

# Perfecting liquefied natural gas analysis techniques and methods

**Following these procedures will improve measurement accuracy and reliability**

**S. HALE**, Emerson Process Management, Houston, Texas

The nature of liquefied natural gas (LNG) raises many challenges when it comes to the measurement and reporting of its composition for the purpose of ship loading and unloading. LNG's extreme temperature, and the difficulty with keeping it in liquid form, introduce unique sample-handling issues, while the batch-handling operation makes reporting difficult. At the same time, the accuracy and reliability of the LNG measurement is uniquely critical since the loading and unloading operations are highly time-sensitive with no second chances. Delays in loading or unloading because of measurement issues are not tolerable when the cost of keeping a ship in port is considered. For example, one LNG operator had two measurement systems fail right before the docking of a large tanker—a problem that could have resulted in significant penalties had the failures not been remedied heroically. Additionally, disparities in the measurement are often not known until after the unloading is complete at the destination and comparisons to the load report are made.

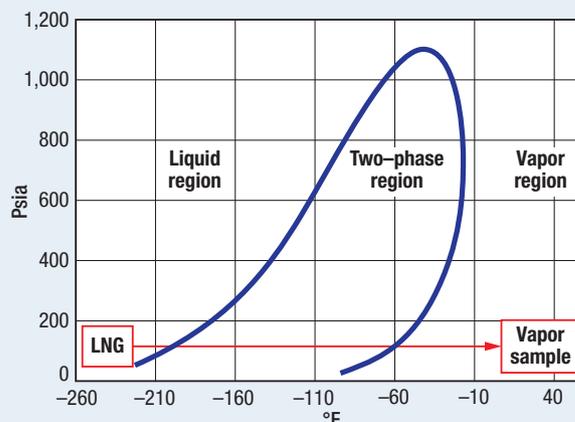
**Sample handling.** The problem that nearly brought the aforementioned LNG operator to its knees was a failure in the sample-handling system that resulted in damage to the measurement technology. The sample-handling challenge is frequently underrated and can be one of the weakest links in an LNG system. Many designers attempt to develop their own sample-handling system without regard for the lessons learned by existing operators and vendors or the standards and guidelines developed by the industry.

For a sample-handling system to measure a truly representative sample, the LNG must be maintained in the liquid phase right up to the point where it is vaporized. At that point, it must be vaporized uniformly into a single-phase vapor state. As illustrated in Fig. 1, there is a significant two-phase region that the sample-handling system (Fig. 2) must move the sample through before it is a single-phase vapor. If the sample is transported while in the two-phase region, the different velocities of the liquid and gas phases will result in a composition change of the sample as a whole once it reaches the point at which it is in the single-phase vapor state. In other words, if the LNG begins to vaporize in the sample lines, the nitrogen and methane will boil off first, produc-

ing pockets of gas in the liquid stream that reach the vaporizer at different times, resulting in varying compositions. The result is that the LNG sample reaching the vaporizer will consist of an unrepresentative liquid sample rich in the heavier components plus slugs of methane-rich vapor. The vapor sample leaving the vaporizer will be inconsistent, with wild swings in composition. This is then fed into the gas chromatograph and sample cylinders resulting in unrepresentative analysis.

To overcome some of the problems associated with LNG vaporization, an accumulator is used immediately after the vaporizer to reconstitute the sample. This step, however, can only correct for small fluctuations. If there is significant vaporization in the sample lines, then large slugs of gas can actually insulate the vaporizer from the LNG, once again resulting in the sampled gas being unrepresentative of the actual flowing stream.

Icing on the sample lines is an indication that the sample is vaporizing in the lines. Modern installations utilize vacuum-jacketed tubing from the sample probe to the vaporizer that is located within 7 ft to ensure that the liquid phase is maintained right up to the vaporizer.



**FIG. 1** LNG phase diagram.

Even if the LNG sample does reach the vaporizer in the pure liquid phase, the vaporizer must be designed to add sufficient heat to the liquid sample and to allow for over 600-to-1 expansion from the liquid phase to the gas phase without causing sample fractionation.

Vaporizer design has also undergone significant changes. “Vaporizing regulators,” common in the process industry, attempt to perform sample vaporizing and pressure regulation, but do not have the heating capacity or volume expansion allowances to do either job well when it comes to LNG.

The best performing vaporizers are designed specifically for LNG and perform the vaporization separate from the gas pressure regulation. These vaporizers take a small volume of liquid sample and flash the sample off quickly, providing very little restriction and allowing the sample to expand over 600 times in volume. To ensure correct operation, the outlet vaporizer’s temperature is monitored to guard against liquid carryover. After the sample is vaporized, it enters the accumulator and is then pressure-controlled and sent to the gas chromatograph for analyzing. Regardless of what approach the LNG operator takes to sample handling, it’s critical that basic standards are met. These include ISO8943 and the requirements listed in *GIIGNL LNG Custody Transfer Handbook*.

**Gas chromatograph operation.** While LNG composition is similar to natural gas, it has unique properties due to the pro-

cess requirements of chilling the feed gas to the low temperatures required to produce LNG. Carbon dioxide (CO<sub>2</sub>) levels must be as low as possible. They typically are less than 50 ppm in LNG streams to prevent possible solid formation in the liquefaction process. CO<sub>2</sub> has a relatively high freezing point of -70.6°F, as do some other hydrocarbons higher than butane.

Typical LNG has a high energy value because of the lack of non-hydrocarbon components, rather than high concentrations of heavy hydrocarbon components typically seen in high heating value “pipeline-quality” gas. As there is virtually no CO<sub>2</sub>, the specific gravity of the gas is also lower than the typical natural gas that may have up to 2 mole % CO<sub>2</sub>. This has a major effect on the Wobbe Index of the gas, which will be much higher from LNG sources. Table 1 shows the typical LNG composition imported into the US.

**Hardware considerations.** Due to the unique characteristics of LNG and the high value placed on measurement accuracy, gas chromatographs used for analysis must be designed for the application and have an analysis repeatability of +/- 0.25 BTU per 1,000 BTU (0.025% of Energy Value). This repeatability must be achieved over the full ambient temperature range of the instrument, which in the case of an LNG gas chromatograph, should be at least 0°F to 130°F.

The ambient temperature range of the gas chromatograph is just one of the ruggedized characteristics demanded by the LNG application. The gas chromatograph instrument is placed on the docks and the closer to the actual loading area the better for the measurement. Therefore, the analyzer must be designed to withstand true maritime conditions. And it must do so without requiring much dock space. Gas chromatographs are frequently mounted directly on the docks where the swing-arm moves across for loading. While LNG gas chromatographs will generally be enclosed in a three-sided shelter for operator comfort, the smaller the footprint, the more desirable for the application.

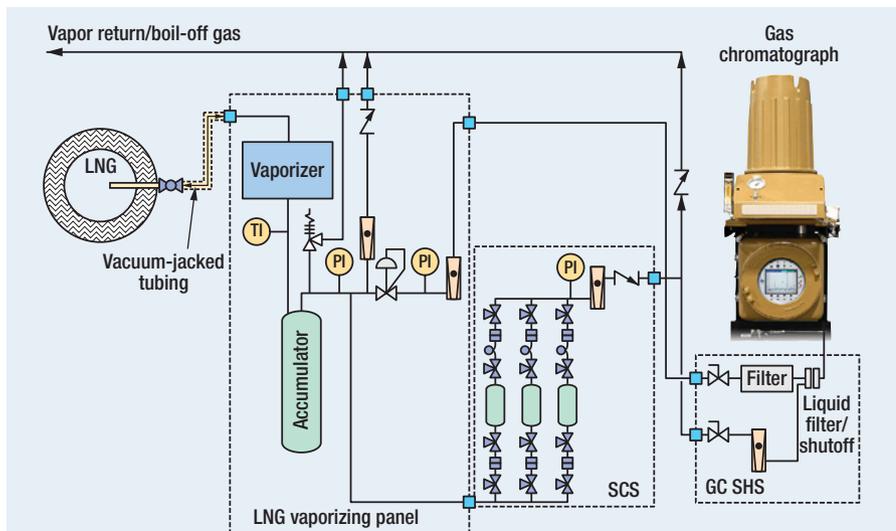
Operators should also pay close attention to utility requirements. Gas chromatographs that require an air-conditioned environment in an analyzer house are not appropriate for LNG applications. They significantly increase utility cost and enlarge the footprint and may increase installation and operational costs by over 50%.

Overall cost-of-ownership should, in fact, be a critical factor in selecting a gas chromatograph for LNG use. The hardware should be easily maintained, but, at the same time, not too expensive to maintain. Frequently, LNG systems may be built by contractors who have little stake in the ongoing operational costs of their systems. It’s unwise for the LNG operator to trade a low-cost gas chromatograph for long-term elevated costs of maintenance. Since 80% of faults that arise in gas chromatographs require the overhaul of analysis valves, this is an area to consider closely. If replacement is too costly, the operating expenses can mount significantly to several multiples of the original cost of the system.

**Software considerations.** As important as the hardware criteria in system selection, software also plays a huge role in LNG analysis. It’s essential that the analysis,

**TABLE 1. Typical compositions of LNG imports into the US**

	1075	1075 High ethane	1130 High ethane	1130 Low ethane	1160	1100
Methane	94.73	92.3	86.53	89.94	88.33	91.8
Ethane	3.8	7.5	12	6	6	6
Propane	1.17	0.2	1.33	3	4.3	1.4
iso-Butane	0.3	–	0.06	0.53	0.5	0.4
n-Butane	–	–	0.08	0.53	0.5	0.4
iso-Pentane	–	–	–	–	0.37	–
BTU	1,063	1,070	1,124	1,125	1,154	1,095
Wobbe Index	1,387	1,391	1,420	1,420	1,436	1,404



**FIG. 2** Typical LNG sample-handling system.

reporting and communication software be purpose-built to the application. Gas chromatographs with laboratory-style software are too complex for LNG and are unsuitable for its operational and diagnostic requirements.

Unlike pipeline or process gas chromatographs which run 24/7, gas chromatographs used for LNG ship loading and unloading will only be run while the ship is in the dock. On a pipeline, an operator can calibrate and start the system locally since it will run continuously for years. For LNG, the gas chromatograph should be able to start, stop and calibrate remotely from the control room to save operator time and make the operation efficient.

LNG gas chromatographs need to be able to communicate to host devices such as flow computers, SCADA systems and distributed control systems (DCSs). Due to the high number of values reported by the gas chromatograph, the MODBus serial communication protocol, over either serial or Ethernet communication links, is used. A recent development is using Foundation fieldbus to connect to the DCS, which may suit the project design philosophy better and tie into plant-wide diagnostic monitoring software with virtually no customization. Whatever the protocol for host system communication, additional provision should be made to allow remote diagnostics. Such capability allows highly-trained personnel to be able to analyze, diagnose and maintain multiple devices from a central location, often off site.

Reporting software is also very specific to LNG requirements. In most custody transfer agreements, there is a reporting requirement for:

- Average composition over the entire load
- Spot sample after stable flow is achieved (typically after one hour)
- Spot sample at the 25%, 50% and 75% ship tank level.

Gas chromatograph systems designed for LNG have dedicated control and reporting software that allow the operator to:

- Run the calibration sequence remotely before the load/unload operation is started
- Start the analysis and log each analysis as part of the load
- Allow operator-initiated storing of spot sample compositions at the 1 hr, 25%, 50% and 75% tank level times
- Allow for suspension of logging due to process disturbances such as pump failure
- Stop the analysis
- Allow for the removal of inconsistent analysis due to process upsets based on the agreement of all parties
- Generate a load report with an average composition, the spot sample analysis, and calculated energy and physical properties for each reported composition.

While some system designers have custom-programmed all of these functions into the host system, gas chromatograph vendors who regularly supply to the LNG market have off-the-shelf packages that do all of these functions already and are used in multiple locations. Using such an off-the-shelf application reduces programming costs, saves time, performs all of the functions correctly, and gains instant acceptance from third-party auditors.

**Meeting the challenge.** The significant value of an LNG ship load justifies the most accurate and reliable LNG analysis system. Fortunately, today's LNG analysis technology allows for reliability and accuracy while maintaining a low ownership cost. System design must assure that the sample is handled appropriately, analyzed accurately and that results are reported correctly in facing the challenges of LNG temperature and batch reporting. There's no room for compromise when you don't get a second chance. **HP**

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**Shane Hale** has been in the oil and gas industry for over 15 years, of which the last 12 have been with Emerson Process Management. Mr. Hale is the natural gas product marketing manager and a member of the AGA Transmission Measurement Committee and the ISO TC193 Committee.