White Paper
WP-TM-705
2019-12-01

Innovative Radar Solution Provides Accurate and Reliable Tank Level Gauging in LNG Marine Fuel Tanks

ROSEMOUNT™

EMERSON™

Abstract

An increasing number of ships are using liquefied natural gas (LNG) as a marine fuel because it emits almost zero sulfur and therefore enables operators to comply with strict new emissions regulations and mandatory safety requirements. Every LNG fuel tank on a ship must be fitted with a liquid level gauging device to provide constant awareness of how much fuel is in the tank. However, the design of typical LNG fuel tanks, and the cryogenic temperatures involved, create certain challenges for level measurement technologies. This paper explains how non-contacting radar transmitters meet these challenges and can be used to provide accurate and reliable level, high-level and overfill measurements.

LNG as a Marine Fuel

From 1st January 2020, the International Maritime Organization's new IMO 2020 regulation will require ships to significantly reduce the amount of sulfur contained in the fuel they use for their propulsion. The aim of this regulation is to diminish the levels of sulfur oxides (SOx) being emitted from ships, which should consequently have a positive impact on both human health and the environment. Heavy fuel oil (HFO) is the most widely used marine fuel, but it produces emissions that contain high levels of SOx. An approach that is gaining momentum as a means of ensuring compliance with IMO 2020, is to use LNG as a marine fuel, rather than HFO. LNG emits almost zero sulfur and in addition, its nitrogen oxide (NOx) emissions are lower than those of HFO or marine gas oil (MGO). This has led to a sharp increase in the number of ships around the world being fueled by LNG.

LNG Fuel Tanks

One of the most prevalent technologies used in LNG fuel tank design is vacuum insulation. A ship will typically carry one or two vacuum-insulated fuel tanks, most commonly of the horizontal bullet type. Each tank consists of two pressure vessels, one of which is installed inside the other. A vacuum is maintained in the annular space between the inner and outer vessels (typically 250-300 mm), to reduce the convective heat transfer. In addition, the annular space is filled with an absorptive material to reduce the heat transfer due to radiation. Vacuum-insulated tanks are typically 3-7 m in diameter, with a volume of around 25-500 m³.

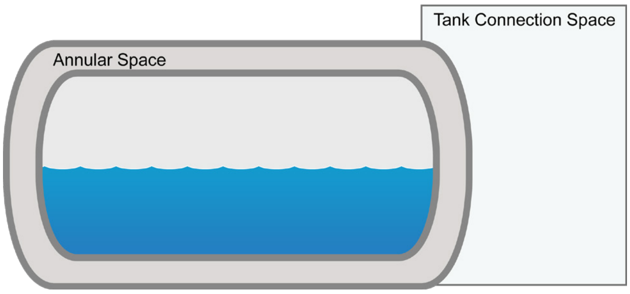

Figure 1: A typical LNG fuel tank design

The Need For Level Measurement

The International Maritime Organization's IGF Code, which came into force on 1st January 2017, covers ships that use gases or other low-flashpoint fuels, including LNG. This mandatory code of safety aims to minimize the risk to ships, their crews and the environment, given the nature of the fuels involved. The code regulates the installation, control and monitoring of machinery, equipment and systems, and stipulates that each LNG fuel tank on a ship must be fitted with a liquid level gauging device. This ensures that a level reading is always obtainable whenever the tank is operational, thereby providing constant awareness of how much fuel there is in the tank.
In addition, each tank must be fitted with an independently operating high-level transmitter as well as an additional overfill prevention transmitter.

Differential Pressure and Radar Transmitters

Accuracy and reliability are vital requirements when implementing level measurement instrumentation. One technology that is regularly considered for installation on ships propelled by LNG is differential pressure (DP) transmitters. In general, this technology is economical, easy to use and well understood. However, variations in density, volume and temperature, all of which are typical of LNG fuel tank applications, will considerably impact the accuracy of DP transmitters.

Non-contacting radar technology provides more accurate and reliable level, high-level and overfill measurement solutions that are well proven in LNG applications. Non-contacting radar transmitters do not require calibration, and do not need to compensate for changes in density, dielectric or conductivity of the fluid. In addition, they have no moving mechanical parts, which therefore minimizes their maintenance requirements.

Non-contacting radar transmitters use one of two main modulation techniques – either pulse or frequency modulated continuous wave (FMCW) – to perform continuous level measurements.
To reliably measure the level in an LNG fuel tank, a radar gauge needs a sufficiently strong echo from the surface. The sensitivity of transmitters based on FMCW technology can be more than 30 times higher than that of pulse transmitters. This means their signal strength is much greater, enabling superior measurement accuracy and reliability. The latest developed non-contacting radar transmitters are available as two-wire devices, which enables simple installation while still providing the same high amount of data and diagnostics that would normally require four wires.

Safe Installation

Non-contacting radar transmitters typically provide a top-down, direct measurement of the distance to a surface. However, the design of vacuum-insulated LNG fuel tanks makes installing these devices at the top of the tank challenging and a safety risk. A top-down installation would require the use of an expansion joint, also known as a bellow, to absorb the changes in dimension that occur when the inner vessel contracts due to the cryogenic temperatures involved. However, bellows are undesirable, as they are not only complicated to design but also costly, as they would need to be constructed from stainless steel to maintain toughness at cryogenic temperatures. In addition, the use of a bellow would increase the size of the tank penetration. This is undesirable because it would also increase the convective heat transfer, thereby raising the temperature of the LNG and causing it to vaporize more quickly.

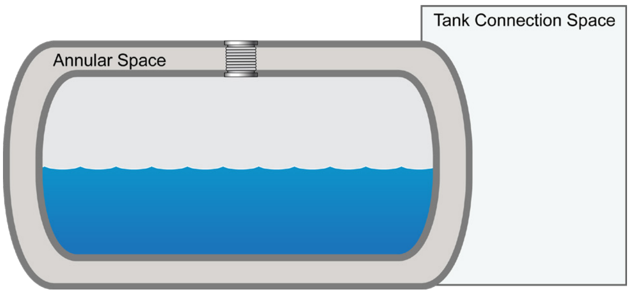

Figure 2. An unwanted solution with the bellow

Bended Piping

To eliminate the need for a bellow, a bended still-pipe can be used with the radar transmitter. Rather than being installed on top of the tank, the piping penetrates the outer vessel from the tank connection space located at its side. The piping then extends through the annular space between the outer and inner vessels, before penetrating through the top of the inner vessel. The same type of bended piping can also be used for the radar transmitters serving as high-level and overfill prevention transmitters, thereby providing a consistent, proven solution that reduces complexity.

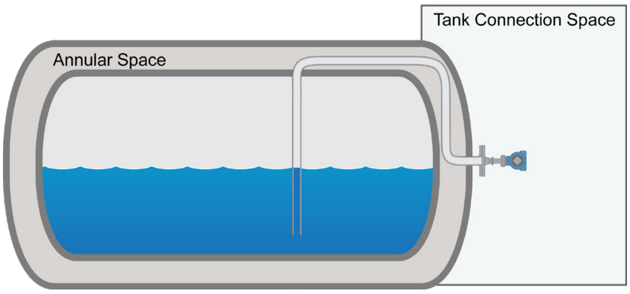

Figure 3. Horizontal C-tank with a bended still pipe entering from the tank connection space

Still-pipe Selection

The use of a still-pipe to guide and contain the microwave signal can further increase the reliability and robustness of the level measurement. However, it is essential to select the correct size of pipe for the specific application. When a radar transmitter is used with a bended still-pipe, more than one microwave mode is generated, and each mode has a unique propagation speed. The number of microwave modes that are generated varies with the frequency of the radar signal and the diameter of the piping. However, as more microwave modes leads to more signal echoes and therefore reduces measurement accuracy, it is desirable to minimize the number of modes generated. Making the diameter of the bended piping as small as possible would achieve this. However, other factors that must also be considered are the amplitude of the microwave signal within the piping, and the measurement distance required.

The smaller the pipe diameter, the more the signal amplitude is weakened, hence this results in shorter measurement distance. In the bigger LNG fuel tanks, measurement accuracy is required over a larger distance, which means that the piping diameter must also be larger, to enable a stronger microwave signal. Taking these factors into account, it is recommended that a bended pipe solution with an inner diameter of between 13.5 mm and 16 mm is used, which will provide an industry-accepted measurement accuracy of ±20 mm over a distance of up to 10 meters.

Conclusion

The use of non-contacting radar transmitters with bended still-piping provides an innovative level, high-level and overfill measurement solution in vacuum-insulated LNG fuel tanks. Radar technology is proven to deliver accuracy and reliability in challenging LNG applications. Using bended still-piping enables the radar transmitters to be installed in the tank connection space at the side of a fuel tank's outer pressure vessel, rather than at its top. This ensures accuracy over the measurement distance required in these tanks, while also eliminating the need for complex and costly bellows. In the end proving a safe and reliable solution for the operators.

To learn more about Emerson's marine solutions, visit Emerson.com/marine.

Emerson Automation Solutions
Rosemount Tank Radar AB
Box 150
SE-435 23 Mölnlycke
Sweden
T +46 31 3370 000
www.Emerson.com/marine