled maintenance periods taking place at several year intervals. Also the often long measuring distances in this application makes non-contact measurement an attractive alternative. Today, most specifications for LNG storage tank building projects specify radar for level measurement.

What is the tank gauging system used for?

Whichever technology is used, the automatic gauging system is a critical part of the LNG site's instrumentation. A typical storage tank for LNG holds more than



Photo courtesy of the Center for Liquefied Natural Gas.

Figure 1. Automatic tank gauging is an essential part of the instrumentation both on shore tanks and on ships.

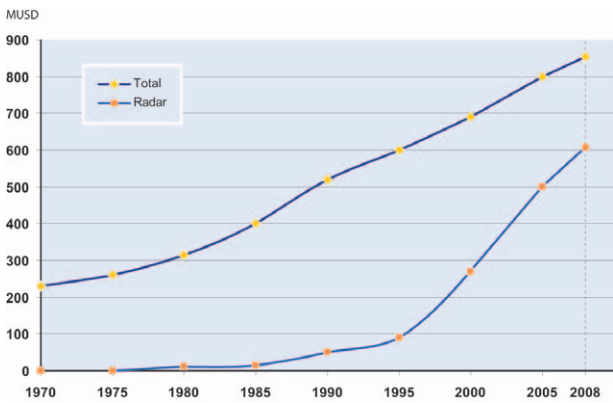


Figure 2. Radar market share as proportion of delivered tank gauges per year.

50 000 m³, representing a value of approximately US\$ 15 million. From an economic, operational and safety aspect, the data measured by the tank gauging system has a large impact.

Normally the following quantities are measured:

- Level.
- Average liquid temperature.
- Skin temperature.

Sometimes also the density and temperature profile is measured.

The measured values are used for the following tasks:

- Operation of the plant during filling and emptying of tanks.
- Skin temperature monitoring during cool-down.
- Safety management and overflow prevention.
- Inventory measurement.
- Monitoring the density profile to prevent rollovers.

In order to perform the above functions adequately, most project specifications stipulate an inherent instrument accuracy of 1 mm or better for level measurement.

As undisturbed operation is of vital importance, more than one instrumentation component is often used for the same purpose in order to have redundant functionality.

An important tool to get accurate volume calculations is the tank calibration table, which is the conversion table between level and volume. The more strapping points the more exact conversion can be made.

All gauging data is collected by an LNG management system for process and storage recording. In addition, data is normally communicated to the DCS system.

Radar compared to other methods

The radar method has been used for cargo tank contents measurement in marine tankers since the 1970s. The world's first radar system with approved custody transfer accuracy for LNG ships was delivered in 1996, and it soon became the preferred method replacing earlier used capacitance-based gauges.

For land based tank terminals and refineries the radar method was introduced around 1986. It has continuously increased its share of the market for high precision bulk liquid management as can be seen in Figure 1. More than 100 000

radar gauges for this application have been put into operation so far.

For land based LNG level measurement the two most common types of gauges used today are mechanical servo gauges and radar gauges (radar is also referred to as microwaves). The first installation of land based radar gauges for LNG was made in the 1990s in a large semi-underground storage tank owned by Tokyo Gas in Japan.

In principle, radar tank gauging is based on a microwave signal transmitted towards the liquid surface and reflected back. The beam propagation can be either free, or a still-pipe can be used as a wave-guide. LNG measurement is always made with a still-pipe.

The mechanical servo-operated gauge

relies on a mechanical displacer attached to a wire on a drum. The displacer is lowered by the servo motor to the liquid and follows the surface movements.

The radar method has the following qualities compared to mechanical gauges:

- No contact with the liquid.
- No moving parts.
- Maintenance and measurement verification can be done without opening the tank. No large diameter ball valves or calibration chambers are required.
- Suitable for long measuring distances in, for example, underground storage tanks or caverns where distances can exceed 100 m.

Most high accuracy microwave tank gauges are based on the frequency modulated continuous wave method (FMCW). The gauge transmits microwaves towards the surface of the liquid.

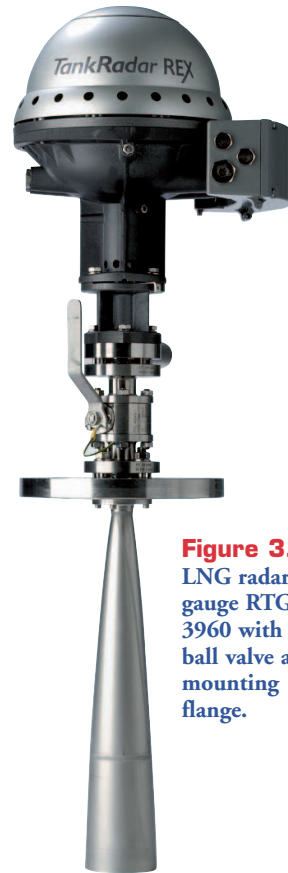


Figure 3. LNG radar gauge RTG 3960 with ball valve and mounting flange.

The signal has a continuously varying frequency around 10 GHz. 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 frequency of the transmitted signal has changed slightly during the time it takes for the echo signal to travel down to the surface and back again. When mixing the transmitted and the received signal the result is a signal with a low frequency. This frequency, which is accurately measured, is proportional to the distance to the surface.

Microwave based gauging systems have a wide range of international custody transfer certifications including the 'International Organization of Legal Metrology' (OIML). Major oil companies often stipulate a higher degree of accuracy for radar gauges than for servo-operated gauges.

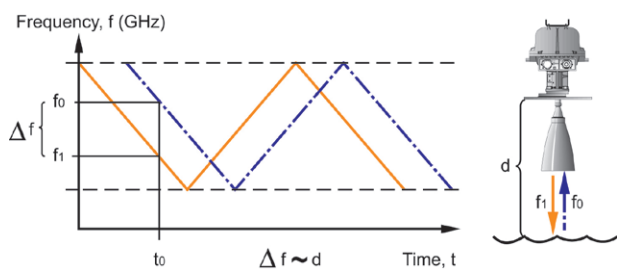


Figure 4. The FMCW method is based on a radar sweep with varying frequency.

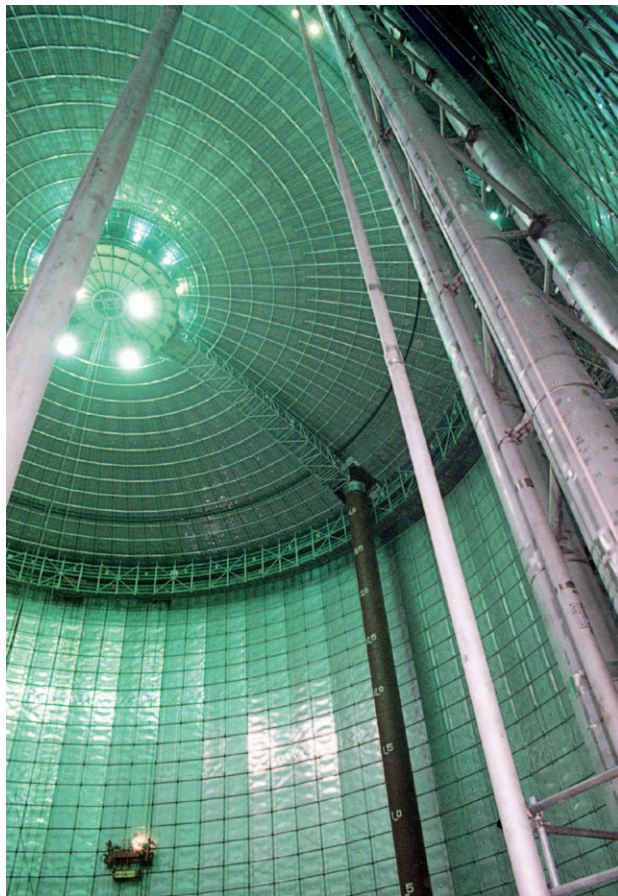


Figure 5. Piping including still-pipes for radar gauges in Japanese 60 m deep underground storage tank.

Special considerations for radar in LNG applications

Since LNG has a dielectric constant of 1.5 which is less than most hydrocarbons, only a small percentage of the microwave power sent towards the surface is reflected; the rest penetrates the liquid. In addition, the surface of the LNG can in some cases be boiling - further reducing the reflected power. In order to get a sufficient signal, a 100 mm (4 in.) still-pipe is normally used to contain the radar signal which increases the proportion of the signal power that reaches the antenna. The still-pipe is perforated over its entire length to allow liquid and vapour to flow freely to and from the tank outside the pipe.

As the tank is closed when operated there is no possibility of verifying level measurement with hand dips as is the case with most other hydrocarbons. However, the use of the still-pipe allows one or more reference pins to be attached to the pipe. The distance to the pins is known, and by altering the microwave mode from the outside the gauge can measure against the pins, allowing a check of the measurement when the tank is in operation.

For cryogenic LNG there is no need to individually compensate for gas composition, as is the case with LPG tanks where the propagation velocity of microwaves somewhat depends on variations in pressure and temperature, as well as the specific proportions of butane and propane.

Overfill prevention: a critical function

Safety and overfill prevention is a major concern for any tank facility used for bulk liquid storage of flammable liquids. Many of the first applications of radar on LNG were for independent overfill prevention combined with a mechanical servo gauge.

For example, the radar based RTG 3960 LNG gauge has been assessed by an independent third party and considered suitable for use in SIL 2 safety functions, according to IEC 61508/61511. This device is also TÜV-tested and approved for overfill protection according to the German WHG regulations. In addition, the RTG 3960 gauge is designed to meet the API standards.

The safety function is based on the relay outputs, by using either one or a combination of two, for overfill or dry run protection. The relay outputs are entirely separated from the digital data bus with measured values.



Photo courtesy of the Center for Liquefied Natural Gas.

Figure 6. LNG regasification plant.

Typical system scope for an LNG storage facility

Instrumentation requirements for contents measurement vary depending on specific site configuration. To illustrate available options, a description of the Rosemount Tank Gauging equipment for a complete LNG gauging package is given as follows:

LNG Radar Level Gauge RTG 3960

The RTG 3960 gauge is designed for radar level measurement of LNG tanks (or LPG tanks). A still-pipe enables the gauge to have a sufficiently strong echo even under surface boiling

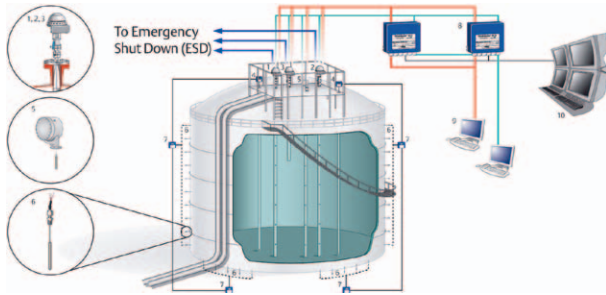


Figure 7. LNG storage facility.

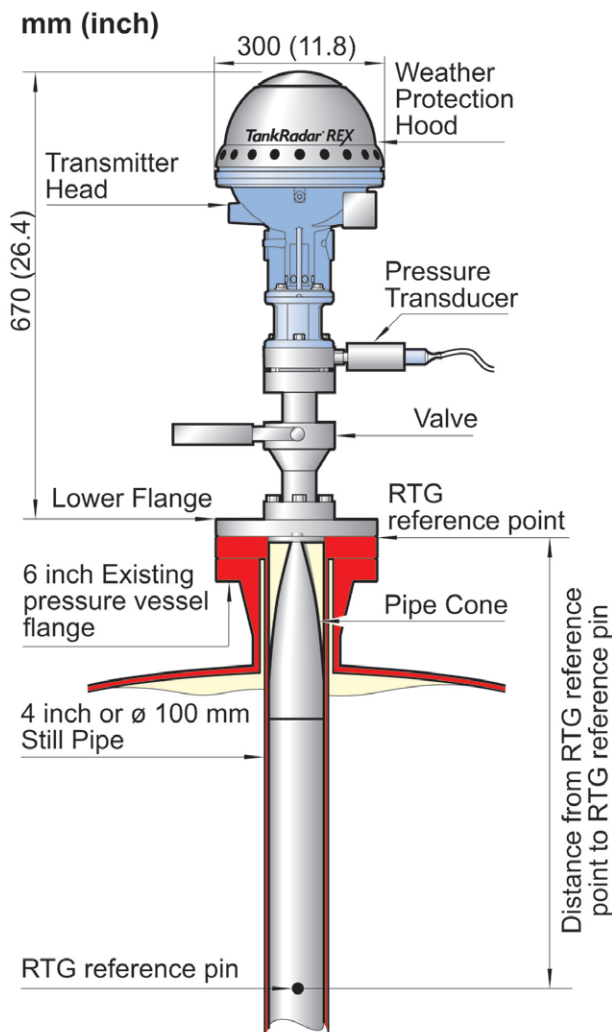


Figure 8. The gauge measures the distance from a reference point to the surface (ullage), which is then recalculated into level.

conditions. The radar signals are transmitted inside the still-pipe equipped with reference pins. The tank sealing is a quartz/ceramic window approved for use in pressure vessels.

RTG 3960 measures the liquid level with an instrument accuracy of 0.5 mm (0.020 in.). The gauge can emulate most other gauges when integrated into an existing system. If redundant communication is required, the RTG 3960 communicates simultaneously via different protocols or buses.

The gauge is equipped with a fireproof ball valve between the transmitter head and the cone antenna which is located inside the tank. If needed, the transmitter head, which contains all electronics, can be switched without taking the tank out of service. Installation is made with the liquid gas tank taken out of operation. Normally at least two gauges are mounted on each LNG tank.

MST Cryo Multiple Spot Temperature Sensor

A multi-spot thermometer (MST) is used to measure average liquid temperature in cryogenic applications with temperatures down to -170°C (-274°F). The sensor can have up to 14 elements positioned at different heights in a stainless steel tube housing.

Cool Down and Leak Detection sensor

This is a small (6 mm diameter) temperature sensor that accurately measures tank shell temperature in order to provide cool down control and leak detection. The stainless steel sheath is made in customised lengths ranging from 0.3 - 200 m.

Field Communication Unit 2160/2165/2175

This Field Communication Unit (FCU) is a data concentrator that continuously polls data from field devices such as tank gauges, LTD profile meters, Data Acquisition Units, I/O Modules and other FCUs. The FCU stores data in a buffer memory and can service requests from any hosts and/or DCS systems using the Modbus protocol.

Data Acquisition Unit 2100

The Data Acquisition Unit (DAU) is used for connection of the MST Cryo temperature sensors to the tank gauging system, as well as for local level and temperature read-out. The intrinsically safe DAU is powered from the RTG 3960 gauge, and also communicates through the gauge.

Level Temperature Density Profiler Gauge 1146

This is a Level, Temperature and Density (LTD) gauge based on Whessoe's single body concept. The LTD gauge samples 250 data points to construct a detailed and accurate temperature and density profile. Density and temperature profiles make it possible to detect liquid stratification in the tank. Communication is made via a redundant Modbus. The LTD has a local digital display, showing both measured and diagnostic data.

LNG Management software

The LNG Manager software monitors and displays, in real time: detailed tank information (level, temperature, density, trends), alarm events (periodic or on-demand

reports), and shutdown alarm parameters. It uses standard and customised databases for volume correction calculation.

The LNG Expert software is based on Gaz de France's LNG Master. It handles all grades of LNG and automatically calculates their actual chemical composition. It continuously monitors data and calculates the expected evolution of possible stratifications.

In the event of a coming LNG rollover, it generates automatic alarms showing the remaining time to rollover, predicted boil-off gas (BOG) level during rollover, and predicted pressure (rise) during rollover.

Wireless can be used to reduce cabling

In order to reduce field cabling cost, a system using radar only for level measurement can use wireless transmission.

Emerson's Smart Wireless concept is based on WirelessHART, the emerging industry standard for wireless field networks. It allows tank gauging devices to communicate with each other. Since every device serves as a network connector, there is no single point of failure.

WirelessHART devices can transmit their own data as well as relay information from other devices in the network. The self-organising mesh network automatically finds the best way around any fixed or temporary obstacle. Nodes can identify a network, join it, and self-organise into dynamic communication paths. Reliability increases when the network expands; the more devices, the more communication paths.

Installation examples

Radar is used as a primary or secondary level gauge or high level alarm in over 30 LNG storage facilities around the world. Some examples of such installation are given below:

Qatargas II project, Qatar

The project includes a complete system delivery for five tanks, made in October 2007. Each tank is equipped with:

- Three radar gauges, type RTG 3960, mounted on still-pipes. One gauge is used as a primary level device, another is used for secondary level and the third for Hi-Hi and Lo-Lo alarm detection. In this project, radar is the preferred technology for all three independent measurements.
- Two LTD Level, Temperature and Density profilers.
- One dedicated PC with inventory and management software in the control room. Tank data is also fed into a DeltaV host computer system.

Qatargas II comprises some of the world's largest Prestress Concrete LNG storage tanks, 50 m high and with a net capacity of 140 000 m³ each.

IHI (Ishikawajima-Harima Heavy Industries Co. Ltd) is responsible for tank construction and instrumentation within the project. The Qatargas II project is split between Qatar Petroleum (65%), ExxonMobil (18.3%) and Total (16.7%).

Fluxys Zeebrugge receiving terminal, Belgium

One more tank was built and installed at the existing terminal in 2007. The instrumentation includes:

- Two high precision RTG 3960 radar gauges for secondary level and Hi-Hi alarm.
- One Multi-spot Thermometer (MST).
- One LNG Manager inventory software license.
- One Level, Temperature and Density profiler.
- Two servo gauges for primary level and Hi-Hi alarm.

Golden Pass LNG, receiving terminal, Texas, USA

The main contractor for this project has specified the following instrumentation for the five tank site:

- One high precision RTG 3960 radar gauge per tank for primary level measurement.
- One Multi-spot Thermometer (MST), per tank.
- One LNG Manager inventory software license.
- One Level, Temperature and Density profiler per tank.

Freeport receiving and regasification terminal, Texas, USA

Two tanks are equipped with radar for all level applications. The delivery included:

- Three high precision RTG 3960 radar gauges per tank; for primary and secondary level, plus a third device for Hi-Hi alarm.
- Two Multi-spot Thermometer (MST), per tank.
- Tank management software.
- One Level, Temperature and Density profiler gauge per tank.
- Zachry was the contractor responsible for instrumentation.

Cheniere, Sabine Pass LNG terminal, Louisiana, USA

Each of the five tanks is equipped with:

- One high precision RTG 3960 radar gauge, for secondary level measurement.
 - Two servo gauges, for primary level and Hi-Hi alarm.
 - One Level, Temperature and Density profiler.
 - MHI (Mitsubishi Heavy Industries Co. Ltd) was responsible for tank construction and instrumentation.
- Some more examples of sites using radar are:
- Nynashamn Gas Terminal, Sweden.
 - Map Ta Phut LNG Terminal, Thailand.
 - Pluto LNG Project, Western Australia.
 - Trunkline LNG Co., Lake Charles Terminal in Louisiana, USA.
 - Xing Xing Energy's LNG Plant in Erdos, China.
 - In addition, RTG 3960 radar gauges have been used for more than 10 years to measure levels at several LNG import terminals in Japan. Many of these tanks are large with a storage capacity of up to 200 000 m³ with a height of 65 m. **LNG**