SAE International™

SURFACE VEHICLE RECOMMENDED PRACTICE

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Liquefied Natural Gas (LNG) Vehicle Metering and Dispensing Systems—Truck and Bus

RATIONALE

This SAE Recommended Practice is intended as a guide for standard practice and is subject to change in order to keep pace with experience and technical advances. Its purpose is to promote safety and efficiency by making available to sellers and buyers of commercial liquefied natural gas (LNG) vehicle metering and dispensing systems a recommended practice for construction, operation, and maintenance of such systems.

This SAE publication necessarily deals to some extent in generalities, since it is not possible to anticipate and address every individual set of conditions that might be found in constructing, operating, and maintaining LNG vehicle metering and dispensing systems. It is intended to be a practical guide illustrating the application of recommended practices. The correct application of these practices in any actual field situation must rely on sound judgment and experience.

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1. SCOPE

This SAE Recommended Practice applies to Liquefied Natural Gas Vehicle Fuel. The purpose of this document is to provide information on issues that are important to consider regarding LNG metering and dispensing systems.

2. REFERENCES

2.1 Applicable Publications

The following publications form a part of this specification to the extent specified herein. Unless otherwise specified, the latest issue of each publication applies.

2.1.1 NIST Publication

Available from National Institute of Standards and Technology, 100 Bureau Drive, Stop 1070, Gaithersburg, MD 20899-1070, Tel: 301-975-6478, www.nist.gov.

NIST Handbook 44 Specifications, Tolerances, and other Technical Requirements for Weighing and Measuring Devices

2.1.2 NFPA Publications

Available from the National Fire Protection Agency, 1 Batterymarch Park, Quincy, MA 02169-7471, Tel: 617-770-3000, www.nfpa.org.

NFPA 52 Vehicular Fuel Systems Code

NFPA 59A Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)

2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of the document.

2.2.1 State of California Publication

Available on the web at http://www.dir.ca.gov/Title8/sub1.html.

California Code of Regulations (CCR), Title 8, Industrial Regulations, Article 7, Compressed and Liquefied Natural Gas Systems

2.2.2 NFPA Publications

Available from the National Fire Protection Agency, 1 Batterymarch Park, Quincy, MA 02169-7471, Tel: 617-770-3000, www.nfpa.org.

NFPA 30 Flammable and Combustible Liquids Code

NFPA 30A Code for Motor Fuel Dispensing Facilities and Repair Garages

NFPA 70 National Electrical Code

NFPA 72 National Fire Alarm Code

NFPA 79 Electrical Standard for Industrial Machinery

NFPA 497 Classification of Flammable Liquids, Gases, or Vapors and of Hazardous Locations for Electrical Installations in Chemical Process Areas

3. DEFINITIONS

Definition 3.1 is taken from NFPA 52 (1998) (Compressed Natural Gas [CNG] Vehicular Fuel Systems Code). Definitions 3.2 to 3.4, 3.7 to 3.10, and 3.14 are taken from NIST Handbook 44 (Specifications, Tolerances, and Other Technical Requirements for Weighing and Measuring Devices), Appendix D. Definitions 3.5 and 3.11 are based on Handbook 44 definitions.

3.1 Authority Having Jurisdiction

The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

3.2 Contract Sale

A sale where there is a written agreement stating the price as either a fixed price, a price above cost, or an adjustment from the posted price.

3.3 Cryogenic Liquids

Fluids with a normal boiling point below –153 °C (–243 °F).

3.4 Derived Mass Units

Units of sale for customer convenience based directly upon mass units, such as:

Diesel Gallon Equivalent (DGE) – 2.71 kg (5.976 lb) of natural gas*
Diesel Liter Equivalent (DLE) – 0.716 kg (1.578 lb) of natural gas*

* Calculation based on Lower Heating Value LHV of LNG at 21 495.5 BTU/lb with a composition of 98% methane and 2% ethane and a diesel LHV of 128 450 BTU/gal

Gasoline Gallon Equivalent (GGE) – 2.567 kg (5.660 lb) of compressed natural gas**
Gasoline Liter Equivalent (GLE) – 0.678 kg (1.495 lb) of compressed natural gas**

** From NIST Handbook 44

3.5 Direct Sale

A sale in which both parties in the transaction are present when the quantity is being determined. An unattended automated or customer-operated weighing or measuring system is considered to represent the device/business owner in transactions involving an unattended device.

3.6 Dispenser

A device designed for the measurement and delivery of fluids used as fuel.

3.7 Liquefied Natural Gas (LNG)

A cryogenic liquid, produced by reducing the temperature of natural gas to about –162 °C (–260 °F) at atmospheric pressure.

3.8 Mass Flow Meter

A device that measures the mass of a product flowing through the system. The mass measurement may be determined directly from the effects of mass on the sensing unit or may be inferred by measuring the properties of the product, such as the volume, density, temperature, or pressure, and displaying the quantity in mass units.

3.9 NBP

Normal boiling point of a cryogenic liquid at 101.325 kPa (14.696 psi absolute).

3.10 NTP

Normal temperature of 21 °C (70 °F) and pressure of 101.325 kPa (14.696 psi absolute) respectively.

3.11 Point of Sale System

An assembly of elements including a weighing or measuring element, an indicating element, and a recording element (and may also be equipped with a “scanner”) used to complete a direct sales transaction.

3.12 Retail Device

A device used for:

a. Single deliveries of less than 378 L (100 gal) or

b. Retail deliveries of motor fuels to individual vehicles.

3.13 Saturation Pressure

The point at which temperature and pressure of a liquid-vapor system are in equilibrium or the pressure at which the liquid will automatically boil. Raise the temperature, and the pressure will rise, lower the pressure and the temperature will fall. As a commonplace example, water will boil at 100 °C (212 °F) at sea level, but will boil at roughly 94 °C (202 °F) in Denver, where there is less air pressure. If a liquid is artificially pressurized, as in a pressure cooker, it will boil at a higher temperature than when in an open pot. Accurate control of the saturation pressure of dispensed LNG may be important because most LNG vehicle systems presently in use rely on this pressure to drive fuel to the engine.

3.14 Two-Phase Flow

A condition where the liquid is not in a compressed liquid state, but contains some percentage of gas entrained in the flowing liquid.

3.15 Wholesale Device

Any device other than a retail device (see 3.11).

4. CRYOGENIC ISSUES

There are challenges to accurately measure LNG. The most critical are addressed in succeeding sections. Note that these issues are interrelated.

4.1 Heat

Cryogenic liquids, under pressure, will gain heat unless the temperature can be kept at equilibrium. This heat transfer can be minimized, but not eliminated. Heat gain or loss will affect liquid density.

4.2 Saturation Pressure

Accurate control of the saturation pressure of dispensed LNG may be important because most LNG vehicle systems presently in use rely on this pressure to drive fuel to the engine. It is difficult to accurately measure the saturation pressure for flowing LNG.

4.3 Density

The density of LNG varies with saturation pressure. At higher saturation pressures (higher boiling points), LNG is less dense. This means that 3.79 liters (one gallon) of LNG at –154 °C (–246 °F) weighs 1.56 kg (3.44 lb) (and automatically boils at 170.3 kPa [24.7 psia]), and at –129 °C (–200 °F) it weighs 1.40 kg (3.08 lb) (and automatically boils at 790.8 kPa [114.7 psia]). Depending on the technology, a dispensing system must be capable of making corrections for density changes related to temperature, pressure and/or composition.

4.4 LNG Composition

Due to variance in feedstock, liquefaction methods, and LNG storage, the LNG's composition (chemical makeup) may vary. The variation of composition of LNG may change density and can thereby cause measurement errors.

4.5 Sub-Cooling

Cryogenic fluids are generally contained in pressure vessels. It is possible to artificially pressurize these vessels, without changing the temperature or the saturation of the liquid, by adding vapor to the top of the vessel. Under these conditions, the liquid is considered to be "sub-cooled." Pumping the fluid at a higher pressure has this same effect. Either method serves to suppress boiling of the liquid.

5. DISPENSING SYSTEM ISSUES

There are many issues outside of the measuring transducers themselves that affect measurement accuracy. Following are the main things to consider in avoiding measurement inaccuracy.

5.1 Hose Volume Corrections

Design consideration should be given to how the dispensing system will account for the amount of liquid or gas downstream of the meter installation. The dispenser may be designed to incorporate a liquid recirculating feature, a hose draining system or other methods to achieve a controlled condition.

5.2 Two-Phase Flow

Flowing LNG is subject to boiling as heat is added or pressure is reduced during its path from the storage tank to the vehicle system. Depending on the piping configuration, a combination of both vapor and liquid may occur in the system. This is especially true during the initiation of the dispensing process. Most meters experience errors due to two-phase flow. An accurate LNG dispensing system may require a means to detect and correct for the presence of two-phase flow.

5.3 Temperature Effects

Temperature changes may affect the dimensions and material properties of the dispensing system and metering device. Temperature will also impact the density of LNG. Dispensing systems should take these effects into account by design, calibration or correction techniques, if necessary.

5.4 Pressure Effects

Changes in pressure within the dispensing system itself (pressure drop) may cause two-phase flow, as well as density changes. Dispensing systems should take these effects into account by design, calibration or correction techniques, if necessary.

5.5 Composition Compensation

LNG is a mixture consisting primarily of Methane, Ethane, Propane, Butane, and Nitrogen. Composition depends on the feedstock and liquefaction methods. As such, the density of LNG can vary depending upon its composition. Chemical composition corrections should be considered in the metering system design.

5.6 Diversion of Measured Flow

In systems subject to metrological control or custody transfer, no means shall be provided by which any measured liquid can be diverted from the measuring chamber of the device or the discharge line therefrom, except that a manually controlled outlet that may be opened for purging or draining the measuring system shall be permitted. Effective means shall be provided to prevent the passage of liquid through any such outlet during normal operation of the device and to indicate clearly and unmistakably when the valve controls are so set as to permit passage of liquid through such outlet. (This requirement is taken from NIST Handbook 44, Section 3.34 - Cryogenic Liquid-Measuring Devices, S.3.1).

5.7 Vapor Equalization Line

A vapor equalization line shall not be used during a metered delivery unless the quantity of vapor displaced from the buyer's tank to the seller's tank is deducted from the metered quantity. (This requirement is taken from NIST Handbook 44, Section 3.38 - Carbon Dioxide Liquid-Measuring Devices, UR.2.3).

6. DISPENSING SYSTEM SELECTION

When selecting an LNG dispenser, the operation of the fleet(s) it serves should be considered. Refueling frequency, accuracy and metrological requirements should help guide the user.

6.1 Private Stations

For these stations, where metering is for internal accounting purposes, and fueling accuracy to each vehicle is not critical, a relatively simple metering system can be used. Typically these systems may have an accuracy of ±2.5%, but can be specified to meet each user's requirements. These devices are typically not subject to weights and measures approvals or requirements.

6.2 Public (Retail) Stations

If the station is accessible to the public, fleets, government vehicles, or other LNG users, and fuel is dispensed as a retail sale, or dispensed under a fleet or price contract, this type of system is subject to metrological control. More stringent accuracy and metrological requirements are required for this type of dispensing system. These systems typically have a minimum accuracy requirement of ±1.5%.

6.3 Refueling Frequency

6.3.1 All Vehicles Fuel During the Same "Fueling Window"

A fleet operator has all vehicles returned to the refueling station at same time. In this case the dispensing system may not require a dispenser cool down between each fill event. Potential losses in time and product associated with stabilizing a metering system become less important.

6.3.2 Intermittent Fueling

The system will be used randomly throughout the day; the dispenser must be stabilized each time to safeguard dispensing accuracy. Potential losses in time and product to perform multiple stabilizing cycles during the day may affect the economics of the station.

7. MEASUREMENT DEVICE TYPES

There are many types of measurement devices. This document cannot list all of the varying types and it does not intend to limit LNG measurement to the devices listed in 7.1 to 7.3.