

Dynamic LNG Measurement

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Flow Management Devices

Abstract

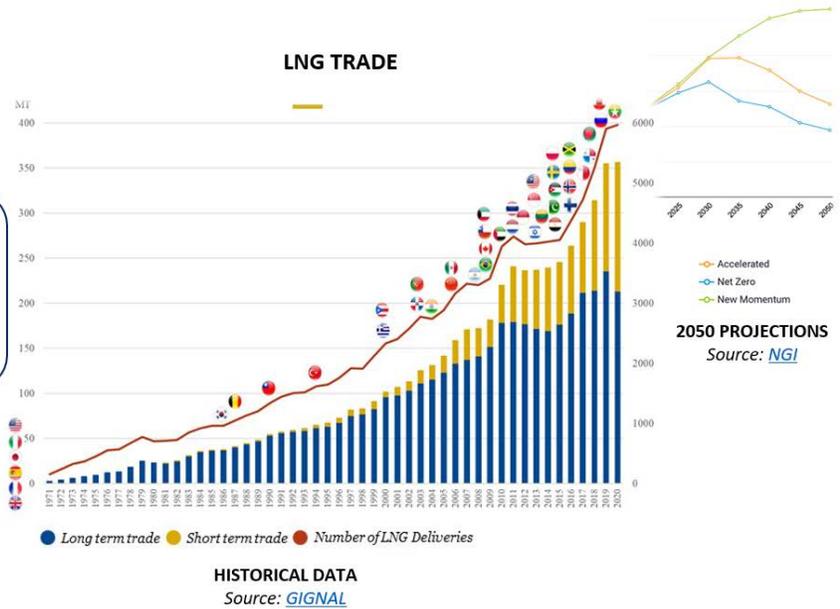
As the world searches for cleaner fuels and to reduce our carbon footprint, LNG (Liquified Natural Gas) transportation is increasing and presents the need to refine the measurement practices of LNG. NIST-LNG and GIIGNL measurement practices effectively state that LNG flow metering devices are currently calibrated using some type of reference fluid, i.e. water, due to the technology for low temperature process meter calibrations not yet existing. Calibrating meters on water versus under actual process conditions yields a loss in accuracy and significant losses over time. This process of calibrating meters is referred to as proving and the specialized equipment to do this is known as a prover. Calibrating a meter under process or actual flowing conditions allows for all process factors such as temperature, pressure, density, and other flowing conditions to be properly compensated for and in return offers up to ten times improvement on measurement accuracy. There have now been significant advances in low temperature metering and proving that allows for dynamic measurement of LNG. Through leveraging an installed base of cryogenic provers in similar low temperature products, ethane, propane, the same low temperature technology can be applied to LNG. The end result being improved LNG measurement accuracy, limit LNG losses, and ensure the world is accurately representing a true LNG capacity.

Intro

Countries and companies globally strive to minimize emissions, making the reduction of greenhouse gases a key objective. Natural gas, emitting only 0.97 pounds of greenhouse gases per kWh in electricity generation, stands out as one of the lowest-emission sources. The flexibility of gas turbines in quick response to electricity production makes natural gas an ideal partner for renewable energy sources. Consequently, global natural gas consumption has surged from 87 trillion cubic feet in 2001 to 144 trillion cubic feet in 2021, with projections indicating further growth.

Current geopolitical scenarios disrupted traditional flows of the natural gas and are pushing countries to look for alternative suppliers geographically far away. The volume of natural gas in its liquid state is about 600 times smaller than its volume in its gaseous state, making it easier for ocean transport. The global liquefied natural gas (LNG) import capacity is poised to expand by 16%, equivalent to 23 billion cubic feet per day (bcf/d) or 173 million tons per annum (mtpa) by the conclusion of 2024, in comparison with 2022. European nations are set to a substantial 36% increase in their regasification capacity by 2024 compared to 2022, while Asian countries, driven by a continually growing demand, are projected to augment their regasification capacity by 13%. The United States exported more liquefied natural gas (LNG) than any other country in the first half of 2023. Australia and Qatar reporting similar trends too.

350+ MT of LNG trade in 2020
 6000 LNG Deliveries in 2020
 All forecasting models show growth through 2030



This all leads to increased LNG exports from the US to Europe, Asia, and the Middle East among other regions. As the amount of global LNG trade goes up the importance for accurate measurement of LNG is also increasing. Throughout the past 10-15 years the technology of low temperature measurement has also significantly improved, namely technology around dynamic or “in-situ” proving of low temperature fluids. While a majority of other products, ethane and propane are accurately metered and proved under flowing cold conditions, or as vessels are unloaded and loaded, LNG is currently not. This presents a need for the LNG industry to adapt measurement technologies also used by similar cold products and ultimately improve measurement accuracy which results in savings to operators.

Regarding meter prover or to further explain what a prover is – a prover is a device that calibrates a meter. The prover verifies the volume recorded by a meter is accurate by displacing a known volume and correcting for flowing conditions. By proving under normal operating conditions or dynamic or “in-situ” proving the system is accurately measuring pressure, temperature, density, and flow rate all to verify the meter’s accuracy and reduce uncertainty. In simpler terms, a prover is often referred to as a syringe which displaces a known volume through a meter. Another explanation is, the prover is to the meter what a calibrated weight is to a scale.

Cost of Uncertainty

Amid this transformative landscape, the significance of accuracy in measurement cannot be overstated. Measurement uncertainties can have substantial economic implications. As more LNG infrastructure comes up, more players emerge in the field offering diverse services in the process pathway of LNG reaching end users necessitating custody transfer more often. One of the import terminal facilities under construction in Brunsbüttel, Germany is planned to have an annual nominal capacity of about 171 billion cubic feet (5 billion cubic meters). As of August 2023, the average LNG export price in the United States is \$6.45 for a thousand cubic feet. A measurement uncertainty of about 0.1% at this facility leads to a million-dollar discrepancy between buyer and seller annually. Furthermore, the uncertainty increases as the LNG is moved through multiple units, such as the receiving terminal, storage,

regasification, recovery, etc., making it more challenging to evaluate the productivity of each unit. Hence it is vital to evaluate the measurement methods employed in the industry.

Overview - Measurement Techniques

$$\text{Energy transferred} = \overbrace{(\text{Volume transferred} * \text{Density})}^{\text{Mass}} * \text{Gross Calorific Value}$$

The majority of LNG fiscal transactions are in terms of the total energy value of the cargo. To determine the energy values, measurements are required of the mass and gross calorific value. The primary aim of measurement is to accurately represent the entirety of the batch/cargo with a reasonably low uncertainty. In addition, measurement accuracy helps to better account for a variety of loss factors, such as fugitive emissions, BOG management efficiencies, transportation consumption, etc.

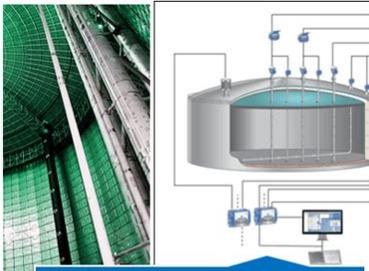
The density of LNG can be determined in two ways, measurement of the value with a densitometer or calculations based on the average composition. The revised Klosek-Mckinley method is one of the common calculation techniques. It is based on an empirical assessment that takes the composition and temperature of LNG into account. Density is obtained from the mixture's molar volume. The GIIGNL Handbook appendix 12 states that the standard uncertainty in density measurement from more than 10,000 observations is 0.23%.

Gross calorific value can be determined or measured using both empirical and experimental methods. Various calorimeter types are used according to system, availability, and location. Empirical techniques depend on the fluid's composition. GCV measures have standardized errors of between 0.04% and 0.07% (GIIGNL Handbook appendix 12).

The mass of a batch/cargo typically require volume measurements and density determination. This can be accomplished dynamically or statically. Dynamic measurement relies on active measuring of flow and quality during the movement of product through meters. The two different meter technologies currently adapted for LNG conditions are Coriolis (CMF) and ultrasonic (UT). In many new applications, the employment of Coriolis flow meters directly measure mass flow rate and can be used to totalize mass quantities. Whereas UT meters output volume rate by sophisticated measurement of the flow profile and process conditions. Both technologies have proven effective in both the gas and liquid measurement arenas and each has overcome several challenges with operating performance and calibration in LNG applications. Traditionally, static volume measurement is used for custody transfer. This is primarily accomplished by both portside tank gauging and ship gauging. In smaller loadings such as in transport trucks, weight bridges can be employed to obtain total mass.

Using gauge tables supplied by the tank manufacturer, tank gauging measures the fluid levels and establishes the relationship between level and volume. Subsequently, taking other measurements such as temperature, pressure, density, ship list and trim, correction factors are applied. Overall, many measurement inputs with various degrees of uncertainty are required to be averaged out to provide the representative volume of the transferred quantity. The volume measurement uncertainty typically has the most significant impact on overall energy transfer uncertainty, in the GIIGNL LNG Custody Transfer Handbook volume measurement uncertainty is noted to range from 0.2% to 0.55%

This compared versus dynamic proving uncertainty at 0.01% to 0.02%, offers a uncertainty of a magnitude of improvement. This can result in savings, loss reduction, erroneous gains, and validity of the transaction of LNG from one party to another.

		
<p>Tank Gauging Uncertainty: 0.2% to 0.55%</p>	<p>LNG Metering Uncertainty: 0.05% to 0.1%</p>	<p>Dynamic Proving Uncertainty: 0.01% to 0.02%</p>
<p>Uncertainty Factors</p>	<p>Uncertainty Factors</p>	<p>Uncertainty Factors</p>
<p>Gauge Tables, Level, Temperatures, Vapor Trim, Tank Details</p>	<p>Meter type – Coriolis and Ultrasonic Options</p>	<p>Prover Details, System Design, Meter Details</p>
<p>Source: GIGNAL</p>	<p>Sources: Coriolis Uncertainty – Emerson & TUV Ultrasonic Uncertainty – Caldon/Sensia</p>	<p>Source: FMD Study</p>

Dynamic Volume Measurement

For more than 75 years, flow meters have been an indispensable tool for liquid measurements. Metering systems for custody transfer applications typically require in situ proving. Liquid meter proving and related instrument accuracy calibration requirements have been developed and detailed extensively by API. When meter systems are properly designed following API standards and perhaps more important, meter and prover manufacturers recommendations on sizing and arrangement, the level of uncertainty can be significantly reduced below what is seen in tank gauging alone. A key reason for this is meter corrections are applied for the actual flow conditions with the actual fluid being measured. This allows installation affects to the meter and piping, both in terms of flow profile and mechanical loading from pressure and thermal strains of the system, to be accounted for. In addition to this, when provers are manifolded in with automated valves the frequency of proving can be increased so that variation in product properties are accounted for as they vary throughout batching.

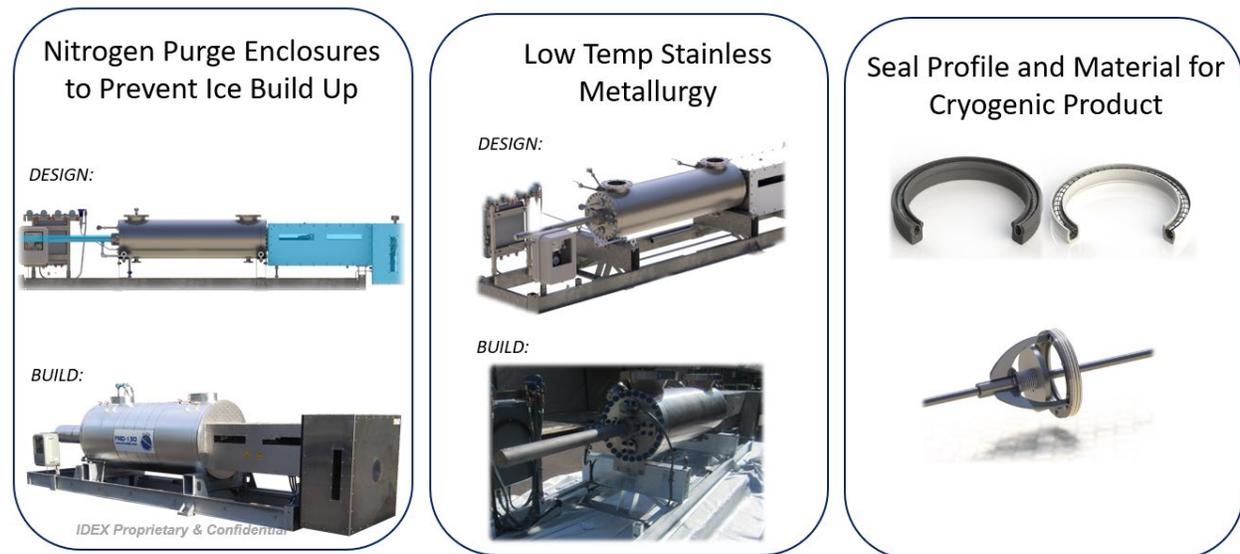
Metering systems with provers have been successfully employed to measure custody transfer of liquid gasses, both compressed (dense gas phase) NGL's and refrigerated NGL (cold liquid phase), particularly C2 to C4. These systems have been developed not without challenges in both system and equipment design. During system design, proper meter and prover matching for the process condition conditions, will minimize pressure drop and vapor breakout concerns which drastically affect measurement performance. In addition to sizing, there can requirements for backpressure in low pressure systems, usually seen in ship loading and tanking terminals. Another key system aspect is ensuring proper purging and cool down/recirc practices are used.

When considering design temperatures for C2, -100°C (-150°F) range, equipment design challenges are generally overcome with good engineering practices. Stainless steels and/or Nickel alloys are typically used. The metallurgy of these materials is well understood, and they retain strength and ductility well below C2 design temperatures. Other design considerations include, low temperature sealing, moisture

purging (N2) for external components and managing static build up on isolated components. Today there are positive displacement provers, particularly small volume provers, currently being designed to make the incremental step from C2 to C1 design temperatures (-100° to -200°C) where the primary engineering challenges have been overcome.

Cryogenic Proving Technology Advancements

In order for a prover to operate at cryogenic temperatures specific advancements are required and have been proven in the field. These included a nitrogen purge system, low temperature metallurgy, and proprietary dynamic seal advancements. The nitrogen purge is protect against moisture development on the reciprocating shafts of a prover. The low temperature metallurgy requires both specific metals and welding procedures to be adequate for cryogenic temperatures, and the seals of a prover must be capable of operating at ambient conditions to calibrate and determine the known volume of the prover while also being able to “shrink” and work under cryogenic process conditions.



These advanced technologies have now been employed on over 75 provers globally with a sample shown in the figure below. While this installed base does not yet include LNG and only other cryogenic products, the technology to prove remains the same. The application of proving for loading and offloading vessels is also very similar in these products.



DESCRIPTION	SERIAL	SHIP DATE	PRODUCT	DESIGN TEMP
PROVER FMD-025	SN:000208	August 2013	Ethane	-150 °F
PROVER FMD-060	SN:000411	December 2015	Ethane	-150 °F
PROVER FMD-060	SN:000397	February 2015	Propane	-50 °F
PROVER FMD-025	SN:000582	July 2017	Propane	-50 °F
PROVER FMD-130	SN:000766	April 2019	Propane	-50 °F
PROVER FMD-130	SN:000768	April 2019	Propane	-50 °F
PROVER FMD-130	SN:000767	April 2019	Propane	-50 °F
PROVER FMD-060	SN:000927	March 2020	Ethane	-150 °F
PROVER FMD-060	SN:000928	April 2020	Propane	-50 °F
PROVER FMD-060	SN:000929	April 2020	Propane	-50 °F
PROVER FMD-200	SN:001193	November 2023	Propane	-50 °F
PROVER FMD-090	SN:001195	December 2023	Propane	-50 °F
PROVER FMD-090	SN:001215	December 2023	Ethane	-150 °F
PROVER FMD-090	SN:001246	August 2024	Ethane	-150 °F
PROVER FMD-015	SN:001259	November 2024	Ethane	-150 °F

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Conclusion

LNG consumption is only going to grow further, and so investments are necessary. Custody transfer becomes norm as more companies specialize need to work together in supply process lines of LNG. Hence the cost of Uncertainty increases. Uncertainty in measuring energy transferred can be minimized and simplified by employing flow meters. However, flow meters are not commonly used in the industry due to concerns surrounding calibration facilities. Those concerns can be alleviated by employing small volume provers that have been used in similar cryogenic applications. Total uncertainty can be brought down to up to 10X through technology advancements in cryogenic proving.

Sources

1. Flow Management Devices, LLC. (n.d.). *Uncertainty analysis* (Patent No. 7650775). US Patent. <https://flowmd.com/wp-content/uploads/2023/03/FMD-060-Uncertainty-Analysis-1.pdf>
2. *LNG fleet may expand 7.5% in 2023 as demand grows | Montel News - English.* (2023, March 15). <https://montelnews.com/news/1459094/lng-fleet-may-expand-75-in-2023-as-demand-grows>
3. Markets, R. A. (2023, June 13). Global LNG Terminal Infrastructure Opportunity Analysis Report, 2023 Half Yearly Insights - Asia-Pacific has Largest LNG Handling Capacity of 1040+ MTPA, with a Total of 298 Operational LNG Terminals. *GlobeNewswire* News Room. <https://www.globenewswire.com/news-release/2023/06/13/2687274/0/en/Global-LNG-Terminal-Infrastructure->

[Opportunity-Analysis-Report-2023-Half-Yearly-Insights-Asia-Pacific-has-Largest-LNG-Handling-Capacity-of-1040-MTPA-with-a-Total-of-298-Operational.html](#)

4. *Price of liquefied U.S. natural gas exports (Dollars per thousand cubic feet)*. (n.d.). <https://www.eia.gov/dnav/ng/hist/n9133us3m.htm>
5. *NIST Handbook 44 - Current Edition | NIST*. (2025, January 10). NIST. <https://www.nist.gov/pml/owm/nist-handbook-44-current-edition>