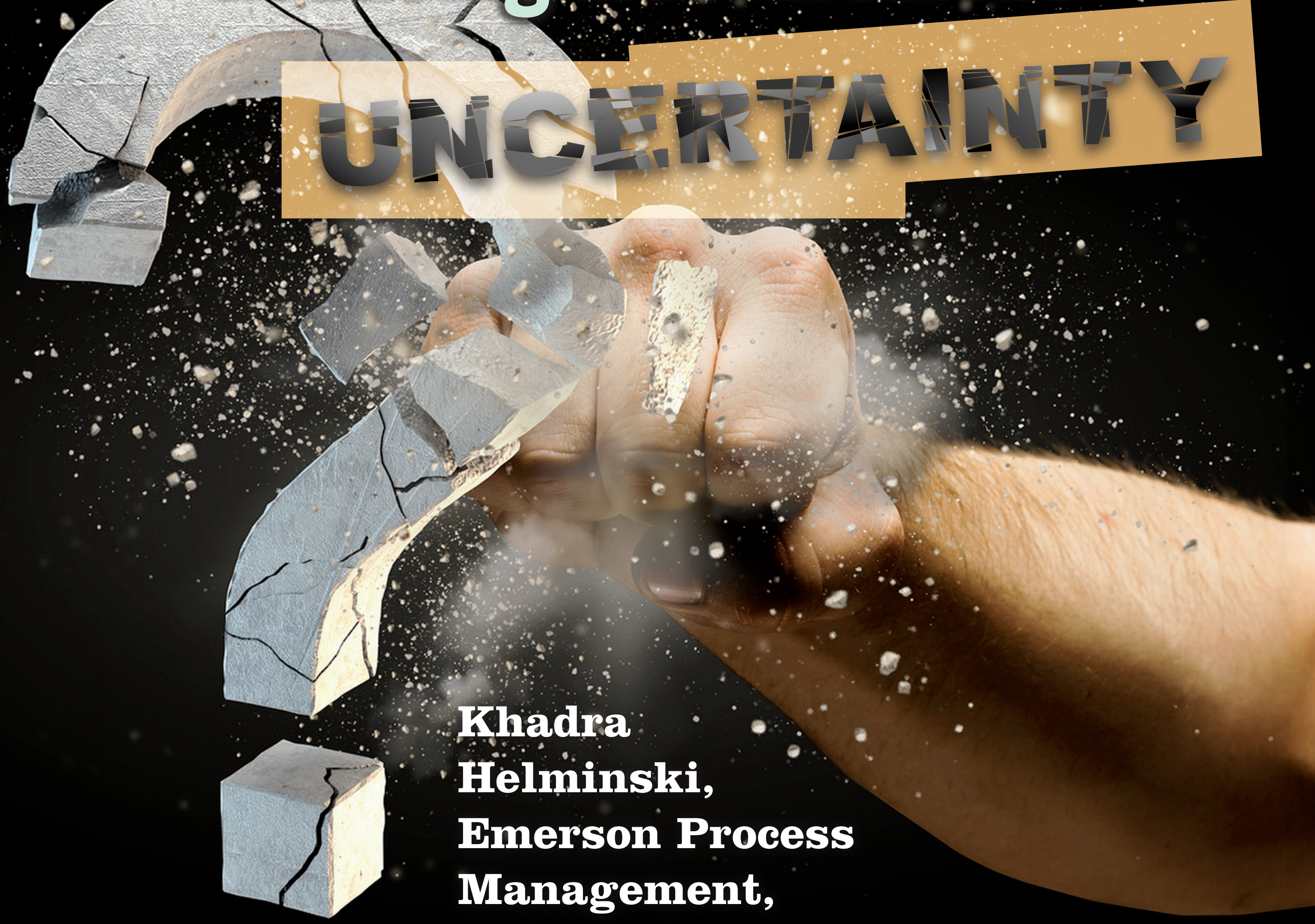
Reducing measurement UNCERTAINTY



Khadra Helminski, Emerson Process Management, looks at dynamic and static measurement methods of LNG.

The global LNG industry is expected to grow by nearly 40% from 2012 to 2016. Increasing demand in Asia is driving export markets in Australasia and the Middle East. With the surge of gas production from shale plays, North America is positioned to become a key export player by 2016.

Europe's importation of natural gas as a major source of clean energy has increased due to efforts to reduce emissions. A considerable amount of this imported gas is in the form of LNG and Europe is therefore expanding its LNG capacity. Capital expenditure in LNG is forecast to increase in the next five years following a decline from 2009 to 2011 due to the beginning of the global recession, as well as a number of facilities coming onstream or entering the final stages of construction.

A typical liquefaction plant moves US$ 4 million/hr of LNG during loading and unloading. With such huge fiscal transactions in the LNG market, measurement accuracy is directly tied to financial exposure and risk in LNG custody transfer. A 0.2% reduction in measurement uncertainty would equate to a US$ 12 000/hr reduction in financial risk. Attention is being directed to the discovery of new measurement methodology to reduce measurement uncertainty and provide traceability of both static and dynamic measurement methods of LNG volume during custody transfer.

LNG trade in perspective

LNG trade has generally been based on long-term, 20-year contracts. Within the context of long-term sales agreements, the industry has mainly used and accepted measurement of tank volume as an established procedure that is understood, inspected and agreed by both parties. Static LNG volume measurement based on tank level gauging has an estimated best uncertainty of ±0.5% under ideal measurement conditions and for large volumes, while the overall measurement uncertainty of ±0.15% is the standard in the transfer of oil or natural gas products (see Table 1). There is general consensus that dynamic LNG flow metering will provide for much higher accuracy in the range of 0.15% - 0.20%, provided there is a means to calibrate the LNG flow meters.

The demand for LNG flow measurement will increase in the future due to:

- The preference for custody transfer to be based on more accurate measurements by all stakeholders in the LNG chain, especially with the emerging LNG spot market where volumes are typically smaller.
- The trend towards floating offshore production, storage/bunkering and regasification of LNG. Sloshing of LNG due to the constant movement of offshore tanks hinders tank level measurements.
- Recent developments with a common LNG production facility where operators share storage capacity and flow meters are used for the allocation of ownership.
- The need for accurate book keeping (mass balance) of both the incoming and regasified LNG for operational and governmental regulation (emission) purposes.

Table 1. The GIIGNL Handbook reports accuracies of measurement parameters used in the energy calculation formula and the overall uncertainty determining the LNG energy transferred

Element calculated	Total accuracy (%)
Volume	±0.21
Density	±0.27
Gross calorific value	±0.35
Overall LNG energy transferred	±0.49

$$E = (V_{LNG} \cdot D_{LNG} \cdot GCV_{LNG}) - E_{gas\ displaced}$$

where

E	Energy transferred. (MMBTU)
V_{LNG}	LNG volume (m^3)
D_{LNG}	LNG density (kg/m^3)
GCV_{LNG}	LNG gross calorific value (MMBTU/kg)
$E_{gas\ displaced}$	Energy of the gas displaced during the transfer of LNG (MMBTU)

Equation 1. To determine the amount of energy exchanged, LNG custody transfer is based on energy transferred. The transferred energy is calculated using this formula.

Static LNG volume measurement

The standard method of measuring the volume of LNG loaded from production facilities into an LNG carrier or unloaded from an LNG carrier to a receiving terminal is made in the form of energy transferred – the quantity invoiced is the LNG energy that is transferred. The energy transferred is calculated using a formula where the following elements must be measured:

- LNG volume.
- LNG density.
- LNG gross calorific value.
- Energy of the gas displaced during the transfer of LNG.

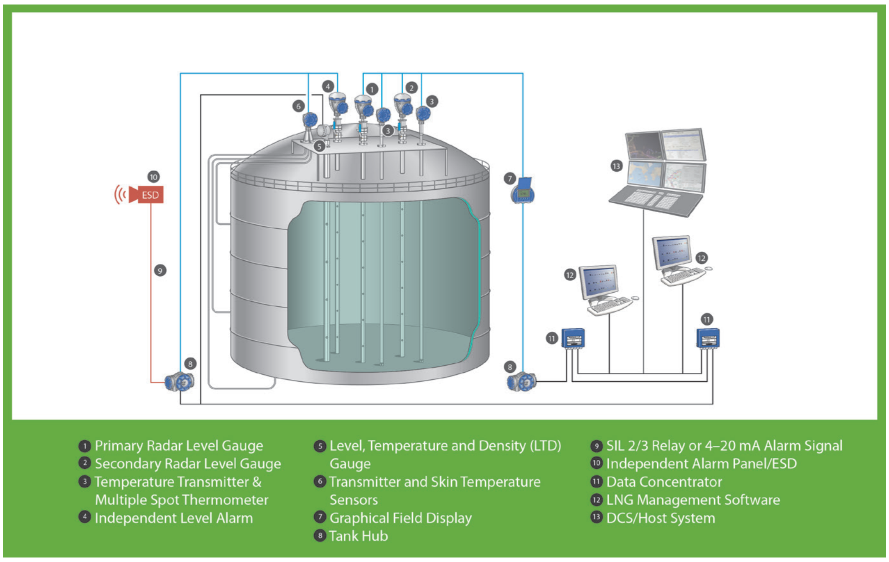


Figure 1. Example of a high performance LNG tank gauging system. (Courtesy of Rosemount® Tank Gauging.)

This static measurement method (see Equation 1) is described in more detail in the International Group of Liquefied Natural Gas Importers Handbook (GIIGNL).[1] The core of this formula is that measurements of liquid volume are made in the ship's tanks rather than measuring the mass or volume flowrate in the transfer lines.

Measuring the volume of LNG transferred is typically based on the use of level gauges and calibration tables, as well as correction factors for trim, list and tank contraction. Capacitance and radar level gauges are widely used as primary custody transfer systems onboard LNG tankers, supported by float gauges as a secondary custody transfer system. Laser gauges were recently introduced to the industry and they are used in a few LNG carriers. Temperature probes distributed over the height of the LNG carrier tanks are also required for the determination of LNG volume (see Figure 1).

The density of LNG is calculated from the average composition obtained from LNG sampling and gas chromatographic analysis, and from the temperature of the LNG measured in the carrier's tanks.

The gross calorific value is calculated based on the composition of the LNG.

Energy of the gas displaced during the transfer of LNG is determined by sampling and analysing the gas displaced and by measuring the pressure and temperature of the gas inside the carrier tank.

The formula for calculating the LNG transferred also depends on the contractual sales agreements. In some agreements, the invoiced LNG transfer is made in the loading port, while other agreements determine the energy transferred in the unloading port. In all cases, energy is calculated using the same formula.

Considering LNG flow metering

With increasing amounts of LNG being traded in short-term (spot) contracts, there is growing demand for dynamic and more accurate measurement of delivered LNG flow, as is currently the case for custody transfer of oil shipments. Additionally, to mitigate risk and high capital costs, shared liquefaction facilities and storage capacity has become more common among producers. This implies capital infrastructure costs would be reduced through shared facilities if LNG could be measured dynamically and allocated to different owners sharing loading and ship facilities. However, there are many challenges that face LNG flow measurement including:

- Lack of large scale cryogenic flow laboratories to calibrate meters at conditions similar to operating conditions.
- Lack of traceable calibration system for inline flow meters at large LNG flow rates.
- The effects of the cryogenic temperature of LNG on the performance of flow metering equipment.
- The unsteady nature of LNG – it is stored and transported at cryogenic temperatures close to its boiling point. As a result, LNG can easily become a two-phase liquid if there are hot spots in the pipeline or if there is an excessive pressure drop anywhere in the system.
- Potential sources for lost and unaccounted for (LAUF) gas in LNG terminals as a result of discrepancies between calculation standards for LNG and natural gas.

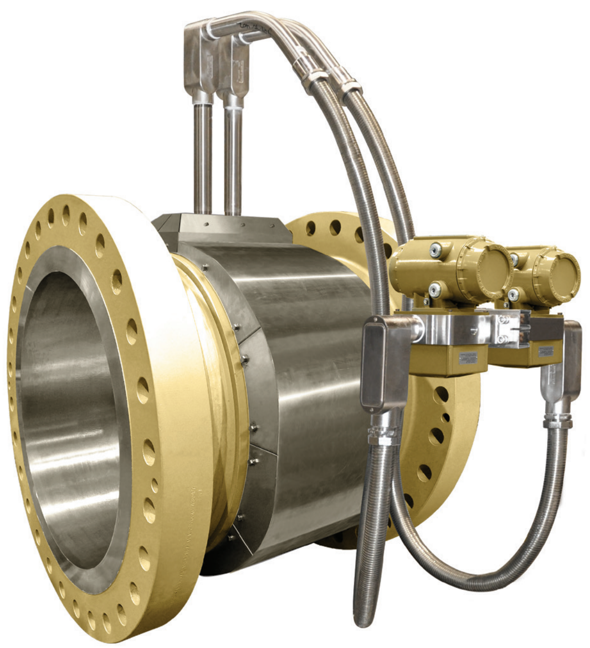


Figure 2. Daniel™ 3818 LNG Ultrasonic Meter with an insulation packaging, cable routing design and termination cables specifically designed for use at cryogenic temperatures.

These factors have led to developments in LNG flow measurement technologies, including Coriolis and ultrasonic meters.

Ultrasonic meters

Ultrasonic flow meters are full-bore meters with no internal moving parts to wear or drift, providing for low pressure drop and minimising the risk of LNG flashing. Also available in large sizes, ultrasonic meters are well suited for high volume LNG transfers, which equates to faster tanker loading and offloading. Ultrasonic metering technology is ideal for high volume jetty loading as well as rundown lines to storage, whether co-mingled or dedicated, enabling producers and receivers of LNG to double-check measurements seen on ships' gauges.

Some ultrasonic meter manufacturers have developed specific solutions for LNG applications (see Figure 2). These include:

- Transducers specifically designed for use at cryogenic temperatures.
- Meter insulation packaging to reduce contact points to the meter body and avoid heat sinks and hot spots.
- Utilising a correctional model for changes in meter geometry as the flow tube is exposed to cryogenic temperatures.
- Full redundancy for continuous long-term reliable operation.

Ultrasonic meters also provide functional and process diagnostics. Access to real-time flow data allows plant managers to manage the flow rate of the LNG, thereby reducing the amount of hydrocarbon lost as boil-off gas (BOG). It is estimated that a 0.1% reduction of LNG lost to BOG as a result of a lack of measurement process control equates to US$ 3 million/year.

Coriolis meters

Coriolis meters measure mass flowrate while ultrasonic meters measure volume flow rate. Since the gross calorific value is expressed per unit mass, Coriolis meters have a potential advantage over ultrasonic meters, due to their ability to measure flow rate directly and avoid the need for density calculations (see Figure 3). However, ultrasonic meters have the advantage of a lower pressure drop and less potential for flashing the LNG within the line. In addition, the relatively small size of Coriolis meters would require parallel installations to accommodate high flow rates in LNG deliveries.

Calibration of LNG flow meters

Calibration of flow meters has been relying on transfer from water data to LNG. Transferring the results of water calibration to other media carries uncertainties about the effects of the LNG cryogenic temperature on flowmeters, and the impact of the low viscosity of LNG.

The National Institute of Standards and Technology (NIST) Cryogenic Flow Facility in Boulder, Colorado, USA, is the only known facility capable of calibrating meters in cryogenic liquids. The NIST facility has been used successfully for proving cryogenic calibration concepts. The working fluid is liquid nitrogen, which has a similar viscosity to that of LNG.

The facility's uncertainty levels are comparable to current facilities used to calibrate natural gas custody transfer meters. However, the low flow capacity of the facility hinders its ability to directly calibrate large diameter flowmeters required for LNG custody transfer.

Various international standard-setting bodies and organisations, such as ISO, CEN, TUV, VSL, OIML, G.I.I.G.N.L, PTB, etc. are working to develop methods and equipment to further expand standards to the LNG industry. VSL is currently working on a research project under the European Metrology Research Program (EMRP). One of the objectives of the project is to develop an SI-traceable primary standard for calibrating LNG flow meters. The first gravimetric LNG flow standard in the world that is currently under development at VSL will be tested, further optimised and used as a starting point for developing large scale calibration facilities.

The best of both worlds

It is recommended to supplement traditional static measurement techniques by adding flow metering points to LNG transferred into, within, and out of the terminal to improve operational efficiency and reduce lost-and-unaccounted-for (LAUF) quantities due to:

- Errors in tank volumes related to tank manufacturing and strapping tables.
- Changes in tank volumes due to continual temperature cycling.
- Errors in terminal inventory created by LNG movements during tank measurements.
- Errors related to ship loading and offloading dynamics (list, trim and tank corrections).
- Unaccounted for BOG and flared gas.

Conclusion

The need for more accurate LNG measurement becomes more evident when looking at the growing LNG spot market. A small measurement error is magnified because it is applied over a much smaller volume instead of a whole vessel load. At the same time, there is an incentive for shared LNG facilities due to significant savings on project costs. It is anticipated that flow metering will be increasingly used to improve accuracy of accounting

Figure 3. Micro Motion® ELITE High Capacity Coriolis.

systems and reduce cost. In this respect, the benefits of using ultrasonic metering technology in conjunction with the tank gauging system can be two-fold:

- Optimised process and improved efficiencies with the introduction of additional measurement points (e.g. run down lines). Plants that add flow metering have more data inputs to plant control systems. Better data leads to better decisions and ultimately better plant efficiencies and safety.
- Improved measurement accuracy to minimise risk associated with the custody transfer financial transaction. By adding a flow meter at the loading arms or jetty, operators will have a means of verifying the static measurement (which will be the contractually stipulated custody transfer technology). **LNG**

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