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TECHNICAL BRIEF—08 February 2022

UNDERSTANDING LNG CUSTODY TRANSFER

What and Why

Liquefied Natural Gas (LNG) is traded globally, with the majority moved by ocean-going LNG Ships (Vessels / Carriers). At the end of 2020, there were 572 active vessels in the fleet and 130 under construction. Of 35 newbuilds delivered in 2020, most ranged between 170,000 m^3 and 180,000 m^3 in LNG capacity (*International Gas Union* (*IGU) 2021 World LNG Report*). Each time an LNG Ship (Vessel / Carrier) is loaded at a shipping / export terminal or unloaded at a receiving / import terminal, a thermal energy calculation is performed to determine the energy content of the cargo. LNG is priced in units of energy, and this energy calculation thus determines the monetary value of the LNG cargo. Because of the importance, thermal energy calculations are performed by expert, third-party custody transfer inspection companies, independent of LNG buyer and seller.

Assuming a cargo of nominally 3,600,000 MMBTU, a 0.5% error in the calculation would correspond to US$180,000, US$360,000, or US$540,000 at LNG prices of US$10/MMBTU, US$20/MMBTU, or US$30/MMBTU. Only recently would a discussion take place about LNG at US$30/MMBTU or higher, but sharp demand spikes and shipping issues in late 2021 brought such pricing into the realm of possibility. When LNG prices increase significantly, the cost of errors in LNG custody measurement and energy calculations also rises significantly.

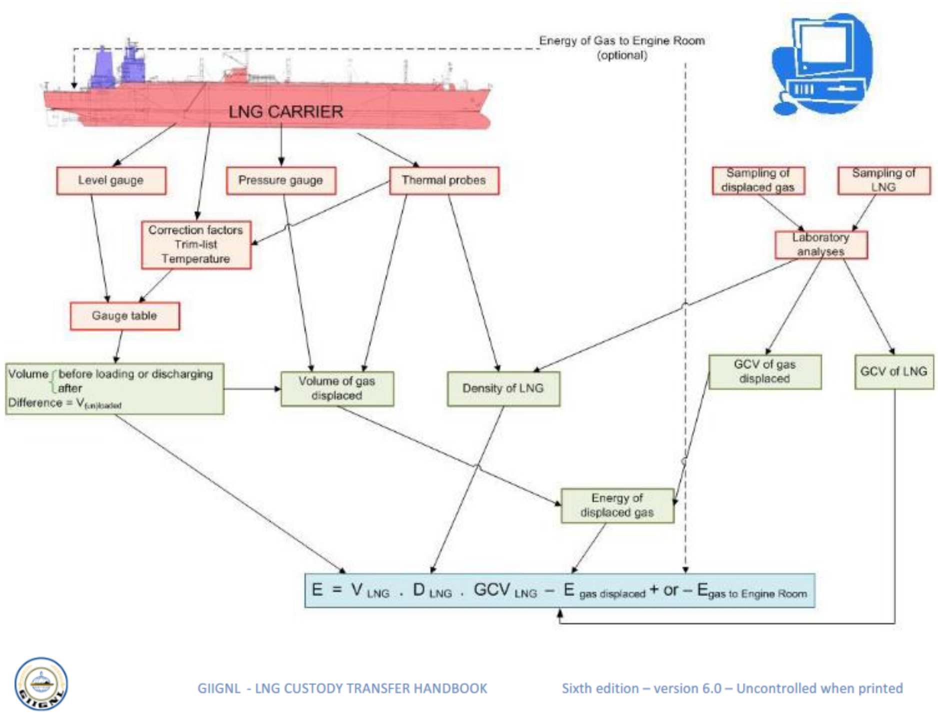
The History

The primary accepted basis for LNG thermal energy calculations is documented by GIIGNL, Groupe International des Importateurs de Gaz Naturel Liquéfié (The International Group of Liquefied Natural Gas Importers) in their publication *LNG Custody Transfer Handbook, 6th Edition: 2021*. This is the latest edition of a handbook based on the measurement methods most used by GIIGNL members that was first published in 1991 and originally inspired by a National Bureau of Standards (NBS) LNG Measurement study publication in 1985. The latest edition reflects current best practice in LNG thermal energy calculations, but there are many legacy methods still used because of older LNG contracts written with reference to older methods and to prior revisions of data tables.

The Calculations

Figure 1 below, taken from the latest GIIGNL *LNG Custody Transfer Handbook*, is an overview of the LNG Measurement process.

Figure 1—LNG Measurement and Custody Transfer Calculation Overview



Shipboard measurements for level, pressure, and temperature in combination with gauge tables, sampling, laboratory analysis, and flow rates for things such as fuel consumption are used to establish the volume of LNG transferred, the density of the LNG, the specific energy content of the LNG, and the energy lost due to displacement, burning as fuel, and flaring.

The overall equation is:

$E = V_{LNG} \times D_{LNG} \times GCV_{LNG} - E_{gas\ displaced} +/- E_{gas\ to\ Engine\ Room}$

The terms of the equation are defined as:

E	the total net energy transferred, usually expressed in millions of British Thermal Units (MMBTU)
V_{LNG}	the volume of LNG loaded or unloaded in m^3
D_{LNG}	the density of LNG loaded or unloaded in kg/m^3
GCV_{LNG}	the gross calorific value of the LNG loaded or unloaded in MMBTU/kg
$E_{gas\ displaced}$	the net energy of the displaced gas in MMBTU (carrier>shore, shore>carrier)
$E_{gas\ to\ Engine\ Room}$	if applicable, the energy of the gas consumed in the LNG carrier's engine room during the time between opening and closing custody transfer surveys ("+" for loading, "-" for unloading)

Simple, right! Well…here are a few questions to ask:

- When was my LNG contract written, and what version of the GIIGNL manual, calculation equations, and standard data tables does it reference?
    - The Measurement and Testing (M&T) details are often documented in a contract appendix and are very specific in describing how LNG thermal energy calculations will be performed for a given LNG contract
- Does my LNG contract agree commercially to anything unique, or different from the standard calculation methods?
- Since even the rounding of raw data numbers prior to calculations can have a significant impact on final results, what does my LNG contract specify for rounding of raw data inputs to calculations?
- Does my LNG contract require use of molar fractions or mass fractions?

And, the questions above are only a few of the contract related questions. There are many more questions related to how measurements are taken during LNG transfer, how calculations are made, and how reports are configured:

- How many cargo tanks does the vessel have?
- What instruments are used to measure tank level, and what corrections to level measurement are necessary?
- Once level is available, what corrections to the tank gauge tables are necessary?
- Will the tanks be stripped, and what contract arrangements are in place to account for remaining liquid and gas?
- How many temperature probes are in each of the storage tanks, how are they spaced, and are they in liquid or vapor spaces when read?
- Are pressure readings in "gauge" or "absolute" pressure?
- What sampling methods are used and where are sample points located?
- What equipment is being used for composition analysis and how does my contract treat heavies and normalization of compositions?
- How are LNG impurities measured?
- What happens to displaced gas; is any of it used as fuel, or is it all transferred between ship and shore?
- What type of error and uncertainties exist in the measurement and calculation techniques used?
- What are the requirements for my report from the cargo inspector?

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The GIIGNL manual has 192 numbered pages and 17 appendices with 21 figures and 44 tables, all of which MIGHT or MIGHT NOT be applicable to a given LNG transfer situation. Much of the information is sourced from ISO (International Organization for Standardization), but there is also information from and reference to EI (Energy Institute), GPA (Gas Processors Association), IP (Institute of Petroleum), and NBS (National Bureau of Standards). Each of the terms in the energy equation above is determined by additional equations using correction factors and other information. LNG cargo inspection companies also have proprietary tools and databases of information used in planning inspections, reading measurements, recording raw data, performing calculations, and reporting.

Despite the complexities, Cloudcroft Systems has a thorough technical understanding of the LNG Custody Transfer process and has modern digital applications under development to promote better understanding of the process, to simplify the scheduling of cargo inspections and transmittal of reports, and to allow the data collected and reported to be better utilized in business planning and decision making. Cloudcroft Systems can also assist in understanding the M&T requirements of an LNG contract if help is needed. Figure 2 below is an excerpt from the LNG Custody Companion output report for paid subscribers (there will also be a limited functionality free version). The application output report is configured to make the complexities of LNG Custody Transfer calculations more intuitive to users by displaying equations and values.

For more information, contact us at support@cloudcroftsystems.com, and please continue to monitor our LinkedIn page for the announcement that our application has been released. We will issue instructions at that time for accessing the Cloudcroft Systems domain and logging onto the LNG Custody Companion application.

Figure 2—Excerpt from Cloudcroft Systems LNG Custody Companion Paid Subscriber Report Calculation Summary

5. DENSITY CALCULATION

Density $$\frac{\Sigma\ (\overline{Xi} * Mi)}{\Sigma\ (Xi * Vi) - Xm * C}$$ WITH $$C = K1 + \frac{(K2 - K1) * Xn}{0.0425}$$

Density = 427.16 kg/m3 at -155°C

= 427.16 kg/m3 at -160.0 °C

K1	=	0.000175	0.000175
K2	=	0.000387	0.000387
C	=	0.000175	0.000175
Σ (Xi x Mi)	=	16.743789	0.044520
Σ (Xi x Vi)	=	0.039366	0.039366

Table Reference: ISO 6578-2017

6. HIGHER HEATING VALUES

Hm (Mass)
60°F

$$\frac{\Sigma\ (Xi * Mi * Hmi)}{\Sigma\ (Xi * Mi)} * 2.20462$$

Hm (Mass) 60°F = 52,665.2778 Btu/kg

Hv (Volume)
60/60°F and 14.696 psia

$$\Sigma\ (Xi * Hvi) / Z$$

Hv (Volume) 60/60°F and 14.696 psia = 1,050.1518 Btu/scf Real Gas

Wobbe Index
60/60°F and 14.696 psia

$$Hv / \sqrt{\frac{\Sigma\ (Xi * Mi)}{28.9626} * \frac{0.99958}{Z}}$$

Wobbe Index 60/60°F and 14.696 psia = 51.6459 Btu/scf Real Gas

Volumetric Energy Facto 23,596.2757 MMBtu/m3

Subscriber: Maury Hudson (Individual) 1 of 2 Version: 1.01