LNG: bunkering

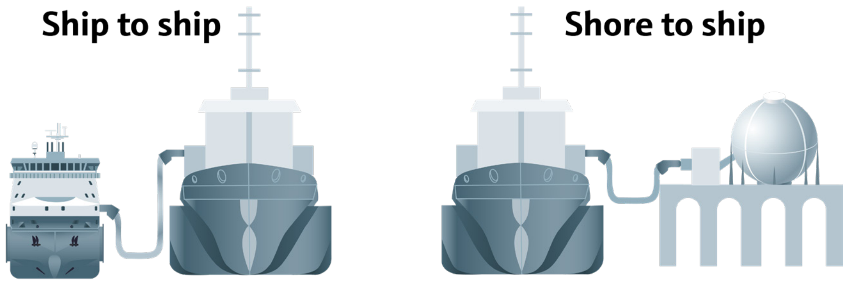

Figure 1: Custody transfer during transport of LNG

Benefits at a glance

- No vaporizer - measures LNG *in situ* in the cryogenic liquid phase
- Simple analyzer installation in control room – no requirement for a dedicated analyzer room
- Low installation costs – no need for vacuum-jacketed tubing for sample transport
- Rxn-41 probe (C1D1/Zone 0) installed up to 500 m from the analyzer
- No analysis delays due to sample transport or vaporization
- Virtually immune to LNG flow variations
- Lower OPEX – no moving parts or consumables

Annex VI of the MARPOL convention, adopted by the International Maritime Organization, came into force in 2005, and established lower limits on nitrogen oxide (NOx) emissions and fuel sulfur content (to reduce emissions of sulfur oxide (SOx)) to reduce air pollution from ships. The use of LNG as a bunkering fuel for ships is a viable alternative to using low sulfur fuel oils or scrubbers to meet the new more stringent standards. The use of LNG is also “future proof” to additional potential future IMO emissions standards for greenhouse gases (GHG) such as CO_2.

Measurement of bunker quality

Several technical references and recommended practices related to LNG bunkering have been developed in the past few years that provide guidance for custody transfer of LNG during bunker events. Two exemplary standards for LNG bunkering include Singapore Technical Reference on LNG Bunkering (TR56), Part 21 and DNV GL (now DNV) Recommended Practice DNVGL-RP-G1052. Both documents recommend that the quantity (mass) and quality (calorific value) of the LNG should be measured to determine the energy content of the LNG transacted for inclusion in the bunker delivery note. LNG quality can be determined either in the liquid phase using Raman spectroscopy, or in the gaseous phase using gas chromatography (GC) after vaporization.

Issues with traditional measurements

LNG composition has been traditionally measured using a gas chromatograph (GC). To use the GC, the LNG sample must be brought from its cryogenic liquid state to a room temperature gas. It is essential to eliminate partial and pre-vaporization of the LNG sample, which requires careful installation and proper maintenance to ensure good insulation and the elimination of hot spots in the sample vaporization and transport paths. Improper or incomplete vaporization is usually the dominant source of uncertainty in the measurement of LNG composition, which translates to added uncertainty in the energy content transferred. Vaporization systems are also sensitivity to LNG flow rates, so data during unstable flow is typically discarded, so less of the overall LNG cargo is measured during bunkering. Kaiser Raman analyzers are essentially immune to LNG flow variations, so can provide a more complete measurement of calorific value. Kaiser Raman analyzers have very low maintenance requirements, since there are no moving parts and no insulation to degrade, and no consumables, such as calibration and carrier gases.

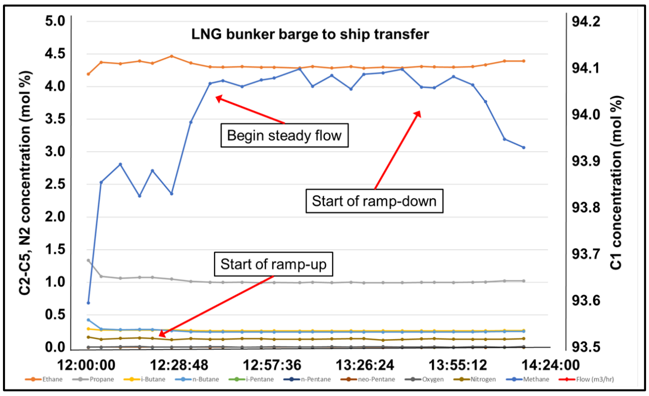

Figure 2: Raman measurement of LNG during a ship-to-ship bunkering event

Raman Rxn4 analyzer for LNG bunkering

The Raman Rxn4 analyzer for LNG with the Rxn-41 fiber optic probe for cryogenic service provides accurate measurement of the WI, GCV, and full composition of bunkered LNG with up to 10 times lower uncertainty than GC-vaporizer systems. This ensures that both buyer and seller have an accurate and precise measure of the energy content of the LNG cargo during custody transfer transactions. The rack-mounted analyzer is easily installed in a control room, with fiber optic coupling to the Rxn-41 probe, which is mounted in the LNG pipe for *in situ* measurement in the liquid phase, eliminating the need for costly vaporization, sample conditioning, and transport of the vaporized gas to the analyzer for measurement.

The Raman Rxn4 analyzer solution for LNG custody transfer consists of the following:

- Raman Rxn4 analyzer base unit with laser and internal calibration
- Rxn-41 fiber optic probe for cryogenic service
- Fiber optic cable (length from 15 to 500 meters, customized to your plant requirements)
- Dedicated LNG custody transfer method valid over LNG temperature range of 93K to 117 K*

*Requires manual entry for fixed temperature, or temperature input (±1 K) via Modbus for varying temperature

**Performance may vary for different cable lengths and analysis time

LNG component ranges and performance

Component	Concentration (Mol %) Min	Max	Uncertainty (k=2)
Methane (CH_4)	87.000	98.170	< 0.46
Ethane (C_2H_6)	1.300	10.500	< 0.38
Propane (C_3H_8)	0.160	3.000	< 0.11
i-Butane (iC_4H_{10})	0.060	0.400	< 0.023
n-Butane (nC_4H_{10})	0.078	0.600	< 0.028
i-Pentane (iC_5H_{12})	0.005	0.120	< 0.031
n-Pentane (nC_5H_{12})	0.005	0.120	< 0.015
Nitrogen (N_2)	0.040	1.050	< 0.056

Table 1: Range of validated LNG with worst case uncertainty for fiber lengths < 500 m and measurement time of 300 seconds**

Component	Range Min – Max	Uncertainty (k=2)
Gross heating value (MJ/m^3)	38.4 - 42.2	< 0.16
Gross heating value (MJ/kg)	53.8 - 55.3	< 0.072

Table 1: Range of validated LNG heating values with worst case uncertainties for fiber lengths < 500 m and measurement time of 300 seconds**

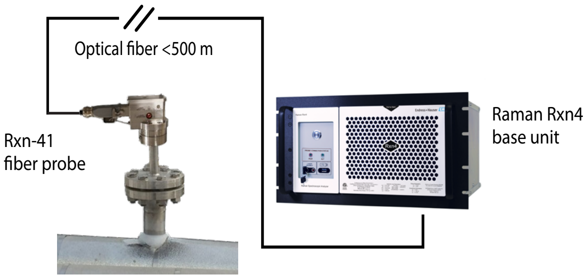

Figure 3: Recommended direct flange mounted installation

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