



CGA G-19.1—2020 STANDARD FOR NATURAL GAS SUPPLY SYSTEMS

SECOND EDITION

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Full document details: [CGA G-19.1-2020](#)

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Work Item 23-010
Natural Gas Technology Committee

SECOND EDITION: 2020

FIRST EDITION: 2018

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1 Scope

This publication is intended to cover the design, installation, maintenance and removal of liquefied natural gas (LNG) and compressed natural gas (CNG) supply systems. It is expected that the reader has a basic understanding of pressure vessel and piping design or operations. This publication is not intended to cover pipeline gas equipment.

This publication provides general information concerning systems that store and supply natural gas in its liquid state, gaseous state, or both. It provides direction for site selection and system considerations, regulatory compliance, selection and installation of equipment, startup, operation, and maintenance of the system.

This publication is not intended to provide requirements for the transportation of natural gas (see CGA G-19.2, *Standard for Natural Gas Transportation and Transfer*) or the liquefaction of natural gas [1].¹

For information regarding health hazards and other general safety considerations, see CGA G-19, *Guideline for Natural Gas Safe Handling and Operations* [2].

Many standards exist for the design, construction, installation, inspection, and examination of natural gas equipment and facilities. A complete list describing the applicability of each standard is beyond the scope of this publication.

Where an applicable standard does exist, its rules shall be followed in conjunction with local codes and regulations.

Natural gas is a combination of several gases in differing concentrations. The guidelines contained in this publication assume that pipeline quality natural gas as defined in CGA G-19 is in use [2]. This publication assumes a liquid natural gas density of 3.57 lb/gal (0.43 kg/L).

2 Definitions

For the purpose of this publication, the following definitions apply.

2.1 Publication terminology

2.1.1 Shall

Indicates that the procedure is mandatory. It is used wherever the criterion for conformance to specific recommendations allows no deviation.

2.1.2 Should

Indicates that a procedure is recommended.

2.1.3 May

Indicates that the procedure is optional.

2.1.4 Will

Is used only to indicate the future, not a degree of requirement.

2.1.5 Can

Indicates a possibility or ability.

2.2 Technical definitions

2.2.1 Asphyxiation

To become unconscious or die from the lack of oxygen.

¹ References are shown by bracketed numbers and are listed in order of appearance in the reference section.

2.2.2 Atmospheric pressure

Pressure exerted by the weight of the atmosphere at sea level. Equivalent to 14.696 psi or 101.325 kPa.² The pressure exerted by a column of mercury (Hg) 760 mm high.

2.2.3 Cavitation

Undesirable vapor bubble formation and subsequent bubble collapse of a saturated or slightly subcooled liquid in a pump that can cause loss of prime and damage the pump.

2.2.4 Compressed natural gas (CNG)

Natural gas that has been cleaned to meet a required quality standard, odorized, and compressed to a specific pressure into an appropriate container.

2.2.5 Confined space

Space not normally occupied by personnel that has limited or restricted openings for entry and exit, can lack adequate ventilation, and can contain or produce dangerous air contamination.

2.2.6 Container

Portable compressed gas cylinder or liquid container made in accordance with the U.S. Department of Transportation (DOT), Transport Canada (TC), or American Society of Mechanical Engineers (ASME) specifications.

2.2.7 Cryogenic

Temperatures below –130 °F (–90 °C).

2.2.8 Dampening device

Device installed at the inlet of a pressure gauge to remove pulsation from the gauge reading.

2.2.9 Design pressure

Most severe condition of coincident pressure and temperature expected in normal operation. This considers the maximum allowable working pressure (MAWP), static head of the product, and the vacuum if vacuum jacketed.

2.2.10 Fatigue

Reduced strength in a material caused by cycling of pressure, temperature, or mechanical load.

2.2.11 Flammable

Degree to which a material is easily ignited in an oxidizing atmosphere.

2.2.12 Gas detector

Device designed to detect the presence of specific gases that could harm individuals if exposed to unacceptable concentrations.

2.2.13 Liquefied natural gas (LNG)

Cryogenic natural gas in the liquid form.

2.2.14 Lockout/Tagout

Safety procedure used to ensure that sources of energy (e.g., electrical, chemical, pressure) are properly shut off, isolated, and labeled prior to the start of maintenance work. This condition is maintained during the work, and reversed when preparing for restart.

2.2.15 Low temperature embrittlement

Transition of materials to exhibit brittle properties when exposed to temperatures below the ductile range of the material.

² kPa shall indicate gauge pressure unless otherwise noted as (kPa, abs) for absolute pressure or (kPa, differential) for differential pressure. All kPa values are rounded off per CGA P-11, *Guideline for Metric Practice in the Compressed Gas Industry* [3].

2.2.16 Lower flammability limit (LFL)

Lower limit of flammability of a gas or vapor at ordinary ambient temperatures and pressures expressed in percent of the gas or vapor in air by volume. The LFL will vary with temperature and pressure.

NOTE—LFL is also referred to as lower explosive limit (LEL).

2.2.17 Make-or-break connection

Connection that is intended to be made, broken, and remade by the operator during the normal operation of the system.

2.2.18 Maximum allowable working pressure (MAWP)

Maximum gauge pressure permissible at the top of a container in its operating position for a designated temperature.

2.2.19 Odorant

Substance added to a product to give it a particular scent or odor.

NOTE—Natural gas is typically odorized with an organic compound containing sulfur resulting in a pungent smell to warn the public of a natural gas leak.

2.2.20 Overpressure

Pressure that exceeds the MAWP or design pressure of a system.

2.2.21 Personal protective equipment (PPE)

Equipment worn by personnel to decrease the risk of injury due to exposures to process hazards.

2.2.22 Pipeline quality natural gas

Natural gas that has been analyzed or conditioned to ensure that the hydrocarbon constituents and impurity levels are suitable for introduction into a pipeline.

NOTE—The physical properties of natural gas vary with composition. The heating value of pipeline natural gas can vary by as much as 20% within the range of representative compositions. Other physical properties such as density, saturation temperature, etc. can also vary. See Table 1 from CGA G-19, *Guideline for Natural Gas Safe Handling and Operations*, and the National Institute of Standards and Technology (NIST) Standard Reference Database 23, Reference Fluid Thermodynamic and Transport Properties Database (REFPROP) [2, 4].

2.2.23 Purge

Flow of an inert medium (e.g., nitrogen) at a rate that will effectively remove any gaseous or suspended combustibles and replace them with the purging medium.

2.2.24 Remotely located, manually activated shutdown control

Control system that is designed to shutdown flow and is activated from a point located some distance from the delivery system.

2.2.25 Retention valve

Valve located as close as practicable to the storage that is intended to isolate the storage in the case of an upset.

2.2.26 Risk assessment

Overall process of risk identification, risk analysis, and risk evaluation.

2.2.27 Risk Identification

Process of finding, recognizing, and describing risks.

2.2.28 Safeguards

Devices and procedures that mitigate risk to an acceptable level.

2.2.29 Source valve

Shutoff valve on the piping system serving a bulk gas supply system where the gas supply (at service pressure) first enters the supply line. Within the scope of this publication, the source valve is the last component of the system that the natural gas passes through before it enters the intended use device or piping.

2.2.30 Test pressure

Highest pressure difference the container wall withstands between the inside and outside during testing to meet the requirements of applicable regulations, codes, standards, or specifications.

3 System considerations

The natural gas supply system shall be designed and constructed according to applicable legislation, codes, and local regulations.

All system equipment, components, pipework, fittings and controls shall be assembled in a manner suitable for their intended use, and for the full range of pressures, type of gas, temperatures, weather conditions (maximum wind, maximum rainfall, maximum snowfall, etc.) and loadings which can occur. Equipment shall be installed and used in accordance with the manufacturer's instructions.

Recommended materials of construction are defined in CGA G-19 [2].

3.1 Applicable standards and publications

Many standards exist for the design, construction, installation, inspection, and examination of natural gas equipment and facilities. In particular, this publication is intended to supplement the requirements of the following most commonly required NFPA codes and standards:

- NFPA 52, *Vehicular Gaseous Fuel Systems Code*;
- NFPA 55, *Compressed Gases and Cryogenic Fluids Code*; and
- NFPA 59A, *Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)* [5, 6, 7].

Metrology shall conform to local regulations such as NIST Handbook 44, *Specifications, Tolerances, and Other Technical Requirements for Weighing and Measuring Devices*, International Organization of Legal Metrology [OIML], and Canadian Institute for National Measurement Standards [INMS] [8].

3.2 System level requirements

The retention control requirements for each piping circuit attached to the storage shall be independently assessed. The category of the natural gas supply system shall be established as the highest category determined by assessing the:

- volume of storage;
- MAWP of storage; and
- highest category of any one piping circuit attached to the storage.

Table 1 shall be used to determine categories for piping and storage. Table 2 shall be used to establish product retention requirements based upon category. The requirements become more stringent as the category number increases. Category II requirements are more stringent than Category I requirements. Category III requirements are more stringent than Category II and Category I requirements.

A supply system shall meet all seven requirements (cryogenic stored volume through noncryogenic piping) in Table 1 for a given category in order to be ranked by that category. If a supply system complies with all the Table 1 requirements for a Category I supply system, the retention requirements of Table 2, Category I shall apply to the supply system. If the supply system does not comply with all the Table 1 requirements for a Category I supply system, the supply system shall be checked against the requirements of Table 1, Category II. If the supply system complies with all the Table 1 requirements for a Category II supply system, the retention requirements of Table 2, Category II shall apply to the supply system. If the supply system does not comply with all the Table 1 requirements for a Category II supply system, the retention requirements of Table 2, Category III shall apply to the supply system.

Table 1—Categories

Piping design attribute	Category I	Category II	Category III
Cryogenic stored volume	Less than or equal to 1000 gal (3785 L)	Greater than 1000 gal but less than or equal to 30 000 gal (3785 L to 113 562 L) for any one storage tank	Any tank size with piping larger than or equal to 2" NPS or greater than 30 000 gal (113 562 L) for any one storage tank
Noncryogenic gas storage volume	Less than or equal to 150 000 SCF (2450 m ³)	Greater than 150 000 SCF (2450 m ³)	Not applicable
Cryogenic stored pressure	Less than or equal to 350 psi (2410 kPa)	Greater than 350 psi (2410 kPa)	By analysis acceptable to authority having jurisdiction (AHJ)
Noncryogenic stored pressure	Less than or equal to 3600 psi (24.8 MPa)	Greater than 3600 psi (24.8 MPa)	By analysis acceptable to AHJ
Liquid cryogenic piping	- Less than or equal to 1000 gal and any pipe size; or - Greater than 1000 gal but less than or equal to 30 000 gallons and with piping smaller than 1/2" NPS	- Greater than 1000 gal but less than or equal to 30 000 gallons; and - Piping larger than 1/2" NPS but smaller than 2" NPS	By analysis acceptable to AHJ
Vapor cryogenic piping	- Less than or equal to 1000 gal and any pipe size; or - Greater than 1000 gallons but less than or equal to 30 000 gallons and piping smaller than 2" NPS	- Greater than 1000 gal but less than or equal to 30 000 gallons; and - Piping larger than 2" NPS	By analysis acceptable to AHJ
Noncryogenic piping	Piping smaller than or equal to 1/2" NPS	Piping larger than 1/2" NPS but smaller than or equal to 2" NPS	By analysis acceptable to AHJ

Table 2—Piping retention requirements

Piping design element	Category I	Category II	Category III
Without make-or-break connections	Manual	Automatic/audible alarm ^{1), 2)}	Automatic/audible alarm ^{1), 2)}
With make-or-break connections	Manual remote ¹⁾	Automatic/audible alarm ^{1), 3)}	By analysis acceptable to AHJ
¹⁾ Where flow is in one direction towards the storage (as is typical for fill circuits), two check valves satisfies this requirement. ²⁾ For automatic retention valve activation and controls, see 4.3. ³⁾ In cases where make-or-break connections are continuously manned by trained personnel and also have remotely located, manually activated shutdown control manual, the requirements for retention philosophy shall be satisfied.			

3.2.1 Category I

Natural gas supply systems within Category I shall meet the following:

- Minimum setbacks shall be in accordance with CGA G-19 [2];
- Storage vessels shall be in accordance with CGA G-19 [2];
- If hoses are used, hoses shall be connected at time of startup and shall not be disconnected except for maintenance and removal;
- System shall be equipped with a means to remotely isolate the supply of natural gas;

- Natural gas that enters an enclosed area such as building or boiler, or transfers custody shall be odorized unless otherwise monitored by a methane gas detection system;
- Installation shall accommodate any movement that can occur between pieces of equipment such as during a fire or seismic event;
- Equipment shall be designed and secured against seismic or wind loads where required by local codes; and
- All other requirements of NFPA 52, NFPA 55, or NFPA 59A as appropriate to the installation [5, 6, 7].

Natural gas supply systems within Category I are exempted from the following:

- LNG storage spill containment and LNG transfer spill containment;
- 2-hour fire rating for equipment supports (e.g., foundations, saddle supports, wheels, landing legs) provided that their failure does not cause the container to overturn;
- Audible and visual alarm, dedicated fire alarm control panel, and automated offsite notification;
- Methane gas or fire/flare detection systems, unless as noted above for enclosed areas; and
- Automated shutdown response systems.

Table 3—Category I cryogenic liquid

Pipe size		Piping circuit length limit							
Outside diameter		Storage MAWP 70 psi (480 kPa)		Storage MAWP 175 psi (1200 kPa)		Storage MAWP 250 psi (1720 kPa)		Storage MAWP 350 psi (2410 kPa)	
0.540 in	13.7 mm	450 ft	137 m	280 ft	85 m	240 ft	73 m	200 ft	61 m
0.675 in	17.1 mm	260 ft	79 m	160 ft	49 m	140 ft	43 m	110 ft	34 m
0.840 in	21.3 mm	160 ft	49 m	100 ft	31 m	85 ft	26 m	72 ft	22 m
1.050 in	26.7 mm	98 ft	30 m	62 ft	19 m	52 ft	16 m	44 ft	13 m
1.315 in	33.4 mm	61 ft	19 m	38 ft	12 m	32 ft	10 m	27 ft	8 m
1.90 in	48.3 mm	33 ft	10 m	21 ft	6 m	17 ft	5.2 m	15 ft	4 m
2.375 in	60.3 mm	18 ft	5 m	11 ft	3 m	10 ft	3 m	8 ft	2 m
3.50 in	88.9 mm	9 ft	2 m	6 ft	1 m	5 ft	1 m	4 ft	1 m

Table 4—Category I cryogenic vapor

Pipe size		Piping circuit length limit							
Outside diameter		Storage MAWP 70 psi (480 kPa)		Storage MAWP 175 psi (1200 kPa)		Storage MAWP 250 psi (1720 kPa)		Storage MAWP 350 psi (2410 kPa)	
0.540 in	13.7 mm	2900 ft	885 m	1300 ft	395 m	940 ft	287 m	690 ft	210 m
0.675 in	17.1 mm	1700 ft	520 m	750 ft	229 m	550 ft	168 m	400 ft	122 m
0.840 in	21.3 mm	1000 ft	335 m	450 ft	137 m	330 ft	101 m	240 ft	73 m
1.050 in	26.7 mm	630 ft	192 m	280 ft	85 m	200 ft	61 m	150 ft	46 m
1.315 in	33.4 mm	390 ft	119 m	170 ft	52 m	120 ft	37 m	93 ft	28 m
1.90 in	48.3 mm	210 ft	64 m	94 ft	29 m	68 ft	21 m	50 ft	15 m
2.375 in	60.3 mm	110 ft	34 m	52 ft	16 m	37 ft	11 m	28 ft	8 m
3.50 in	88.9 mm	58 ft	18 m	25 ft	7 m	18 ft	5 m	14 ft	4 m

Table 5—Category I compressed gas

Pipe size		Piping circuit length limit							
Outside diameter		Storage MAWP 1500 psi (10.3 MPa)		Storage MAWP 3000 psi (20.7 MPa)		Storage MAWP 3600 psi (24.8 MPa)		Storage MAWP 5000 psi (34.5 MPa)	
0.540 in	13.7 mm	240 ft	73 m	120 ft	37 m	100 ft	31 m	82 ft	25 m
0.675 in	17.1 mm	140 ft	43 m	77 ft	24 m	66 ft	20 m	49 ft	15 m
0.840 in	21.3 mm	90 ft	27 m	48 ft	15 m	41 ft	13 m	30 ft	9 m
1.050 in	26.7 mm	56 ft	17 m	30 ft	9 m	26 ft	8 m	19 ft	5 m
1.315 in	33.4 mm	36 ft	11 m	19 ft	5 m	16 ft	4 m	12 ft	3 m
1.90 in	48.3 mm	20 ft	6 m	11 ft	3 m	9 ft	2 m	7 ft	2 m

3.2.2 Category II

Natural gas supply systems within Category II shall meet the following:

- Liquid pump discharge pressure shall not exceed 350 psi (2410 kPa);
- LNG spills shall be confined such that they are contained within the owner/operator's property limits, do not enter a sewer drain, and are supported by analysis acceptable to the AHJ;
- Topography shall be considered a viable means for LNG spill containment;
- Connections between equipment shall consider any displacements that can occur (e.g., during a fire or seismic event);
- Equipment shall be designed and secured against seismic or wind loads where required by local codes;
- Automated shutdown response with local notification shall be required (e.g., audible alarm, visible alarm);

NOTE—Remote manual activation by a trained operator in continuous line of sight attendance satisfies this requirement.

- Automated gas and fire/flare detection systems shall be in place;
- NOTE—Remote manual activation by a trained operator in continuous line of sight attendance satisfies this requirement.
- Hoses that make up part of a piping circuit in LNG service shall be connected in accordance with Section 8;
 - Hoses that are connected and disconnected as part of a transfer operation that is manned by individual(s) not trained to respond in an emergency shall be 1 nominal pipe size (NPS) or smaller, for example, LNG fueling hoses;
 - Hoses larger than 1 NPS that are connected and disconnected as part of a transfer operation shall be manned by an individual(s) trained to respond in an emergency, for example, offloading;
 - Natural gas that enters an enclosed area (e.g., building, boiler) or transfers custody shall be odorized unless otherwise monitored by a methane gas detection system;
 - All other requirements of either NFPA 52, NFPA 55, or NFPA 59A as appropriate to the installation [5, 6, 7]; and
 - Volumetric LNG storage spill containment shall be by analysis acceptable to the AHJ or alternatively 100% of the full volume of the largest storage tank in the system.

Natural gas supply systems within Category II are exempted from the following:

- A 2-hour fire rating for equipment supports (e.g., foundations, saddle supports, wheels, landing legs), provided that their failure does not cause the container to overturn; and
- Dedicated fire alarm control panel and automated offsite notification shall not be required unless specified by the AHJ.

Table 6—Category II cryogenic liquid

Pipe size		Piping circuit length limit							
Outside diameter		Storage MAWP 70 psi (480 kPa)		Storage MAWP 175 psi (1200 kPa)		Storage MAWP 250 psi (1720 kPa)		Storage MAWP 350 psi (2410 kPa)	
0.540 in	13.7 mm	5800 ft	1770 m	3700 ft	1130 m	3000 ft	915 m	2600 ft	790 m
0.675 in	17.1 mm	3400 ft	1040 m	2100 ft	640 m	1800 ft	550 m	1500 ft	455 m
0.840 in	21.3 mm	2000 ft	610 m	1300 ft	395 m	1000 ft	305 m	920 ft	280 m
1.050 in	26.7 mm	1200 ft	365 m	790 ft	240 m	660 ft	201 m	560 ft	171 m
1.315 in	33.4 mm	770 ft	235 m	490 ft	149 m	410 ft	125 m	340 ft	104 m
1.90 in	48.3 mm	420 ft	128 m	260 ft	80 m	220 ft	67 m	180 ft	55 m
2.375 in	60.3 mm	230 ft	70 m	140 ft	43 m	120 ft	37 m	100 ft	31 m
3.50 in	88.9 mm	110 ft	34 m	72 ft	22 m	60 ft	18 m	51 ft	16 m

Table 7—Category II cryogenic vapor

Pipe size		Piping circuit length limit							
Outside diameter		Storage MAWP 70 psi (480 kPa)		Storage MAWP 175 psi (1200 kPa)		Storage MAWP 250 psi (1720 kPa)		Storage MAWP 350 psi (2410 kPa)	
0.540 in	13.7 mm	35000 ft	10 700 m	15000 ft	4570 m	11000 ft	3350 m	8300 ft	2530 m
0.675 in	17.1 mm	20000 ft	6100 m	9100 ft	2770 m	6600 ft	2010 m	4800 ft	1460 m
0.840 in	21.3 mm	12000 ft	3560 m	5500 ft	1680 m	3900 ft	1190 m	2900 ft	880 m
1.050 in	26.7 mm	7600 ft	2320 m	3300 ft	1010 m	2400 ft	730 m	1800 ft	550 m
1.315 in	33.4 mm	4700 ft	1430 m	2000 ft	610 m	1500 ft	460 m	1100 ft	335 m
1.90 in	48.3 mm	2500 ft	760 m	1100 ft	335 m	810 ft	247 m	600 ft	180 m
2.375 in	60.3 mm	1400 ft	430 m	610 ft	186 m	440 ft	134 m	330 ft	101 m
3.50 in	88.9 mm	690 ft	210 m	300 ft	91 m	220 ft	67 m	160 ft	49 m

Table 8—Category II compressed gas

Pipe size		Piping circuit length limit							
Outside diameter		Storage MAWP 1500 psi (10.3 MPa)		Storage MAWP 3000 psi (20.7 MPa)		Storage MAWP 3600 psi (24.8 MPa)		Storage MAWP 5000 psi (34.5 MPa)	
0.540 in	13.7 mm	3100 ft	945 m	1600 ft	450 m	1400 ft	430 m	1000 ft	305 m
0.675 in	17.1 mm	1800 ft	550 m	990 ft	300 m	840 ft	256 m	620 ft	189 m
0.840 in	21.3 mm	1100 ft	335 m	610 ft	185 m	520 ft	158 m	390 ft	119 m
1.050 in	26.7 mm	720 ft	220 m	380 ft	115 m	320 ft	98 m	240 ft	73 m
1.315 in	33.4 mm	450 ft	135 m	240 ft	73 m	200 ft	61 m	150 ft	46 m
1.90 in	48.3 mm	250 ft	75 m	130 ft	40 m	110 ft	34 m	87 ft	27 m

3.2.3 Category III

All natural gas installations not falling within the requirements of Category I or Category II are included in Category III and shall fully comply with the requirements of NFPA 52, NFPA 55, or NFPA 59A as appropriate to the installation [5, 6, 7].

3.3 Safety monitoring and shutdown design

The monitoring and shutdown of the natural gas supply system piping shall be accomplished by one of the following:

- manual retention valve for Category I piping when make-or-break connections are not present;
- remotely located, manually activated shutdown valve for Category I when make-or-break connections are present; or
- automatic retention valve for Category II as described in 4.2 and the following sections.

3.3.1 Manual emergency shutdown buttons

Manual emergency shutdown buttons (ESD), when required per 4.2 shall be at each point of transfer and at each point of egress from equipment areas. A manual ESD button shall also be available in the remote location of system controls (if present), clearly noted by signage, and visible from the operation area.

Manual ESD switch activation shall initiate shutdown to a failsafe condition and close source valves. The local operator(s) shall address the reason for the shutdown and take appropriate action or secure the system.

3.3.2 Methane gas detection

Methane gas detection devices, when required per 4.2, shall be placed to monitor points of transfer and other areas of operation and maintenance. The effect of prevailing wind and enclosures shall be considered.

3.3.3 Fire/flame detection

Fire or flame detection devices, when required per 4.2, shall be placed to monitor points of transfer and other areas of operation and maintenance. Optical devices can be used to cover multiple points.

3.3.4 Dedicated fire alarm control panel

Dedicated fire alarm control panels (FACP), when required per 4.2, shall be installed in accordance with local requirements, and shall have the ability to communicate that an automatic system shutdown occurred to a remote monitoring location.

3.3.5 Uninterruptible power supply

An uninterruptible power supply (UPS) shall be supplied in accordance with local requirements and shall provide power to the safety monitoring and shutdown systems for at least 24 hours. If the system is automatically shut down under loss of primary power, battery power shall be required only for fire/flame detection and FACP.

3.3.6 Independent nature of safety controls

Gas detection, fire/flame detection, and ESD functions shall be segregated from operational functions.

3.3.7 Equipment design for classified areas

Safety monitoring and shutdown system equipment shall comply with applicable standards on electrical equipment in classified areas, if located in those areas.

3.3.8 Response design

3.3.8.1 Automated shutdown response

Indications of gas, flame, failure of power or instrumentation, or manual ESD button activation when required per 4.2 shall initiate an emergency shutdown and shall close the product retention valves at the storage container and source valves at points of transfer, and de-energize electrical process equipment such as process pumps, compressors, electrically heated vaporizers, and similar equipment.

The emergency shutdown shall activate an audible and visual alarm. The station operating company shall be automatically notified by means of an alarm, an electronic communication, or other similarly effective means.

3.3.8.2 System reset

In the event of an emergency shutdown the system shall be manually reset by an authorized individual after the cause of the shutdown has been addressed.

3.3.8.3 Onsite documentation of response plan

The response of the control system in shutting down and annunciating, and potential auxiliary alarms shall be documented and available on site for ESD, fire, and gas detection level. This automated response plan is subject to approval by the AHJ. Examples are shown in Table 9.

Table 9—Example of an event and alarm schedule

Event	Local Alarm	Remote Alarm	Action
ESD	Yellow strobe	None	Interrupt normal operation
Fire detection	Red strobe and horn	Call fire department	Interrupt normal operation and close retention valves
20% LFL gas detection	Blue strobe	None	Interrupt normal operation
40% LFL gas detection	Red strobe and horn	Call fire department	Interrupt normal operation and close retention valves

3.3.8.4 Personnel training and emergency response plan

An emergency response plan (ERP) shall be created in accordance with CGA G-19 and shall be available on site [1]. It shall be coordinated with existing safety and ERP for the site. Personnel shall be trained on how to respond to indications from the fire, gas, and ESD system.

3.3.9 Overpressure due to overfill protection

Vessels being filled with LNG by pump or pressure transfer can be at risk of overpressurization and can rupture if the fill system is not properly engineered or protected from overpressure due to overfill.

If an LNG vessel is being filled by a pump that has a maximum discharge pressure greater than the test pressure of the vessel, protection to prevent overpressurization during filling can be required. In addition, LNG vessels being filled by pressure transfer from a vessel that has an MAWP greater than the test pressure of the filled vessel can also need protection from overpressure during filling. In these cases, see CGA P-59, *Prevention of Overpressure During Filling of Cryogenic Vessels* [9].

3.3.10 Low temperature embrittlement protection

Piping and equipment supply systems with a cryogen as a source (e.g., LNG) shall either be constructed of materials compatible with the temperature and pressure of the cryogen or be equipped with protection systems to prevent the embrittlement of the materials that are not compatible. This is required even in the case of a process upset (e.g., vaporizer failure). LNG supply systems that have non-resilient piping materials and equipment down stream of vaporization (e.g., carbon steel, plastic, etc.) shall have protection systems installed to prevent the embrittlement of the non-resilient materials. For further guidance, see CGA P-56, *Cryogenic Vaporization Systems—Prevention of Brittle Fracture of Equipment and Piping* [10].

3.4 Installation and startup

The system design, installation and start up should be conducted by qualified personnel familiar with the applicable codes and standards. The hazards and risks associated with natural gas are high. Seek the guidance of a professional if the process, safeguards, and risks are unclear.

3.4.1 General

3.4.1.1 Personnel protection

All work on a natural gas supply system shall be performed by trained personnel. A pre-startup safety and purging review should be considered before filling the system with natural gas.

Proper personal protective equipment (PPE) is required before working with a natural gas supply system, for example, gloves, safety glasses, steel toed shoes, flame retardant clothing, etc.

3.4.1.2 Documentation, inspection, and testing

The natural gas supply system shall be inspected to verify that all components are in place.

All equipment received on site should be inspected for dents, scrapes, scratches, or other defects or damage that can be caused by shipping or handling.

To ensure the system is installed safely and correctly before putting natural gas into the tank, verify that the following items are completed:

- local permits, if necessary, are obtained;
- system is constructed in accordance with engineering documents;
- piping system (i.e., process piping, houseline, and all the pneumatic lines) is leak checked and found to be leak free;
- piping and equipment are pressure tested;
- piping is purged with an inert gas before the introduction of natural gas; and
- atmosphere in the vessel is checked to ensure oxygen concentration is below 1%; otherwise, the vessel shall be purged with an inert gas.

CAUTION: Always assume that the vessel contains air even if placards on the vessel state otherwise. Analyze for oxygen before introducing natural gas into the vessel.

3.4.2 LNG systems

3.4.2.1 Preoperational checks

The warm tank vacuum should be checked before unloading the tank from the delivery trailer. If the tank vacuum does not comply with the manufacturer's requirements, the unit shall not be filled until approval is obtained from the owner's representative.

Liquid nitrogen shall be used to qualify systems prior to the introduction of LNG. Care shall be taken to ensure that the support structures of the LNG equipment are not overloaded as liquid nitrogen is denser than LNG. Nitrogen loads should not exceed the design load of LNG by weight. If a differential pressure system is used for indicating LNG level, not exceeding the full differential pressure level for LNG is a reasonable means to ensure loading is not excessive.

All components that are subject to cryogenic temperatures in service shall be tested with liquid nitrogen. Final leak checks shall be performed after cold shocking.

Valves, instrumentation, pumps, and controls shall be checked for functionality while under liquid nitrogen test.

3.4.2.2 Initial fill with liquefied natural gas

Trained personnel shall be present on all filling operations on the initial LNG fill.

The unit shall not be filled if there is an electrical storm presenting visible lightning bolts within the last 30 minutes.

If filling has started, it shall be stopped and the tank and tanker secured in the event of an electrical storm. Venting from the vessel or the delivery vehicle tank shall not be permitted during an electrical storm.

Ensure that all fill hoses used in the transfer process from the LNG source to the LNG vessels are purged with natural gas vapor prior to opening the fill valves. Water in the form of condensate can form ice crystals which can then be transferred to the vessel. Ice can foul component parts like valve and relief valve seats and seals.

Monitor the tank vacuum throughout the fill process, as a rising vacuum pressure can be an indication of tank problems.

3.4.3 Gaseous natural gas supply systems

3.4.3.1 Initial purge and cycle purging with natural gas (inert to flammable gas)

Prior to introducing natural gas, the system shall be dry and inert.

All purge gas shall be vented where no gas can collect in a confined area. Hoses or a tall stack can be used to direct the exhaust away from people. With any of these procedures, proper safety measures shall be followed to ensure that injury to personnel does not occur.

See NFPA 56, *Standard for Fire and Explosion Prevention During Cleaning and Purging of Flammable Gas Piping Systems*, NFPA 55, and CGA H-5, *Standard for Bulk Hydrogen Supply Systems* for information addressing purging into and out of service [11, 6, 12].

3.4.3.2 Initial fill with gaseous natural gas

Trained personnel shall be present on all filling operations for a gaseous natural gas supply system.

3.4.4 Training

Operating personnel shall be qualified through training in operation and emergency procedures and shall have access to an operating manual and all safety data sheets (SDS).

3.5 System removal

Natural gas supply system removal shall be conducted by qualified and trained personnel familiar with the system, products, and hazards. Taking a natural gas supply system out of service shall not be regarded as a normal operation. The activities of system removal require the preparation of detailed procedures.

Before a natural gas supply system can be removed from service, all components that could contain natural gas shall be purged with an inert gas until the flammable gas concentration detected in the vicinity of the discharge of the purge is not greater than 10% of the LFL. Only experienced and trained personnel shall purge systems containing natural gas.

A clear scope of work along with a safety review should be conducted with the system owner and all contractors prior to beginning the natural gas supply system removal.

The following procedures are recommended prior to removal of any natural gas supply system from service:

- continuously monitor the area to ensure a flammable atmosphere does not exist or develop;
- where there is potential for a flammable atmosphere, no person may enter until monitoring shows that any flammable gas is less than 10% of the LFL;
- immediately exit the area and instruct others to do so if the flammable gas exceeds 10% of the LFL;
- inspect the vent stack before venting to ensure it is in proper working condition;
- ensure the natural gas is piped to a vent stack designed and located in accordance with 5.7.5;
- isolate the system from the user's process line;

- disable the fill system, if applicable; and
- ensure all valves or accessories that are removed are not under pressure.

Refer to Sections 6 and 9 for equipment removal instructions.

4 Site considerations

A site analysis shall take place prior to consideration of either a permanent or temporary natural gas supply system.

4.1 General site requirements

4.1.1 Security requirements

Security measures shall be in place in accordance with CGA G-19 [2]:

- Natural gas supply systems within Category I shall comply with the security requirements for “small volume facilities” (less than 3500 lb);
- Natural gas supply systems within Category II shall comply with the security requirements for “medium volume facilities” (between 3500 lb to 1 000 000 lb); and
- Natural gas supply systems within Category III shall comply with the security requirements for “large volume facilities” (greater than 1 000 000 lb).

4.1.2 Use of fire barriers as acceptable by the AHJ

Fire barrier walls used to reduce distances to exposures shall be permitted where acceptable to the AHJ. When used, the following requirements shall apply:

- The fire barrier shall have a minimum fire-resistance rating of 2 hours;
- The fire barrier wall shall interrupt the line of sight between the natural gas supply system and the exposure;
- The configuration of the fire barrier shall allow natural ventilation to prevent the accumulation of hazardous gas concentrations;
- The number of fire barrier walls used to separate individual systems shall be limited to three;
- The fire barrier wall shall not have more than two sides at 90 degrees, or not more than three sides with connecting angles of 135 degrees;
- Connecting angles between fire barrier walls shall be permitted to be reduced to less than 135 degrees for installations consisting of three walls when in accordance with CGA P-41, *Locating Bulk Storage Systems in Courts* [13];
- Fire barrier walls shall be designed and constructed as a structure in accordance with requirements of building and fire codes without exceeding specified allowable stresses for materials of construction. Structures shall be designed to resist overturning effects caused by lateral forces due to wind, soil, flood, and seismic events;
- Adequate clearance between the natural gas supply system and the barrier wall for performance of service or maintenance related activities shall be provided between the structure and the system; and
- The fire barrier wall shall be either an independent structure or the exterior wall of the building adjacent to the storage or use area.

4.1.3 Siting near occupied buildings

When siting near occupied buildings, see CGA P-64, *Guideline for the Location of Occupied Buildings in Industrial Gas Plants* for guidance [14].



4.2 Containment and prevention of potential spills

4.2.1 Credible piping leak sources and quantities

For Category III systems, the designer shall determine the maximum credible source of leakage from the storage system piping and subsequent controls. For each potential breach, the determination shall take into account the highest anticipated pressure in the system, the highest reasonable restriction for the breach, and the thermodynamic state of the fluid being relieved. The predicted mass flow rate from the largest breach (predicted loss of containment [LOC]) shall be assessed for its impact on the neighboring facilities as outlined in 4.2.2.

4.2.2 Assessing potential for cryogenic pooling

For Category II and Category III systems, the rain out (i.e., liquid pooling) of the mass flow from the predicted LOC shall be determined for its maximum. This pool size shall be the largest possible pool for the full quantity of liquid in the largest storage tank through the breach as described in 4.2.1 and as acceptable to the AHJ, see NFPA 59A [7]. Alternatively to the rain out analysis, the pool size may be considered to be 110% of the largest storage tank, see NFPA 59A [7].

4.2.2.1 Spill containment

For Category II and Category III systems, spill containment shall be for the largest predicted pool as outlined in 4.2.2. Containment shall include provisions for rain, water, and snow removal. Consideration shall be taken for containment areas that create the potential for confined spaces [15]. Containment areas with walls higher than 3.28 ft (1 m) or having less than 2 points of egress shall be considered confining.

4.2.2.2 Man holes, storm drains, etc.

For Category II and Category III systems, pooling as outlined in 4.2.2 shall be prevented from entering storm sewers, underground conduits, and buildings. Pooling shall also be demonstrated to stay within the site property lines. For Category I systems, storm sewer and underground conduits shall not be located within the required setback in 4.3.1.1.

4.3 Setback requirements

4.3.1 Setbacks distances

Setback distances from property lines, areas where sources of ignition cannot be controlled and areas where unauthorized personnel can congregate shall be determined and subject to review by the AHJ. Setback requirements shall conform to distances outlined in NFPA 59A [7]. Setbacks may be modified if mitigations can be demonstrated and when approved by the AHJ.

4.3.1.1 Minimum setback distances for Category I LNG systems

Minimum setback distances for Category I LNG systems as measured from the fill connection of the tank are as follows:

- 25 ft (7.6 m) from parked vehicles [7];
- 25 ft (7.6 m) from places of public assembly [7];
- 25 ft (7.6 m) from weeds, long grass, and combustible debris [7];
- 25 ft (7.6 m) from open flames or welding [7];
- 25 ft (7.6 m) to underground sewers or drains;
- 25 ft (7.6 m) from air compressor intakes or inlets to HVAC equipment;
- LNG systems shall not be located where exposed to failure of overhead electric power lines over 600 volts [7];

- 25 ft (7.6 m) between LNG unloading and tank filling areas and uncontrolled sources of ignition, process areas, control buildings, offices, shops, and other structures [7];
- 20 ft (6.1m) from other types of flammable gas storage [16];
- 50 ft (15.2 m) from above ground bulk storage of flammable and combustible motor vehicle fuels [16];
- 25 ft (7.6 m) from combustible solids [16];
- 25 ft (7.6 m) from vent or fill openings of below ground bulk storage of flammable or combustible liquids;
- 25 ft (7.6 m) from the tanker truck unloading impounding area to property lines that can be built upon [7]; and
- 25 ft (7.6 m) between the points of transfer, property lines that can be built upon, and sources of ignition [5].

4.3.1.2 Minimum setback distances for Category II and Category III LNG systems

Minimum setback distances for Category II and Category III LNG systems as measured from the edge of the largest predicted pool as outlined in 4.2.2 are as follows:

- 25 ft (7.6 m) from parked vehicles [7];
- 25 ft (7.6 m) from places of public assembly [7];
- 25 ft (7.6 m) from weeds, long grass, and combustible debris [7];
- 25 ft (7.6 m) from open flames or welding [7];
- Inlets to underground sewers or drains shall be outside of impoundment for tanker transfer connection to LNG equipment;
- 25 ft (7.6 m) from air compressor intakes or inlets to HVAC equipment;
- LNG systems shall not be located where exposed to failure of overhead electric power lines over 600 volts [7];
- 25 ft (7.6 m) between LNG unloading and tank filling areas and uncontrolled sources of ignition, process areas, control buildings, offices, shops, and other structures [7];
- 20 ft (6.1 m) from other types of flammable gas storage [16];
- 50 ft (15.2 m) from above ground bulk storage of flammable and combustible motor vehicle fuels [16];
- 25 ft (7.6 m) from combustible solids [16];
- 25 ft (7.6 m) from vent or fill openings of below ground bulk storage of flammable or combustible liquids;
- 25 ft (7.6 m) from the tanker truck unloading impounding area to property lines that can be built upon [7]; and
- 25 ft (7.6 m) between the points of transfer, property lines that can be built upon, and sources of ignition [5].

Setbacks shall be considered for attended or otherwise supervised transfer operations.

Points of transfer represent a high risk area for loss of containment. In addition, these areas are by definition attended by a person.

4.3.1.3 Minimum setbacks and safe distances for CNG systems

See Table 10 for required minimum setbacks for CNG.

The minimum required distances do not apply where fire barriers without openings or penetrations and having a minimum fire resistive rating of 2 hours interrupt the line of sight between the storage and the exposure. The configuration of the fire barriers shall be designed to allow natural ventilation to prevent the accumulation of hazardous gas concentrations.

Table 10—Distance to exposures for CNG [6]

Stored amount of gas (scf)	Distance between storage areas	Distance to property lines that can be built upon	Buildings inside the property line
0 – 4 225	5 ft (1.5 m)	5 ft (1.5 m)	5 ft (1.5 m)
4 226 – 21 125	10 ft (3.0 m)	10 ft (3.0 m)	10 ft (3.0 m)
21 126 – 50 700	10 ft (3.0 m)	15 ft (4.6 m)	20 ft (6.1 m)
50 701 – 84 500	10 ft (3.0 m)	20 ft (6.1 m)	20 ft (6.1 m)
84 501 – 200 000	20 ft (6.1 m)	25 ft (7.2 m)	20 ft (6.1 m)
Greater than 200 000	Refer to NFPA 55 [5]		

The following requirements shall apply to CNG systems:

- CNG storage shall not be within 50 ft (15.2 m) of air intakes [6];
- CNG storage shall not be within 25 ft (7.6 m) of building openings [6];
- at least 3 ft (0.9 m) of access shall be provided between CNG storage containers where maintenance or inspection is required [5];
- storage area shall be the connected network of CNG storage where there is less than 3 ft (0.9 m) of access surrounding said network of storage; and
- CNG systems shall not be located where exposed to potential failure of overhead electric power lines over 600 volts [6].

4.3.2 Delivery trailer locations

LNG transfer areas shall be designated NO PARKING. Tankers shall have easy access and exit to and from installations at all times.

Filling or discharging of road tankers or tank containers shall be completed in open-air conditions. They shall not be located in walled enclosures where the escape of liquid or cold vapor is restricted. Attention should be given to areas with overhangs or roof structures where buoyant gases can be collected. Trailers should not be vented under overhangs or roof structures.

The bulk transfer area should be large enough to accommodate the tractor, trailer, and driver without the need for excessive movement and be free of debris.

The area should be flat and slightly above grade to prevent ice buildup from rain water.

Natural gas delivery locations and equipment shall not be located where exposed to failure of overhead electric power lines over 600 volts.

The driver should have an ample work area that is free from tripping hazards in the event of an emergency.

A stable surface shall be provided under the delivery trailer.