PEI RP-1600
Recommended Practices for the Design, Construction, Installation, Operation and Maintenance of Liquefied Natural Gas/Liquefied Compressed Natural Gas Vehicle Fueling Facilities
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1. INTRODUCTION

1.1 Origin. The Petroleum Equipment Institute (PEI) has produced this document as an industry service. These practices are the consensus recommendations of the PEI LNG Fueling System Installation Committee. This committee includes experienced representatives from service and installation contracting companies, liquefied natural gas (LNG) equipment manufacturers, natural gas suppliers, and engineering firms. In addition, the committee has had the benefit of thoughtful comments submitted by parties interested in the LNG fueling industry.

FIGURE 1-1. Example of an LNG Fueling Facility.

1.2 Background. LNG fueling facilities are not very common in many parts of the world. Although they were first introduced in the U.S. in the 1970s, LNG fueling facilities remain relatively rare in the U.S. today. Environmentally, natural gas vehicles are considerably cleaner in terms of combustion byproducts compared to other petroleum fuels. Recent dramatic increases in natural gas production in the U.S. have given LNG a potential cost advantage over traditional liquid motor fuels. This cost advantage has provided incentive for many fleet operators to significantly reduce fuel costs. Demand for LNG fueling facilities has created a need for
information regarding the basic design, installation, operation and maintenance of these facilities. LNG and petroleum fueling processes have numerous similarities. However, they also have significant differences.

1.3 Purpose. The primary purpose of these recommended practices is to provide a basic reference to promote the safe and reliable design, engineering, construction, operation and maintenance of LNG fueling systems. This document may be useful to those considering using LNG for vehicle fueling and who want to learn about how these facilities work, and to those seeking information about the design and performance factors that should be considered before investing in such a facility. Code enforcement personnel who are charged with permitting and inspecting LNG fueling facilities also may find this document a useful reference.

This document provides basic background information regarding LNG fueling systems. This document by itself will NOT provide all of the information required to successfully design, build, operate, service or inspect an LNG fueling system. These recommended practices present basic information that should allow the careful reader to understand:

- the terminology used to describe LNG fueling systems;
- the various types of LNG fueling systems;
- the concepts involved in planning and designing LNG fueling systems;
- the basic construction of an LNG fueling system;
- the basic steps required to properly operate and maintain an LNG fueling system;
- references for further information.

This document is not intended to endorse or recommend particular materials, equipment, suppliers or manufacturers.

1.4 Scope. These recommended practices apply to outdoor public and private LNG vehicle fueling facilities that receive LNG via cryogenic transport from nearby liquefiers and/or storage facilities. These LNG fueling facilities store limited quantities of LNG and dispense the LNG into vehicle fuel tanks. The scope of this document includes offloading, storage and dispensing at:

- private fueling facilities;
- commercial fleet fueling facilities (which may be open to the public as well);
- retail fueling facilities.

There are many other types of gaseous fuels and gaseous fuel facilities that are not included in the scope of this document. These recommended practices do NOT apply to:

- propane (LPG) fueling facilities;
- LNG facilities that include below-grade storage vessels;
bulk fueling depots where large quantities of LNG are transferred to ships, trains or mobile trailers;
utility applications such as peak shaving;
oilfield applications;
vehicles or skid-mounted systems equipped with storage tanks, a pump and a dispensing system designed as self-contained, mobile fueling facilities for LNG vehicles;
trailer-mounted LNG fueling systems intended to provide temporary fueling services;
facilities designed to fill portable LNG tanks;
garages or other buildings where maintenance work is performed on LNG vehicles.

This document provides generalized design and installation considerations, and guidelines for proper operation and maintenance of LNG fueling facilities. This document is not a how-to manual. Facility owners should rely on:

- reputable equipment manufacturers, packagers and distributors to provide quality equipment with operation and maintenance instructions;
- qualified and experienced engineers to provide risk assessment and site-specific design specifications;
- knowledgeable and experienced contractors to build LNG fueling facilities;
- knowledgeable and experienced maintenance personnel to perform maintenance and repair tasks.

These recommended practices are not intended to provide interpretation of regulatory requirements related to LNG storage systems or LNG vehicle fueling facilities. Nothing in this document is intended to discourage the development and implementation of new equipment, installation methods, procedures and/or applications of LNG.

1.5 Sources. The information in this document has been provided by equipment manufacturers, experienced installers, contractors, service providers, engineers and the members of the PEI LNG Fueling System Installation Committee.

1.6 Codes and Standards. There are a variety of widely used codes and standards published by the National Fire Protection Association (NFPA), the International Code Council (ICC), the American Society of Mechanical Engineers (ASME), the American National Standards Institute (ANSI), the Canadian Standards Association (CSA), the International Organization for Standardization (ISO), and the National Board of Boiler and Pressure Vessel Inspectors (NBBI) that apply to LNG fueling facilities. Refer to Appendix A, Publication Reference of this document for a listing of codes, standards and recommended practices of other industry organizations, which have some relation to design, installation, operation and maintenance of LNG fueling equipment and facilities.
The PEI LNG Fueling System Installation Committee believes that the information in this document is generally consistent with the current versions of widely used codes as of the publication date of these recommended practices. Many jurisdictions also have state or local regulations that apply to LNG fueling facilities. While the general requirements of regulations are similar, specific requirements may differ from jurisdiction to jurisdiction. Consult with local and state code enforcement authorities when designing any LNG fueling facility. If the project is located on a military base, national park or other federal land, federal authorities also should be consulted.

The PEI LNG Fueling System Installation Committee has not attempted to describe or interpret specific regulations in this document. The committee makes no warranty that following these recommendations will comply with all code requirements. It is the responsibility of owners and operators of LNG fueling facilities to verify that their LNG fueling systems meet all applicable regulatory requirements.

**WARNING:** LNG fueling facilities present risks in addition to those of conventional fueling systems due to potential exposure to cryogenic liquids and release of non-odorized flammable vapor clouds. These risks need to be mitigated through proper training and implementation of LNG-specific procedures. Only properly trained, competent personnel should operate, maintain and repair LNG fueling systems.

### 1.7 Importance of Competent Installers and Technicians.

The design and construction of LNG vehicle fueling systems is a specialized trade requiring knowledge and skills that are unique to these types of facilities. Only knowledgeable, experienced and competent engineers, equipment manufacturers, contractors and maintenance personnel should undertake LNG vehicle fueling system work. The use of personnel who have the specialized training experience and integrity to do the job correctly provides the greatest assurance that the facility will operate safely, reliably and efficiently.

### 1.8 Importance of Competent LNG Facility Operators.

A knowledgeable and conscientious facility operator is key to the reliable and safe operation of LNG vehicle fueling systems. The facility operator is responsible for frequent inspection of the facility to listen and check for leaks and to record operating parameters. A successful LNG fueling program requires the active participation of the facility operator.
2. DEFINITIONS

When used in this document, the terms listed below have the following meanings.

2.1 Approved. Acceptable to the individual responsible for determining whether equipment, materials, an installation or a procedure are appropriate for a specified purpose. The individual may be someone employed by a regulatory agency, the owner of the facility, or an individual employed by a company hired to design or build a facility.

2.2 Bleed Valve. A small valve used to relieve pressure to atmosphere so that a pressurized system can be safely disassembled. A bleed valve is often installed between two isolation valves so that a small section of a pressurized system can be isolated, the pressure released and a component of the system safely removed or serviced.

2.3 Breakaway Connector. A device installed in LNG fuel and vent hoses connecting the fueling nozzle to the dispenser or fueling post. Breakaway connectors are intended to prevent the release of flammable gas and to protect dispensers and fueling posts from damage when vehicles leave the fueling area with the LNG nozzle still connected to the vehicle fuel receptacle. See Section 5.15.2 for additional information.

2.4 British Thermal Unit (BTU). The amount of energy needed to raise the temperature of one pound of water 1°F. A standard cubic foot (scf) of natural gas contains approximately 1,030 BTUs of energy.

2.5 Classified Area. A general term for a location where fire or explosion hazards due to the presence of natural gas may be present. Only specialized electrical equipment can be used in classified areas. See Chapter 10 for additional information. See also the definitions for Class I, Division 1 and Class I, Division 2 in this chapter.

2.6 Class I, Division 1. Part of a classification system used by the National Electrical Code (NFPA 70) to describe the fire or explosion hazard present in a specific area. In a Class I, Division 1 location, at least one of the following statements is true.

- Ignitable concentrations of flammable gases or vapors can exist under normal operating conditions.
- Ignitable concentrations of flammable gases or vapors may exist frequently because of repair or maintenance operations or because of leakage.
- Breakdown or faulty operation of equipment may release ignitable concentrations of flammable gases or vapors, and may also cause simultaneous failure of electrical equipment.
2.7 **Class I, Division 2.** Part of a classification system used by the National Electrical Code (NFPA 70) to describe the fire or explosion hazard present in a specific area. In a Class I, Division 2 location, at least one of the following statements is true.

- Flammable gases are handled, processed or used in the location, but the gases are normally confined within a closed system. The flammable gases can be released only if there is accidental rupture or breakdown of the system, or the equipment is operating abnormally.
- Ignitable concentrations of flammable gases are normally prevented from accumulating in the location by positive mechanical ventilation. The location may become hazardous if the ventilating equipment fails or operates abnormally.
- Ignitable concentrations of flammable gases may occasionally migrate from an adjacent Class I, Division 1 location, unless such migration is prevented by positive pressure ventilation from a source of clean air, and effective safeguards against failure of the ventilation system are provided.

2.8 **Deflagration.** A fire in which the flame travels at a subsonic speed. Flammable concentrations of natural gas in air at ambient pressure combus via deflagration.

2.9 **Diesel Gallon Equivalent (DGE).** The amount of natural gas that contains the same amount of energy as 1 gallon of diesel fuel. The diesel gallon equivalent has not been officially defined by any standard setting organization, but it is generally considered to be equal to 6.45 pounds of natural gas. See Section 4.2 for additional information.

2.10 **Dispenser Pump.** A centrifugal type pump with a variable frequency drive (VFD) electric motor drive. The pump is normally vertical, installed in a vacuum jacketed sump and submerged in cryogenic liquid. It is normally designed/installed to provide cryogenic liquid flow from the storage tank to the vehicle fuel dispenser. In some cases, it also may be used to provide cryogenic liquid off-loading. The dispenser pump is normally installed on a skid with control valves, pressure relief valves and pressure/temperature transmitters, and is normally controlled by the site programmable logic controller (PLC).

2.11 **Downstream.** A term used to indicate the relative position of gas handling components in a fueling system. The position is defined relative to the direction of gas flow inside the piping or tubing. For example, if a breakaway fitting is “downstream” of an isolation valve, the gas would first pass through the isolation valve and then through the breakaway fitting. Compare “Upstream.”

2.12 **Drip Leg.** A short, vertical length of piping or tubing installed at the bottom of a pressure relief valve vent riser. The drip leg extends the vent riser downward below the outlet of the
pressure relief valve so any water that enters the vent riser will not interfere with the operation of the pressure relief valve. See Section 13.4 for additional information.

2.13  **Dual Phase Flow.** Process piping conveying both LNG as a cryogenic liquid and gas phase methane. The dual phase flow mixture may be transient, separated gas and liquid, bubbles or droplets. Heat transfer and pressure drop can induce dual phase flow in LNG systems.

2.14  **Emergency Shutdown Device (ESD).** A general term often used in the LNG industry to reference a component of the emergency shutdown system. Collectively, multiple ESD’s work together to form a complete system. The system is designed to quickly shut down the operation of an LNG fueling facility and de-energize electrical circuits in the fueling area(s). See Section 8.2 for additional information.

2.15  **Emergency Stop Switch.** A clearly identified switch intended to be used when emergency situations arise at LNG fueling facilities. Activating the switch automatically:
- shuts off the gas supply to the compressor, dispenser(s) and fueling posts;
- shuts down the compressor(s);
- disconnects all electrical power to the fueling area(s).
See Section 8.2.1 for additional information.

2.16  **Enclosure.** A structure containing the electrical controls and related equipment that provides protection from the weather and noise reduction. See Sections 5.22 and 10.6 for additional information.

2.17  **Extended Stem Valves.** Extended stems and bonnets position the stem packing above the cryogenic fluid, providing a column of warmer vapor that insulates the stem seal from the effects of low temperatures.

2.18  **Full-Port Valve.** A type of valve that provides minimal restriction to flow when in the open position.

2.19  **Hose Assembly.** A length of hose with fittings at each end. In an LNG fueling system, hose assemblies are used to connect the dispenser cabinet to the breakaway connector and the breakaway connector to the nozzle.

2.20  **Hydrocarbon.** Any of a class of compounds consisting of hydrogen and carbon atoms. Gasoline, diesel fuel and natural gas are all composed primarily of hydrocarbon compounds.

2.21  **Intrinsically Safe Circuit.** A specially designed electrical circuit that cannot generate enough heat or spark energy to ignite a flammable material, even when the intrinsically safe
circuit is faulty. Intrinsically safe circuits can be used in Class I, Division 1 or Division 2 areas. Compare “Non-Incendive Circuit.” See Section 11.3.2 for additional information.

2.22 **Isolation Valve.** Any type of valve that is used to close off flow through a tube or pipe. Types of isolation valves commonly used in LNG service include ball valves, gate valves and butterfly valves.

2.23 **Listed.** Equipment or materials included on a list published by a nationally recognized testing laboratory, inspection agency or other organization concerned with product evaluation. The listing indicates that equipment or materials meet nationally recognized standards and have been tested and found suitable for use in a specified manner. The listing organization conducts periodic inspections of production facilities where listed equipment or materials are manufactured. A listed product bears a stamp or label indicating the listing organization.

2.24 **Liquefied to Compressed Natural Gas (LCNG).** An LNG fueling facility that uses liquefied natural gas (LNG) as a source of methane gas rather than a local natural gas distribution system to produce compressed natural gas (CNG) for fuel. CNG is methane compressed to several thousand pounds per square inch to reduce its volume and make it practicable as a motor-vehicle fuel. See Chapter 6 The LCNG Option.

2.25 **Liquefied Natural Gas (LNG).** Natural gas cooled to -260°F to convert the gas to liquid form. The process of liquefying natural gas is not covered in this document.

2.26 **Liquid Level Gauge.** An Analog dial type gauge connected with stainless tubing through the outer tank wall and into the inner space of an LNG tank. Typically, 1 tube into the bottom of the tank in the liquid space and 1 tube in the vapor space allows for tank pressure and level indication utilizing a simple mechanical pressure method.

2.27 **LNG Containment.** Impoundment (dikes) topography, concrete walls, stainless steel or other compatible methods used to direct or confine an LNG spill.

2.28 **LNG Equipment Packager.** LNG equipment packagers typically buy components such as storage tanks, pumps, valves, motors and controls from manufacturers. LNG equipment packagers then fabricate skids, pump systems and enclosures, and assemble these components. Packagers typically also offer design services to select appropriate components for a specific application. An experienced LNG equipment packager can provide compatible equipment that will minimize start-up and operational problems. See Section 9.2 for additional information.
2.29 **LNG Nozzle.** An LNG fueling nozzle. Typically, the mechanism that latches the nozzle to the vehicle fuel receptacle and the valve that controls the flow of gas are both controlled by a single lever. See Section 5.15.1 for additional information.

2.30 **LNG Sump.** A system for the safe storage of LNG. The system consists of a storage vessel located in a containment area designed to allow for the safe capture of the LNG product if a rupture or spill from the fueling system should occur.

2.31 **Lower Explosion Limit (LEL).** The lowest concentration of a gas or a vapor in air capable of producing a flash of fire when an ignition source is present.

2.32 **Maximum Allowable Working Pressure (MAWP).** The maximum pressure the weakest point of the equipment, system or vessel can handle at a specific temperature when in normal operation.

2.33 **Mercaptan.** A class of organic sulfur compounds with a strong odor. Mercaptans are added to natural gas to facilitate leak detection. See Section 3.5 for additional information.

2.34 **Methane.** A compound consisting of four hydrogen atoms bound to a single carbon atom. The chemical formula is CH₄. Methane is the dominant component of natural gas. See Section 3.1 for additional information.

2.35 **Natural Gas.** Gas that is produced directly from wells drilled into the earth. It is a mixture of hydrocarbon gases composed primarily of methane with minor amounts of ethane, propane and butane. See Chapter 3 for additional information.

2.36 **Non-Incendive Circuit.** A specially designed electrical circuit that cannot generate enough heat or spark energy to ignite a flammable material when the circuit is operating normally. Non-incendive circuits can be used in Class I, Division 2 areas. Compare “Intrinsically Safe Circuit.” See Section 11.3.2 for additional information.

2.37 **Offload Pump.** A centrifugal, electric powered cryogenic pump that is normally located near the LNG storage tank/LNG tanker off-loading connections. The offload pump is typically skid mounted and contains control valves, pressure/temperature sensors and pressure relief valves. The offload pump is controlled by the site PLC.

2.38 **Permissives.** A control system where one or more process conditions or states all must be met before a motor or other equipment is started. Each condition or state is referred to as permissive for the process to start.
2.39 **Pneumatic Testing.** A procedure for establishing the absence of leaks and the structural integrity of components and fittings in an LNG fueling system. The test procedure consists of pressurizing the LNG fueling system with a gas and using a leak detection solution to identify leaks. See Section 15.2 for additional information.

2.40 **Pound per Square Inch (PSI).** The unit of force commonly used in the English measurement system to describe the pressure exerted by a gas on its container.

2.41 **Pressure Regulator.** A normally open valve installed at the upstream end of a piping system to reduce the pressure downstream of the valve. Spring pressure keeps the valve in the open position until the pressure downstream of the valve is sufficient to overcome the spring pressure and close the valve. The pressure regulator may be used to provide lower pressure gas for downstream components or to protect pressure sensitive equipment downstream of the regulator from pressure spikes.

2.42 **Pressure Relief Valve (PRV).** A normally closed valve that opens automatically when the pressure in a fueling system component exceeds the pressure set point at which the valve is intended to open. A pressure relief valve should be set to open at slightly less than the maximum allowable working pressure of the component(s) the pressure relief valve is protecting. Also known as a “pressure relief device” (PRD) or a “safety relief device” (SRD). See Sections 7.6 and 8.3 for additional information.

2.43 **Pressure Sensor.** A pressure measuring device where the voltage output of the device is proportional to the pressure. Pressure transducers are typically connected to programmable logic controllers (PLCs) and used to monitor the operating pressure of various portions of the LNG fueling system. See Section 7.3.1 for additional information.

2.44 **Programmable Logic Controller (PLC).** An industrial computer that monitors and controls the operation of various components in an LNG fueling system. See Section 5.19 for additional information.

2.45 **Pull Box.** A four-sided frame with a cover usually installed in the ground at grade level. A pull box often is used to pull wires through buried electrical conduit.

2.46 **Purge System.** A method for reducing or eliminating the hazard classification of an enclosed area. Purging prevents the accumulation of flammable gas or vapors in an enclosed area by providing a continuous supply of clean air or inert gas into the area. See Section 11.3.3 for additional information.
2.47 **Purple K (PKP).** Dry chemical fire extinguisher media consisting primarily of potassium bicarbonate. Purple K is the fire extinguisher agent typically specified for use at LNG facilities.

2.48 **Receiver Tank.** A tank that stores compressed air discharged by an air compressor. The compressed air flows from the receiver tank to its point of use.

2.49 **Receptacle.** The fitting in a vehicle fueling system where the nozzle attaches to deliver LNG to the vehicle fuel cylinder. See Section 5.15.1 for additional information.

2.50 **Safety Relief Valve.** See Pressure Relief Valve.

2.51 **Saturation.** The process of adding external heat to a cryogenic liquid that results in temperature and pressure increases. The use of saturation for LNG is primarily for LNG tank pressure as required for vehicle fueling and engine performance.

2.52 **Saturation Vaporizer.** An ambient air fin type heat exchanger that is integrated into the cryogenic tank liquid circuit to provide the ability to add heat to the cryogenic liquid. This process is normally referred to as saturation. The vaporizer is typically made out of aluminum or stainless steel, includes tubes/fins, and utilizes pressure/temperature sensors and valves to control the liquid passing through the vaporizer.

2.53 **Standard Conditions.** Specific conditions of temperature and pressure that are used to define a volume of gas. For natural gas, standard conditions are one atmosphere of pressure (14.7 pounds per square inch) and a temperature of 70°F.

2.54 **Storage Tank Compound.** The area in an LNG fueling facility where all the major components (storage tank, pumps, valves, etc.) except the dispensers or fueling posts are located.

2.55 **Trycock.** A mechanical hand valve located in the piping section of all LNG cryogenic vessels. Its connected into the liquid space via stainless pipe or tube utilized for determining upper end tank level given you cannot “stick” or visually see the level inside a double walled pressure vessel. Typically, there are 2 levels of measurement with the trycock method, a 95% and 85% (depending on tank manufactures). It is also used when calibrating pressure transducers and liquid level gauges to determine exact liquid level so as to not overfill the tank.

2.56 **Tube or Tubing.** Tubing is specified by its outer diameter, and tubing fittings are designed to mate with the outside surface of the tube.

2.57 **Unattended LNG Fueling Facility.** An LNG fueling facility where an attendant is not routinely present to monitor end-users as they fuel their vehicles.
2.58 **Upstream.** A term used to indicate the relative position of gas-containing components in a fueling system. The position is defined relative to the direction of gas flow inside the piping or tubing. For example, if an isolation valve is “upstream” of a breakaway connector, then the gas would first pass through the isolation valve and then through the breakaway connector. See also “Downstream.”

2.59 **Vacuum Jacketed Piping.** Double-wall piping or two pipes in one—an inner carrier pipe in which the cryogenic liquid is transferred, and an outer pipe that supports and seals the vacuum insulation, forming the “vacuum jacket” around the inner pipe.
3. CHARACTERISTICS OF NATURAL GAS

3.1 Composition of Natural Gas. As the name implies, most natural gas is produced directly from the ground. When it comes out of the wellhead, natural gas is a mixture of hydrocarbon gases primarily composed of methane with lesser amounts of ethane, propane, butane and other hydrocarbons. Carbon dioxide, nitrogen and hydrogen sulfide also are present. (See Table 3-1.) Natural gas is then processed to remove certain components. Ethane, propane and butane are valuable gases in their own right and are separated so that they can serve other commercial purposes. These gases are relatively easy to liquefy and are often referred to as natural gas liquids (NGLs). Ethane is difficult to remove completely, so some ethane usually remains in the processed natural gas. Carbon dioxide and hydrogen sulfide can cause corrosion issues, so they are removed from natural gas to protect equipment. After processing, natural gas often is referred to as “pipeline quality gas” because it should meet the quality standards for long distance transport through pipelines.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Chemical Formula</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane</td>
<td>CH₄</td>
<td>70-90%</td>
</tr>
<tr>
<td>Ethane</td>
<td>C₂H₆</td>
<td></td>
</tr>
<tr>
<td>Propane</td>
<td>C₃H₈</td>
<td>0-20%</td>
</tr>
<tr>
<td>Butane</td>
<td>C₄H₁₀</td>
<td></td>
</tr>
<tr>
<td>Carbon Dioxide</td>
<td>CO₂</td>
<td>0-8%</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>N₂</td>
<td>0-5%</td>
</tr>
<tr>
<td>Hydrogen Sulfide</td>
<td>H₂S</td>
<td>0-5%</td>
</tr>
<tr>
<td>Oxygen</td>
<td>O₂</td>
<td>0-0.2%</td>
</tr>
<tr>
<td>Rare Gases</td>
<td>Argon, Helium, Neon, Xenon</td>
<td>Trace</td>
</tr>
</tbody>
</table>

**TABLE 3-1. Typical Composition of Natural Gas at the Wellhead.** While methane is the primary component, a number of other compounds are present when natural gas is produced from the wellhead and must be removed to meet the standards for pipeline quality gas.

The exact composition of pipeline quality natural gas varies from place to place depending on the source of the gas and the degree of processing. The composition of the gas also may vary over time due to variations in the composition of the source gas. The typical composition of pipeline quality natural gas is given in Table 3-2. Methane is the dominant component. All of the compounds listed in Table 3-2 are gases and, except for carbon dioxide and nitrogen, are hydrocarbons that will burn in a natural gas engine.
<table>
<thead>
<tr>
<th>Compound</th>
<th>Range (Percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane</td>
<td>74.5–98.1%</td>
</tr>
<tr>
<td>Ethane</td>
<td>0.5–13.3%</td>
</tr>
<tr>
<td>Propane</td>
<td>0.0–2.6%</td>
</tr>
<tr>
<td>Other Hydrocarbons</td>
<td>0–2.1%</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>0–10%</td>
</tr>
<tr>
<td>Carbon Dioxide</td>
<td>1%</td>
</tr>
</tbody>
</table>

**TABLE 3-2. Typical Composition of Natural Gas in Pipelines.**

### 3.2 Characteristics of LNG

Liquefied natural gas (LNG) is stored and handled as an extremely low-temperature cryogenic liquid. The low temperatures densify the LNG, which creates unique conditions that must be addressed. Although LNG tanks require some pressure to minimize evaporation, the pressure is relatively low. However, each containment vessel must be provided with a pressure relief mechanism that allows pressures to remain within the specified operation ranges. Boiloff and subsequent venting from LNG tanks must be done safely and in consideration of nearby sources of ignition, air handling equipment and regulatory restrictions.

#### Properties of Liquefied Natural Gas

<table>
<thead>
<tr>
<th>Property</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flammable Range</td>
<td>A mixture of 5% to 15% of natural gas to air at atmospheric pressure will burn if an ignition source is present. If the mixture is less than 5% or more than 15% of natural gas to air, the mixture will not ignite.</td>
</tr>
<tr>
<td>Ignition Temperature</td>
<td>Natural gas has a high ignition temperature of approximately 1,076°F. By comparison, diesel ignites at 410°F and gasoline at 536°F.</td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>The specific gravity of natural gas ranges from approximately 0.6 to 0.7. By definition, the specific gravity of air is 1.0. This means that natural gas is a little more than half as dense as air and will rise and disperse if it is released into the atmosphere. At a temperature of -166°F, natural gas has the same density as air. It is important to recognize that LNG fuel density may have considerable effects on fire prevention and firefighting procedures.</td>
</tr>
<tr>
<td>Boiling Temperature</td>
<td>At atmospheric pressure, natural gas changes from a liquid to a gas at a temperature of -259°F. Another way of looking at this is that natural gas must be cooled to -259°F to convert the gas into LNG.</td>
</tr>
<tr>
<td>Color</td>
<td>Natural gas is colorless. It typically burns with a blue flame.</td>
</tr>
<tr>
<td>Odor</td>
<td>Natural gas is odorless. Currently LNG cannot be odorized with existing technology.</td>
</tr>
</tbody>
</table>
Energy Content | A gallon of LNG contains approximately 78,000 British Thermal Units (BTUs) of energy compared to 126,000 BTUs in a gallon of petroleum diesel fuel. (Source: Engineering Toolbox)

| Volatility | LNG, as a cryogenic fluid, will readily change phase from liquid into gas when exposed to warmer environmental temperatures. LNG dispersion is an important consideration in facility planning. |

**TABLE 3-3. Properties of LNG.**

3.3 **Distribution of Liquefied Natural Gas.** After liquefaction, LNG is transported in cryogenic trailers to the end-user locations.

3.4 **Hazards of Natural Gas.** Natural gas burns very rapidly. It can produce an explosion in a confined space when the gas/air mixture is in the flammable range and a source of ignition is present.

Natural gas is not toxic, but it can displace oxygen and produce an oxygen-deficient atmosphere. Breathing air that does not contain enough oxygen can result in loss of consciousness and death by asphyxiation.

![Methane molecule](image)

**FIGURE 3-1.** *A molecule of methane, the second-most common molecule in the known universe.*

3.5 **Odorant.** LNG is odorless. If LNG is to be converted to other forms of fuel gas, odorants are added for detection purposes, for example, in the case of LCNG.
**WARNING:** LNG is not currently capable of being odorized. Special care must be taken around all LNG equipment. Use of a handheld methane detector or a four-gas personnel monitor is highly recommended.

3.6 **Safety.** Due to the flammable nature of natural gas and the special material requirements of cryogenic fluids, all components of an LNG fueling system should be approved or, where applicable, listed for their intended use. (Refer to Chapter 2 for definitions of “approved” and “listed.”)

**NOTE:** All components of an LNG fueling facility must be carefully assembled and conscientiously maintained to safely contain and handle LNG. In addition to the hazards posed by natural gas, LNG poses additional hazards including the following:

- fittings, valves or other low-temperature components that are compromised could cause fatal injuries if they strike a person.
- a gas or liquid stream could cause injury if it contacts a person.
- the release of LNG can produce a flammable vapor cloud of evaporating LNG.
- large amounts of natural gas can displace the oxygen necessary for breathing.
- cryogenic burns can cause permanent skin damage or blindness.
- cryogenic temperatures may cause failures in incompatible or misapplied materials, including structural items.
4. FILLING A VEHICLE WITH LNG

4.1 Introduction. Due to the differences in the physical properties of liquids and gases, the processes for filling vehicle fuel tanks with petroleum fuel versus liquefied natural gas (LNG) are very different. The most important differences in the physical properties of these substances are cryogenic temperatures and boil-off characteristics.

![Image of LNG refueling](image)

**FIGURE 4-1. LNG Refueling is Different from Conventional Fueling.**

4.2 Diesel Gallon Equivalent. To make the LNG refueling process seem as familiar as possible to end users, LNG dispensers measure the amount of natural gas that is dispensed in diesel gallon equivalents (DGEs). This is the amount of LNG that contains the same amount of energy as 1 gallon of diesel fuel. The National Conference of Weights & Measures (NCWM) has equated 6.059 pounds of LNG as having 100% of the energy of 1 gallon of diesel fuel as described in the National Institute of Standards and Technology (NIST) Handbook 44, Specifications and Tolerances and Other Technical Requirements for Weighing and Measuring Devices.

4.3 Fueling Process. LNG fueling is a semiautomated process controlled by the fueling personnel, the programmable logic controller (PLC) and the flow computer. The fuel dispensed into the vehicle tank is measured using a Coriolis flow meter and flow computer. The dispensers
may be linked to a point-of-sale (POS) system authorize and record the transaction. To meet metrological requirements, the dispensing loop must be sufficiently cooled down before dispensing may commence. Product always shall be returned back to the storage tank.

Typically, there are three connections between the dispenser and the LNG vehicle fuel tank: the ground connection; the fill line (containing liquid); and the return line (containing vented gas that is being returned to the bulk storage tank). In most retail cases, a cryogenic pump boosts pressure to provide the fill rates specified by the vehicle tank manufacturer. In some industrial cases, differential pressure is used without requiring a boost pump. In the case of two lines, the displaced volume from the vehicle fuel tank is returned at cryogenic temperatures.

Typical procedures for LNG fueling include the following steps.
1. Instructions for fueling are presented and followed.
2. Personal protective gear is worn.
3. A grounding connection is established between the dispenser and the vehicle.
4. The vent hose is removed from the holder and attached to the vehicle vent adaptor.
5. The fuel hose is removed from the holder and attached to the vehicle fill adaptor.
6. The product is selected and the dispenser begins the recirculation process, after which filling begins.
7. The dispenser goes into a paused state when the tank is full. If additional tanks are present, the driver first moves the vent hose and then the filling hose to the next tank. In such cases, the driver presses the pause/resume button to fill the connected tank.

4.4 Typical LNG Vehicle Fuel Tank Capacities. The capacity of fuel tanks in LNG vehicles is generally stated as the number of DGEs the fuel tank can hold. Typical fuel tank capacities for LNG vehicles produced today have 100 to 150 DGEs for heavy-duty trucks. Larger vehicles often will have multiple fuel tanks to achieve these fuel capacities.

4.5 Frost on LNG Hanging Hardware. Because of the cryogenic nature of LNG and the high fueling transfer rate, a heat transfer is created and the hanging hardware becomes very cold. Below the dew point of the ambient air, considerable frost will form on the hardware. Personal protective equipment is appropriate for handling hanging hardware.
5. BASIC COMPONENTS OF AN LNG FUELING SYSTEM

5.1 **Introduction.** This chapter presents an overview of the main components of a liquefied natural gas (LNG) fueling facility and how these components function together to create a safe and efficient vehicle fueling system. The components are described in the order in which the natural gas would flow from the LNG delivery transport to the customer vehicle. Not all the components described in this chapter are present in every LNG fueling system. In this discussion we address only the LNG aspect of a system, which may include liquefied compressed natural gas (LCNG). That subject is considered in Chapter 6, The LCNG Option. The basic configuration of an LNG system is illustrated in Figure 5-1.

![LNG Station Process Diagram](http://www.ngvamerica.org/stations/lnglcng/)

**FIGURE 5-1. LNG Station Process Diagram.** [http://www.ngvamerica.org/stations/lnglcng/](http://www.ngvamerica.org/stations/lnglcng/)

5.2 **LNG Supply.** This recommended practice addresses LNG fueling systems where the natural gas is supplied to the facility from a local LNG liquefaction plant. The LNG supplier will provide LNG via cryogenic transport trailer to the facility. The LNG will then be transferred to the site storage via an offload pump.

5.3 **Off-Load Hoses and Connections.** Cryogenic-rated hoses and connections typically have outside diameters of 2 or 3 inches; connections are typically LNG-300 or quick-connect couplers.

5.4 **Grounding Equipment.** The facility must be verifiably connected to ground with permissive ground interconnections for offloading and the fueling vehicle should be connected to
the facility ground for refueling. This equipment is available from various manufacturers in packaged systems.

5.5 **Containment System.** Containment is used to safely restrict the spread of LNG due to spills, leaks or equipment failures at the facility. Offloading and the operational containment system should be consistent with the requirements of NFPA52.

5.6 **Transfer Piping.** Piping and fittings between the delivery hoses and the LNG storage system must be stainless steel, insulated and/or vacuum jacketed, and rated for the temperatures and pressures of an LNG fueling facility.

5.7 **LNG Offload Pump.** The offload pump transfers the tanker contents to the facility storage. Once the LNG transport arrives and is properly grounded, cryogenic-rated hoses are connected from the transport to the offload panel and pump connections. The pump is then started (normally by the site programmable logic controller [PLC]) and the transport is offloaded into the storage tank. Depending on the saturation condition of the storage tank, there may be multiple filling parameters to manage the receiving tank pressure. There could be bottom fill, top fill and/or a combination of the two in order to provide the best pressure and level of LNG fill.

5.7.1 **Ground-Mount Pump.** This is a skid-mounted or submersible pump that transfers the delivered product from the tank truck to the facility storage.

5.7.2 **Trailer-Mounted Pump.** This performs the same function as the ground-mount pump, but is part of the delivery vehicle.

5.8 **Saturation Heat Exchanger (Ambient Air).** LNG dispensing typically requires that the storage tank be at a saturated pressure to correspond to the vehicles being fueled. This saturation is normally handed by a heat exchanger that is part of the system. The heat exchanger routes the liquid and introduces ambient temperatures to allow the liquid to build pressure and temperature to the saturation point, allowing it to meet customer specifications.

5.9 **Storage Tank.** The storage tank for LNG is either a vertical or horizontal insulated tank designed specifically for cryogenic LNG storage purposes. Tanks are sized according to peak throughput rates, reserve quantity desired and delivery tanker capacity. Considerations such as available space and height clearances as well as future growth expectations are covered in Chapter 10.

5.10 **Safeguarding System.** Protection against over-pressure of equipment may include electronic shutdown devices (ESDs), relief valves, methane detectors, rupture discs, high- and low-temperature detectors, block valves, flame detection, fire valves, impact protection, and
similar failure protective process equipment, depending on design parameters and risk analysis. See Chapter 8 for additional information about safety systems.

5.11 **Warnings and Informational Signage.** Warnings include signs for operation, delivery, maintenance, safety and emergency procedures and equipment intended to protect operators, customers and the public. See Chapter 14.

5.12 **Boil-off Gas Management System.** This includes various solutions to minimize or eliminate fugitive emissions of methane due to boil-off of LNG. These may include power generation for local use or utility grid, re-liquefaction, CNG compressor, boiler heat, reintroduction to gas distribution utilities, etc.

5.13 **LCNG Interface Equipment.** LCNG interface equipment includes optional equipment necessary to interface with CNG resale systems. This equipment may include pumps, vaporization, compression, odorization and other process equipment. See Chapter 6 for additional information.

5.14 **Dispenser.** LNG dispensers typically look and work like petroleum fuel dispensers, measuring and dispensing LNG. Normally, the dispenser will have been designed to provide a fill based on vehicle tank pressure, saturated pressure in the storage tanks and ambient temperatures. At facilities where fuel is purchased, the dispenser calculates the total cost of the fuel delivered. Such calculating capabilities may be governed by an authority having jurisdiction (AHJ).

An LNG dispenser typically consists of an upper electrical compartment that contains the electronic components required to operate the customer interface (which may include a card reader) and the displays for the price per unit, total sale and quantity dispensed. The electrical compartment must be designed for operation in an electrically hazardous location. In retail or card-lock facilities, the electrical compartment also contains communication components to transfer the sales information to a remote location. Because of the proximity of these electrical components to the dispenser components carrying natural gas, the electrical components must be designed for use in a classified area. Refer to Chapter 11 for additional information about classified areas.

The dispenser also includes a lower fuel handling compartment containing components that measure and control the flow of LNG. Typical components of the fuel handling compartment include the following:

- an operable valve on each incoming LNG line and vent line so the dispenser can be isolated from the system;
- valves controlled by the fill system that determine when to start fueling;
• bleeder valves that allow the pressure in the dispenser components to be vented so that maintenance and servicing tasks can be safely performed;
• a meter that measures the amount of gas flowing into the vehicle and communicates this information to the electronics in the upper cabinet of the dispenser or to a fuel management system;
• a thermal relief device;
• a sensor to measure the pressure of the gas being delivered to the vehicle;
• a hose that carries the LNG from a connection on the outside of the dispenser cabinet to the nozzle;
• a hose that vents gas from the vehicle tank to the site storage tank.;
• electronic, pneumatic or mechanical breakaway devices that activate the emergency shutdown device (ESD); disconnect the fuel and vent hoses from the dispenser; and automatically seal off the gas supply in the event a vehicle drives away with the nozzle still attached to the vehicle fueling receptacle to minimize the release of product;
• an outside-air purge system to allow electronics to safely occupy otherwise classified areas or alternatively a methane detector that disables operation of the dispenser in the case of releases into the electronics enclosure;
• incoming electrical service and communications wiring;
• a grounding connector and ground wire;
• an airline for clearing debris and frost from vehicle connection (if desired);
• a means of closing off fuel flow in the event a dispenser is dislodged from its mounting point on a fuel island.

**FIGURE 5-2. LNG Shear Valve. Suitable for under dispenser placement.**
5.14.1 Dispenser Listing. A current issue in the LNG industry is that listing organizations have not developed a standard applicable to LNG dispensers at time of this publication, so it is not possible for an LNG dispenser to be listed. In place of listing, most dispenser manufacturers will provide third-party certification of the dispenser assembly by a nationally recognized testing laboratory to facilitate approval by local authorities. Consult with AHJs to identify specific requirements for dispenser approval.

NOTE: Dispensing meters that sell LNG to the public are required to have a Certificate of Conformance issued by the National Type Evaluation Program (NTEP) which is administered by the NCWM.

5.15 Hanging Hardware (Dispenser). Hanging hardware represents the connectable, flexible components that make the link between the fixed fueling components and the vehicle being serviced. Inasmuch as these components represent the majority of user interface points, they may be expected to receive considerable wear and tear. Typical components of hanging hardware include the nozzle, fueling hose and breakaway, vent line hose and breakaway, a grounding connector ground wire and a retractor system.

5.15.1 Nozzle. The nozzle is the device that attaches the fuel hose to the fuel receptacle of the vehicle. LNG nozzles are designed so that gas will flow only if a secure connection is established between the nozzle and the vehicle receptacle. Nozzles also are designed so that only a very small amount of gas is vented when the nozzle is disconnected from the vehicle receptacle. Nozzles also may include deicing provisions.

The typical nozzle used in the LNG industry is equipped with a quick-connect, a dry-break and a positive locking mechanism. Applicable standards for the construction of LNG fueling nozzles and vehicle LNG receptacle components include ANSI/CAN/CSA ISO 12617.

FIGURE 5-3. Typical LNG Fueling Nozzle.
5.15.2 Breakaway Connectors. Customers occasionally will drive away from a dispenser without disconnecting the fueling nozzle or other apparatus from the vehicle. When this happens, breakaway connectors installed in the fueling hose are designed to disconnect and close off the flow of product. This protects the dispenser or dispensing point from damage and prevents the release of product. Breakaway connectors should be installed on both the fuel hose and vent line of all LNG dispensers.

FIGURE 5-4 a, b, c. Various Breakaways. A. Liquid-side LNG Breakaway (Macro Technologies) B. Vent Side LNG Breakaway (Macro Technologies). C. K2 Breakaway (KLAB Products LTD.).
5.15.3 Retractor System. The retractor system on an LNG dispenser withdraws the nozzle and hoses to protect them from unnecessary damage due to contacting the ground surface, vehicles and pedestrians in the area.

5.16 LNG Pump Package. To make LNG practical as a fleet motor fuel, a substantial amount of it must be dispensed in a very short period. This means pumping the LNG from the storage tank to the dispenser at operating pressures and flow rates equivalent to or better than traditional high-speed diesel fueling. Included items are:

- a submersible cryogenic pump and motor;
- insulated piping to carry the LNG;
- valves to control the flow of the LNG;
- instruments to measure, monitor and control various aspects of the LNG pumping system;
- a skid or framework on which to securely mount all of these different components.

5.17 Pump Drives. Pumping of the LNG requires a moderate amount of energy. In most cases, a heavy-duty, three-phase, 480-volt power supply will be required to run the variable frequency pump drive, electric motors and control systems. (See Section 9.7 for additional information.)
5.18 **Vaporizers (Also Known as Heat Exchangers).** These devices are used to saturate cryogenic liquid to within engine manufacturer specified pressure and temperature parameters. Dispensers may be provided with an option to select desired pressures according to vehicle requirements.

5.19 **Programmable Logic Controller.** The programmable logic controller (PLC) is an industrial computer that monitors and controls the operation of the various components of the LNG fueling system. PLCs receive information from various sources, such as sensors that monitor the pressure, temperature and liquid levels at various points in the system, as well as emergency shutoff switches that indicate that the system must be shut down. PLCs process this information according to pre-programmed instructions; activate various valves and switches in the appropriate sequence to start or stop the system; operate flow control valves; or close all of the appropriate valves to shut down the flow of LNG in an emergency situation. Depending on the type and complexity of the LNG fueling system, a single PLC or several different PLCs may monitor the operation of individual components such as the offload pump, dispenser pump, LCNG pump, dispensers and valves. The PLC also may interface with the alarm panel and offsite responders. Refer to Section 7.2 for additional information about PLCs.

5.20 **Control Center Structure.** These are structures that serve to protect the electrical control components from the weather and keep unauthorized personnel from accessing the equipment. Structures may be shop-fabricated or field constructed. Shop-fabricated structures are often provided as an option by the LNG equipment provider. Shop-fabricated structures typically have all of the electrical components preassembled and mounted and are made of metal or other noncombustible material. The structure is typically located in an unclassified area. Refer to Chapter 11 for additional information about classified areas.

Field-erected structures are predominantly open buildings constructed of masonry, metal or other noncombustible materials that provide a roof and walls to protect the electrical control equipment from the weather. Refer to Chapter 12 for additional information about electrical component structures. Designated spaces within existing structures appropriately situated may be an alternative to purpose-built enclosures.

5.21 **Tubing and Piping.** Insulated and/or vacuum jacketed stainless-steel piping is typically used to carry the LNG within or between the various components of the LNG fueling system, including the pumps, storage tanks, vaporizers, valves and dispensers. Typical piping is 1 to 3 inches in diameter and must be rated for the maximum allowable working pressure and temperature ranges appropriate for the service requirements. Refer to Chapter 13 for more detailed information about tubing and piping.
5.22 **Instrumentation and Valves.** Instrumentation consists of temperature, pressure and flow measurement elements used to monitor and control site process conditions. Automatic valves may be actuated via instrument air, nitrogen or electric methods.
6. THE LCNG OPTION

6.1 Introduction. This chapter deals with the highlighted segment of the diagram below. For the balance of the liquefied compressed natural gas (LCNG) system, the reader should refer to PEI/RP1500: Recommended Practices for the Design, Installation, Operation and Maintenance of Compressed Natural Gas Vehicle Fueling Facilities.

6.2 Description of an LCNG Station. An LCNG facility combines LNG and CNG in one station. For example, a company may have a substantial fleet of smaller delivery vehicles as well as a number of heavy-duty vehicles that require large volumes of LNG. In another scenario, LNG may be brought in with the intent of exclusively producing CNG.

A typical LCNG station is supplied with LNG and has dispensers for both LNG and CNG vehicles. Like an LNG refueling station, an LCNG station relies on a local LNG supply that can be delivered by tanker trucks, similar to diesel and gasoline. The advantage of an LCNG station is that it can offer both LNG and CNG. This type of station also can be set up in areas where there is no local natural gas distribution.

To produce CNG at an LCNG station, the LNG is pressurized to CNG fueling pressures by a cryogenic pump, vaporized through a heat exchanger, odorized and stored in pressure vessels for CNG dispensing. In certain applications, CNG may be produced as a method of managing boil-off gases from LNG storage. For further discussion of boil-off management, see Section 5.12.

FIGURE 6-1. Typical LCNG Configuration.
FIGURE 6-2. Typical LCNG Components.

Investment and maintenance costs for an LCNG station are lower than the costs of setting up separate stations for CNG and LNG. Power consumption to produce CNG also is significantly lower than at a typical compressor-based CNG station of the same throughput rate. Note that while the production of LCNG from LNG may be appropriate for certain applications, CNG produced from pipeline gas is typically less expensive to provide.
6.3 LNG to LCNG Conversion Process.

FIGURE 6-3. LCNG System Design.

The following components are unique to an LCNG system:
- LCNG pump;
- ambient or fan-assisted vaporizer;
- trim heater;
- odorization system.

The balance of the CNG refueling system will be common with all other CNG stations. See PEI/RP1500: Recommended Practices for the Design, Installation, Operation and Maintenance of Compressed Natural Gas Vehicle Fueling Facilities for additional information.

6.3.1 LCNG Pump. This is a reciprocating cryogenic piston pump that pressurizes the LNG up to 5,000 psig. These pumps normally are ground-mounted, and can be mounted horizontally or vertically, depending on the manufacturer. They usually are electric motor-driven units. The pumps are external to the LNG storage tank and are designed for cryogenic service. Multiple pumps may be mounted in parallel for increased flow capacity.

6.3.2 Ambient and/or Fan-Assisted Vaporizer. Ambient air vaporizers use the relative heat of the atmosphere to derive the energy necessary for the vaporization of the liquid cryogen. These vaporizers are the most cost-effective equipment to vaporize or regasify liquid cryogens. Following installation, operational and maintenance costs are minimal. Typically made of aluminum, the vaporizers are rated for high-pressure applications, up to 5,000 psig. The size of the vaporizers is determined by the site application and anticipated requirements for CNG at the location. If normal ambient vaporizers are used, a longer defrost period will be needed between CNG filling requirements. A fan-assisted vaporizer can provide shorter defrost periods as the fan provides air movement over the vaporizer vanes.
6.3.3 Trim Heaters. When LNG is vaporized for use as CNG, it may be necessary to provide heating in the form of a trim heater to avoid excess frost buildup and stresses on non-cryogenic-rated downstream components, along with the odorizer system. Considerations for this process must include ambient conditions and throughput rate.

6.3.4 Odorizer System. In order to produce CNG compatible with regulatory requirements, odorant must be introduced to the non-odorized LNG. Typical odorant feedstock is based on mercaptan compounds. Odorant systems are generally provided as a package and are integrated into the facility maintenance process. Special care in handling odorants is necessary to avoid unwanted releases of these highly toxic substances.

6.3.5 CNG System. Once the LNG is converted to CNG standards, the system is identical to other CNG systems. An advantage of LCNG includes the virtual absence of water and oil in the CNG product. See PEI/RP1500: Recommended Practices for the Design, Installation, Operation and Maintenance of Compressed Natural Gas Vehicle Fueling Facilities.
7. INSTRUMENTATION AND CONTROL DEVICES

7.1 **Introduction.** To ensure safe and efficient operation, liquefied natural gas (LNG) fueling systems must be closely monitored and controlled. In today’s LNG fueling systems, many of the safety and operational functions are carried out automatically. This chapter describes the various instrumentation and control components commonly found at LNG vehicle fueling facilities, their functions within the system, and the locations in the system where these components are typically located.

7.2 **Programmable Logic Controller.** The programmable logic controller (PLC) is the central control device for LNG fueling systems. PLCs monitor and control all system processes to maintain the fueling system within specified operating parameters.

PLCs typically include a display/interface panel that will indicate the operational status of the system and the presence of any warnings or fault conditions detected by sensors. The PLC panel also includes manually operated controls that can be used to turn the fueling system on and off and reset the controller after fault conditions have occurred.

An intrinsically safe barrier and/or non-incendive circuitry may be applied where appropriate.

![FIGURE 7-1. Programmable Logic Controller (PLC), with cover removed.](image)
PLCs typically monitor and control the following parameters and processes. During the offload process, they monitor:

- the startup and shut down permissives (temperature, pressure, gas detection and valve positions) for the pump;
- the pump operating conditions, pressure and temperature to verify that the pump is operating properly;
- the pressure and level in the storage vessels to determine when to start and stop the pump and protect against overfill.

During the fueling process, PLCs typically monitor and control the following parameters and processes:

- the startup and shut down permissives (temperature, pressure, gas detection and valve positions) for the pump/dispenser;
- the pressure of the LNG flowing to vehicle fuel tanks to determine when to stop the flow to the vehicle;
- the rate of flow of LNG into a vehicle fueling tank to determine the filling rate;
- a separate dispenser controller and fire/safety control panel (in some cases).

PLCs also may be equipped with remote communication capabilities. One-way communication transmits operating information, warnings or alarms from the fueling facility to an off-site monitoring center, phone number or email address. Two-way communication allows adjustment of the PLC programming from a remote location.

### 7.3 Sensing Devices

PLCs rely on inputs from numerous sensing devices to provide information about the operation of the fueling system. The following types of sensors are commonly used in LNG fueling systems.

#### 7.3.1 Pressure Sensors

Pressure sensors measure the operating pressures from numerous areas in the fueling system and send this information to the PLC.

#### 7.3.2 Temperature Sensors

Temperature sensors measure operating temperatures at numerous areas in the fueling system and send this information to the PLC.

#### 7.3.3 Methane Sensors

Methane sensors are typically installed at various locations around the site to detect the presence of natural gas. The methane sensor is connected to the PLC/fire safety panel and will shut down the LNG components and activate the emergency shutdown system and alarm to warn personnel if the methane concentration exceeds a programmed limit.
Because LNG is not odorized, methane sensors should be installed over dispensers, beneath canopies, in containment areas or in other areas where natural gas could accumulate. Multiple methane sensors can be connected to a PLC. Methane sensors also may be connected directly to fire alarm panels.

7.3.4 **Flame Detection System.** Flame detection devices are usually located around the offload, dispenser and containment areas. These are connected to an emergency shutdown device (ESD) and alarm panel systems.

7.3.5 **Dispenser Impact Sensor.** Dispensers are vulnerable to vehicle impacts. To reduce the potential for fires and to prevent the release of large amounts of gas that can result from vehicle impacts, an impact sensor may be mounted inside the dispenser cabinet. This sensor activates the emergency shutdown system and shuts down the LNG supply to the dispenser. Refer to Section 8.4 for additional information about dispenser impact sensors.
7.3.6 **Liquid Level Indicators.** Liquid level indicators determine the LNG level in the storage tank. Various methods are available to indicate levels within the LNG storage tank. These include:

- liquid level trycock;
- pressure differential sensor;
- analog level gauge.

7.4 **Pressure Gauges.** In addition to pressure sensors connected to the PLC, mechanical pressure gauges are typically installed at a number of locations in an LNG fueling facility to provide a direct reading of the pressure. Mechanical gauges are convenient to read and can help troubleshoot sensor readings by providing an independent measurement of the pressure.

7.5 **Flow Control.** Many types of flow control components are available for proper operation of an LNG fueling system. For each function, several different types of flow control components typically can be used, each with different features, advantages and disadvantages. The following sections describe the general types and primary functions of the flow control components that are typically found in LNG fueling systems.

7.5.1 **Remotely Operated Valves.** The PLC uses remotely operated cryogenically suitable valves to control the flow of LNG between components, such as the pumping units, the storage tanks and the vehicle. An electrical signal from a PLC triggers the opening and closing of valves. Valves may be either normally open or normally closed. Valves always are configured to fail in a safe condition.

7.5.1.1 **Valves Operated by Electricity.** PLCs typically use the electrical signal from the PLC for flow control valve operation. When the solenoid is energized, a valve mechanism is actuated that opens or closes in response to the applied pressure. Removal of the electric signal allows the system to fail safely or return to its normal position.

7.5.1.2 **Valves Operated by Instrument Air Pressure.** Valves operated by compressed air work in the same way as valves operated electrically, as described in the previous section, but air-operated valves use compressed air or nitrogen. Air-operated valves need an instrument air supply to operate the valves. This instrument air needs to be very dry or “instrument quality.” Standard shop air is not sufficient.

7.5.1.3 **Valves Operated by Differences in Pressure.** Check valves allow gas to flow through a tube or pipe in one direction only. When the pressure on the upstream side of the valve is greater than the pressure on the downstream side, the valve mechanism opens and gas is allowed to flow. If the gas pressure on the
downstream side of the valve is greater than on the upstream side, the valve remains closed and does not allow the gas to flow.

7.5.2 **Manually Operated Valves.** Manually operated valves are used in an LNG fueling system to separate various components, such as the storage vessels or the dispenser from the fueling system so they can be serviced. These valves are commonly called isolation or shutoff valves. Closing an isolation valve allows the pressure to be vented from a component so that maintenance or repair tasks can be safely conducted without affecting the pressure in other portions of the LNG system.

Isolation valves should be lockable or compatible with lockout/tagout devices to protect technicians during repair and maintenance activities. Isolation valves are typically long-stem, cryogenically rated globe valves designed to be used with cryogenic fluids and rated for the pressures and temperatures that the valve will be required to contain. Isolation valves typically are installed in the following applications:
- at the liquid inlet/outlet for each storage vessel;
- between the storage vessel and the pressure relief valve;
- in each dispenser liquid supply line where the line enters the base of the dispenser cabinet;
- on the inside of the dispenser cabinet to shut off the liquid supply to the dispenser hose;
- with other manual valves for maintenance isolation of components.

**NOTE:** For safety reasons, when isolation valves share a pipe section, the capability to allow the relief of line pressure must be provided.

7.6 **Pressure Relief Devices.** Pressure relief devices are important pressure control devices that protect components of the LNG system against exposure to pressures in excess of their maximum allowable working pressure. These may be found in the following locations:
- any segment of piping, hose or component that may hold or trap LNG;
- LNG storage tanks;
- all pump discharges.

7.7 **Drain Valves.** Drain valves are installed to remove condensation that may accumulate at the low point on the tank vent stack.

7.8 **Bleed Valves.** Manually operated bleed valves are used to safely release the pressure in a component of the fueling facility so that maintenance tasks can be done safely. Bleed valves are typically located adjacent to valves, meters, gauges and other components that may require periodic maintenance, adjustment or replacement.
7.9 **Flow Measurement Components.** In retail or other applications where it is important to measure the amount of liquid being dispensed, a Coriolis mass flow meter is typically installed. This is the most common method of quantifying LNG for sale in the U.S.

**NOTE:** Dispensing meters that sell LNG to the public are required to have a Certificate of Conformance issued by the National Type Evaluation Program (NTEP) which is administered by the NCWM.
8. SAFETY SYSTEMS

8.1 Introduction. This chapter describes the safety related equipment that must be in place at liquified natural gas (LNG) fueling facilities. The combination of cryogenic and flammable gas under pressure, electrical equipment, machinery and vehicle traffic in close proximity to fueling equipment means that emergency situations at LNG facilities must be addressed quickly to protect life safety and property. When unsafe conditions, accidents or equipment malfunctions occur, appropriate protective actions may include:

- Operational system shutdown;
- Alarm activation;
- Stoppage of the LNG flow to limit potential fire hazards;
- Disconnection of electrical power to limit sources of ignition.

8.2 Emergency Shutdown Device. The general term emergency shutdown device or (ESD) is often used in the LNG industry to include all the different components of the emergency shutdown system. The ESD is not a single device but rather a group of devices that work together to quickly shutdown the operation of an LNG fueling facility. The emergency shutdown system typically consists of the following components:

- switches or sensing devices, such as methane, heat and flame detection, grounding and overfill permissives that trigger the operation of the other components.
- one or more remotely operated valves that stop the flow of LNG to the various components in the system.
- one or more electrical relays that de-energize electrical circuits in fuel dispensing, LNG storage and pump areas.
- the PLC that controls the operation of the LNG components.
- visual and audible alarms to notify onsite personnel.
- alarm panel, email or text message communication hardware to notify off-site fire service, service technicians and facility management personnel who can immediately address the emergency situation.

Each of these components will be described in the sections that follow.

8.2.1 Emergency Stop Switches. Emergency stop switches are manually operated switches that trigger the process of shutting down the LNG fueling facility. The shutdown process includes:

- stopping the gas supply to the various LNG components and to the fueling areas;
- de-energizing electrical conductors located in classified areas;
- signaling the PLC to stop the pumps/dispensers.

Emergency stop switches are typically located in the LNG System Area and near the fueling positions. Additionally, since these areas are subject to deflagrations, ancillary emergency stop switches are generally provided at a safe distance from operating
equipment. In all cases, the authority having jurisdiction (AHJ) has discretion as to the actual placement of emergency stop switches and signage.

If the emergency stop switch will be located in a classified area (See Chapter 11), it is important to install a switch that is rated for use in areas where flammable gas may be present. Emergency stop switches should be positioned so they are clearly visible and easily accessible to people using the fueling facility. Emergency stop switches in heavy customer use areas may need transparent plastic covers or similar devices to prevent nuisance trips of the switch.

Emergency stop switches should be provided with a permanent sign that clearly indicates the function of the switch (See Table 14-1). Signs using large white block letters on a red background are often used to identify emergency stop switches. The AHJ may require specific wording, style or location of the signage.

Some pedestal mounted card readers that control the operation of LNG dispensers include a stop switch as part of the console. This switch will de-authorize the dispenser so fuel cannot be dispensed, but it may not shut down the LNG supply or de-energize electrical circuits in the dispensing area. Such switches cannot be counted as emergency stop switches unless they provide all of the functions of an emergency stop switch. In general, it is best not to have misleading labeling of switches, that are not fully functional as emergency stop switches, that may tend to confuse the user. For example, a card reader stop would be more sensibly labeled “CANCEL” rather than “STOP” to imply a process correction rather than an emergency.

When an emergency shutdown has occurred, no part of the fueling system should be capable of automatically restarting. The emergency stop switch should latch when tripped so that it stays tripped, preventing the fuel system from restarting without intervention by authorized personnel.

8.2.2 Location of Emergency Stop Switches at LNG Facilities. A minimum of two emergency stop switches should be installed in the dispensing area. One emergency stop switch should be located within 10 feet of each fueling position with a second emergency stop switch at a safe distance, typically more than 25 feet from the dispensing area. The nearer switch is for quick response convenience, while the farther switch is positioned so that, in the event of a fire, the switch is likely to be safely accessible. Keep in mind that the far switch still should be near enough to be seen clearly from the dispensing area in normal conditions.
NOTE: Fueling facilities dispensing conventional motor fuels may have different requirements for the location and function of emergency stop switches than LNG facilities. Do not confuse the conventional motor fuel requirements with the LNG requirements. It is important to consider the shutdown of operations unrelated to LNG fueling that may otherwise be governed by separate emergency stop systems, as they may contribute to potential hazards.

8.2.3 Location of Emergency Stop Switches at Facilities Dispensing Both LNG and Conventional Motor Fuels. At time of publication codes do not address the location or function of emergency stop switches at facilities that dispense both LNG and conventional motor fuels. Because the code specifications for the location of emergency stop switches for conventional motor fuels and LNG may be different, attempting to meet all the individual code requirements could require an unreasonably large number of emergency stop switches. In addition, the codes provide no guidance as to whether an emergency shutoff switch should shut down only the liquid fuel, only the LNG fuel, or both. At facilities that dispense LNG and conventional motor fuels, detailed analysis may be necessary to create solutions for the integration of these adjacent fueling system safeguards.

8.2.4 Emergency Stop Sensors. In addition to manually operated emergency stop switches, various sensors also may be installed that automatically trigger an emergency shutdown of the LNG fueling facility when hazardous conditions are detected. Examples of sensors include the following:

- LNG storage tank overfill sensors;
- strategically placed temperature sensors;
- strategically located methane sensors in the LNG offload, equipment and dispenser area;
- strategically located flame detectors;
- impact sensors installed in dispenser cabinets to indicate when a dispenser has suffered a serious impact (see Section 8.4);
- pressure sensors monitoring various parts of the fueling system for excessively high or low pressures in the storage vessels or the pressure of the LNG being dispensed into a vehicle.

8.2.5 Valves Used for Emergency Shutdown. When an LNG emergency stop switch is activated, remotely operated valves should shut off the flow of LNG and position valves in their respective fail-safe states.

Some valves that function as emergency shutdown valves also may serve to shut off the flow of LNG during normal operation of the facility.
8.2.6 Emergency Shutdown Switch Function. Activation of emergency stop switches or sensors de-energizes electrical conductors that could be a source of ignition. Additionally, in an LNG application, the disconnection of power will cause all system components to revert to the fail-safe condition.

In the fuel dispensing area, all electrical circuits (e.g., power, fuel management system, communications, data and video circuits) within the classified area (see Chapter 10) surrounding dispensers should be de-energized. Specialized switchgear may be required to interface low-voltage items with the emergency shutdown system.

Lighting, PLC, audible/visual alarm and remote communication circuits in the LNG equipment area that are not associated with the operation of the system itself may remain energized.

8.2.7 Emergency Shutdown for Instrumentation Failure. In the event of a power or instrumentation failure, the entire LNG system must go into a fail-safe condition (meaning all user operations are terminated and cannot be restarted without operator intervention). The control system should be programmed for this functionality.

8.3 Pressure Relief Valves. Pressure relief valves, also known as pressure relief devices (PRDs) or safety relief devices (SRDs), are installed at various points in the LNG fueling system to protect pumps, valves, heat exchangers, piping, storage vessels, dispensers and vehicle fuel tanks from pressures that exceed their maximum allowable working pressures.

Pressure relief valves are critical safety components that rarely operate. Because the moving parts of the pressure relief valve rarely move, they may become corroded or frozen in place and may not operate when needed. To ensure that pressure relief valves will operate when required, they should be tested periodically according to the manufacturer recommendations or applicable regulations. The testing verifies that valves are still properly calibrated and will function as intended. This work must be done by the manufacturer of the valve or a specialized pressure relief valve recertification company.

8.4 Limiting Damage from Vehicle/Dispenser Collisions. Experience at traditional fueling facilities has shown that despite the presence of raised islands, bollards and similar protective devices, vehicle collisions with dispensers do occur. While such incidents are infrequent, when they do occur it is imperative that the fuel supply to the dispenser is shut off to prevent a major fire from occurring. Suitable fuel supply shut down equipment is available for this application.
The most commonly used approach to limiting the release of gas when a dispenser is struck by a vehicle is to install an impact-sensing/vibration switch in the dispenser that is tied into the facility’s emergency shutdown system. The switch should be normally closed so that any significant impact to the dispenser cabinet or any interruption of the circuit will activate the emergency shutdown system, shutting off the gas supply to all the dispensers. If a vibration
switch has not been provided by the dispenser manufacturer, it will need to be installed as part of the dispenser installation.

8.5 **Flame Detectors.** A flame detector is a sensor designed to detect the presence of a flame or fire. In this application, flame detectors will trigger the ESD and activate alarms.

![FIGURE 8-3. Flame Detector.](image)

8.6 **Methane Detectors.** A methane detector is a device that detects the presence of methane in an area, often as part of a safety system. This type of equipment is used to detect a gas leak or other emission and can interface with an alarm, ESD or other control system so a process can be automatically shut down. A methane detector is critical in an LNG system, since the escaping gas is not odorized.

![FIGURE 8-4. Typical Methane Detector.](image)
8.7 **Fire Extinguishers.** Fire-extinguishing equipment should be part of every LNG fueling facility. Provide sufficient Purple K dry chemical fire suppression agent portable fire extinguishers so that they are readily accessible from all fueling areas.

8.8 **Emergency Responder Requirements.** The fire marshal or AHJ may require the following during the design review or at the final signoff:

- submittals and specification sheets on all equipment, devices, safety systems and fire protection equipment used throughout the facility;
- fuel storage permit and registration, if applicable
- listing or third-party certification on pumps and dispensers;
- windsock to assist emergency personnel in identifying potential plume direction;
- coordination and test with listed fire alarm and monitoring services;
- facility address and emergency contact information posted in various locations;
- emergency access routes and clearances posted and/or marked.

8.9 **Signage.** See Chapter 14 for signage relating to safety.

8.10 **Wind Sock.** A wind sock is used to visually signify the principal direction of local wind conditions. This is useful for anticipating the direction (on flat terrain) and estimating the rate of dispersion of liquid and gas that might be present.

![FIGURE 8-5. Typical Wind Sock.](image-url)
9. LNG SYSTEM DESIGN CONSIDERATIONS

9.1 Introduction. This chapter describes the major factors that should be considered in order to design a liquefied natural gas (LNG) fueling facility for a specific location and purpose. This chapter will not provide instruction about how to design an LNG fueling facility. The goal is to introduce the thinking behind the design process so the user will be able to intelligently discuss these design issues with service providers experienced in LNG facility design.

9.2 Personnel Resources for LNG Fueling Facility Design. Designing and building an LNG fueling facility is a complex undertaking. The presence of flammable gas, high pressures, cryogenic temperatures, high voltages, complex mechanical equipment, sophisticated electronic controls and a variety of regulatory requirements means that only knowledgeable and experienced personnel should be involved in the detailed design and construction of LNG fueling facilities.

The challenge of producing a successful LNG fueling system is further complicated because it is made up of various components from many different sources that must interact smoothly and efficiently. Equipment manufacturers have developed varying approaches to solving such issues. As a result, one equipment manufacturer’s solution to a particular issue may interfere with the operation of some other system component. Working knowledge of the equipment from different manufacturers is required to design and construct a fueling facility with components that will work together effectively, minimizing start-up and ongoing operational problems.

Planning, designing, constructing and operating a successful LNG fueling facility is a team effort. A variety of LNG professionals will need to work closely with the facility owner and permitting authorities to ensure the success of the completed project. Typical members of an LNG facility team include:

- LNG equipment manufacturer – manufactures major components, such as pumps, heat exchangers, controls, instrumentation, storage tanks and dispensers;
- LNG equipment packager – obtains components from manufacturers and assembles them into a unit specifically intended for LNG fueling;
- LNG equipment sales representative – seeks out potential LNG facility owners and connects them to LNG equipment manufacturers, packagers, distributors, etc.;
- LNG equipment distributor – offers a variety of services that may include sales representative, facility design, construction and service;
- LNG facility design engineer – provides site plans, foundation design and details of the facility layout and construction; may provide permitting services and interfaces;
- LNG contractor – builds or oversees construction of the facility; may provide permitting services; responsible for safety during construction;
- LNG service technician – provides maintenance and repair services for the facility after it is operating.

The LNG team members all may work under one roof for a single company or they may work for separate companies that provide specialized LNG services. The facility owner may choose to work with a large company that provides a complete turnkey project or the owner may choose to work with several smaller companies that provide only partial services, such as facility design or facility construction. Alternatively, the owner may hire a specific company, such as an equipment distributor or design engineer, to coordinate and supervise the project on the owner’s behalf.

In this document, the term experienced LNG service provider will be used to reference any one or any combination of the LNG team members mentioned above.

9.3 Factors to Consider in LNG Fueling Facility Design. There are many factors to consider when planning an LNG fueling facility. Making the best choices to meet the requirements of a specific application requires detailed information concerning:

- commercial goals of the owner and the LNG customers’ performance expectations;
- proximity to buildings and population;
- source of the LNG;
- available electric supply;
- planning and zoning regulations;
- amount of space available to develop the facility;
- number and type of vehicles to be fueled in a given period of time;
- availability of maintenance support for the chosen equipment.

The decisions made may significantly affect the cost of the facility. The factors listed above are discussed below.

9.4 Owner and End-Users’ Expectations. Keeping the owner’s expectations realistic by clearly communicating how the LNG facility will perform is an important role of the experienced LNG team. Prospective LNG fueling facility owners should discuss the fueling rates, fueling capacity and cost trade-offs for the contemplated facility with an experienced LNG service provider in order to be fully aware of the potential advantages and limitations that may arise. Commonly, end users expect that LNG fueling is as fast and as convenient as liquid fueling. When the facility is completed and operational, the vehicle fueling time is likely to be the most important factor in an end-user’s judgment of whether the facility is satisfactory.

9.5 Proximity to Buildings, Structures, Population and Land Uses. NFPA 52 provides the basic spacing relationships as viewed from a fire protection standpoint. However, additional
consideration may require further study such as a quantitative risk assessment (QRA) that details additional measures to mitigate risks.

9.6 **Source of the LNG.** Consult with the potential suppliers of LNG as an early step in LNG fueling facility design. The characteristics of potential sources of LNG may be such that only a limited number of suppliers can be used for the proposed fueling location. It may be possible to set up sources at extended distances from the site if the usage is adequate.

It is important to obtain the following additional information from the LNG supplier:

- composition and quality of the LNG that will be supplied to the facility;
- quantity of LNG that can be reliably supplied;
- rate schedule for the cost of the LNG product.

9.7 **Available Electrical Supply.** A typical LNG facility requires a 480-volt, three phase electrical supply. This type of electrical supply is common in industrial settings, but it may not be readily available in all locations. If not already present, it may be costly to install and supply this type of power to a specific location. Confirm that the required power is available early in the design process.

It is important to obtain the following information concerning the electrical supply:

- whether 480-volt, three phase power is available;
- cost of any upgrades to provide adequate power to the site, including transformers and power conditioners;
- whether the power line will be above or below ground on site;
- whether an easement is required to bring the power line on site;
- cost of electrical service, including peak demand charges, power factor charges and use charges;
- lead time for electric service construction.

9.8 **Planning and Zoning Regulations.** Local and regional regulations may impact the allowable land uses on certain parcels. This is a critical element of site selection and qualification. Prior to siting your location verify with the local AHJ that an LNG facility is a permittable use for the property identified.

9.9 **Space Requirements.** A typical single tank LNG fueling facility needs approximately 5,000 square feet of space. This includes the compound and offloading and dispensing areas. See Chapter 10 for additional information concerning facility site planning.

9.10 **Fueling Rate Requirements.** The greater the amount of fuel to be supplied and the shorter the desired transaction time, the larger the system, the greater the storage capacity and the more fueling positions required. There are a number of ways to meet a given demand. It is important to determine accurately what the fueling pattern at the facility will be so that the appropriate size and configuration of equipment, along with the number of dispensers, can be
determined. Design decisions regarding these factors will have a substantial effect on the ultimate satisfaction of the end user fueling a vehicle.

9.11 Availability of Maintenance Support for the Chosen Equipment. The market for equipment supply may be very competitive and the features and benefits, including prices offered, may be tempting. However, the development of a satisfactory LNG fueling facility must include consideration of the availability of support services for the equipment chosen. As discussed elsewhere, this is very specialized equipment that may not be maintainable by more generic service providers available locally. Accordingly, some diligence is recommended in the qualifications process. This may include consideration of the following questions:

- What is the acceptable wait time for services?
- What are the travel costs and maintenance rates for the nearest authorized service provider (ASP) for the equipment chosen?
- If someone other than an ASP performs work, is the warranty affected?
- What is the reputation of the ASP in the locale of the facility for a particular line of equipment? There can be variations from one area to another with ASPs for the same brand of equipment.

9.12 LNG Customers’ Performance Expectations. Reliability and uptime are important considerations for users and owners, especially those dependent on the site. The relative availability of alternative refueling locations can drive the need for additional safeguards against failures.
10. LNG FACILITY PLANNING

10.1 Introduction. A number of planning considerations for liquefied natural gas (LNG) fueling stations are similar to those for a liquid motor fuel facility with aboveground storage tanks (ASTs). For both types of facilities, the site layout must consider the location of fueling system components with regard to property boundaries, buildings, underground utilities and structures, power lines, public roads, and other factors. Convenient traffic flow patterns should be laid out, and storage vessels and dispensers should be appropriately positioned. Site drainage, insulated piping runs, potential for flooding and site security also should be considered.

The peak hourly demand for LNG fueling is the largest consideration in sizing the facility and its components. Number and size of expected vehicles, tolerable queuing and fueling durations are additional factors. If the goal is to have an LNG fueling procedure that is competitive with conventional petroleum fueling, then the fueling pattern is very important. Is the fueling pattern such that almost everyone will want to fuel without delay at 9:00 a.m. every day? Or will fueling activity be spread throughout the day so there is typically only one vehicle refueling at a time? These varying scenarios must be analyzed with an eye toward the question that is fundamental to every fueling facility: How much time does the customer expect a single fueling transaction to take?

Due to the cryogenic nature of LNG and its energy content, there also are planning issues unique to LNG fueling facilities. These include fire spread, flow of spilled product and venting of boil-off product.

This chapter describes site-specific issues that must be considered in planning and building a safe and efficient LNG fueling facility.

10.2 Location of LNG-Related Equipment. In an LNG fueling system, major components, such as the LNG storage vessels, LNG pumps and heat exchangers most often will be located within the LNG containment area. The LNG equipment should be positioned on the site in accordance with the following statements:

- setbacks from property lines, roads, buildings, railroads and power lines specified in this recommended practice as well as municipal requirements are met.
- the components do not interfere with traffic flow.
- electrical controls, such as the breaker panel, service disconnects, motors, motor controls, transformers and similar devices, should be located outside of classified areas unless listed for hazardous locations.
- the length of all piping/ tubing runs and the number of piping/tubing crossovers is minimized.
• sufficient space is allotted between equipment and components for maintenance and repair activities.
• anything within the containment area is able to withstand the presence of LNG temperatures.
• any structure above an LNG spill dispersal area should be designed so as not to trap rising methane gas.
• site drainage should be configured to keep precipitation from creating pools in the vicinity of the LNG components.
• the location of LNG fueling facilities in flood plains or areas prone to flooding should be avoided.

A typical single tank LNG fueling facility with the containment area sized for a single pump and two single hose LNG dispensers will require an area outside of the traffic flow pattern that can range from 3,000 to 5,000 square feet. In addition, approach and exit routes must be sized for Class 8 trucks and provide a flow-through traffic pattern without the need for backing up. Peripheral equipment, such as a building to house accessories or a generator for backup power, will increase the space requirements. Space requirements may be reduced by reconfiguring the LNG containment area or equipment layout. Consult with the LNG facility design engineer to determine how best to minimize the equipment footprint.

10.3 Offloading Connections. Offloading connections should be integrated into the overall LNG station design. The LNG delivery transport truck/trailer typically delivers its contents from the rear of the trailer, so the facility offload connection can be located on either side. However, sufficient pull-through space should be provided to accommodate the full length of the transport truck/trailer, allowing delivery without unnecessary blockage of other traffic.

![FIGURE 10-1. LNG Delivery to a Site.](image)
The typical delivery hose for LNG is 18 to 20 feet long, so planning should allow for truck positioning relative to LNG product intake fittings. Additionally, suitable ingress/egress lanes should facilitate transport positioning without backing up. Although refueling lanes may be double-purposed for offloading lanes as a space-saving measure, keep in mind that this may inhibit the main purpose of the fueling facility. Pavement markings to optimally locate the delivery truck, including traffic safety cone positioning, make deliveries more consistent, quicker and safer.

The following items should be conveniently located near the delivery point:

- clearly-marked vehicle grounding/earthing connections;
- off-loading instructions and safety information, including emergency and shutdown procedures;
- any controls and readouts necessary for delivery, including tank level, temperature and pressure gauges to protect against overfill or overpressure;
- emergency stop switches with clearly visible signage.

Since the offloading connections at a given site may require multiple, competing considerations, a qualified and experienced LNG facility design engineer should review all LNG offload connection details.

**FIGURE 10-2. Typical Grounding Connection for Offloading.**

**10.3.1 Offloading Containment.** Since LNG potentially could be released as a result of a delivery mishap, provisions should be made for safely retaining the quantity of product that could spill within a 10-minute time period, plus an allowance for the expected snow or rainwater accumulation that also might occupy the impoundment area. The LNG facility design engineer should determine the expected transfer rate of LNG as part of the planning process. An example of LNG transfer rates from transport trucks/trailers to stationary tanks could be as high as 300 gallons per minute, yielding the expected requirement of 3,000 gallons of constantly available surface impoundment for the
delivery area. The authority having jurisdiction (AHJ) may modify the requirement according to conditions at a given site and other life-safety or firefighting considerations.

Surface containment for deliveries may be integrated with the impoundment provided for the stationary LNG tanks. In all cases, accurate and explicit calculations for impoundment areas and provisions for the disposition of received snow and rainfall within them are essential to the facility planning/design.

**NOTE:** Containment berms and sloping may not meet some aspects of handicap accessibility, so the combination of off-loading and refueling in the same lane may not be practical.

### 10.4 Location of Dispensers.

Dispensers are typically installed on raised concrete islands, such as those used for liquid motor fuels. Depending on the configuration of the dispenser itself and accessibility requirements prevailing in the jurisdiction, raised islands may not be appropriate. In all cases, dispensers should be protected from vehicle impact using guard posts or other barriers sized to withstand low-speed impacts from the largest vehicles that are expected to use the facility. The length of piping runs between the dispensers and the LNG tank/pump skid should be minimized.

Some dispensers incorporate all the electronic components normally associated with a sales transaction such as card readers and printers within the dispenser cabinet itself. Other dispenser designs having components that could serve as a source of ignition must be placed at least 5 feet away from the LNG dispenser cabinet. Dispensers should be placed in a location convenient to the filler port on the vehicle. Filler ports on LNG vehicle tanks are typically accessed from the driver’s side. Code requirements limit LNG hose assemblies to 18 feet in length, so lanes should be tight enough that the need for a longer hose does not arise.

When adding LNG dispensers to an existing site, it may be necessary to install a dedicated LNG fuel controller depending on the capabilities of the existing site’s conventional motor fuel controller.

Special considerations are required if conventional fuels and LNG dispensers are to be located in the same service lane. Vapors produced by adjacent motor fuels may accumulate on the ground surface because they are denser than air. As a result, some parts of other fuel dispensers may not be designed to meet the requirements for classified areas created by rising gaseous fuels and could present an ignition hazard. A thorough investigation of existing dispensers should be undertaken to ensure their appropriateness for co-location with LNG dispensers. Consult with the AHJ to verify that planned separation distances between conventional liquid fuel and LNG dispensers are acceptable.
10.5 Emergency Shutdown Switches. When liquid fuel and LNG dispensers are located at the same fueling facility, consult with the AHJ to determine acceptable locations for emergency shutdown switches and to identify which electrical circuits will need to be de-energized when the emergency shutdown system is activated. Generally, it is recommended to shut down all fueling of any type under a given canopy for any hazard that could be worsened by adjacent fuel dispensing. However, the initial operation and tuning of a highly interconnected safety, monitoring and operating emergency shutdown (ESD) system—such as that likely to be in place for LNG—may result in nuisance shutdowns that disrupt conventional fuel operations. In cases where LNG dispensing is remote from other fueling, there may be reasons for having separate shutdown circuitry; however, this will be within the purview of the AHJ.

10.6 Control Center Structure. Stand-alone sites that have no activities other than LNG fueling likely will require a small structure to house peripheral equipment and facility documents. Typical items that can be housed in a control center structure include:

- all electronic equipment, including service, distribution, switchgear, controls and the programmable logic controller (PLC);
- paperwork, such as maintenance logs, equipment manuals, site drawings, and permits;
- payment processing system that will need a power supply and should be located in a temperature-controlled space;
- computer to monitor the equipment and process data;
- telephone line and internet connection;
- small air compressor and air tank if the facility uses compressed air to actuate valves;
- purge fans;
- spare parts such as pump seals, valves and supplies;
- facility maintenance equipment such as a lawn mower or snow blower.

When planning an LNG fueling facility, thoroughly consider all of the peripheral equipment that will be needed to operate and maintain the facility.

10.7 Unattended Facilities. If the fueling facility will operate unattended all or some of the time, additional measures may be necessary to improve facility safety and security. Additionally, whether a particular location can be approved for unattended fuel dispensing is within the purview of the AHJ. Considerations may include prevention of fires, minimization of injury and loss of life in the event of fire, and minimization of property damage in the event of fire.

Either attended or unattended, consider including the following features in the design of all LNG facilities:

- fire alarm pull box;
- flame and gas detection system with sensors located in the control center that will activate the facility emergency shutdown system;
• video surveillance system to remotely monitor activities at the site;
• data gathering system to remotely monitor fueling system parameters, such as fuel pressure and temperature, with automatic notification of appropriate personnel if there is a problem;
• dedicated emergency phone;
• prominently posted phone contact information for end users to report operational or equipment problems to appropriate personnel;
• prominent signage describing normal fueling procedures and emergency response procedures;
• fueling instructions for end users at public facilities (Instructions may be provided using dispenser displays, readily visible brochures, prominent instructions on the dispenser cabinet or other effective means.);
• identification of end users prior to each fueling event (may be required).

10.8 LNG Compound Surface Materials. Raised concrete equipment pads typically are used to support LNG storage tanks, pumps, pipes, valves, fittings and heat exchanger equipment. Tank pads will include a foundation designed to support the equipment loads and wind loads given the local soil conditions and any seismic considerations. Extend the dimensions of concrete pads beyond the footprint of the equipment to provide a reasonable place for service personnel to access maintenance items. Any materials employed should be suited to the temperature and permeation of spilled or leaking LNG, along with resistance to any expected local weather conditions. Refer to Chapter 12 for additional information about equipment pads and foundations.

10.9 Lighting. Adequate lighting to facilitate nighttime offloading, end-user fueling, security, repairs and maintenance should be provided. Electrical codes require control of ignition sources such as lighting in classified hazardous areas.

Depending on the location, localized concerns about light intensity may require additional attention to the configuration of site lighting.

10.10 Safety and Security. LNG tanks, heat exchangers, and other LNG saturation equipment, pump skids and electrical switchgear normally are located aboveground and are much more obvious to passersby than typical conventional fuel systems. Security measures to keep the public away from the LNG processing equipment are required. A field-erected locked chain-link fence or its equivalent is the preferred security measure. Dispensers open to the public are normally not kept in fenced areas.

10.10.1 Fencing. In the absence of a fully remote location for the LNG containment/equipment, fencing should be installed around the LNG equipment to keep
unauthorized personnel out. The LNG fueling system components other than dispensers should be located within a chain-link or similarly secure fence at least 6 feet high and set off from the equipment to allow for convenient inspection, operation and maintenance. Provide lockable gates in the fencing for personnel and/or vehicle access suitable for the site layout. For fencing enclosing LNG storage tanks, include a minimum of two gates on opposite sides of the facility to create multiple exit pathways in case of fire or gas discharge. Depending on the AHJ, life-safety requirements may require that egress points be provided with panic hardware that allows ready escape for individuals within the LNG equipment area in the event of an emergency.

In some environments, landscaping measures, such as decorative fencing, might be used to help camouflage LNG equipment. However, AHJ requirements for visibility and firefighting access will govern, so it is advised to review this topic prior to committing to decorative installations.

10.10.2 Vehicular Protective Barriers. LNG facility components that can be approached by any type of vehicle must be protected from vehicle impacts. Protect system components, such as offloading ports, LNG storage tanks, accessory buildings, heat exchangers, control panels, electrical distribution panels, dispensers and similar items, with guard posts (also known as bollards), concrete barriers, steel guard rail or other measures that will provide equivalent protection.

In the absence of particular AHJ requirements, the following vehicular protection barriers may be considered.

![FIGURE 10-3. Steel Pipe Bollard.](image-url)
By their nature, dispensers are located in traffic areas and are the fueling facility component most likely to be struck by vehicles. Dispenser protective barriers typically are placed only at the ends of dispenser islands.

In self-serve scenarios, local enforcement of the Americans with Disabilities Act (ADA) may require lowering the typical dispenser island height or elimination of the island altogether. If a dispenser island is not present or will not be effective in keeping vehicles away from the dispenser, additional vehicular protection near the dispenser cabinet may be installed to protect the dispenser from traffic. The height and swing of driver doors should be considered when locating vehicular protection near islands to avoid interference. When placing vehicular protection, care should be taken that normal maintenance procedures requiring removal of the dispenser or parts of it can be accomplished without undue interference.

10.11 Equipment Location Considerations. To improve site safety, security and access, LNG equipment should be located away from overhead power lines and set back from property lines, roads, buildings, waterways, drainage swales and pipes as well as railroads.

Releases from an LNG system typically result in a cold blanket of evaporating liquid and methane gas near the ground. It is important to understand that the contours of adjacent surfaces and/or wind action may conduct the flow of LNG to distances greater than expected. No fixed specification should be taken as all-encompassing. An experienced LNG facility design engineer should be engaged to undertake a thorough evaluation of site characteristics before a particular location or site configuration is chosen.
Refer to Table 10-1 for a summary of typical equipment setback and separation distances. Note that in all cases, the AHJ is empowered to make final determinations of safety requirements.

<table>
<thead>
<tr>
<th>Site Feature</th>
<th>Minimum Setback and Separation Distances (Feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LNG Process Equipment and Heat Exchanger</td>
</tr>
<tr>
<td>Property Line</td>
<td>50²</td>
</tr>
<tr>
<td>Public Right of Way</td>
<td>50²</td>
</tr>
<tr>
<td>Navigable Waterway</td>
<td>50²</td>
</tr>
<tr>
<td>Source of Ignition</td>
<td>50²</td>
</tr>
<tr>
<td>Important Building¹</td>
<td>25²,7</td>
</tr>
<tr>
<td>Combustible Building or Materials</td>
<td>25⁷</td>
</tr>
<tr>
<td>LNG Storage Tank</td>
<td>5</td>
</tr>
<tr>
<td>Liquid Fuel Dispenser (regardless of electrical area classification)</td>
<td>50⁶,7</td>
</tr>
<tr>
<td>Minimum 6 ft. Height Security Fence</td>
<td>5</td>
</tr>
<tr>
<td>Aboveground Tank Storing Liquid Petroleum Fuel or LPG</td>
<td>20</td>
</tr>
</tbody>
</table>

¹ This is taken to be the Point of Transfer as referenced in NFPA 52.
² The distance given is typical for aboveground LNG tanks. The actual required setback distance varies with the size of the container and its setting above or below ground. The AHJ may approve reduced distances, but the minimum is 10 feet. See NFPA 59.
³ Do not locate LNG components beneath power lines or in any location where a broken power line that falls to the ground could contact any component. See NFPA 59A.
⁴ An important building is any occupied building, any building that contains critical equipment, an unoccupied building that contains substances that might pose a hazard to human health if the building were to burn, or any building considered important by the facility owner.
⁵ The dispenser separation distance may be reduced if the building is of concrete or masonry construction with a fire resistance rating of at least two hours, but the nozzle still must be at least 10 feet from any building opening when the dispensing hose is fully extended.
⁶ A liquid fuel dispenser can be closer than the specified distance if the entire dispenser is listed for use in a Class I, Division 2, Group D area.
⁷ This is a suggested value. Per NFPA 52 “The spacing of LNG dispensing equipment relative to other equipment, activities, nearby property lines, and other exposures in a fuel dispensing forecourt shall be approved by the AHJ.”
11. CLASSIFIED AREAS, GROUNDING AND BONDING

11.1 General. Electrically powered equipment makes up a great deal of a liquefied natural gas (LNG) fueling system. Special measures must be taken to prevent sparks or heat generated by adjacent equipment from igniting natural gas vapor that may be released from an LNG fueling system. Electrical codes define the extents of classified areas—those in which concentrations of flammable or explosive substances may be present in quantities sufficient to produce explosive or ignitable mixtures.

Grounding and bonding of all LNG and liquefied compressed natural gas (LCNG) equipment is required to minimize the potential for static discharges to ignite releases of natural gas. Examples of potential static accumulation include the following:

- For LCNG applications, pressurized gas flowing at high velocity through narrow tubing can generate static electricity.
- The characteristics of over-the-road vehicles and tire compounds may be a source of static charge accumulation.
- The connection of filling and dispensing equipment may result in a path for static discharge.
- Lightning, power quality and other environmental considerations may require additional design features.

11.2 Classified Areas. To guide electricians in the installation of electrical equipment designed for use in hazardous areas, the National Electrical Code (NEC-70) contains a classification system that describes the type of hazard presented by various ignitable vapors, gases and dusts (see Table 11-1), and areas where these hazards are commonly found (see Figure 11-1). The NEC specifies wiring methods, electrical equipment and procedures that must be used in classified areas. When working in a classified area, electricians and other technicians must be certain to use wiring methods, components and procedures appropriate for the hazard classification.

**WARNING:** Use only qualified electricians and technicians with experience working in classified areas to perform electrical work at LNG fueling facilities.
<table>
<thead>
<tr>
<th>Class</th>
<th>Division</th>
<th>Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>1</td>
<td>Ignitable concentrations of gases are frequently present.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A Acetylene</td>
</tr>
<tr>
<td>II</td>
<td>2</td>
<td>Ignitable concentrations of gases are present under abnormal conditions.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B Hydrogen</td>
</tr>
<tr>
<td>III</td>
<td></td>
<td>C Ethylene, hydrogen sulfide</td>
</tr>
<tr>
<td></td>
<td></td>
<td>D Methane, propane, gasoline, diesel, ethyl alcohol</td>
</tr>
</tbody>
</table>

**TABLE 11-1. Overview of the National Electrical Code (NEC-70) Classification System for Hazardous Areas.** This table lists only representative gases in the “Group” column. Refer to the NEC for a full description of the classification system. Natural gas falls under Class I, Group D. Both Divisions 1 and 2 apply to natural gas.

In the NEC classification system, natural gas is a Class I, Group D substance. Depending on the likelihood that ignitable concentrations of natural gas may be present, an area can be classified as either Division 1 or Division 2. The following tables are reproduced courtesy of the National Fire Protection Association (NFPA) from their codes NFPA 52 *Vehicular Natural Gas Fuel Systems Code* and NFPA 59A *Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)*.

<table>
<thead>
<tr>
<th>Table 13.3.2.25.1 LNG Fueling Facility Electrical Area Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part</td>
</tr>
<tr>
<td>A</td>
</tr>
<tr>
<td>Outdoor, aboveground containers (other than portable)</td>
</tr>
<tr>
<td>Outdoor, belowground containers</td>
</tr>
<tr>
<td>B</td>
</tr>
<tr>
<td>Outdoor, in open air at or above grade</td>
</tr>
<tr>
<td>C</td>
</tr>
<tr>
<td>D</td>
</tr>
<tr>
<td>E</td>
</tr>
<tr>
<td>Outdoor, in open air at or above grade</td>
</tr>
</tbody>
</table>

See Article 500, Hazardous (Classified) Locations, in NFPA 70 for definitions of classes, groups, and divisions.

*The classified area shall not extend beyond an impervious wall, roof, or solid opaque partition.*

*Ventilation is considered adequate when provided in accordance with the provisions of this code.*

**TABLE 11-2. NFPA 52 Vehicular Natural Gas Fuel Systems Code**

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<table>
<thead>
<tr>
<th>Part</th>
<th>Location</th>
<th>Group D, Division¹</th>
<th>Extent of Classified Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>LNG storage containers with vacuum breakers Inside containers</td>
<td>2</td>
<td>Entire container interior</td>
</tr>
<tr>
<td>B</td>
<td>LNG storage container area Indoors</td>
<td>1</td>
<td>Entire room</td>
</tr>
<tr>
<td></td>
<td>Outdoor aboveground containers (other than small containers)⁶</td>
<td>1</td>
<td>Open area between a high type dike and the container wall where the wall height exceeds distance between dike and container walls (see Figure 10.7.2(c))</td>
</tr>
<tr>
<td></td>
<td>Outdoor belowground containers</td>
<td>2</td>
<td>Within 15 ft (4.5 m) in all directions from container walls and roof plus area inside a low type dike or impoundment area up to the height of the dike impoundment wall (see Figure 10.7.2(b))</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>Nonfired LNG process areas containing pumps, compressors, heat exchangers, pipelines, connections, small containers, and so forth Indoors with adequate ventilation⁷</td>
<td>2</td>
<td>Entire room and any adjacent room not separated by a gastight partition and 15 ft (4.5 m) beyond any wall or roof ventilation discharge vent or lower</td>
</tr>
<tr>
<td></td>
<td>Outdoors in open air at or above grade</td>
<td>2</td>
<td>Within 15 ft (4.5 m) in all directions from the equipment and within the cylindrical volume between the horizontal equator of the sphere and grade (see Figure 10.7.2(a))</td>
</tr>
<tr>
<td>D</td>
<td>Pits, trenches, or sumps located in or adjacent to Division 1 or 2 areas</td>
<td>1</td>
<td>Entire pit, trench, or sump</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>Discharge from relief valves</td>
<td>1</td>
<td>Within 5 ft (1.5 m) in all directions from point of discharge</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Beyond 5 ft (1.5 m) but within 15 ft (4.5 m) in all directions from point of discharge</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>Operational bleed, drips, vents, or drains Indoors with adequate ventilation⁷</td>
<td>1</td>
<td>Within 5 ft (1.5 m) in all directions from point of discharge</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Beyond 5 ft (1.5 m) and entire room and 15 ft (4.5 m) beyond any wall or roof ventilation discharge vent or lower</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Outdoors in open air at or above grade</td>
<td>1</td>
<td>Within 5 ft (1.5 m) in all directions from point of discharge</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Beyond 5 ft (1.5 m) but within 15 ft (4.5 m) in all directions from point of discharge</td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>Tank car, tank vehicle, and container loading and unloading Indoors with adequate ventilation⁷</td>
<td>1</td>
<td>Within 5 ft (1.5 m) in all directions from connections regularly made or disconnected for product transfer</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Beyond 5 ft (1.5 m) and entire room and 15 ft (4.5 m) beyond any wall or roof ventilation discharge vent or lower</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Outdoors in open air at or above grade</td>
<td>1</td>
<td>Within 5 ft (1.5 m) in all directions from connections regularly made or disconnected for product transfer</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Beyond 5 ft (1.5 m) but within 15 ft (4.5 m) in all directions from a point where connections are regularly made or disconnected and within the cylindrical volume between the horizontal equator of the sphere and grade (see Figure 10.7.2(a))</td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>Electrical seals and vents specified in 10.7.5 through 10.7.7</td>
<td>2</td>
<td>Within 15 ft (4.5 m) in all directions from the equipment and within the cylindrical volume between the horizontal equator of the sphere and grade (see Figure 10.7.2(a))</td>
</tr>
<tr>
<td>I</td>
<td>Marine terminal unloading areas (see Figure 10.7.2(a))</td>
<td>2</td>
<td>Within 15 ft (4.5 m) in all directions, above the deck, from the open sump</td>
</tr>
</tbody>
</table>

¹See Article 500 in NFPA 30 for definitions of classes, groups, and divisions. Article 500 can be used as an alternate to Article 500 for classification of hazardous areas using an equivalent zone classification to the division classifications specified in Table 10.7.2. Most of the flammable vapors and gases found within the facilities covered by NFPA 59A are classified as Group D. Ethylene is classified as Group C. Most of the available electrical equipment for hazardous locations is suitable for both groups.

²Small containers are portable and of less than 100 gal (460 L) capacity.

⁷Ventilation is considered adequate where provided in accordance with the provisions of this standard.

### TABLE 11-3. NFPA 59A Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)
FIGURE 11-1. Plan View of a Dispenser Island and Canopy with Appropriate Classified Areas Delineated.

FIGURE 11-2. Detailed View of a Dispenser Cabinet with Appropriate Classified Areas Delineated.
11.3 Methods of Minimizing Electrical Ignition Hazards. Methods commonly used to minimize the ignition hazard of using electricity in areas where natural gas may be present are described in the following sections.

**FIGURE 11-3. An Overall Plan View of an LNG Fueling Facility with Appropriate Classified Areas Delineated.**

11.3.1 Explosion-Proof Construction. Explosion-proof construction is used with electrical devices that can produce arcing or high temperatures. In these types of devices, sufficient electrical energy is present to ignite natural gas. To make these devices safe, the electrical device is enclosed in a box strong enough to contain any explosion resulting from the ignition of gas that might be present inside the box. While ignition of the gas is not prevented, it is safely contained and safely exhausted.
Physical barriers in the form of vapor-tight partitions or conduit seals must be used to prevent the passage of natural gas out of a classified area or from process equipment, such as pressure sensors, into connected electrical equipment. In general, conduit seals are required whenever a conduit run passes through a classified area and into an unclassified one. In such cases, a seal-off is required at the first unburied fitting in either the classified or unclassified spaces. This is to prevent gaseous leakage through non-sealable fittings, which could result in transmission of ignitable concentrations of vapors occurring in unclassified spaces.

11.3.2 Energy Limiting Systems. Energy limiting systems often are used for sensing and control circuits where low voltages and low current are all that are required. By limiting the electrical energy in the circuit, sparks or heat with sufficient energy to cause ignition cannot be produced. There are two types of energy limiting circuits: Non-incendive or intrinsically safe circuits that cannot produce ignition under normal operating conditions and intrinsically safe circuits that cannot produce ignition even under fault conditions.

11.3.3 Purging. Purging is used where an enclosed space can be made reliably gas free by pressurizing the space with air from a source outside of the hazardous area. In most cases, a small fan or blower located some distance away in a non-hazardous area blows air through duct, pipe or a hose to the space to be purged. A source of pressurized and/or compressed air also can be used to provide the flow of clean air. The positive pressure created by the fan or compressor creates a flow of air out of the enclosed space, preventing any gas from entering.

Various types of purging are specified in electrical codes. The type most often used in LNG equipment requires the immediate disconnection of electrical power to the purged area if the pressurization fails. By automatically cutting off the power to the purged area when the pressurization fails, the normally classified area becomes de-energized and free of potential ignition sources. At the present time, card readers and printers cannot be made using energy limiting circuits, so they cannot be installed in a classified area.

Purging is used in the electrical compartment of some LNG dispensers to create an unclassified area so that card readers and receipt printers can be installed in the dispenser cabinet. If purging or physical barriers (see Section 11.3.4) are not used to make the dispenser electrical cabinet an unclassified area, card readers and receipt printers must be located at least 15 feet away from the dispenser so they are outside of the classified area associated with LNG dispensers. (See Figure 11-2.)
11.3.4 **Physical Barriers.** Constructing a physical barrier between the gas and electrical compartments of LNG dispensers is another method of making the electrical compartment of a dispenser an unclassified area. This technique is used by some dispenser manufacturers to enable them to install card readers and printers in the electrical cabinet of LNG dispensers.

11.4 **Grounding and Bonding.** LNG fueling facilities typically involve electrical voltages ranging from 24 VDC to 480 VAC, along with communication and data circuits, a variety of metallic components and liquefied gas, a combination of factors that can produce:

- shock hazards;
- electrical arcs;
- sparks from static electricity;
- transient voltage surges;
- electrical interference that will disrupt sensitive electronic components.

To minimize electrical shock, spark and interference hazards, the installer must provide common ground conductors for powered equipment and bond to ground all metallic components at an LNG fueling facility. This includes:

- LNG storage vessels (and associated vent stacks);
- heat exchangers;
- pumps (including mounting skid/framework);
- dispensers;
- metallic fencing, canopy/canopy columns and structures;
- any other metallic component present at the fueling facility.

The grounding system for LNG equipment must be connected to the service ground for the facility. Follow electrical code and electrical permit requirements as well as the site-specific grounding design provided by the facility design engineer when constructing the grounding system.

11.5 **Minimizing Non-Electrical Ignition Hazards.** Non-electrical ignition hazards typically include hot or moving metallic components. Any sources of heat or ignition must be located outside of the classified area. Only materials and components listed for the classified hazard may be used.

11.6 **Lightning Protection.** Lightning is an ever-present hazard for any outdoor equipment that handles fuels. In the case of LNG, vertical tanks (and the associated vent stacks) might be the tallest structures on the site. In order to safeguard against lightning strikes, as well as to protect electronic equipment from the effects of large power surges, the following precautions are recommended.
11.6.1 Qualified Designer. Ensure that the LNG design engineer has reviewed the site/equipment and has included a lightning protection plan for the site. If the LNG design engineer does not have specific lightning protection capability, engage a consultant who specializes in lightning protection systems.

11.6.2 Best Technology. Determine the best system for the application. Surge protection provisions are the first line of defense against lightning effects. Multipoint ionizers act to dissipate lightning energy and even render the site less attractive to strikes. Remember that the investment in an LNG system is considerable and the effects of a lightning strike can range from annoying equipment irregularities to fatalities. Generally, prevention is less expensive and a more provident alternative, particularly when long-term plans for multi-site rollouts of LNG fueling are considered.
12. CONSTRUCTION OF FOUNDATIONS AND ENCLOSURES

12.1 General. Liquefied natural gas (LNG) storage vessels, pumps, vaporizers and related equipment should be set on appropriate concrete foundations that will securely support the equipment over time. Foundations for pump skids and LNG storage vessels in particular require careful design based on site-specific factors.

If the load-bearing capacity of the soil is low, foundations for pump skids and LNG storage vessels may require significant engineering effort. Soils sufficient to support typical service station items using a standard foundation design will require substantial foundation engineering to address the concentrated weight of the mechanical equipment. Soil conditions, wind exposure and seismic requirements may affect the cost of LNG equipment foundations. The most widely referenced publication used for establishing environmentally imposed loads on structures is the American Society of Civil Engineers (ASCE) *Minimum Design Loads and Associated Criteria for Buildings and Other Structures* (ASCE/SEI 7).

Designing an appropriate foundation will require a geotechnical investigation, including a standard penetration test and test borings. The geotechnical consultant should be an experienced, licensed engineer who incorporates appropriate climate and environmental factors into the foundation design. These factors include the depth of frost and the likelihood, frequency and severity of flooding, hurricanes, tornadoes and earthquakes. Care must be taken to ensure fidelity between the design configuration and as-built structures.

The LNG containment area should be constructed of poured concrete and/or a reinforced concrete block wall with a pitched floor. The containment area should have either a low temperature-protected sump pump or capped drain connection for the removal of any accumulated water.

12.2 Equipment Foundations. Depending on size, the static load produced by an LNG storage tank will vary with the orientation of the tank (vertical or horizontal). Limited dynamic loads may be produced, for example, by wind loading.

The substantial weight of LNG storage vessels will be placed within a relatively small footprint. The load-bearing capacity of the underlying soil as well as the length of reinforcement development in the concrete slab should be considered to prevent settling of the LNG storage vessels over time. LNG storage tank anchoring instructions should be carefully followed. The exact size and type of bolts specified by the LNG tank manufacturer and/or the foundation engineer should be used.
12.3 Dispenser Islands. Like liquid fuel dispensers, LNG dispensers are typically mounted on concrete islands higher than the surrounding grade. Standard liquid fuel island shapes may be used to form the concrete LNG dispenser island. If dispensers are to be installed at grade rather than on an island, the fueling area should be graded away from the dispensers. LNG dispensers are anchored using steel mounting frames that are embedded in the concrete. The dispenser frame typically has metal skirts extending downward that create an opening through the concrete. LNG piping and electrical conduit pass through this opening to enter the dispenser from below. The dispenser cabinet should be anchored using bolts that are supplied with the dispenser mounting frame. The dispenser manufacturer instructions for the size and location of bolts should be followed.

Under-dispenser sumps or skirts equipped with dispenser mounting frames similar to those installed beneath liquid fuel dispensers may be used beneath LNG dispensers with supply piping routed underground. Under-dispenser sumps provide a clean and dry accessible area in which to work, making it easier to install the LNG piping and electrical conduit to the dispenser. Overhead piping arrangements also are an option. The LNG facility design engineer should be consulted for a full appraisal of the various benefits and limitations of each option.

12.4 Control Center Structure. In milder climates, the controls and switchgear for LNG fueling facilities may be completely exposed to the weather, but most locations include some type of weather protection. A common configuration is to have a structure around the switchgear and controller system.

Check local building codes for applicable requirements. Aesthetic design elements of a durable, noncombustible character can be considered to help the control center structure blend in with adjacent structures.

FIGURE 12-1. Control Center Structure. This structure is built inside a shipping container at an LNG site in Texas. Note the HVAC unit and purge fans.
13. CONNECTING THE COMPONENTS

13.1 Introduction. Several different types of connections between the various liquefied natural gas (LNG) fueling system components will need to be made on-site. These connections include the following.

- LNG supply piping from the offload connection to the pump skid and LNG storage tank (This piping usually is constructed of vacuum jacketed stainless-steel pipe. Typical operating pressures are less than 300 psi.);
- Piping attached to pressure relief devices directing vented gas to a safe location (These vents are usually constructed of stainless-steel pipe or tubing 2 inches or less in diameter. This vent piping will normally be at atmospheric pressure, but may be subject to additional pressure when a pressure relief valve opens.);
- Any purge piping that conveys fresh air from a non-hazardous location to the electronic cabinet of the dispenser;
- Liquid supply and vent hoses connecting the fueling nozzle and vehicle tank vent connection to the dispenser;
- If so equipped, instrument air tubing runs between a compressed air supply and valve actuators.

Each of these applications has specific requirements, and all require some measure of field construction. This chapter will describe the typical techniques involved in the installation of these tubing and piping systems.

Cryogenic and/or high-pressure components of LNG and liquefied compressed natural gas (LCNG) fueling facilities must be built using appropriate materials and good workmanship. Establish relationships with reputable suppliers of components suitable for the application. Request documentation such as mill test reports and certificates of conformance from suppliers that equipment and materials conform to applicable standards.

Use only piping, tubing, valves and fittings intended for LNG service when connecting fueling system components that will carry LNG. Verify that all piping, tubing, valves and fittings located downstream of the LNG pumps are rated for cryogenic temperatures. Carefully select piping, tubing, valves and fittings based upon pressure rating, compatibility with natural gas, design flow rate and operating temperature range.

13.2 LNG Piping. The sizing of the LNG piping depends on the LNG flow rate and length of pipe run. Consideration of expansion, contraction, and thermal gain and loss should be included in the piping configuration. Follow the pipe sizing specifications provided by the experienced LNG facility design engineer.
Welded/vacuum jacketed stainless steel pipe is typically used for LNG supply piping. Follow all quality control and testing steps described in American Society of Mechanical Engineers (ASME) Standard B31.3 *Process Piping*. Provide piping supports as specified by the experienced LNG facility design engineer.

![FIGURE 13-1. View Inside an LNG Containment Wall. Welded, jacketed LNG piping can be identified by the 3-inch sleeves around 1-inch diameter piping. The very large diameter sleeves are factory installed foam insulation.](image)

Connections between the LNG piping and the various components typically are made with bolted flange connections. Use flanges and gaskets rated for the temperatures and pressures that will be present in the LNG piping. Use gaskets compatible with the flange design and LNG to help ensure a tight seal.

The LNG supply piping normally contains the types of valves and equipment listed below. The quantity and placement of this equipment may vary. Follow the piping design provided by the experienced LNG facility design engineer.
• A manually operated shutoff valve is installed in the LNG supply piping to isolate each component in the system for emergency situations or general maintenance. This manual valve will be useful in cutting off the gas supply during maintenance and repair of downstream components of the fueling system.
• A strainer is placed at the offload pump inlet and between the storage tank and the dispensing pump to capture any large particles in the LNG.
• Check valves are used to prevent backflow, for example in the offload process and the dispensing process.
• Piping line pressure relief devices (PRDs) are installed between valved components to protect the line from over-pressurization.
• Additional valves or fittings may be required to address site-specific issues or may be specified by the design engineer. Install all valves and fittings specified in the design drawings.

13.3 Instrument Air Tubing. If air or nitrogen is used to operate the valves, the tubing and fittings supplying the air do not need to meet the same material and pressure requirements as the tubing carrying natural gas. Acceptable instrument air tubing materials include stainless steel, copper, high-density polyethylene or aluminum ½ inch or less in diameter. Typical operating pressures are 80 to 125 psi. Connectors for this tubing must be intended for use with the tubing material, rated for the pressures that will be present in the tubing and suitable for use in an industrial application.

**WARNING:** Never connect, disconnect, tighten, loosen or adjust any fitting while it is under any amount of pressure.

13.4 LNG Storage Tank Vents. At least two PRDs are required by federal law for each LNG storage tank (Reference 46 CFR 54.15-5 - Protective Devices). PRDs are typically installed at the factory by the manufacturer of the storage tank. These pressure relief valves are typically set to open at 135 to 275 psi or at the maximum allowable working pressure of the lowest rated component of the fueling system. Pressure relief valves must be removed and recertified for proper operation according to timelines specified by the authority having jurisdiction (AHJ) or the National Board of Boiler and Pressure Vessel Inspectors. LNG installations must include an isolation valve locked in the open position between the storage tank and the pressure relief valve.

The use of an isolation valve requires a method to bleed pressure between the isolation valve and the pressure relief valve. If the isolation valve installation does not include a bleed method, a needle valve can be installed in a “T” fitting between the isolation valve and the pressure relief valve so that the pressure between the two valves can be released safely.
Connect the outlet of the pressure relief valve to a vertical vent pipe. The PRD vent piping and fittings are constructed of stainless steel or aluminum pipe or tubing. Match the vent pipe diameter to the diameter of the PRD outlet. Vents from multiple PRDs may be manifolded together. If vents are manifolded, the vent pipe diameter must be increased so that it can handle the flow from several PRDs at once. The weight of the vent piping must not place any additional stress on the connection between the PRD and the storage vessel. The vent piping must be securely mounted so that it is supported independently of the PRD.

Extend the vent pipe above the LNG storage tank as specified by the LNG facility design engineer.

It is important that any water that does enter the pressure relief vent pipe does not accumulate at the outlet of the relief device. Also, in colder climates, an ice plug in the vent pipe could interfere with the operation of the device or the venting of gas. To prevent water accumulation, include a drip leg at the base of the vent pipe.

![FIGURE 13-2. Storage Vessel Configuration. One configuration that is used for the storage vessel vent at an LNG site.](image)

13.5 **Dispenser Purge Piping.** Dispensers that use purging (see Section 11.3.3) require a continuous supply of clean air to the electronic portion of the dispenser cabinet. Install a continuously operating purge fan in a non-hazardous area to provide a reliable source of air. Provide piping from the blower to the base of the dispenser cabinet. Use standard 2 to 4 inch diameter schedule 40 PVC pipe to provide the air flow from the fan to the dispenser cabinet.
Where the pipe runs underground, bury the piping a minimum of 18 inches below grade. Provide a riser to grade with a suitable cap at the low point of the piping to drain any condensate from the pipe. Heavy-duty, large-diameter flexible plastic hose may be used to connect the PVC pipe at the base of the dispenser cabinet to the purge fitting in the upper part of the dispenser cabinet.

Wherever the purge fan is mounted, follow dispenser manufacturer instructions to ensure that the dispenser receives an adequate flow of air.

13.6 Hoses, Breakaways and Nozzles. The fittings used to connect product supply hoses, nozzle vent hoses, breakaway fittings and the nozzles themselves are specific to individual equipment manufacturers. If these components will be purchased from alternate suppliers, verify they have compatible fittings or are supplied with suitable adaptors to allow connection.

Both the LNG hose connecting the nozzle to the dispenser and to the nozzle vent hose must be equipped with breakaway connectors that will separate safely if a vehicle drives away with the nozzle still attached to the fuel receptacle.

![FIGURE 13-3. Explanation of a Breakaway Fitting Function.](image-url)
14. SIGNAGE

14.1 Introduction. Signs are an important safety element in any fueling environment and no less so at liquefied natural gas (LNG) fueling facilities. Warning and instructional signs and placards conveying the following types of information are required:

- hazards present in the fueling area (e.g. electrical, chemical, thermal, flammability and explosive hazards);
- requirements for personal protective equipment (PPE);
- actions end users can take to minimize risks in the fueling area;
- instructional signage at user interfaces with equipment;
- reminders to service technicians of the hazards present in the equipment compound;
- locations of emergency shut-down switches, fire extinguishers and other safety equipment;
- signs indicating the types of hazards present using symbols familiar to first responders.

14.2 Signage Details. The location and wording of warning and instructional language that should be present at LNG fueling facilities are summarized in Table 14-1. Signs intended for customers at public fueling facilities should be clearly visible and legible from each fueling position. Note that specific requirements for actual installations may vary depending on the site configuration and availability for public or private fueling, in addition to LNG facility design engineer and authority having jurisdiction (AHJ) requirements.

<table>
<thead>
<tr>
<th>Signage/Wording</th>
<th>Suggested Location of Signage and Special Notes</th>
<th>Example Sign</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Instructions on how to fuel an LNG vehicle</td>
<td>At each dispensing point</td>
<td>Procedures will vary according to dispenser and nozzle chosen, so custom signs will be required. Often Dispenser manufacturers provide these signs as part of the equipment. See Chapter 16 for example procedures</td>
</tr>
<tr>
<td>2. “Stop Engine”</td>
<td>At each dispensing point</td>
<td></td>
</tr>
<tr>
<td>3. “No Smoking”</td>
<td>At each dispensing point At each entrance to equipment compound Minimum Text size 1” height</td>
<td><img src="image" alt="DANGER NO SMOKING STOP ENGINE WHILE FILLING" /></td>
</tr>
<tr>
<td></td>
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<td>---</td>
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</tr>
</tbody>
</table>
| 4.  | “Flammable Gas” | At each dispensing point  
On each storage vessel, near any venting outlet. At each entrance to equipment compound  
Minimum Text size 1” height |
|   |   | ![DANGER](image) |
| 5.  | No Smoking or open flames | At any point where connections are made, fuel is dispensed, or venting may occur in normal operation;  
Along impoundment fencing at frequency sufficient to be seen from 100 feet away from fence.  
Minimum Text size 1” height |
<p>|   |   | <img src="image" alt="NO SMOKING OR OPEN FLAMES" /> |
| 6.  | Unodorized Gas | At any potential venting point, dispensing point and offloading point. Minimum Text size 1” height |
|   |   | <img src="image" alt="Unodorized Gas" /> |
| 7.  | “Authorized Personnel Only” | At each entry to equipment compound. Minimum Text size 1” height |
|   |   | <img src="image" alt="NOTICE" /> |
| 8.  | Electrical Closet/ no storage permitted | At all Electrical Closets. Minimum Text size 1” height |
|   |   | <img src="image" alt="NOTICE" /> |</p>
<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>9.</td>
<td>Arc Flash Warning</td>
<td>At all High Voltage Enclosures</td>
</tr>
<tr>
<td>10.</td>
<td>Personal Protection Equipment required beyond this point</td>
<td>At each entry to equipment compound</td>
</tr>
<tr>
<td>11.</td>
<td>Personal Protective Equipment stored here</td>
<td>On PPE Locker</td>
</tr>
<tr>
<td>12.</td>
<td>Danger-Cryogenic Liquid/ Liquefied Nitrogen Cryogenic Liquid</td>
<td>At each dispensing point At Truck connection, dispensers and any other point of potential User interface. Minimum Text size 1” height</td>
</tr>
<tr>
<td>13.</td>
<td>Cryogenic Notice</td>
<td>At Truck connection, dispensers and any other point of potential User interface.</td>
</tr>
<tr>
<td>14.</td>
<td>PPE Notice</td>
<td>At each dispensing point. At Truck connection, dispensers and any other point of potential User interface.</td>
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<td></td>
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<tr>
<td>15. Caution: Equipment starts automatically</td>
<td>On each storage vessel. At each entry to equipment compound.</td>
<td></td>
</tr>
<tr>
<td>16. Danger- Keep Guards in Place</td>
<td>On any fixed guards for motors or other equipment.</td>
<td></td>
</tr>
<tr>
<td>17. Fire Extinguisher</td>
<td>Prominently above any fire extinguisher. Minimum Text size 1” height</td>
<td></td>
</tr>
<tr>
<td>18. Emergency Shutoff General</td>
<td>At General E-Stop if appropriate. Minimum Text size 1” height</td>
<td></td>
</tr>
<tr>
<td>19. Emergency Shutoff- LNG</td>
<td>At LNG E-stop If appropriate to shut down ONLY LNG. Minimum Text size 1” height.</td>
<td></td>
</tr>
<tr>
<td>20. Emergency Shutoff- Diesel</td>
<td>At Diesel E-stop If appropriate to shut down ONLY Diesel. Minimum Text size 1” height</td>
<td></td>
</tr>
<tr>
<td>21. First Aid Kit</td>
<td>At the point of safety/ first aid equipment storage</td>
<td></td>
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<td></td>
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<td>---</td>
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</tr>
<tr>
<td>22. NFPA 704 warning diamond</td>
<td>All vehicles, vessels or containers for LNG, anywhere where firefighting of an LNG hazard might occur</td>
<td>![140 diamond warning]</td>
</tr>
<tr>
<td>23. Offloading Procedures</td>
<td>Near Offloading Connection. See Footnote to table for text.</td>
<td>![Offloading Procedures]</td>
</tr>
<tr>
<td>24. Pressure Relief Device</td>
<td>At any automatically operated PRV. Pressure may vary according to facility parameters</td>
<td>![Pressure Relief Device]</td>
</tr>
<tr>
<td>25. Emergency Instructions</td>
<td>At any user interface or common point of maintenance. Minimum Text size 1” height</td>
<td>![Emergency Instructions]</td>
</tr>
<tr>
<td>26. Facility Owner Identifier</td>
<td>Near Emergency Response Information</td>
<td>![Facility Owner Identifier]</td>
</tr>
</tbody>
</table>
27. Emergency Response Information

At any user interface or common point of maintenance.
Minimum Text size 1” height

28. “Do Not Operate” tag

At any operating point where lockout/ tagout must be accomplished.
A supply of these tags should be kept available on site.

29. CCTV in Use

At least one on each face of the fence enclosure around the LNG impoundment;
Reference 49 CFR 2905 and 193.2913

| TABLE 14-1. Signage and Display Locations for LNG Fueling Facilities. |
FIGURE 14-1. Signage Placement at Example Site (Note numbering is as indicated in TABLE 14-1)
OFFLOADING PROCEDURES

Warning! Only properly trained and site-authorized personnel are qualified to perform the offload procedures. Hazards include: cryogenics, flammables, asphyxiants.

Always wear the proper protective clothing and safety equipment.

Do not offload during a lightning storm or severe flooding.

If you run into unexpected problems, call (930) 788-5815.

1. Make sure that the transport tractor and trailer are correctly located on the spill pad (tractor and trailer to be located such that backing is not required upon arrival or departure). The ball hitch is set and the trailer wheels are chocked.

2. Ensure that the truck engine is off. Set out safety cones. Ensure exclusion zone is established.

3. Before unloading, check that the product identification on the receiving storage tank exactly matches the product you are transporting. If anything does not match, STOP, and contact your terminal manager or dispatcher for further instructions.

4. Connect the Scully grounding/ESD static line to the trailer and push the TRAILER CONNECTION lighted pushbutton. Once the TRAILER CONNECTION ON light illuminates, both the trailer and the site ESD circuits are ready. This line must be connected and ready for the offload process to continue.

5. Once all pressure steps are completed, the ULLAGE FILL light on the offload vessel is illuminated. The light will stay on until the system pressure is below 1.5 psi. Otherwise, the light will blink on and off indicating that a partial offload is possible. Also check the fuel indicator on the offloading gauge panel. If the ULLAGE FILL light is on and there is an issue with one or more of the above connections required to continue the offloading process, inspect the hoses and all connections to ensure they are suitable for use.

6. Release the valve from the return-offload connections, FC-201 and FC-202, and connect the hoses. Ensure that the hoses stay level (use supports if needed, as in the picture below).

7. Line up the valves on the trailer or that natural gas (NOT LIQUID) from the trailer flow into both fill and return hoses.

8. Purge the hoses using natural gas (NOT LIQUID) from the trailer flow into both fill and return hoses. Purge the hoses using natural gas (NOT LIQUID) from the trailer flow into both fill and return hoses. Purge the hoses using natural gas (NOT LIQUID) from the trailer flow into both fill and return hoses. Purge the hoses using natural gas (NOT LIQUID) from the trailer flow into both fill and return hoses.


10. Close the return-offload valves, HV-201 and HV-204, to establish pressure feed and begin cooling the pump. Check for leaks.


12. Open the return-offload valves, HV-201 and HV-204, to establish pressure feed and begin cooling the pump. Check for leaks.

13. Open the bypass valves HV-202 and HV-203 to discharge the liquid supply and vapor return lines. The READY TO DEPRESSURIZE light will turn off.

14. Open the bypass valves HV-202 and HV-203 to discharge the liquid supply and vapor return lines. The READY TO DEPRESSURIZE light will turn off.

15. Where both hoses have been discharged, close bypass valves HV-202 and HV-203.


17. Open bypass valves HV-202 and HV-203 to discharge the liquid supply and vapor return lines. The READY TO DEPRESSURIZE light will turn off.

18. Open bypass valves HV-202 and HV-203 to discharge the liquid supply and vapor return lines. The READY TO DEPRESSURIZE light will turn off.


Note: If the READY TO DEPRESSURIZE light is flashing rapidly during the offload process, the depressurizing mode has failed and will be unable to sense when the majority of liquid has vaporized. Wait until the pump on line pressure is between 100, which is an indication that the LNG has vaporized.

FIGURE 14-2. Sample Offloading Procedures Sign (Courtesy Shell LNG).
15. TESTING, COMMISSIONING, STARTUP AND TRAINING

15.1 Introduction. After the construction phase of a liquefied natural gas (LNG) fueling facility, testing, startup, commissioning and training must be completed. The integrity and tightness of field-installed components must be verified and the operation of the facility must be initiated. Process equipment controls, emergency shutdown devices (ESDs) and other safeguards should be verified to be within operating limits and full functionality prior to the introduction of LNG product. On-site personnel must receive training in routine facility operation and maintenance and in how to respond to emergency situations. First responders should be familiarized with the site and its unique characteristics for firefighting and other emergency response procedures. This chapter provides an overview of the testing, startup and training activities that should occur as a new LNG facility is commissioned.

NOTE: Dispensing meters that sell LNG to the public are required to have a Certificate of Conformance issued by the National Type Evaluation Program (NTEP) which is administered by the NCWM. Dispensing meters are inspected and placed into service by local weights and measures agencies. Inspection may be conducted done by authorized personnel.

15.2 Joint Integrity and Leak Testing. All field-installed piping, tubing, fittings and components should be tested for integrity and tightness after assembly and before introducing LNG into the system. Proper testing of a fueling system is critical to its safe operation. X-ray examination of welded connections and testing compressed air/nitrogen pressure are the preliminary steps. Generally, purging of moisture and contaminants occurs at this point. Cryogenic liquid nitrogen testing, to at least the normal operating pressure, is most commonly used to proof, test and condition the LNG system.

WARNING: Cryogenic testing of newly assembled components to operating pressures and cold temperatures will cause significant material stresses from expansion and contraction, which may result in hazards including component failure.

Use the following guidelines when conducting testing.

- Thoroughly test and document the results of tests for all system components of the completed fueling facility prior to the introduction of LNG product.
- A testing and commissioning plan and flow chart should be developed and applied to a calendar format to ensure full coverage of testing and adjustments so that expectations for facility in-service dates are realistic.
- Closely follow an established health and safety plan during all system testing activities.
- Preliminarily test system segments with air pressure.
- Use nitrogen to fully test the system.
• Increase the pressure in steps and hold the final pressure for the minimum period stipulated in the test plan.
• Identify leaks by applying commercial leak detection fluid (not dish detergent) to joints and fittings, looking for bubbles, clouds, frost, etc. Gas detectors also may be used.
• Note that leaks that were not apparent at lower pressures will appear at higher pressures. Do not assume that a system is tight simply because it has successfully passed a lower pressure test.
• Do not attempt to repair leaks while the leaking component is under pressure.
• Keep an accurate record of each step in the testing procedure and submit this record to the facility owner at the completion of the project.
• Cool down the system with liquid nitrogen.
• Perform all system functions.

NOTE: Only experienced, knowledgeable professionals should conduct and document LNG system testing.

15.3 Startup Procedure. Starting up an LNG fueling facility is a major, carefully coordinated process involving representatives of the LNG equipment manufacturer/packager, the LNG supplier, design engineer, mechanical contractor, electrical contractor, owner and other interested parties. The startup procedure will include a final leak check of the entire system and system tests to ensure that all controls including the emergency shutdown system are operating correctly. Vehicles should be available to fill up as part of the testing. Weights and measures personnel may need to calibrate dispensers at facilities offering fuel for sale.

The startup procedure is specific to each site. Authorized representatives of the manufacturer of the LNG equipment or general contractor typically are responsible for coordinating and overseeing the startup. The startup requires working closely with the owner’s authorized representative so that all required equipment and personnel are present when needed.

15.4 Training. LNG is a different type of motor fuel than gasoline or diesel. While most adults in the U.S. are familiar with gasoline fueling, they probably are unfamiliar with LNG fueling. LNG end users may not understand why ice can form at the nozzle/receptacle connection or why it may sometimes take a lot longer to fill the vehicle. Additionally, observing personal protective equipment (PPE) requirements for LNG fueling is critical.

The differences between LNG and traditional liquid fuels may include the need for the following:
• Users receiving specific training on the operation and safe handling of LNG. Modern LNG dispensers are configured to replicate the appearance and general functions of
conventional fuel dispensers, but there are some differences to consider, including hoses, nozzles, breakaways and their handling.

- First responders trained in what to do when an LNG fuel-powered vehicle is on fire.
  Close coordination with local first responders will be part of a comprehensive safety plan for any LNG facility.

A great deal of information covering many different topics and audiences must be communicated as LNG vehicles and fueling facilities become more widespread. The development of LNG fueling is progressing well in some regions of the country and more slowly in others. That is why substantial differences are present in the relative levels of understanding among vehicle repair technicians, LNG equipment technicians and first responders. Part of the planning for any new LNG fueling facility should be an assessment of the level of understanding of all personnel who will deal with LNG fueling facilities and LNG vehicles.

This recommended practice only addresses the training issues associated with the fueling of vehicles and the operation of fueling facilities.

15.5.1 Training Vehicle Refuelers. It is the facility operator’s responsibility to provide fueling instructions to end users who will be fueling vehicles at the facility. These instructions typically focus on proper connection and disconnection of the nozzle and operation of the dispenser. Additional information may include PPE requirements and warnings against leaving the engine running, smoking and leaving the vehicle unattended while fueling, as well as the location of the emergency shutdown switches. Refer to NFPA 52 for additional information about training vehicle refueling personnel.

Facilities that fuel fleet vehicles may hold specific training events covering required information for fleet drivers. At fueling facilities open to the public, dispensers with video capabilities may be provided that play a short video of fueling procedures, or the owner may provide a brochure describing correct fueling procedures at the dispenser. At some facilities, end users who have received training are assigned a personal identification number (PIN). In such cases, the PIN must be entered on a dispenser keypad before the dispenser will authorize fueling to proceed.

Staff who are routinely on-site at public facilities also should know fueling procedures so they can assist customers on an as-needed basis.

15.5.2 Training of On-Site Personnel. The facility operator should include language in contractual agreements that require contractors and/or equipment suppliers to provide site-specific training to the operator’s personnel. Training should occur prior to the start of fueling operations and should include how to properly operate and maintain the equipment. Training also should include how to implement the operational procedures.
described in Chapter 16; the elements of an emergency response plan; the hazards of LNG and natural gas; safety procedures; and contact information for service and emergency response personnel.
16. GUIDELINES FOR PROPER OPERATION AND MAINTENANCE OF AN LNG FUELING SYSTEM

16.1 Introduction. A liquefied natural gas (LNG) facility represents a significant capital investment. LNG fueling systems operate under pressure and cryogenic temperature conditions. To provide safe and reliable service, regular maintenance activities must be performed. Even a well-designed and carefully installed LNG fueling facility will not perform well over time unless it is properly operated and maintained. Care in establishing maintenance schedules and procedures will help protect the investment and assure a greater satisfaction level for all involved.

LNG fueling facilities require oversight so minor issues do not become major problems. The exact nature and timing of oversight activities will vary depending on the facility design, the equipment manufacturer and the volume of gas dispensed. The thermal cycling present with cryogenic liquids presents a unique set of considerations at LNG facilities. The primary goal of this chapter is to impress upon prospective owners and operators that LNG fueling facilities require a higher and more technical level of attention than conventional motor fuel facilities. Additionally, this chapter intends to describe the general types of maintenance activities required at LNG fueling facilities. Not all of the tasks described in this chapter will apply to all LNG fueling facilities.

NOTE: Always follow the instructions provided by the LNG equipment manufacturer or LNG equipment packager to determine the requirements applicable to a given facility.

Many tasks described in this chapter are monitoring activities that can be performed by a typical facility owner or operator with limited training. If desired, these tasks could be contracted to a qualified LNG service company. Some of the more complex maintenance tasks should be performed only by a qualified LNG service technician. The details and frequencies of the tasks described here may differ among equipment manufacturers.

The frequency for conducting the tasks described here (daily, weekly, monthly, etc.) is intended to provide an approximate time frame for planning how often these tasks should be conducted. It is not a universal timetable that applies in all situations. Due to wear and tear, a facility that sees heavy use may need to perform certain operational tasks on a very different frequency than a lightly used facility with the same equipment. Facilities in constant use may have less problems associated with thermal cycling but they may have more pump- and dispenser-related problems. Typically, LNG equipment manufacturers publish specific directions on task requirements and their frequency.
16.2 **Types of LNG Facility Operators.** LNG facilities may be operated by on-site facility operators or by a remote LNG site manager. At unattended fueling locations, the operator may not be present at all times the facility is operating. Such an operator should visit or remotely view the site at minimum on a daily basis to verify that the facility is operating normally and/or to conduct walk-through inspections.

16.2.1 **Characteristics of an On-Site LNG Facility Operator.** An on-site LNG facility operator is a person who is:

- routinely present at the facility;
- designated as the person responsible for monitoring the operation of the LNG facility;
- knowledgeable about the facility emergency response plan (ERP);
- capable of conducting training of refueling personnel;
- trained in how to conduct visual inspections of the equipment and record facility operating parameters.

16.2.2 **Characteristics of a Remote LNG Site Manager.** An LNG remote site manager is a person who is:

- monitoring system operational data online (remotely);
- typically, in possession of advanced operational knowledge of the LNG system;
- able to interpret operational data;
- capable of conducting training of refueling personnel.

16.3 **Approaches to LNG Facility Operation and Maintenance.** Diligent attention to facility maintenance details in all matters should be part of ownership planning. Industry experience shows that when recommended operational and maintenance procedures are ignored, fueling system reliability suffers and the safety of facility personnel may be threatened. Unreliability of fueling equipment is a logistical problem for vehicles and operators who utilize the LNG system. An LNG facility owner or operator might choose to follow any of three basic approaches in operation and maintenance of the facility.

16.3.1 **Predictive Operation and Maintenance.** Predictive maintenance involves keeping a close watch on the operating parameters of the facility. System parameters are valuable for predictive and preventive maintenance purposes. Repairs are scheduled proactively for times that will interfere least with the fueling activity at the facility. All maintenance tasks specified by equipment manufacturers are carefully carried out exactly on schedule. While requiring more effort, this approach to operation and maintenance maximizes the reliability and safety of the fuel supply. The life of the equipment also will be extended and user satisfaction will be enhanced. As an unconventional fuel, LNG’s viability overall partially will be a function of the experiences that end users report, so reliability has effects beyond a specific site.
16.3.2 Preventive Operation and Maintenance. Preventive maintenance is the level of maintenance practiced by a typical vehicle owner. It is a more passive, but not an indifferent, approach that relies on schedules and alerts to trigger maintenance. The preventive approach to operation and maintenance generally will keep the fueling system equipment running, but some problems may be neglected until fuel system reliability suffers or the system simply stops working. As a fuel system ages, interruptions in fueling activity likely will become more frequent. Particular attention should be paid to corrosion, ice accumulation, insulation breakdown, leaking fittings and hanging hardware deterioration.

16.3.3 Reactive Operation and Maintenance. In a reactive maintenance program, nothing much is done to the fueling system until a failure and shutdown occurs. Initially, simple repairs may restore operation. However, before long, shutdowns will occur for worsening factors that require more extensive repairs. Fueling interruptions may occur fairly frequently, and the life expectancy of the equipment will be significantly reduced. The system will not provide a reliable supply of fuel, leading to a loss of clientele. Reactive maintenance practices may void equipment warranties. Frequent breakdowns in LNG systems most often are traceable to a reactive operation and maintenance program, rather than the poor quality of the equipment.

NOTE: Predictive operation and maintenance is the PEI LNG Fueling System Installation Committee’s recommended approach. If on-site personnel are not willing or able to operate an LNG facility at the predictive maintenance level, they should contract with a qualified LNG service company to provide these services.

16.4 Leak Awareness. Aside from the methane detectors and liquid sensors in sumps, no other sensors typically monitor LNG facilities for leaks. However, conscientious monitoring of facility components with human senses can be very effective in identifying leaks.

LNG is odorless, so the mercaptan odor associated with natural gas is not present. However, leaks can be identified by either a vapor cloud or by ice accumulation. Look for extended frost or moisture on fittings. For facilities with temperature sensors in the vent system, leaks in pressure or thermal relief valves can be identified by lower than normal temperatures in the vent piping. These signs of leaks may be observed on any gas-containing component of an LNG fueling facility. Facility personnel should be trained to recognize leak indicators and how to respond if a leak is detected.
**WARNING:** Only qualified and authorized personnel should attempt to repair any leak in an LNG system. Do not tighten or adjust any fitting while it is under any amount of pressure.

16.5 **Daily Inspections.** At attended facilities where on-site personnel are routinely present, a walk-through inspection should occur daily. At unattended facilities where on-site personnel are not normally present, remote monitoring reviews should occur daily with walk-through inspection visits occurring periodically.

16.5.1 **Walk-Through Inspections.** The purpose of a walk-through inspection is to make sure that important components of the fueling system are in proper order and no obvious defects in the fueling equipment are identified.

**WARNING:** Entering an LNG compound may require confined space or other life-safety measures.

A typical walk-through inspection includes the evaluation of the following items. For specific instructions about periodic inspection techniques, consult equipment manufacturer recommendations. A handheld methane detector should be used to identify invisible discharges.

- **Nozzles.** Inspect for broken parts and signs of wear, abuse or damage. Check condition of seals within the nozzle outlet that couple with the vehicle. Nozzles not in use should be hung up properly.
- **Hoses.** Inspect for abrasions, cracks, kinks, or any other type of wear or damage. Inspect breakaway fittings for damage.
- **Dispensers.** Inspect the dispenser cabinet for dents or any other damage that may indicate vehicle impact or other abuse. Check gas sensor operation and look for evidence of frost or moisture on any gas fittings outside the dispenser cabinet. If any signs of a gas leak are observed, close the supply valve, check for ignition sources in the area and call a qualified LNG service company immediately.
- **Piping.** Inspect for signs of leaking, damage to insulation, corrosion and other damage.
- **Valves and Pressure Relief Devices.** Inspect actuators and operability and condition of the instrument air system.
- **Signage.** Review all warning and instructional signs to ensure they are present, in clear view, easily legible and securely fastened.
- **Fire Extinguishers.** Verify that all portable fire extinguishers are present and have current inspection tags. See section 16.7.3 Fire Extinguisher Inspection.
- **Emergency Shutdown Switches.** Confirm that all emergency shutdown switches are in clear view and labels are readily visible. Periodically operate the emergency
shutdown switches to test for functionality. This is best done during non-fueling periods.

- LNG Storage Tank. Verify the area around storage tanks is neat and clean with no readily ignitable materials within 15 feet or at any distance within the impoundment volume. Use a portable gas detector and look for evidence of frost or moisture on any gas fittings. If any signs of a gas leak are noted, call a qualified LNG service company immediately.

- Vent Stack. If equipped with a temperature sensor, record temperature on vent stack.

- Programmable Logic Controller (PLC). Look for any warning lights or fault messages displayed on the PLC. Note the fault message and call a qualified LNG service company immediately if any problems are noted.

- Site Security. Check the condition of site security fencing to ensure it is serving its purpose. Check gates and locks to verify they are secure.

- Results. The walk-through inspection results should be recorded on a checklist or other convenient form such as a facility log (See 16.6.4). Note unusual conditions in any area of the facility. All forms should be signed and dated.

16.6 Daily Recording of Operating Parameters. LNG fueling systems typically are equipped with a number of temperature and pressure sensors and/or gauges that measure important operating conditions. A predictive maintenance strategy includes daily recording of temperature and pressure data and tracking trends in these data.

Trends in temperature and pressure conditions can indicate a developing problem. Early identification allows the problem to be addressed before a system shutdown occurs. In addition, a log of pressure and temperature readings over time can provide a knowledgeable LNG service technician the information required to troubleshoot and analyze a problem much more quickly than if this information is lacking. PLC logging is preferred to manual logging.

Some equipment manufacturers require documentation of frequent equipment inspection as a condition of warranty coverage. Inspection forms should be kept organized and available throughout the life of the equipment. At facilities where daily readings are not practical, remote monitoring of the various equipment status readings from the pump, vaporizer, dispenser and storage tank should be completed, and printed records should be kept organized and available.

16.6.1 Record LNG Pressure Readings. System operating pressure readings can be taken from pressure gauges or from the PLC display and should be recorded. Pressure information will vary by manufacturer. In some PLCs with internet connections, this information can be obtained remotely and recorded in a spreadsheet or database program.
16.6.2 Record LNG Level Readings. LNG storage tank level readings determine usage and when a shipment of LNG is needed for the facility. This information should be recorded in an organized fashion. In some PLCs with internet connections, this information can be obtained remotely and recorded in a spreadsheet or database program.

16.6.3 Record Hour Meter Readings. The timing of some maintenance operations on LNG equipment is determined by the number of operating hours. Examples include submersible pumps, offload pumps and instrument air compressors. In some PLCs with internet connections, this information can be obtained remotely and recorded in a spreadsheet or database program.

16.6.4 Facility Log. A written or electronic record of maintenance tasks and when they are performed should be kept at the facility. A complete and accurate maintenance log can help qualified LNG service technicians troubleshoot problems and identify components that are due for servicing, repair or replacement. Any checklists employed for completion of the facility log should have provisions for noting nonstandard items and abnormal or emergency conditions for analysis and troubleshooting.

16.7 Scheduled Maintenance Tasks. A regular review of the recommended maintenance tasks provided by the process equipment and dispenser manufacturers should occur to determine whether any scheduled maintenance will be required in the coming time period. If maintenance work will be needed, contact a qualified LNG service company and schedule a time for the work to be done.

Maintenance tasks and intervals vary widely among manufacturers because of differences in equipment design. The following list is presented in general order of more frequent to less frequent tasks. Many of these tasks are tied to the number of hours the system has run rather than the passage of time on the calendar. In all cases, follow equipment manufacturer instructions for performing each of these tasks.

NOTE: The section headings indicating monthly and annual maintenance intervals are provided only to give a general idea of how frequently these tasks should be performed. Consult the maintenance manual for your specific equipment to determine the requirement and recommended interval for these tasks at your facility. Some items may not be found in manufacturer maintenance manuals.

Examples of maintenance items that may be unique to LNG facilities include:
- nozzle seals;
- cryogenic flange connections;
- torqueing of flange bolts;
• valve stem leaks;
• ice accumulation indicating leaks;
• offload pump seals;
• containment water, snow, ice and debris;
• containment pump operability;
• flame and gas detector testing and recalibration.

16.7.1 Monthly Operational Tasks. There are a few operational tasks that should be conducted on a monthly basis. These include checking the LNG storage tanks and ensuring that all records, including employee training and scheduled maintenance activities, are up to date.

16.7.2 Monthly Maintenance Tasks. In addition to a daily inspection, the following tasks should be performed monthly. Consult equipment manufacturer instructions to determine which of these tasks apply to your facility, specific instructions about how to perform them and guidelines about how often to perform them.

- Perform the hardware-related operational checks described in this chapter to verify that they are being correctly conducted by facility personnel. Review the walk-through inspection checklists described in this chapter and investigate any abnormalities that may be noted.
- Review the daily temperature and pressure logs and the PLC fault log for all PLCs to evaluate system efficiency and performance. Record findings in the facility log.
- Inspect the inside of dispenser cabinets. Look for signs of damage or tampering. LNG dispensers incorporate various safeguards to segregate environments that may be subject to explosive accumulations of gases. Follow manufacturer inspection procedures.
- Verify that the periodic recertification of pressure relief devices is not expired.

16.7.3 Fire Extinguisher Inspection. Check fire extinguishers to see whether they have been discharged and to verify that any gauges are in the green zone. If any fire extinguishers have been discharged or have gauges that are not in the green zone, have them serviced immediately by a qualified fire extinguisher service company. Check inspection dates to ensure they are current. If any inspection dates fall within the next month, schedule the required maintenance with a qualified fire extinguisher service company.

16.8 Periodic Tasks. The following are important tasks that are conducted less frequently but must not be overlooked.
16.8.1 Annual Review of Emergency Response and Hazard and Operability (HAZOP) Plans. An important element of the ERP is the contact information for various safety organizations (e.g., fire department and ambulance) and company personnel who need to be notified in case of accidents, fires or other emergency situations. Check to ensure that names and contact information for all organizations and personnel on the list are up to date.

Review any changes made to the fueling facility that might produce emergency situations not considered in the original emergency response and HAZOP plans. Examples of such changes might include additional storage of flammable liquid or the installation of additional LNG dispensers. If changes have occurred, take steps to revise the emergency response and HAZOP plans to address the new hazards.

16.8.2 Annual Maintenance Tasks. Consult the LNG equipment manufacturer instructions to determine which annual or 12-month tasks apply to your facility, specific instructions for how to perform them, and the recommended interval at which to perform them.

- Visually inspect pressure relief devices to ensure they are properly mounted, not isolated from vents and tagged.
- Inspect LNG storage tanks for abnormalities, such as:
  - variations from installation requirements;
  - signs of corrosion;
  - settlement of the foundation;
  - changes in insulating/fireproofing of supports;
  - frost accumulation on the tank as evidence of insulation failure;
  - icing, nests or other obstructions in the vent stack;
  - other evidence of deterioration.
- Check the calibration of dispenser meters used at both public and private facilities as required to ensure the displays accurately indicate the quantity of LNG delivered to end users.

**NOTE:** Dispensing meters that sell LNG to the public are required to be inspected annually by local weights and measures agencies.

- Test the electrical continuity of dispensing hoses from the nozzle to the dispenser, and check manufacturer recommendations for the acceptable range.
- Verify that each E-stop switch is working properly.
- Service offload pump drive motor bearings according to manufacturer instructions.
- Service instrument air system as required.
- Inspect purge air system.
• Inspect control structure HVAC system, lighting and general condition.
• Check grounding system integrity.
• Check flame sensor operability.
• Check gas detector with reference gas.
• Check all piping and tubing mounting clamps to verify that instrument piping is secure.

16.8.3 Recertification of Pressure Relief Valves (PRVs). PRVs will need to be recertified as required by regulation. In most cases, this means the valves will need to be either replaced with new valves or recertified by an Association of Mechanical Engineers (ASME) or National Board of Boiler and Pressure Vessel Inspectors Recertification shop and tested for proper operation. Remember, PRVs are installed in heat exchangers, dispensers and LNG storage tanks. All of these valves will need to be inspected and recertified.

To minimize the interruption of facility operations, the operator is recommended to have a set of replacement PRVs on hand. Replacement valves should be purchased or recertified shortly before the scheduled replacement date. The newly certified PRVs can then simply be installed when the old ones are removed. In the next test cycle, the first set of valves can be tested and recertified and the process repeated.

**WARNING:** The servicing of pressure relief devices (PRDs) should only be performed by a qualified technician.

16.9 Unscheduled Maintenance and Repairs. Accidents and equipment failures will happen. Vehicles can drive off with fuel nozzles still connected, vehicles can hit dispensers, fueling nozzles can be dropped and hoses run over. Whenever any incident occurs that damages or may have damaged a fueling system component, a qualified LNG technician must inspect the system to replace damaged components and confirm that all components of the fueling system that may have been affected by the incident are operating normally.

Until the inspection can be completed, all of the affected or potentially affected components of the fueling system should be isolated by manually closing appropriate valves.

**WARNING:** Dispensing LNG from portions of the fueling system that are damaged or may have been damaged in any type of accident or incident must be prohibited until satisfactorily reauthorized for service.

All personnel who are routinely on-site must have a basic familiarity with the LNG fueling system and what to do in the event of an accident or fueling system malfunction. All facility
personnel should know the location and function of E-stop switches and under what circumstances to activate them. All facility personnel should know whom to notify when an accident or any type of fueling system malfunction has occurred.

Designated facility personnel should know the location of manual valves that can be operated to isolate various portions of the fueling system. Upon thorough inspection and any required corrections of an unsafe condition that has necessitated the deployment of an E-stop system, only designated authorized employees should be permitted to restart the LNG fueling operations.