LNG Sampling, Analytically Accurate Practices & Techniques

Ken Thompson
President/CEO
LNG is a Global Market

Figure 1: LNG Market in 2002 (Left) and 2020 (Right)
Key Features

• North America net LNG export to exceed about half of today’s total market
• North America projected to lead supply
• Europe and Asia demand continues to dominate market

LNG’s share in traded gas increases sharply...

Net LNG exports and imports 2035 (Bcf/d)
**Key Features**

- Global population exceeds 7 billion
- Expected to reach between 12 and 20 billion by 2100
- World energy consumption prior to about 1960 is insignificant compared to total since
- Both trends are expected to continue positively
Global Liquefaction Plans

**Figure 4.2: Global Liquefaction Capacity Build-Out, 1990-2017**

*Sources: PFC Energy Global LNG Service, Company Announcements*
Traditional LNG Market
LNG Vehicle Fueling

How to Fuel with LNG

[Diagram showing LNG fueling process]

CONFIDENTIAL
Marine Bunkering Custody Transfer
Harvey Gulf in Port Fourchon, LA

LNG Sourcing
Various Small Scale Merchant Facilities

Custody Transfer Measurement
Combination Coriolis w/ GC
Small scale LNG allows for the production and transportation of natural gas without pipelines.

**Common Applications**
- Mining & quarries
- Drilling Rigs
- Transportation fleets
- Rail
- Ships
- Peak Shaving
Emission Control Areas of the World

Eliminating Pollutants of Diesel Fuel
Standards and Publications that cover the sampling of LNG
Refrigerated light hydrocarbon fluids
First edition published in 1991
Standard was last reviewed in 2010
Methods for continuous and intermittent sampling of LNG
- Sample probe
- Sample Vaporizer
- Sample Holders
- Sample Cylinders
LNG Custody Transfer Handbook
First edition written in 1987
Second edition 2001
Third edition Mar. 2010
Improve existing procedures with random updates
Used in purchase & sales agreements
Measurement methods most used by GIIGNL members
Additional Standards

- ISO 10715-2001 – Natural Gas Sampling Guidelines
- API 14.1-2006 – Collecting & handling of natural gas samples for custody transfer
- BS EN ISO 12838-2001 – Installations & equipment for liquefied natural gas-suitability testing of LNG sampling systems
Installation of LNG analysis measurement system.

LNG facility operator training.

Measurement system maintenance.
Sample probe location is critical

- Install sample probe in straight pipe run, do not install near elbows or expansion loops.
- Install sample probe in side of pipe, not on top.
- Insulate sample probe and isolation valve – minimum 6” insulation recommended.
- Install sample probe & vaporizer at the coldest point in the transfer system.
Installation of System

Vacuum Jacketed Tubing

- Recommended maximum length 7 meters.
- Recommend inner process tube be ¼” ODT x .065 wall, 304 or 316 SS.
- Recommend to insulate the outer ends of the VJT outer tube a minimum of 6” each end.
LNG Vaporizer

- Install as close to sample probe as possible.

- Insulate the header to the vaporizer – minimum 6” insulation recommended.

- Pipe vaporizer speed loop to BOG header, insure return point has a lower pressure than the sample point. Maintains steady flow rate thru vaporizer regardless of inlet pressure.
Ensure LNG Facility Operators are trained to operate the analysis equipment on every shift.

- Correct knowledge to operate the vaporizer, GC & Composite or Continuous sample system.
- Correct knowledge to take manual samples.
  - (including cleaning sample cylinders for reuse)
- Knowledge of consecutiveness sampling period at a constant LNG transfer flow rate.
- NOTED as - Stable Sample Time
System must be monitored and maintained on a regular schedule.

- GC calibrated weekly (utilizing proper calibration gas mix standard to match LNG components).
- After each cargo transfer run calibration gas as a unknown and verify component values.
- Vaporizer settings checked for heat rod temperatures, bypass flow rate, regulator temperature & gas flow to GC.
- Composite or Continuous Sample system settings, flow rates and sample pumps.
Measurement System Maintenance

- As Operators and Maintenance personnel are replaced make sure the new personnel are properly trained on all of the equipment.

- Monitor the insulation on the transfer pipe, sample probe, isolation valve, VJT and vaporizer header.

- Over time the insulation becomes wet from rain (due to improper covering or normal wear of insulation outer jacket).

- Insulation regardless of type will eventually deteriorate and become ineffective.
Sampling Process

- Provide consistent, repeatable analyzed results during Cargo Transfer.

- Stable Sampling Time is most important for consistency.

- Sample analysis taken outside the stable sampling time should be removed from final results.

- Any samples taken during interruptions to temperature, pressure or LNG flow taken during the Stable Sampling Time will effect the results and have to be removed.
7.3 Suspension of sampling

Regardless of whether the sampling method is continuous or intermittent, if a sudden change in the flow rate or in the pressure occurs in the LNG transfer line during the sampling period due to a cargo pump being tripped or an emergency shut-off device being activated, sampling shall be temporarily suspended until the flow rate of LNG is normalized.

7.4 Continuous sampling

7.4.1 Filling the gas sample holder with gasified LNG

a) Prior to initiating the sampling, any residual gas of the last operation that might remain in the gas sample holder shall be completely purged.

b) In case the water-seal-type gas sample holder is used, prior to initiating the sampling, the seal water shall be subjected to bubbling.

c) In case the water-seal-type gas sample holder is used, in order to prevent the possibility of contamination by atmospheric gases, the sample shall be transferred to the gas sample containers without delay following the completion of sampling.

d) In case the waterless-type gas sample holder is used, prior to initiating the sampling, it shall be confirmed that there is no leakage of gas between inner and outer compartments within the gas sample holder.
Sampling and analysis must be performed at cargo transfer to show differences due to weathering and boil-off.

Weathering (or aging) – Describes the on-going process of boil-off.

Boil-off – As the cargo gains heat, the lighter components of the LNG exit the cargo tank and often used as ship’s fuel.

Engine Manufactures require Methane/Ethane content to maintain warranty of engines.
Sampling Issues

- Sample Probe Location (mount in the side of the pipe not on top) (mount in a straight run of pipe, avoid elbows)

- Avoid Pre-Vaporization (always utilize Vacuum Jacketed Tubing for sample transport from probe to vaporizer)

- Provide proper insulation at sample probe and top entry to LNG Vaporizer.

- Unstable flow in transport pipe (laminar or turbulent)

- Sampling in the two phase region of LNG will effect analysis accuracy. Data log inlet temperature and pressure for Phase Curve Analysis.
Phase Diagram
Soave-Redlich-Kwong EOS

Pressure - bars
10
20
30
40
50
60
Temperature - °C
-140 -120 -100 -80 -60

Com ponent Molar Ratio
Propane 0.0400
Nitrogen 0.2900
Ethane 6.1600
Methane 93.5100
The design and accuracy of the LNG sampling system will have a direct effect on the calculated density and gross calorific value of the LNG being transferred.

Example: LNG ship ranges in dollar value of 20-40 million US dollars.

1% error in the energy calculation can equal $200-$400 thousand US dollars during custody transfer of a single ship's cargo.
Any time you or your client question the operation or accuracy of your LNG Measurement System that has been working correctly take time to review each area of the system based on the previous comments.

Look for any area that the operating procedure or flow rates have been changed.

Look at all of the insulated points for signs of Pre-Vaporization. Normally number one problem.

Review the data reports for any upsets to the flow rates during cargo transfer that interrupted Stable Sample Time.
Import Terminals

Export Terminals

Ship to Ship Transfers

Bunkering – process of supplying fuels to Marine Vessels for their own use.

Fueling Vehicles & Rail
- Continuous
  - Sample vaporizer system
  - Gas chromatograph
  - Continuous sample with constant stable flow rate
- Spot
  - Sample cylinders (namely 3)
  - Manual or automatic sampling
  - Predetermined Intervals
- Composite or Continuous
  - Automatic providing an averaged sample
  - Sample pump(s)
    - 1-5 Liter sample holder
    - 2-6 sample cylinders
- Cargo Cylinder
  - 300-500 cc gas cylinder sampling during loading
  - Transported with ship
  - Analyzed with Unloading Terminal GC
## Multi Sampling Analysis

### Vessel: Mekaines
**Date:** 28-Aug-14

<table>
<thead>
<tr>
<th></th>
<th>Ship C or Q</th>
<th>Load Port Analysis</th>
<th>Acceptable Range</th>
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<tbody>
<tr>
<td>C1</td>
<td>93.39%</td>
<td>93.35%</td>
<td>93.20% - 93.45%</td>
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<tr>
<td>C2</td>
<td>6.29%</td>
<td>6.31%</td>
<td>6.27% - 6.52%</td>
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<tr>
<td>C3</td>
<td>0.03%</td>
<td>0.03%</td>
<td></td>
</tr>
<tr>
<td>C4+</td>
<td>0.00%</td>
<td>0.00%</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>0.29%</td>
<td>0.31%</td>
<td>0.20% - 0.30%</td>
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### Composite Sample

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<thead>
<tr>
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<th>Valtronics</th>
<th>GC Average (V2)</th>
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<tbody>
<tr>
<td>C1</td>
<td>93.36%</td>
<td>93.35%</td>
</tr>
<tr>
<td>C2</td>
<td>6.33%</td>
<td>6.33%</td>
</tr>
<tr>
<td>C3</td>
<td>0.03%</td>
<td>0.03%</td>
</tr>
<tr>
<td>C4+</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>N</td>
<td>0.28%</td>
<td>0.29%</td>
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### Spot Samples

<table>
<thead>
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<th></th>
<th>25%</th>
<th>50%</th>
<th>75%</th>
<th>Average</th>
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<tbody>
<tr>
<td>C1</td>
<td>93.37%</td>
<td>93.37%</td>
<td>93.36%</td>
<td>93.37%</td>
</tr>
<tr>
<td>C2</td>
<td>6.30%</td>
<td>6.32%</td>
<td>6.34%</td>
<td>6.32%</td>
</tr>
<tr>
<td>C3</td>
<td>0.03%</td>
<td>0.03%</td>
<td>0.03%</td>
<td>0.03%</td>
</tr>
<tr>
<td>C4+</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>N</td>
<td>0.30%</td>
<td>0.28%</td>
<td>0.27%</td>
<td>0.28%</td>
</tr>
</tbody>
</table>
LNG Vaporizer System

- SS Sample probe w/ isolation valve
- Vacuum jacketed sample tubing
- Inlet LNG temp. sensor
- Sample vaporizer coil(s) & control system
- Vaporizer outlet temp. sensor
- Accumulator/Mixing chamber
- Vaporizer flow control/regulator system & control system
- Outlet gas temp. sensor
- Outlet pressure sensor
- Sample holders & cylinders
- Heat trace sample tubing
- Gas Chromatograph
- Data acquisition & processing system
Sampling & Analysis System

- Tank 1 (Single-Path Vaporization)
- Tank 2 (Single-Path Vaporization)
- Insulated Vapor Return Line
- Insulated LNG Line
- LNG In
- LNG Out
- LNG Storage Tanks
- LNG
- Vapor Return (Single-Path Vaporization)
- Terminal
- Sample Conditioning System
- Grab Sample Cabinet
- Revaporization System
- Sample Extractor
- Custom-Designed Vacuum Jacketed Tubing
- Min 2 Stream 1
- Min 2 Stream 2
- Min 2 Stream 3
- Min 2 Stream 4
- Min 1 Stream 1
- Analyzers
LNG Sample System
Sample Probe

Direct connection on main LNG line (cross section view)
Manual Sample System
Fundamentals of Sampling (LNG)
Analytically Accurate® Methods & Processes
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QUESTIONS