

NFPA® 59A

**Standard for the Production,
Storage, and Handling of
Liquefied Natural Gas (LNG)**

2019



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NFPA® 59A

Standard for the

Production, Storage, and Handling of Liquefied Natural Gas (LNG)

2019 Edition

This edition of NFPA 59A, *Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)*, was prepared by the Technical Committee on Liquefied Natural Gas. It was issued by the Standards Council on November 5, 2018, with an effective date of November 25, 2018, and supersedes all previous editions.

This edition of NFPA 59A was approved as an American National Standard on November 25, 2018.

Origin and Development of NFPA 59A

A committee of the American Gas Association began work on a standard for liquefied natural gas circa 1960. In the autumn of 1964, a draft was submitted to NFPA with the request that it be considered as the basis for an NFPA standard. The Sectional Committee on Utility Gas prepared a standard that was adopted tentatively at the 1966 NFPA Annual Meeting at the recommendation of the Committee on Gases.

With the formation of the Committee on Fuel Gases in the summer of 1966, the standard was assigned to that committee and its subcommittee on Utility Gas Plants. The first official edition was adopted at the 1967 NFPA Annual Meeting under the sponsorship of the Committee on Fuel Gases.

By early 1969, it was apparent that the use of LNG was expanding considerably beyond the utility gas plant applications covered by the 1967 edition. The American Petroleum Institute suggested that one of its standards, PUBL 2510A, *Design and Construction of Liquefied Petroleum Gas (LPG) Installations*, be used to help develop a standard having a broader scope. The Committee on Liquefied Natural Gas was established for that purpose. The 1971 edition was the first edition of NFPA 59A developed under the broadened scope. Subsequent editions were adopted in 1972, 1975, 1979, 1985, 1990, 1994, 1996, and 2001.

The 2006 edition included revisions in compliance with the *Manual of Style for NFPA Technical Committee Documents*. Chapter 5 was revised to cover double and full containment LNG storage containers. Definitions of these types of containers were also added to the standard. Seismic design criteria for LNG containers were revised to correlate with the requirements of ASCE 7, *Minimum Design Loads for Buildings and Other Structures*. Chapter 11 was revised to add requirements for a contingency plan for potential LNG marine transfer incidents.

In the 2009 edition, additional vapor dispersion models were allowed where they are evaluated and approved by an independent body using the new Model Evaluation Protocol developed by the NFPA Research Foundation. The Design Spill table was revised to separate the design spill requirements for over-the-top fill/withdrawal containers, other containers, and process areas. Scope statements were added to each chapter, and the term *radiant heat flux* replaced *thermal radiation* throughout the document.

In the 2013 edition, Annex E, Performance-Based Alternative Standard for Plant Siting, was revised and relocated to the mandatory text as new Chapter 15, Performance (Risk Assessment) Based LNG Plant Siting. Use of the performance-based option required approval of the authority having jurisdiction. The performance-based option required analyzing the risks to persons and property in the area surrounding the proposed LNG plant based on risk mitigation techniques incorporated into the facility design. All of the minimum requirements of earlier chapters of NFPA 59A also had to be met. Chapter 15 provided several tables and figures to assist a facility designer in identifying those risks and determining if the risks are tolerable, as defined in Chapter 15.



The 2013 edition also incorporated several revisions to promote consistency between NFPA 59A and the Code of Federal Regulations, as well as some new terminology for tank systems. In addition, Chapters 7 and 14 were reorganized for easier use.

In the 2016 edition, several definitions were revised to establish a hierarchy of components, facilities, and plants. A new definition for *LNG facility* was added, and the definitions for *LNG plant* and *component* were revised to maintain consistency. Subsequent chapters were revised to correspond to the new definitions.

Additional changes were made to improve the fire safe design of outer concrete containers to avoid explosive spalling during a fire event. Revisions were made to requirements for inspections after repairs, detection of leaks, and post seismic events to provide greater confidence in the system's continued safety and integrity.

The 2016 edition also incorporated several revisions to enhance the use of Annex A. NFPA documents that had been listed in Annex A as informational references in previous editions were moved into Chapter 12 as enforceable code to address the design and installation requirements for fire protection systems. New and revised annex material was added to numerous sections to provide additional information, guidance, and clarification, as well as to point users to reference materials for further guidance.

The 2019 edition of the standard presents a reorganization of the requirements for plant siting and layout to facilitate better focus and implementation of these requirements. Elements of what had been in Chapter 5, Layout and Siting, are now presented separately as plant siting (Chapter 5), plant layout (Chapter 6), plant design (Chapter 12), impounding areas (Chapter 13), and mobile and temporary LNG facilities (Chapter 14). Annex C, Security, and Annex D, Training, are removed because their content in previous editions is now incorporated into the mandatory requirements of the standard. Also in this revision, the committee standardized the use of terminology.

Another notable change for NFPA 59A, 2019 edition, is the addition of a chapter to address small-scale LNG facilities. This chapter was built on what had been presented as requirements for ASME containers in this standard. However, the growth in the small- to mid-scale segment of the global LNG market prompted a re-evaluation of available storage technologies, including a single-wall ASME container with supplementary design and fabrication requirements. The committee developed Chapter 17, Requirements for Stationary Applications for Small Scale LNG Facilities, to establish the framework under which single-wall ASME containers used for LNG storage can be safely implemented at LNG facilities.

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Committee Scope: This Committee shall have primary responsibility for documents on safety and related aspects in the liquefaction of natural gas and the transport, storage, vaporization, transfer, and use of liquefied natural gas.

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2019 Edition

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A reference in brackets [] following a section or paragraph indicates material that has been extracted from another NFPA document. As an aid to the user, the complete title and edition of the source documents for extracts in mandatory sections of the document are given in Chapter 2 and those for extracts in informational sections are given in Annex C. Extracted text may be edited for consistency and style and may include the revision of internal paragraph references and other references as appropriate. Requests for interpretations or revisions of extracted text shall be sent to the technical committee responsible for the source document.

Information on referenced publications can be found in Chapter 2 and Annex C.

Chapter 1 Administration

1.1* Scope.

1.1.1 This standard shall apply to the following:

- (1) The siting, design, construction, maintenance, and operation of facilities that produce, store, and handle liquefied natural gas (LNG)
- (2) The training of personnel involved with LNG

1.1.2 This standard shall not apply to the following:

- (1) Frozen ground containers
- (2) Portable storage containers stored or used in buildings
- (3) All LNG vehicular applications, including fueling of LNG vehicles

1.2 Purpose. The purpose of this standard is to provide minimum fire protection, safety, and related requirements for the siting, design, construction, security, operation, and maintenance of LNG plants.

1.3* Equivalency. Nothing in this standard is intended to prevent the use of systems, methods, or devices of equivalent or superior quality, strength, fire resistance, effectiveness, durability, and safety over those prescribed by this standard.

1.3.1 Technical documentation shall be submitted to the authority having jurisdiction to demonstrate equivalency.

N 1.3.2 The operator shall include any additional requirements to achieve equivalency in their procedures, as applicable.

1.3.3 The system, method, or device shall be approved for the intended purpose by the authority having jurisdiction.

1.4 Retroactivity. The provisions of this standard reflect a consensus of what is necessary to provide an acceptable degree of protection from the hazards addressed in this standard at the time the standard was issued.

1.4.1 Unless otherwise specified, the provisions of this standard shall not apply to facilities, equipment, structures, or installations that existed or were approved for construction or installation prior to the effective date of the standard. Where specified, the provisions of this standard shall be retroactive.

1.4.2 In those cases where the authority having jurisdiction determines that the existing situation presents an unacceptable degree of risk, the authority having jurisdiction shall be permitted to apply retroactively any portions of this standard deemed appropriate.

1.4.3 The retroactive requirements of this standard shall be permitted to be modified if their application clearly would be impractical in the judgment of the authority having jurisdiction, and only where it is clearly evident that a reasonable degree of safety is provided.

1.5* SI Units. SI units in this standard shall be based on IEEE/ASTM SI 10, *American National Standard for Use of the International System of Units (SI): The Modern Metric System*.

1.5.1 Alternate usage of U.S. customary units and SI units on a single project shall not be used to lessen clearance distances.

1.6 Pressure Measurement. All pressures expressed in this document are gauge pressures unless specifically noted otherwise.

1.7 Referenced Standards. Reference is made to both U.S. and Canadian standards, because this standard is prepared for use in both the United States and Canada, as well as in other countries.

1.7.1 Where this standard is adopted, the adoption shall include a statement of which U.S. or Canadian reference standards shall be used.

1.7.2 If no such statement is made, the user shall use either all available U.S. or all available Canadian reference standards.

1.7.3 If other reference standards are to be used, it shall be so stated.

Chapter 2 Referenced Publications

2.1* General. The documents or portions thereof listed in this chapter are referenced within this standard and shall be considered part of the requirements of this document.

2.2 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471.

NFPA 4, *Standard for Integrated Fire Protection and Life Safety System Testing*, 2018 edition.

NFPA 10, *Standard for Portable Fire Extinguishers*, 2018 edition.

NFPA 11, *Standard for Low-, Medium-, and High-Expansion Foam*, 2016 edition.

NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*, 2018 edition.

NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems*, 2018 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 2019 edition.

NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, 2019 edition.

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*, 2017 edition.

NFPA 16, *Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems*, 2019 edition.

NFPA 17, *Standard for Dry Chemical Extinguishing Systems*, 2017 edition.

NFPA 20, *Standard for the Installation of Stationary Pumps for Fire Protection*, 2019 edition.

NFPA 22, *Standard for Water Tanks for Private Fire Protection*, 2018 edition.

NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*, 2019 edition.

NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*, 2017 edition.

NFPA 30, *Flammable and Combustible Liquids Code*, 2018 edition.

NFPA 37, *Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines*, 2018 edition.

NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work*, 2019 edition.

NFPA 56, *Standard for Fire and Explosion Prevention During Cleaning and Purging of Flammable Gas Piping Systems*, 2017 edition.

ANSI Z223.1/NFPA 54, *National Fuel Gas Code*, 2018 edition.

NFPA 58, *Liquefied Petroleum Gas Code*, 2017 edition.

NFPA 59, *Utility LP-Gas Plant Code*, 2018 edition.

NFPA 68, *Standard on Explosion Protection by Deflagration Venting*, 2018 edition.

NFPA 69, *Standard on Explosion Prevention Systems*, 2019 edition.

NFPA 70®, *National Electrical Code®*, 2017 edition.

NFPA 72®, *National Fire Alarm and Signaling Code*, 2019 edition.

NFPA 101®, *Life Safety Code®*, 2018 edition.

NFPA 110, *Standard for Emergency and Standby Power Systems*, 2019 edition.

NFPA 274, *Standard Test Method to Evaluate Fire Performance Characteristics of Pipe Insulation*, 2018 edition.

NFPA 385, *Standard for Tank Vehicles for Flammable and Combustible Liquids*, 2017 edition.

NFPA 496, *Standard for Purged and Pressurized Enclosures for Electrical Equipment*, 2017 edition.

NFPA 600, *Standard on Fire Brigades*, 2015 edition.

NFPA 750, *Standard on Water Mist Fire Protection Systems*, 2019 edition.

NFPA 1221, *Standard for the Installation, Maintenance, and Use of Emergency Services Communications Systems*, 2019 edition.

NFPA 1901, *Standard for Automotive Fire Apparatus*, 2016 edition.

NFPA 1961, *Standard on Fire Hose*, 2013 edition.

NFPA 1962, *Standard for the Care, Use, Inspection, Service Testing, and Replacement of Fire Hose, Couplings, Nozzles, and Fire Hose Appliances*, 2018 edition.

NFPA 1963, *Standard for Fire Hose Connections*, 2019 edition.

NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems*, 2018 edition.

NFPA 5000®, *Building Construction and Safety Code®*, 2018 edition.

2.3 Other Publications.

2.3.1 ACI Publications. American Concrete Institute, 38800 Country Club Dr., Farmington Hills, MI 48331.

ACI 304R, *Guide for Measuring, Mixing, Transportation and Placing of Concrete*, 2000, reapproved 2009.

ACI 318, *Building Code Requirements for Structural Concrete and Commentary*, 2014.

ACI 350, *Code Requirements for Environmental Engineering Concrete Structures*, 2006.

ACI 376, *Code Requirements for Design and Construction of Concrete Structures for the Containment of Refrigerated Liquefied Gases*, 2011.

2.3.2 ALPEMA Publications. Braze Aluminum Plate-Fin Heat Exchanger Manufacturer's Association, IHS (secretariat), 321 Inverness Drive South, Englewood, CO 80112.

The Standards of the Braze Aluminum Plate-Fin Heat Exchanger Manufacturer's Association, 3rd Edition, 2012.

2.3.3 API Publications. American Petroleum Institute, 1220 L Street, NW, Washington, DC 20005-4070.

API 510, *Pressure Vessel Inspection Code: In-service Inspection, Rating, Repair, and Alteration*, 10th edition, 2014, with addendum 1 2017.

API RP 576, *Inspection of Pressure-Relieving Devices*, 4th edition, 2017.

API Spec 6D, *Specification for Pipeline and Piping Valves*, 24th edition, with errata 1-8 and addendums 1-2, 2014.

API Std 620, *Design and Construction of Large, Welded, Low-Pressure Storage Tanks*, 12th edition, with addendum 1, 2014.

API Std 625, *Tank Systems for Refrigerated Liquefied Gas Storage*, with addendums 1-2, 2010.

API Std 650, *Welded Tanks for Oil Storage*, 12th edition, 2013, errata 1 2013, errata 2 2014, and addendum 1 2014, and addendum 2 2016.

API Std 2510, *Design and Construction of Liquefied Petroleum Gas (LPG) Installations*, 8th edition, 2001, reaffirmed 2011.

2.3.4 ASCE Publications. American Society of Civil Engineers, 1801 Alexander Bell Drive, Reston, VA 20191-4400.

ASCE 7, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*, 2016.

2.3.5 ASME Publications. American Society of Mechanical Engineers, Two Park Avenue, New York, NY 10016-5990.

ASME B31.1, *Power Plant Piping*, 2016.

ASME B31.3, *Process Piping*, 2016.

ASME B31.4, *Pipeline Transportation Systems for Liquids and Slurries*, 2016.

ASME B31.5, *Refrigeration Piping and Heat Transfer Components*, 2016.

ASME B31.8, *Gas Transmission and Distribution Piping Systems*, 2016.

Boiler and Pressure Vessel Code, 2017.

2.3.6 ASTM Publications. ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959.

ASTM E84, *Standard Test Method for Surface Burning Characteristics of Building Materials*, 2016.

ASTM E136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*, 2016a.

ASTM E2652, *Standard Test Method for Behavior of Materials in a Tube Furnace with a Cone-shaped Airflow Stabilizer, at 750°C*, 2016.

2.3.7 CGA Publications. Compressed Gas Association, 14501 George Carter Way, Suite 103, Chantilly, VA 20151-1788.

CGA 341, *Standard for Insulated Cargo Tank Specification for Cryogenic Liquids*, 2007, reaffirmed 2011.

CGA S-1.3, *Pressure Relief Device Standards — Part 3 — Stationary Storage Containers for Compressed Gases*, 2008.

2.3.8 CSA Publications. CSA Group, 178 Rexdale Blvd. Toronto, ON M9W 1R3, Canada.

CSA B51, *Boiler, Pressure Vessel and Pressure Piping Code*, 2014.

CSA C22.1, *Canadian Electrical Code*, 2015.

2.3.9 IEEE Publications. IEEE, 3 Park Avenue, 17th Floor, New York, NY 10016-5997.

IEEE/ASTM SI 10, *American National Standard for Use of the International System of Units (SI): The Modern Metric System*, 2010.

2.3.10 ISA Publications. The International Society of Automation, 67 T.W. Alexander Drive, PO Box 12277, Research Triangle Park, NC 27709.

ISA 12.27.01, *Requirements for Process Sealing Between Electrical Systems and Flammable or Combustible Process Fluids*, 2011.

2.3.11 NACE Publications. NACE International, 15835 Park Ten Place, Houston, TX 77084-4906.

NACE SP0169, *Control of External Corrosion of Underground or Submerged Metallic Piping Systems*, 2013.

NACE SP0198, *Control of Corrosion Under Insulation and Fireproofing Materials — A Systems Approach*, 2016.

2.3.12 UL Publications. Underwriters Laboratories, Inc., 333 Pfingsten Road, Northbrook, IL 60062–2096.

ANSI/UL 723, *Standard for Test for Surface Burning Characteristics of Building Materials*, 2008, revised 2013.

2.3.13 Other Publications.

ANSI/NB-23, *National Board Inspection Code, Part 2, Inspection, Section 2, The National Board of Boiler and Pressure Vessel Inspectors*, Columbus, OH, 2017.

ASNT SNT-TC-1A, *Personnel Qualification and Certification in Nondestructive Testing*, 2016.

BS EN 14620, *Design and manufacture of site built, vertical, cylindrical, flat-bottomed, steel tanks for the storage of refrigerated, liquefied gases with operating temperatures between 0°C and –165°C*, Parts 1–5, 2006.

CEB Bulletin 187, *Concrete Structures Under Impact and Impulsive Loading — Synthesis Report*, International Federation for Structural Concrete, Switzerland, 1988.

Merriam-Webster's Collegiate Dictionary, 11th edition, Merriam-Webster, Inc., Springfield, MA, 2003.

2.4 References for Extracts in Mandatory Sections.

NFPA 52, *Vehicular Gaseous Fuel Systems Code*, 2019 edition.

NFPA 54, *National Fuel Gas Code*, 2018 edition.

NFPA 101®, *Life Safety Code®*, 2018 edition.

Chapter 3 Definitions

3.1 General. The definitions contained in this chapter shall apply to the terms used in this standard. Where terms are not defined in this chapter or within another chapter, they shall be defined using their ordinarily accepted meanings within the context in which they are used. *Merriam-Webster's Collegiate Dictionary*, 11th edition, shall be the source for the ordinarily accepted meaning.

3.2 NFPA Official Definitions.

3.2.1* Approved. Acceptable to the authority having jurisdiction.

3.2.2* Authority Having Jurisdiction (AHJ). An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.

3.2.3 Shall. Indicates a mandatory requirement.

3.2.4 Should. Indicates a recommendation or that which is advised but not required.

3.2.5 Standard. An NFPA Standard, the main text of which contains only mandatory provisions using the word “shall” to indicate requirements and that is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions are not to be considered a part of the requirements of a standard and shall be located in an appendix, annex, footnote, informational note, or other means as permitted in the NFPA Manuals of Style. When used in a generic sense, such as in the phrase “standards development process” or “standards development activities,” the term “standards” includes all NFPA Standards,

including Codes, Standards, Recommended Practices, and Guides.

3.3 General Definitions.

N 3.3.1 ASME Container. See 3.3.5.2, Pressure Vessel.

3.3.2 Bunkering. The loading of a ship's bunker or tank with fuel for use in connection with propulsion or auxiliary equipment.

3.3.3 Cargo Tank Vehicle. A tank truck or trailer designed to transport liquid cargo.

3.3.4 Component. A part or a system of parts that functions as a unit in an LNG facility and could include, but is not limited to, piping, processing equipment, containers, control devices, impounding systems, electrical systems, security devices, fire control equipment, and communication equipment.

3.3.5* Container. A vessel, tank, portable tank, or cargo tank used for or capable of holding, storing, or transporting liquid or gas.

3.3.5.1 Frozen Ground Container. A container in which the maximum liquid level is below the normal surrounding grade, that is constructed essentially of natural materials, such as earth and rock, that is dependent on the freezing of water-saturated earth materials, and that has appropriate methods for maintaining its tightness or that is impervious by nature.

N 3.3.5.2 Pressure Vessel. A container designed and fabricated in accordance with the ASME *Boiler and Pressure Vessel Code*, Section VIII, Division 1 or Division 2, or with CSA B51, *Boiler, Pressure Vessel, and Pressure Piping Code*.

3.3.5.3 Prestressed Concrete Container. A concrete container where the concrete is placed into compression by internal or external tendons or by external wire wrapping.

Δ 3.3.5.4 Tank System. Low-pressure (less than 15 psi) equipment designed for storing liquefied natural gas or other hazardous liquids, consisting of one or more containers, together with various accessories, appurtenances, and insulation.

3.3.5.4.1* Double-Containment Tank System. A single-containment tank system surrounded by and within 20 ft (6 m) of a self-standing containment wall (i.e., secondary container) that is open to the atmosphere and designed to contain LNG in the event of a spill from the primary or inner container.

Δ 3.3.5.4.2* Full-Containment Tank System. A tank system in which the self-standing inner (i.e., primary) container is surrounded by a separate self-standing secondary container designed to contain LNG in the event of a spill from the inner container, and the secondary container is enclosed by a steel or concrete roof designed such that excess vapor caused by a spill of LNG from the primary container will discharge through the relief valves.

Δ 3.3.5.4.3* Membrane-Containment Tank System. A tank system consisting of a thin metal liquid barrier and load-bearing thermal insulation supported by a self-standing outer container jointly forming an integrated composite tank system designed to contain liquid and vapor during tank operation as well as LNG in the event of leakage from the liquid barrier, and where the vapor-containing roof of

the outer container is either steel or concrete configured such that the excess vapor caused by a spill of LNG from the liquid barrier will discharge through the relief valves.

Δ 3.3.5.4.4* Single-Containment Tank System. A tank system in which the self-standing inner (i.e., primary) container is designed to contain LNG and is surrounded by a separate container that is not designed to contain LNG.

3.3.6 Controllable Emergency. An emergency where operator action can minimize harm to people or property.

3.3.7 Design Pressure. The pressure used in the design of equipment, a container, or a pressure vessel for the purpose of determining the minimum allowable thickness or physical characteristics of its parts.

3.3.8 Dike. A structure used to establish an impounding area or containment. [52, 2019]

3.3.9* Engineering Design. Documentation governing the specification and design of components and systems within an LNG facility.

N 3.3.10 Event. The combination of successive outcomes of LNG or hazardous material releases and their subsequent hazard to persons exposed.

3.3.11 Fail-safe. A design feature that provides for the maintenance of safe operating conditions in the event of a malfunction of control devices or an interruption of an energy source.

3.3.12* Fire Protection. Fire prevention, fire detection, and fire suppression.

3.3.13 Fired Equipment. Any equipment in which the combustion of fuels takes place.

3.3.14 Flame Spread Index. A number obtained according to ASTM E84, *Standard Test Method for Surface Burning Characteristics of Building Materials*, or ANSI/UL 723, *Standard for Test for Surface Burning Characteristics of Building Materials*.

3.3.15 Hazardous Fluid. A liquid or gas that is flammable, toxic, or corrosive.

3.3.16 Impounding Area. An area defined through the use of curbing, spill conveyances, dikes, the site topography, or other means for containing any accidental spill of LNG or other hazardous liquid.

N 3.3.17 Individual Risk. The frequency, expressed in number of realizations per year, at which an individual, with continuous potential exposure, can be expected to sustain irreversible harm and fatal injury.

3.3.18 Liquefied Natural Gas (LNG). A fluid in the cryogenic liquid state that is composed predominantly of methane and that can contain minor quantities of ethane, propane, nitrogen, and other components normally found in natural gas.

3.3.19* LNG Facility. A collection of components used to produce, store, vaporize, transfer, or handle LNG.

3.3.20 LNG Plant. An LNG facility or collection of LNG facilities functioning as a unit.

N 3.3.21 Marine Vessel. A water craft or other artificial contrivance used as a means of transportation in or on the water.

3.3.22 Maximum Allowable Working Pressure (MAWP). The maximum gauge pressure permissible at the top of completed

equipment, a container, or a vessel in its operating position for a design temperature.

3.3.23 Model. A mathematical characterization intended to predict a physical phenomenon.

▲ **3.3.24 Noncombustible Material.** See Section 4.10. [101, 2018].

3.3.25 Out-of-Service. The deactivation of a component for any purpose, including repairs or inspections.

3.3.26 Overfilling. Filling to a level above the maximum design liquid level.

3.3.27 Pipe Insulation Assembly. The set of materials used for insulation of pipes, including the insulation, outer jacket, vapor barrier and lap-seal adhesives.

3.3.28 Pressure Relief Device. A device designed to open to prevent a rise of internal pressure in excess of a specified value due to emergency or abnormal conditions.

N **3.3.29 Societal Risk.** The cumulative risk exposure by all persons sustaining irreversible harm and fatal injury from an event in the LNG plant.

3.3.30 Sources of Ignition. Appliances or equipment that, because of their intended modes of use or operation, are capable of providing sufficient thermal energy to ignite flammable gas-air mixtures. [54, 2018]

N **3.3.31 Stationary System.** All equipment associated with the system is fixed from movement and does not incorporate “make or break” connections between each associated piece of equipment, except for those connections used for transfer of fluids into or from the system that are manned by trained personnel during those transfers.

N **3.3.32 Storage Tank.** A low-pressure container designed for an internal gas pressure of 15 psi or less, in accordance with API Std 620, *Design and Construction of Large, Welded, Low-Pressure Storage Tanks*, or API Std 650, *Welded Tanks for Oil Storage*.

N **3.3.33 Tank.** See 3.3.32, Storage Tank.

N **3.3.34 Tank Car.** A type of railroad car, tank wagon, or rolling stock designed to transport liquid and gaseous commodities.

3.3.35 Tank Vehicle. See 3.3.3, Cargo Tank Vehicle.

3.3.36* Transfer Area. The portion of an LNG plant where LNG or other hazardous fluids are introduced into or removed from the plant and where necessary connections are connected or disconnected routinely.

3.3.37 Transition Joint. A connector fabricated of two or more metals used to effectively join piping sections of two different materials that are not amenable to the usual welding or joining techniques.

3.3.38* Vacuum-Jacketed. A method of construction that incorporates an outer shell designed to maintain a vacuum in the annular space between the inner container or piping and outer shell.

3.3.39* Vaporizer. Equipment designed to introduce thermal energy in a controlled manner for changing a liquid to a vapor or gaseous state.

3.3.39.1 Ambient Vaporizer. A vaporizer that derives its heat from naturally occurring heat sources, such as the atmosphere, seawater, or geothermal waters.

3.3.39.2 Heated Vaporizer. A vaporizer that derives heat for vaporization from the combustion of fuel, electric power, or waste heat, such as from boilers or internal combustion engines. [52, 2019]

3.3.39.2.1 Integral Heated Vaporizer. A vaporizer, including submerged combustion vaporizers, in which the heat source is integral to the actual vaporizing exchanger. [52, 2019]

3.3.39.2.2 Remote Heated Vaporizer. A heated vaporizer in which the primary heat source is separated from the actual vaporizing exchanger, and an intermediate fluid (e.g., water, steam, isopentane, glycol) is used as the heat transport medium.

3.3.39.3 Process Vaporizer. A vaporizer that derives its heat from another thermodynamic or chemical process to utilize the refrigeration of the LNG.

N **3.3.40 Vessel.** See 3.3.5.2, Pressure Vessel.

3.3.41 Water Capacity. The amount of water at 60°F (16°C) required to fill a container. [52, 2019]

Chapter 4 General Requirements

4.1 Scope. This chapter covers the general requirements for facilities covered under this standard.

N **4.2* Designer and Fabricator Competence.**

N **4.2.1*** Soil and general investigations shall be made to determine the adequacy of the intended site for the facility.

N **4.2.2** Designers, fabricators, constructors, installers, inspectors, and those performing testing shall be competent and qualified by training or experience and accomplishments in performing their assigned functions in their respective fields.

N **4.2.2.1** Each operator shall periodically determine whether construction, installation, and testing inspectors are satisfactorily performing their assigned functions.

N **4.2.3** Supervision shall be provided for the fabrication, construction, and acceptance tests of facility components to verify that the facilities are structurally sound and otherwise in compliance with this standard.

N **4.3* Soil Protection for Cryogenic Equipment.** LNG containers (see 8.3.4), cold boxes, piping and pipe supports, and other cryogenic apparatus shall be designed and constructed to prevent damage to these structures and equipment due to freezing or frost heaving in the soil, or means shall be provided to prevent damaging forces from developing.

N **4.4 Falling Ice and Snow.** Measures shall be taken to protect personnel and equipment from falling ice or snow that has accumulated on high structures.

N **4.5 Concrete Design and Materials.**

N **4.5.1** Concrete structures that are normally or periodically in contact with LNG, including the foundations of cryogenic containers, shall be designed to withstand the design load, applicable environmental loadings, and anticipated temperature effects.

N 4.5.1.1 The material and design of the structures other than LNG containers shall be in accordance with the provisions of ACI 318, *Building Code Requirements for Structural Concrete and Commentary*.

N 4.5.2 Structural concrete for pipe supports shall comply with Section 10.6.

N 4.5.3 Other Concrete Structures.

N 4.5.3.1 All other concrete structures shall be investigated for the effects of potential contact with LNG.

N 4.5.3.2 If failure of these structures would create a hazardous condition or worsen an existing emergency condition by exposure to LNG, the structures shall be protected to minimize the effects of such exposure, or they shall comply with 8.4.13.2.

N 4.5.4* Nonstructural concrete for incidental nonstructural uses, such as slope protection, impounding area paving, and other nonstructural slabs-on-grade, shall conform to ACI 304R, *Guide for Measuring, Mixing, Transportation and Placing of Concrete*.

N 4.5.5 Minimum Reinforcement.

N 4.5.5.1 Reinforcement for concrete structures designed for LNG containment or cold vapor containment, other than those in 4.5.1; or for concrete structures covered in 4.5.2 and 4.5.3 shall be a minimum of 0.5 percent of the cross-sectional area of concrete for crack control in accordance with Appendix G of ACI 350, *Code Requirements for Environmental Engineering Concrete Structures*.

N 4.5.5.2 Minimum reinforcement for concrete for incidental nonstructural uses covered in 4.5.4 shall be in accordance with the shrinkage and temperature reinforcement provisions of ACI 318, *Building Code Requirements for Structural Concrete and Commentary*.

N 4.5.6 Concrete that is not constantly exposed to LNG and that has been subjected to sudden and unexpected exposure to LNG shall be inspected, and repaired if necessary, as soon as is practical after it has returned to ambient temperature.

4.6 Engineering Review of Changes.

Δ 4.6.1 Components shall not be constructed or significantly altered in accordance with 4.6.2 until a qualified person from each of the following disciplines, as applicable, reviews the design drawings and specifications and determines that the design will not impair the safety or reliability of the component or any associated components:

- (1) Process engineering
- (2) Mechanical engineering
- (3) Geotechnical and civil engineering
- (4) Electrical and instrumentation engineering
- (5) Materials and corrosion engineering
- (6) Fire protection and safety engineering

4.6.2 The repair, replacement, or significant alteration of components shall be reviewed only if the action to be taken involves or is due to one of the following:

- (1) A change in the original components specified
- (2) A failure caused by corrosion
- (3) A failure resulting in a loss of containment
- (4) An inspection that reveals a significant deterioration of the component

4.7 Control Center.

Δ 4.7.1 Each LNG plant, other than those complying with Chapter 17, shall have a control center from which operations and warning devices are monitored.

4.7.2 A control center shall have the following capabilities and characteristics:

- (1) It shall be located apart from or be protected from other components so that it is operational during a controllable emergency.
- (2) Each remotely actuated control system and each automatic shutdown control system required by this standard shall be operable from the control center responsible for monitoring as required by 18.6.1.
- (3) It shall have personnel in attendance while process systems (e.g., vaporization, liquefaction, transfers of LNG) under its control are in operation, with exceptions described in Section 18.6 during any operations monitoring or when another manned control center has control or the facility has an automatic emergency shutdown system.
- (4) Onsite control centers when unattended during operations monitoring as described in 18.6.1.1 shall have the capability of initiating an audible or visual signal, or both, to alert operating personnel performing operations monitoring.
- (5) If more than one is located at an LNG plant, each control center shall have more than one means of communication with every other center.
- (6) It shall have a means of communicating a warning of hazardous conditions to other locations within the plant frequented by personnel.

4.8 Sources of Power.

Δ 4.8.1 Electrical control systems, means of communication, emergency lighting, fire-fighting systems, and security-related systems (including lighting) shall have at least two sources of power that function so that failure of one source does not affect the capability of the other source.

4.8.2 Where auxiliary generators are used as a second source of electrical power, the following shall apply:

- (1) They shall be located apart from or be protected from components so that they are not unusable during a controllable emergency.
- (2) The fuel supply shall be protected from hazards.
- (3) Where installed, emergency power systems and standby power systems shall be installed in accordance with NFPA 110, and the emergency power supply system level and class shall be determined by an engineering review.

4.9 Records.

4.9.1 Each plant shall have a record of materials of construction for components, buildings, foundations, and support systems used for containment of LNG or other hazardous liquids.

4.9.2 The records shall verify that the material properties meet the requirements of this standard.

4.9.3 The records shall be maintained for the life of the components, buildings, foundations, and support systems.

4.10* Noncombustible Material. A material that complies with any of the following shall be considered a noncombustible material:

- (1)* In the form in which it is used and under the conditions anticipated, it will not ignite, burn, support combustion, or release flammable vapors when subjected to fire or heat.
- (2) It passes the noncombustible criterion of ASTM E136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*.
- (3) It passes the noncombustible criterion of ASTM E136 when tested in accordance with the test method and procedure in ASTM E2652, *Standard Test Method for Behavior of Materials in a Tube Furnace with a Cone-shaped Airflow Stabilizer, at 750°C*.

4.11 Ignition Source Control.

4.11.1 Smoking shall be permitted only in designated and sign-posted areas.

4.11.2 Welding, cutting, and hot work shall be conducted in accordance with the provisions of NFPA 51B and shall include continuous flammable gas monitoring in areas not covered by other hazard detection systems.

4.11.3 Portable electric tools and extension lights capable of igniting LNG or other flammable fluids shall not be permitted within classified areas except where the area has been identified as free of flammable fluids.

4.11.4 Vehicles and other mobile equipment that constitute potential ignition sources shall be prohibited within hazardous (electrically classified) locations, except where designated by the operator and at loading or unloading at facilities specifically designed for the purpose.

Chapter 5 Plant Siting

Δ 5.1 Scope. This chapter presents the criteria for plant siting.

5.2* Plant Site Provisions.

5.2.1 A written plant and site evaluation shall identify and analyze potential incidents that have a bearing on the safety of plant personnel and the surrounding public. The plant and site evaluation shall also identify safety and security measures incorporated in the design and operation of the plant considering the following, as applicable:

- (1) Process hazard analysis
- (2) Transportation activities that might impact the proposed plant
- (3) Adjacent facility hazards
- (4) Meteorological and geological conditions
- (5) Security threat and vulnerability analysis

N 5.2.2 An analysis shall be performed and documented to demonstrate the consequences associated with potential incidents from identified hazards in accordance with Chapter 5 or Chapter 19.

Δ 5.2.3 All-weather accessibility to the plant for personnel safety and fire protection shall be provided.

5.3 Site Provisions for Spill and Leak Control.

5.3.1 General.

Δ 5.3.1.1 Provisions shall be made to minimize the potential of discharge of LNG or other hazardous liquids at containers, piping, and other equipment such that a discharge from any of these does not endanger adjoining property, occupied buildings, or important process equipment and structures or reach waterways.

N 5.3.1.2 LNG containers and hazardous liquid storage tanks shall be provided with one of the following methods to contain any release:

- (1) An impounding area surrounding the container(s) that is formed by a natural barrier, dike, impounding wall, or combination thereof complying with Chapter 13 and Chapter 6
- (2) An impounding area formed by a natural barrier, dike, excavation, impounding wall, or combination thereof complying with Chapter 13 and Chapter 6, plus a natural or man-made drainage system surrounding the container(s) that complies with Chapter 13 and Chapter 6
- (3) Where the container is constructed below or partially below the surrounding grade, an impounding area formed by excavation complying with Chapter 13 and Chapter 6
- (4) Secondary containment as required for double-, full-, or membrane-containment tank systems complying with Chapter 13 and Chapter 6.

5.3.1.3 Where there is a possibility for hazardous liquid releases to accumulate on the ground and endanger adjoining property, occupied buildings, important process equipment and structures, or reach waterways, the following areas shall be graded, drained, or provided with impoundment:

- (1) Process areas
- (2) Vaporization areas
- (3) Liquefaction areas
- (4) Transfer areas for LNG, flammable refrigerants, and flammable liquids
- (5) Areas immediately surrounding flammable refrigerant and flammable liquid storage tanks

N 5.3.1.4 Secondary containment systems designed in accordance with 10.13.3.2 shall be permitted to serve as an impounding area.

5.3.1.5 If impounding areas also are required in order to comply with 5.3.1.7, such areas shall be in accordance with Chapter 13 and Chapter 6.

Δ 5.3.1.6 The provisions of 5.3.1.7, 5.3.1.1, 5.3.1.2 and 5.3.1.3 that apply to adjoining property or waterways shall be permitted to be waived or altered at the discretion of the authority having jurisdiction where the change does not constitute a distinct hazard to life or property or conflict with applicable federal, state, and local (national, provincial, and local) regulations.

5.3.1.7 Site preparation shall include provisions for retention of spilled LNG and other hazardous liquids where liquids might accumulate on the ground within the limits of plant property and for surface water drainage.

N 5.3.2 Hazard Analysis.

N 5.3.2.1 The following types of hazards and calculations of the extent of hazards shall be evaluated as follows, with the exception of feed gas and send out gas lines:

- (1) Distance to limit concentration levels arising from flammable gas or vapor dispersion
- (2) Distance to limit concentration levels arising from toxic gas or vapor dispersion
- (3) Distance to limit overpressure levels arising from explosions
- (4) Distance to limit heat flux or heat dosage levels arising from pool fires
- (5) Distance to limit heat flux or heat dosage levels arising from jet fires
- (6) Distance to limit heat flux or heat dosage levels arising from fireballs

N 5.3.2.2* The use of active mitigation techniques in the calculation of hazard distances and cascading potential shall be subject to the approval of the AHJ.

N 5.3.2.3* Each LNG plant shall define a set of design spills in accordance with Table 5.3.2.3 and the design spill duration period set in 5.3.2.4.

N 5.3.2.3.1 The bounding hazard distances associated with design spills as defined in Table 5.3.2.3 shall be documented.

N 5.3.2.3.2 Each portion of the plant that could produce a distinct hazard distance shall be represented.

N 5.3.2.4 Design Spill Duration. The design spill duration shall be the shortest among the following:

- (1) The demonstrated and approved shutdown time based on automated surveillance and detection that does not require human intervention, which can be verified in detailed design and operation.
- (2) Ten minutes for approved surveillance and detection that requires human intervention for shutdown
- (3) The time needed to empty the available system inventory if no approved surveillance and detection is present

N 5.3.2.5 Source term models shall have a creditable scientific basis and shall not ignore phenomena that can influence vapor evolution rate as follows:

- (1) During discharge from piping or equipment and associated flashing and jetting effects
- (2) During conveyance of liquid to an impoundment and subsequent vaporization
- (3) Due to liquid flow into and retention within an impoundment

Table 5.3.2.3 Design Spill

Design Spill Source	Design Spill Criteria	Design Spill Rate
<i>Storage Containers</i>		
Containers with penetrations below the liquid level without internal shutoff valves in accordance with 10.4.2.5	A liquid spill through an assumed opening at, and equal in area to, that penetration below the liquid level resulting in the largest flow from an initially full container If more than one container in the impounding area, use the container with the largest flow	Use the following formula: $q = \frac{4}{3}d^2\sqrt{h}$ For SI units, use the following formula: $q = \frac{1.06}{10,000}d^2\sqrt{h}$ until the differential head acting on the opening is 0.
Containers with penetrations below the liquid level with internal shutoff valves in accordance with 10.4.2.5	The liquid spill through an assumed opening at, and equal in area to, that penetration below the liquid level that could result in the largest flow from an initially full container	Use the following formula: $q = \frac{4}{3}d^2\sqrt{h}$ For SI units, use the following formula: $q = \frac{1.06}{10,000}d^2\sqrt{h}$
<i>Piping and Other Equipment</i>		
Process systems or transfer areas involving hazardous fluids	For piping, arms, and hoses that are: (1) Greater than or equal to 6 in. diameter, a hole size of 2 in. diameter is applied at any location along the piping segment (2) Less than 6 in. diameter, a full-bore rupture is applied at any location along the piping segment	The calculated flow* based on the following: (1) The physical and thermodynamic properties of the released fluid (2) The physical characteristics of the process or containment system
Pipe-in-pipe systems designed in accordance with Section 10.13 to serve as secondary containment	No design spill — setback in accordance with Table 6.3.1 based on isolatable volume within the pipe-in-pipe system	

Note: q = flow rate [ft³/min (m³/min)] of liquid; d = diameter [in. (mm)] of penetration below the liquid level; h = height [ft (m)] of liquid above penetration in the container when the container is full, plus the equivalent head for the vapor pressure above the liquid.

*See A.5.3.2.2.

N 5.3.2.6* Weather and Modeling Parameters. Models employed in 5.3.2.9 through 5.3.2.12 shall be approved and shall have available documentation that demonstrates the following:

- (1) The scientific assessment of the physical phenomena observed in experimental data applicable to the physical situation
- (2) Verification processes for the details of the physics, analysis, and execution process
- (3) Validation with experimental, including available field-scale, data applicable to the physical situation

N 5.3.2.7 Models employed in 5.3.2.8 and 5.3.2.9 shall incorporate the following:

- (1) In calculating hazard distances, the combination of wind speed adjusted to or at a reference height of 33 ft (10 m), ambient temperature, atmospheric stability, and relative humidity that produces the maximum distances shall be used except for conditions that occur less than 10 percent of the time based on recorded data for the area.
- (2) As an alternative, the maximum distances shall be permitted to be calculated using a wind speed of 4.5 mph (2 m/sec) at a 33 ft (10 m) measurement height, atmospheric stability class F, average ambient temperature for the region, and 50 percent relative humidity.
- (3) All wind directions shall be considered.
- (4) The surface roughness that is representative of the area upwind of the site shall be used.
- (5) The effects of passive and approved active mitigation techniques shall be permitted to be incorporated into the modeling.

N 5.3.2.8 Jet fire and pool fire models employed in 5.3.2.12 shall incorporate the following:

- (1) In calculating hazard distances, the combination of wind speed adjusted to or at a reference height of 33 ft (10 m), ambient temperature, and relative humidity that produces the maximum distances shall be used except for conditions that occur less than 10 percent of the time based on recorded data for the area.
- (2) As an alternative, the maximum distances shall be permitted to be calculated using weather parameters of 20 mph

(9 m/sec) winds measured at a reference height of 33 ft (10 m), average ambient temperature for the area, and 50 percent relative humidity shall be applied as default conditions.

- (3) All wind directions shall be considered.
- (4) The effects of passive and approved active mitigation techniques shall be incorporated into the modeling.

N 5.3.2.9* Flammable Gas or Vapor Dispersion. The siting of the plant shall be such that, in the event of an LNG or other flammable or combustible fluid release as specified in 5.3.2.3, a predicted concentration to the lower flammability limit (LFL) does not extend beyond the property line that can be built upon.

N 5.3.2.10 Toxic Gas or Vapor Dispersion. The siting of the plant shall be such that, in the event of a toxic fluid release as specified in 5.3.2.3, a predicted maximum concentration from a release does not exceed the limits listed in Table 5.3.2.10.

N 5.3.2.11 Vapor Cloud Explosions. The siting of the plant shall be such that, in the event of the ignition of a flammable cloud in a confined or congested area based on a design spill as specified in 5.3.2.3, a maximum overpressure from an explosion does not exceed the limits listed in Table 5.3.2.11.

N 5.3.2.12 Fires. The siting of the plant shall be such that, in the event of an LNG or other flammable or combustible fluid release as specified in 5.3.2.3, a maximum radiant heat flux from a fire shall not exceed the limits listed in Table 5.3.2.12.

N 5.3.2.12.1 For fireballs, the exposure extent shall be calculated using a dose equivalent to 1,600 Btu/hr/ft² and 40-second exposure time (7.5×10^5 (Btu/hr/ft²)^{4/3}s).

N 5.3.2.13* The hazard footprint calculated in 5.3.2.9 through 5.3.2.12 shall account for the uncertainty factors determined in 5.3.2.7 and 5.3.2.8.

N 5.3.2.14 Cascading Damage. Equipment shall be located or protected so that impacts from 5.3.2.11 and 5.3.2.12 shall not cause major structural damage to any LNG storage container, LNG marine carrier, refrigerant storage vessel, buildings, or equipment required for the safe shutdown and control of the hazard.

Table 5.3.2.10 Toxic Concentration Limits to Property Lines and Occupancies

Toxic Concentration		
Acute Exposure Guideline Levels (AEGL)	Description	Exposure
AEGL-1	Toxic concentration at which notable discomfort, irritation, or certain asymptomatic non-sensory effects; however, the effects are not disabling and are transient and reversible upon cessation of exposure	The area that will be potentially notified for toxic clouds in the emergency response plan required in Section 18.4
AEGL-2	Toxic concentration at which irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape	The nearest point on the building or structure outside the owner's property line that is in existence at the time of plant siting and used for assembly, educational, health care, detention and correction, or residential occupancies for a toxic cloud
AEGL-3	Toxic concentration at which life-threatening health effects or death can occur	A property line that can be built upon for dispersion of a design spill resulting in a toxic cloud

Table 5.3.2.11 Overpressure Limits to Property Lines and Occupancies

Overpressure		
Overpressure	Description	Exposure
1 psi	Overpressure at which persons can be indirectly affected	The nearest point on the building or structure outside the owner's property line that is in existence at the time of plant siting and used for assembly, educational, health care, detention and correction, or residential occupancies for a vapor cloud explosion
3 psi	Overpressure at which persons can be directly affected	A property line that can be built upon for ignition of a design spill resulting in a vapor cloud explosion

Table 5.3.2.12 Radiant Heat Flux Limits to Property Lines and Occupancies

Radiant Heat Flux		
Btu/hr/ft ²	W/m ²	Exposure
1,600	5,000	A property line at ground level that can be built upon for ignition of a design spill resulting in a fireball ^a , jet fire, or pool fire
1,600	5,000	The nearest point located outside the owner's property line at ground level that, at the time of plant siting, is used for outdoor assembly by groups of 50 or more persons for a pool fire in an LNG storage tank impounding area ^b
3,000	9,000	The nearest point on the building or structure outside the owner's property line that is in existence at the time of plant siting and used for assembly, educational, health care, detention and correction, or residential occupancies for a pool fire in an LNG storage tank impounding area ^{b,c}
10,000	30,000	A property line at ground level that can be built upon for a pool fire over an LNG storage tank impounding area ^b

Notes:

^aSee 5.3.2.12.1.^bThe requirements for LNG storage tank impounding areas are located in Chapter 13.^cSee NFPA 101 or NFPA 5000 for definitions of occupancies.

N Chapter 6 Plant Layout

N 6.1 Scope. This chapter presents the criteria for plant and equipment layout.

N 6.2 General Layout.

N 6.2.1* The layout between components and facilities shall allow for the necessary access to operate and maintain the plant.

N 6.2.2* The layout between components and facilities shall consider prevailing wind direction and ignition sources.

N 6.2.3 If cameras are required for security or operational purposes by 16.8.1.1 or Section 18.6, respectively, the camera layout shall allow for operators and security personnel to clearly monitor the facilities.

N 6.2.4 The layout between components and facilities shall allow for the access and egress by personnel and emergency responders.

N 6.3 Container Spacing.

N 6.3.1 The minimum separation distance associated with any type of LNG container or tanks containing flammable refrigerants shall be in accordance with Table 6.3.1 or with the approval of the authority having jurisdiction at a shorter distance from buildings or walls constructed of concrete or masonry but at least 10 ft (3.0 m) from any building openings.

N 6.3.2 Double-, full-, and membrane-containment tank systems shall be separated from a fire in an adjacent single- or double-containment impoundment area such that a fire within the adjacent impoundment or from a design spill will not cause loss of containment. This shall be accomplished by ensuring that the storage container roof, walls, insulation, or its impoundment structure do not reach temperatures at which mechanical properties of the container roof, wall, insulation, or its impoundment are reduced to levels where the LNG tank system, roof, insulation, or impoundment will collapse or burst

or product liquid or uncontrolled vapor release will occur. The application of engineering analyses shall be used to determine this by including the following conditions in the analyses:

- (1) The analyses shall be performed for a fire involving the complete loss of containment of the primary liquid container to an impoundment area that complies with the requirements of Section 13.1.
- (2) The analyses shall account for the following:
 - (a) The duration of the fire, the radiant heat emission characteristics of the fire, and the physical attributes of the fire under the anticipated atmospheric conditions
 - (b) Atmospheric conditions that produce the maximum separation distances — except for conditions that occur less than 10 percent of the time based on recorded data for the area and using an LNG fire model in accordance with 5.3.2
 - (c) Active or passive systems to reduce thermal heat flux incident on the surface or to limit the surface temperature
 - (d) The materials, design, and methods of construction of the target LNG tank being analyzed

N 6.3.2.1 The outer concrete container shall be designed for the external fire in accordance with ACI 376, *Code Requirements for Design and Construction of Concrete Structures for the Containment of Refrigerated Liquefied Gases*, unless fire protection measures are provided. The outer tank thermal analysis shall be performed to determine temperature distribution for the heat flux and duration of exposure as specified by the facility designer.

N 6.3.2.1.1 The applicable load components and the ultimate state load factors for the fire load combinations shall be in accordance with ACI 376, *Code Requirements for Design and Construction of Concrete Structures for the Containment of Refrigerated Liquefied Gases*, Table 7.3. For membrane tank systems, an additional liquid pressure load in accordance with ACI 376, Table 7.2, shall be included. For all tanks, assessment during fire shall assume that design positive internal gas pressure applies.

N Table 6.3.1 Distances from Containers and Exposures

Container Water Capacity		Minimum Distance from Edge of Impoundment or Container Drainage System to Property Lines That Can Be Built Upon		Minimum Distance Between Storage Containers	
gal	m ³	ft	m	ft	m
<125*	<0.5	0	0	0	0
125–500	≥0.5–1.9	10	3	3	1
501–2,000	≥1.9–7.6	15	4.6	5	1.5
2,001–18,000	≥7.6–63	25	7.6	5	1.5
18,001–30,000	≥63–114	50	15	5	1.5
30,001–70,000	≥114–265	75	23		
>70,000	>265	0.7 times the container diameter but not less than 100 ft (30 m)		¼ of the sum of the diameters of adjacent containers [5 ft (1.5 m) minimum]	

*If the aggregate water capacity of a multiple container installation is 501 gal (1.9 m³) or greater, the minimum distance must comply with the appropriate portion of this table, applying the aggregate capacity rather than the capacity per container. If more than one installation is made, each installation must be separated from any other installation by at least 25 ft (7.6 m). Do not apply minimum distances between adjacent containers to such installation.

Shaded text = Revisions. **N** = Text deletions and figure/table revisions. • = Section deletions. **N** = New material



N 6.3.2.1.2 The design of the outer concrete container shall take into account the following factors:

- (1) Reduction in the wall post-tensioning due to the difference in the coefficient of thermal expansion of post-tensioning steel and wall concrete at the temperature to which the post-tensioning steel is exposed, taking into consideration the effects of the concrete aggregate type on the concrete coefficient of thermal expansion
- (2) Reduction in strength and modulus of elasticity of the outer tank concrete, reinforcing and post-tensioning steel due to elevated temperature
- (3) Reduction in the wall post-tensioning due to pre-stressing steel softening and relaxation at elevated temperature

N 6.3.3 A clear space of at least 3 ft (0.9 m) shall be provided for access to all isolation valves serving multiple containers.

N 6.3.4 LNG containers of greater than 125 gal (0.5 m³) capacity shall not be located in buildings.

N 6.3.5 Flammable liquid and flammable refrigerant storage tanks shall not be located within an LNG container impounding area.

N 6.4 Vaporizer Spacing.

N 6.4.1 Vaporizers using flammable heat transfer fluids and their primary heat sources shall be located at least 50 ft (15 m) from any other source of ignition.

N 6.4.1.1 Where more than one vaporizer is installed at one location, an adjacent vaporizer or primary heat source shall not be considered to be a source of ignition.

N 6.4.1.2 Process heaters or other units of fired equipment shall not be considered to be sources of ignition with respect to vaporizer siting if they are interlocked so that they cannot be operated while a vaporizer is operating or while the piping system serving the vaporizer either is cooled down or is being cooled down.

N 6.4.2* The fired components of an integral heated vaporizer shall be located as follows

- (1) At least 50 ft (15 m) from any impounded LNG, flammable refrigerant, or flammable liquid (*see Section 6.3*) or the paths of travel of such fluids between any other source of accidental discharge and the impounding area
- (2) At least 50 ft (15 m) from LNG, flammable liquid, flammable refrigerant, or flammable gas storage containers or tanks; unfired process equipment containing such fluids; or loading and unloading connections used in the transfer of such fluids
- (3) At least 50 ft (15 m) from control buildings, offices, shops, and other occupied or important plant structures
- (4) At least 100 ft (30 m) from property line that can be built upon (*see 6.4.4*)

N 6.4.3 Heaters or heat sources of remote heated vaporizers shall comply with 6.4.2.

N 6.4.4 Remote heated, ambient, and process vaporizers shall be located at least 100 ft (30 m) from a property line that can be built upon.

N 6.4.5 Vaporizers used in conjunction with LNG containers having a capacity of 70,000 gal (265 m³) or less shall be located with respect to the property line in accordance with Table

6.3.1, assuming the vaporizer to be a container with a capacity equal to the largest container to which it is connected.

N 6.4.6 A clearance of at least 5 ft (1.5 m) shall be maintained between vaporizers.

N 6.5 Process Equipment Spacing.

N 6.5.1 Process equipment containing LNG, refrigerants, flammable liquids, or flammable gases shall be located at least 50 ft (15 m) from sources of ignition, a property line that can be built upon, control centers, offices, shops, and other occupied structures.

N 6.5.2 Where control centers are located in a building housing flammable gas compressors, the building construction shall comply with Section 12.5.

N 6.5.3 Fired equipment and other sources of ignition shall be located at least 50 ft (15 m) from any impounding area or container drainage system.

N 6.6 Loading and Unloading Facility Spacing.

N 6.6.1 A pier or dock used for pipeline transfer of LNG shall be located so that any marine vessel being loaded or unloaded is at least 100 ft (30 m) from any bridge crossing a navigable waterway.

N 6.6.2 The loading or unloading manifold shall be at least 200 ft (61 m) from such a bridge.

N 6.6.3* LNG and flammable refrigerant loading and unloading connections shall be at least 50 ft (15 m) from uncontrolled sources of ignition, process areas, storage containers, control buildings, offices, shops, and other occupied or important plant structures unless the equipment is directly associated with the transfer operation.

N 6.6.4* Impounding areas shall be located so that the heat flux from a fire over the impounding area shall not cause major structural damage to any LNG marine carrier that could prevent its movement.

N 6.7 Buildings and Structures.

N 6.7.1 Buildings or structural enclosures not covered by Sections 12.5 through 12.7 shall be located, or provisions otherwise shall be made, to minimize the possibility of entry of flammable gases or vapors.

N 6.7.2 Buildings not covered by Sections 12.5 through 12.7 shall be located no less than 50 ft (15 m) from tanks, vessels, and gasketed or sealed connections to equipment containing LNG and other hazardous fluids.

N 6.8 Impoundment Spacing.

N 6.8.1 Impoundments shall be located such that design spill hazards do not extend offsite in accordance with Chapter 5.

N 6.8.2 Impoundments shall be located such that they meet the spacing requirements in Table 6.3.1.

N 6.8.3 Impoundments shall be at least 50 ft (15 m) from uncontrolled sources of ignition, control buildings, offices, shops, and other occupied or important plant structures.

Chapter 7 Process Equipment

7.1 Scope. This chapter applies to the requirements for the design and installation of process equipment.

N 7.1.1 General Requirement. Equipment including associated foundations shall be designed in accordance with the seismic, wind, ice, flood, and snow criteria in Section 12.2.

7.2 Installation of Process Equipment.

7.2.1 Process system equipment containing LNG or other hazardous fluids shall be installed in accordance with one of the following:

- (1) Outdoors, for ease of operation, to facilitate manual fire-fighting, and to facilitate dispersal of accidentally released liquids and gases
- (2) Indoors, in enclosing structures that comply with Sections 12.5 through 12.7

Δ 7.2.2 Welding and brazing of process equipment shall conform to the following:

- (1) Welding and brazing of process equipment shall conform to the requirements of the standard to which the equipment is designed and constructed (see 7.5.2 through 7.5.6.2).
- (2) All welding or brazing operations shall be performed with procedures qualified to Section IX of the ASME *Boiler and Pressure Vessel Code*.
- (3) All welding or brazing shall be performed by personnel qualified to the requirements of Section IX of the ASME *Boiler and Pressure Vessel Code*.

7.3* Pumps and Compressors.

N 7.3.1* Pumps and compressors shall be designed and fabricated in accordance with recognized standards.

N 7.3.2* Seals shall be designed in accordance with recognized standards.

7.3.3 Pumps and compressors shall be constructed of materials selected for compatibility with the design temperature and pressure conditions.

7.3.4* Valving shall be installed so that each pump or compressor can be isolated for maintenance.

7.3.5 Where pumps or centrifugal compressors are installed for operation in parallel, each discharge line shall be equipped with a check valve.

7.3.6 Pumps and compressors shall be provided with a pressure-relieving device on the discharge to limit the pressure to the maximum design pressure of the casing and downstream piping and equipment, unless they are designed for the maximum discharge pressure of the pumps and compressors.

7.3.7 Each pump shall be provided with a vent, relief valve, or both that will prevent overpressuring of the pump case during the maximum possible rate of cooldown.

7.3.8 Compression equipment that handles flammable gases shall be provided with vents from all points where gases normally can escape. Vents shall be piped outside of buildings to a point of safe disposal.

N 7.3.9* Blowers and fans shall be designed in accordance with recognized standards.

N 7.3.10* Turbines shall be designed in accordance with recognized standards.

N 7.3.11* Motors shall be designed in accordance with recognized standards.

7.4 Flammable Refrigerant and Flammable Liquid Storage.

N 7.4.1 Storage containers and equipment for hazardous fluids other than LNG shall comply with NFPA 30; NFPA 58; NFPA 59; API Std 2510, *Design and Construction of Liquefied Petroleum Gas (LPG) Installations*, as applicable; or Section 5.3 of this standard.

N 7.4.2* Design and specification of storage tanks for hazardous liquids shall be in accordance with recognized standards.

N 7.4.3* Venting of atmospheric and low-pressure hazardous liquid tanks shall be in accordance with recognized standards.

7.5 Process Equipment.

7.5.1 The maximum allowable working pressure shall be documented for process equipment.

7.5.2 Boilers shall be designed and fabricated in accordance with the ASME *Boiler and Pressure Vessel Code*, Section I, or with CSA B51, *Boiler, Pressure Vessel and Pressure Piping Code*.

N 7.5.3* Fired heaters shall be designed in accordance with recognized standards.

N 7.5.4* Burner management systems shall be designed in accordance with recognized standards.

Δ 7.5.5* Pressure vessels shall be designed and fabricated in accordance with Section VIII, Division 1 or Division 2, of the ASME *Boiler and Pressure Vessel Code* or with CSA B51, *Boiler, Pressure Vessel and Pressure Piping Code*, and shall be code-stamped. Pressure vessels (austenitic stainless steel) designed and manufactured utilizing cold stretching techniques shall be approved for use by the AHJ.

7.5.6* Heat exchangers shall be designed and fabricated in accordance with recognized standards.

N 7.5.6.1 Shell and tube heat exchangers shall be designed and fabricated in accordance with Section VIII, Division 1 or Division 2, of the ASME *Boiler Pressure Vessel Code* or with CSA B51, *Boiler, Pressure Vessel and Pressure Piping Code*, where such components fall within the jurisdiction of the pressure vessel code.

Δ 7.5.6.2 Brazed aluminum plate fin heat exchangers shall be designed and fabricated in accordance with Section VIII, Division 1 or Division 2, of the ASME *Boiler and Pressure Vessel Code* and ALPEMA *Standards of the Brazed Aluminum Plate-Fin Heat Exchanger Manufacturer's Association*.

7.5.7* Installation of internal combustion engines or gas turbines not exceeding 7500 horsepower per unit shall conform to NFPA 37.

N 7.5.8* Flares installed to serve as part of a system emergency depressurization or other process purposes shall be in accordance with recognized standards.

7.5.9 A boil-off and flash gas-handling system separate from container relief valves shall be installed for the safe disposal of vapors generated in the process equipment and LNG containers.

7.5.9.1 Boil-off and flash gases shall discharge into a closed system or into the atmosphere so that they do not create a hazard to people, equipment, or adjacent properties.

7.5.9.2 The boil-off venting system shall be designed so that it cannot inspire air during normal operation.

7.5.10 If internal vacuum conditions can occur in any piping, process vessels, cold boxes, or other equipment, either the piping and equipment subject to vacuum shall be designed to withstand the vacuum conditions or provision shall be made to prevent vacuum. If gas is introduced for the purpose of preventing a vacuum condition, it shall not create a flammable mixture within the system.

Chapter 8 Stationary LNG Storage

Δ 8.1 Scope. This chapter presents the requirements for the inspection, design, marking, testing, and operation of stationary LNG tank systems and ASME containers.

8.2 General.

8.2.1 Storage Tank Systems.

8.2.1.1 Storage tank systems, including membrane containment tank systems, shall comply with the requirements of API Std 625, *Tank Systems for Refrigerated Liquefied Gas Storage*, and the additional provisions of this chapter. The API Std 625 risk assessment shall be approved by the AHJ.

Δ 8.2.1.2 Metal containers that are part of an LNG storage tank system shall comply with API Std 620, *Design and Construction of Large, Welded, Low-Pressure Storage Tanks*, and the further requirements in Section 8.4.

8.2.1.3 Concrete and metal-lined composite concrete containers that are part of an LNG storage tank system shall comply with ACI 376, *Code Requirements for Design and Construction of Concrete Structures for the Containment of Refrigerated Liquefied Gases*, and the requirements of Section 8.4.

8.2.1.4 The metallic membrane, load-bearing insulation, and the outer container moisture barrier specific to the membrane tank system shall comply with EN 14620, *Design and manufacture of site built, vertical, cylindrical, flat-bottomed, steel tanks for the storage of refrigerated, liquefied gases with operating temperatures between 0°C and -165°C*, Parts 1–5, for material selection, design, installation, examination, and testing and further requirements of Section 8.4. All other components of the membrane tank system shall comply with API Std 625, *Tank Systems for Refrigerated Liquefied Gas Storage*; API Std 620, *Design and Construction of Large, Welded, Low-Pressure Storage Tanks*; ACI 376, *Code Requirements for Design and Construction of Concrete Structures for the Containment of Refrigerated Liquefied Gases*; and additional requirements in Section 8.4.

8.2.1.5 Should any conflict exist among the requirements in 8.2.1.1 through 8.4.7, the most stringent requirement shall apply.

8.2.2 ASME Containers. ASME containers shall comply with the requirements of Section 8.5 and Section VIII of the ASME *Boiler and Pressure Vessel Code* and shall be ASME-stamped and registered with the National Board of Boiler and Pressure Vessel Inspectors or other agencies that register pressure vessels.

8.3 Design Considerations.

8.3.1 General.

8.3.1.1 Those parts of LNG containers that normally are in contact with LNG and all materials used in contact with LNG or cold LNG vapor [vapor at a temperature below -20°F (-29°C)] shall be physically and chemically compatible with LNG and intended for service at -270°F (-168°C).

8.3.1.2 The density of the liquid shall be assumed to be the actual mass per unit volume at the minimum storage temperatures, except that the minimum density for design purposes shall be 29.3 lb/ft³ (470 kg/m³).

8.3.2 Wind, Flood, and Snow Loads.

Δ 8.3.2.1 The wind, flood, including hurricane storm surge, and snow loads for the design of LNG tank systems and LNG storage containers shall be determined using the procedures outlined in ASCE 7, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*, as modified in this standard.

8.3.2.1.1 For determining flood and hurricane storm surge design hazards, a 500-year mean occurrence interval including relative sea level rise and wind-driven wave effects shall be used.

N 8.3.2.1.2 For snow loads, where a probabilistic approach is used, a 100-year mean occurrence interval shall be used.

N 8.3.2.1.3 LNG tank systems and LNG containers shall be designed for or otherwise protected from wind, flood, storm surge, and snow loads.

8.3.2.2* Basic design wind speed shall be based on a 10,000-year mean occurrence interval for LNG storage containers and for structures, equipment, and piping supported by the LNG storage containers and ASCE 7, Risk Category IV for all other structures supporting equipment.

8.3.3 Marking of LNG Tank Systems and ASME Containers.

8.3.3.1 Each LNG tank system shall be identified by the attachment in an accessible location of a corrosion-resistant nameplate as defined in API Std 625, *Tank Systems for Refrigerated Liquefied Gas Storage*.

Δ 8.3.3.2 ASME containers shall be identified by the attachment of a corrosion-resistant nameplate as required by Section VIII of the ASME *Boiler and Pressure Vessel Code*.

8.3.3.3 Storage tank systems shall have all penetrations marked with the function of the penetration.

8.3.3.4 Penetration markings shall be visible if frosting occurs.

8.3.4 Foundations.

8.3.4.1* LNG containers shall be installed on foundations designed by a qualified engineer and constructed in accordance with recognized structural engineering practices.

8.3.5 Inspection.

8.3.5.1 Prior to initial operation, tank systems shall be inspected to ensure compliance with the engineering design and material, fabrication, assembly, and test provisions of this standard.

8.3.5.2 The inspection shall be conducted by inspectors who are employees of the operator, an engineering or scientific

organization, or a recognized insurance or inspection company.

8.3.5.3 Inspectors shall be qualified in accordance with the code or standard applicable to the container and as specified in this standard.

N 8.3.6 Welding on Containers after Acceptance Testing is Completed.

Δ 8.3.6.1 After acceptance tests are completed, there shall be no field welding on the LNG containers, except as permitted in **8.3.6.1.1** and **8.3.6.1.2**.

8.3.6.1.1 Field welding shall be limited to saddle plates or brackets provided for the purpose and to repairs and temporary opening restorations permitted under the code or standard of fabrication.

8.3.6.1.2 Retesting by a method appropriate to the repair or modification shall be required only where the repair or modification is of such a nature that a retest actually tests the element affected and is necessary to demonstrate the adequacy of the repair or modification.

N 8.3.7 Buried and Underground Containers.

N 8.3.7.1 Buried and underground containers shall be provided with means to prevent the 32°F (0°C) isotherm from penetrating the soil.

N 8.3.7.2 Where heating systems are used, they shall be installed such that any heating element or temperature sensor used for control can be replaced.

N 8.3.7.3* All buried or mounded components in contact with the soil shall be constructed from material resistant to soil corrosion or protected to minimize corrosion.

8.4 Tank Systems.

8.4.1 General.

8.4.1.1* Certification. Upon completion of all tests and inspections of each LNG tank system, the contractor shall certify to the purchaser that the LNG tank system has been constructed in accordance with the applicable requirements of this standard.

8.4.2 All piping that is a part of an LNG tank system shall comply with requirements in this chapter and requirements within API Std 625, *Tank Systems for Refrigerated Liquefied Gas Storage*.

8.4.2.1 Tank system piping shall include all piping internal to the container, within insulation spaces and within void spaces, external piping attached or connected to the container up to the first circumferential external joint of the piping, and external piping serving only tank system instrumentation (including tank system pressure relief valves). All liquid piping with a source of external line pressure shall be designed for the external line relief valve setting but not less than 50 psi (345 kPa). Double, full, and membrane containment tank systems shall have no pipe penetrations below the liquid level.

8.4.2.2 Inert gas purge systems wholly within the insulation spaces and relief valve discharge piping shall be exempt from compliance.

8.4.3* All LNG tank systems shall be designed for both top and bottom filling unless other process means are provided to mitigate stratification.

8.4.4 Any portion of the outer surface area of an LNG tank system or external members whose failure could result in loss of containment from accidental exposure to low temperatures resulting from the leakage of LNG or cold vapor from flanges, valves, seals, or other nonwelded connections shall be designed for such temperatures or otherwise protected from the effects of low-temperature exposure.

8.4.5 Where two or more tank systems are sited in a common dike, each tank system foundation shall be capable of withstanding contact with LNG or shall be protected against contact with an accumulation of LNG that might endanger structural integrity.

8.4.6* Provisions shall be made for removal of the tank system from service.

8.4.7 All the membrane tank system components, including insulation, primary membrane, and the secondary barrier of the thermal protection system where required, shall be designed in such a way that they can withstand all credible combinations of static and dynamic actions throughout the tank system lifetime.

8.4.8 Container Insulation.

8.4.8.1 Exposed insulation shall be noncombustible, shall contain or inherently shall be a vapor barrier, shall be water-free, and shall resist dislodgment by fire hose streams.

8.4.8.1.1 Where an outer shell is used to retain loose insulation, the shell shall be constructed of steel or concrete.

8.4.8.1.2 Exposed weatherproofing shall have a flame spread index not greater than 25. (See 3.3.14.)

8.4.8.2 The space between the inner container and the outer container shall contain insulation that is compatible with LNG and natural gas and that is noncombustible as installed for all conditions in service and meet the requirements in 8.4.8.2.1 through 8.4.8.2.6.

8.4.8.2.1 A fire external to the outer container shall not cause damage to the insulation system and a reduction to the internal containment system performance due to damage to any component of the insulation systems.

8.4.8.2.2 The load-bearing bottom insulation shall be designed and installed so that cracking from thermal and mechanical stresses does not jeopardize the integrity of the container.

8.4.8.2.3 It shall be shown by test that the combustion properties of the material do not increase significantly as a result of long-term exposure to LNG or natural gas at the anticipated service pressure and temperature.

N 8.4.8.2.4 The materials in the installed condition shall be demonstrated to be capable of being purged of natural gas to the point where the natural gas remaining after purging does not increase the combustibility of the material.

8.4.8.2.5 The materials in the installed condition shall not support continued progressive combustion in air.

8.4.8.2.6 The following mitigation measures are to be provided during construction and after decommissioning for repair work:

- (1) No hot work, which can cause insulation combustion, shall be performed in the vicinity of insulation after it's installed or after decommissioning for repair work unless insulation is properly protected from ignition sources.
- (2) Any tool or equipment used during insulation construction or repair that has potential to introduce hazardous levels of heat to combustible insulation components shall require fail-safe temperature controls to ensure that applied heat does not exceed required limits.
- (3) The repair procedures in insulation vicinity shall be approved by the AHJ.

8.4.8.3 Tank systems insulation shall meet the requirements of Section 9 of API Std 625, *Tank Systems for Refrigerated Liquefied Gas Storage*.

8.4.9 Container Drying, Purging, and Cooldown. Before an LNG tank system is put into service, it shall be dried, purged, and cooled in accordance with 18.3.5 and 18.6.5, and tank systems shall include the provisions within API Std 625, *Tank Systems for Refrigerated Liquefied Gas Storage*, and/or ACI 376, *Code Requirements for Design and Construction of Concrete Structures for the Containment of Refrigerated Liquefied Gases*, as applicable to the type of tank system construction.

8.4.10 Relief Devices.

8.4.10.1 All LNG containers shall be equipped with vacuum and pressure relief valves as required by the code or standard of manufacture.

8.4.10.2 In-service pressure and vacuum relief devices shall communicate directly with the atmosphere.

8.4.10.3 Vacuum-relieving devices shall be installed if the container can be exposed to a vacuum condition in excess of that for which the container is designed.

8.4.10.4 Each pressure and vacuum safety relief valve for LNG tank systems shall be able to be isolated from the tank systems for maintenance or other purposes by means of a manual full-opening stop valve.

8.4.10.4.1 The stop valve(s) shall be lockable or sealable in the fully open position.

8.4.10.4.2 Pressure and vacuum relief valves shall be installed on the LNG tank system to allow each relief valve to be isolated individually while maintaining the required relieving capacity.

8.4.10.4.3 Where only one relief device is required, either a full-port opening three-way valve connecting the relief valve and its spare to the container or two relief valves separately connected to the container, each with a valve, shall be installed.

8.4.10.4.4 No more than one stop valve shall be closed at one time.

8.4.10.4.5 Safety relief valve discharge stacks or vents shall be designed and installed to prevent an accumulation of water, ice, snow, or other foreign matter and shall discharge vertically upward.

8.4.10.5 Pressure Relief Device Sizing.

8.4.10.5.1 The capacity of pressure relief devices shall be based on the following:

- (1) Fire exposure
- (2) Operational upset, such as failure of a control device
- (3) Other circumstances resulting from equipment failures and operating errors
- (4) Vapor displacement during filling
- (5) Flash vaporization during filling, as a result of filling or as a consequence of mixing of products of different compositions
- (6) Loss of refrigeration
- (7) Heat input from pump recirculation
- (8) Drop in barometric pressure

8.4.10.5.2 Pressure relief devices shall be sized to relieve the flow capacity determined for the largest single relief flow or any reasonable and probable combination of relief flows.

8.4.10.5.3* The minimum pressure-relieving capacity in pounds per hour (kilograms per hour) shall not be less than 3 percent of the full tank system contents in 24 hours.

8.4.10.6 Vacuum Relief Sizing.

8.4.10.6.1 The capacity of vacuum relief devices shall be based on the following:

- (1) Withdrawal of liquid or vapor at the maximum rate
- (2) Rise in barometric pressure
- (3) Reduction in vapor space pressure as a result of filling with subcooled liquid

8.4.10.6.2 The vacuum relief devices shall be sized to relieve the flow capacity determined for the largest single contingency or any reasonable and probable combination of contingencies, less the vaporization rate that is produced from the minimum normal heat gain to the container contents.

8.4.10.6.3 No vacuum relief capacity credit shall be allowed for gas-repressuring systems or vapor makeup systems.

8.4.10.7 Fire Exposure.

8.4.10.7.1 The pressure-relieving capacity required for fire exposure shall be computed by the following formulas:

For U.S. customary units:

$$H = 34,500 FA^{0.82} + H_n \quad [8.4.10.7.1a]$$

For SI units:

$$H = 71,000 FA^{0.82} + H_n \quad [8.4.10.7.1b]$$

where:

H = total heat influx [Btu/hr (watt)]

F = environmental factor from Table 8.4.10.7.1

A = exposed wetted surface area of the container [ft² (m²)]

H_n = normal heat leak in refrigerated tanks [Btu/hr (watt)]

Table 8.4.10.7.1 Environmental Factors

Basis	F Factor
Base container	1.0
Water application facilities	1.0
Depressuring and emptying facilities	1.0
Underground container	0
Insulation or thermal protection*	
U.S. customary units	$F = \frac{U(1660 - T_f)}{34,500}$
SI units	$F = \frac{U(904 - T_f)}{71,000}$

* U = overall heat transfer coefficient Btu/(hr · ft² · °F) [W/(m² · °C)] of the insulation system using the mean value for the temperature range from T_f to +1660°F (904°C); T_f = temperature of vessel content at relieving conditions, °F (°C).

8.4.10.7.2 The exposed wetted area shall be the area up to a height of 30 ft (9 m) above grade.

8.4.10.7.3* Where used, insulation shall resist dislodgment by fire-fighting equipment, shall be noncombustible, and shall not decompose at temperatures up to 1000°F (538°C) in order for the environmental factor for insulation to be used.

8.4.10.7.4 Pressure Relief Valve Capacity.

8.4.10.7.4.1 The relieving capacity shall be determined by the following formula:

[8.4.10.7.4.1]

$$W = \frac{H}{L}$$

where:

W = relieving capacity of product vapor at relieving conditions [lb/hr (g/s)]

H = total heat influx, Btu/hr (watt)

L = latent heat of vaporization of the stored liquid at the relieving pressure and temperature, Btu/lb (J/g)

8.4.10.7.4.2 The equivalent airflow shall be calculated from the following formulas:

For U.S. customary units:

[8.4.10.7.4.2a]

$$Q_a = 3.09W \frac{\sqrt{TZ}}{\sqrt{M}}$$

For SI units:

[8.4.10.7.4.2b]

$$Q_a = 0.93W \frac{\sqrt{TZ}}{\sqrt{M}}$$

where:

Q_a = equivalent flow capacity of air at 60°F (15°C) and absolute pressure of 14.7 psi (101 kPa) [ft³/hr (m³/hr)]

W = relieving capacity of product vapor at relieving conditions [lb/hr (g/s)]

T = absolute temperature of product vapor at relieving conditions [°R (K)]

Z = compressibility factor of product vapor at relieving condition

M = product vapor molecular mass [lbm/lb mol (g/g mol)]

8.4.11 Foundations.

8.4.11.1 Tank systems foundations shall be designed in accordance with ACI 376, *Code Requirements for Design and Construction of Concrete Structures for the Containment of Refrigerated Liquefied Gases*.

8.4.11.2 Investigation and Evaluation.

8.4.11.2.1 Prior to the start of design and construction of the foundation, a subsurface investigation and evaluation shall be conducted by a geotechnical engineer to determine the stratigraphy and physical properties of the soils underlying the site.

8.4.11.2.2 A liquefaction evaluation in accordance with 11.8.3 of ASCE 7, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*, shall be included as part of the evaluation in 8.4.11.2.1.

8.4.11.3 The bottom of the outer container shall be above the groundwater table or protected from contact with groundwater at all times.

8.4.11.4 The outer container bottom material in contact with soil shall meet one of the following requirements:

- (1) Selected to minimize corrosion
- (2) Coated or protected to minimize corrosion
- (3)* Protected by a cathodic protection system

8.4.11.5 Where no air gap exists under the tank system foundation, a heating system shall be provided to prevent the 32°F (0°C) isotherm from penetrating the soil.

8.4.11.5.1 The heating system shall be designed to allow functional and performance monitoring.

8.4.11.5.2 Where there is a discontinuity in the foundation, such as for bottom piping, attention and separate treatment shall be given to the heating system in this zone.

8.4.11.5.3 Heating systems shall be designed, selected, and installed so that any heating element and temperature sensor used for control can be replaced after installation.

8.4.11.5.4* Provisions shall be incorporated to prevent moisture accumulation in the conduit.

8.4.11.6 If the foundation is designed to provide air circulation in lieu of a heating system, the bottom of the outer container shall be of a material compatible with the temperatures to which it can be exposed.

8.4.11.7 A container bottom temperature monitoring system capable of measuring the temperature on a predetermined pattern over the entire surface area in order to monitor the performance of the bottom insulation and the container foundation heating system (if provided) shall be installed.

8.4.11.8 Benchmarks for foundation elevation surveys shall be installed and used before, during, and after hydrostatic testing, and at three-month intervals until the settlement has become predictable.

8.4.12 Metal Containers.

8.4.12.1 Welded containers designed for not more than 15 psi (103 kPa) shall comply with API Std 620, *Design and Construction of Large, Welded, Low-Pressure Storage Tanks*.

8.4.12.2* Appendix Q of API Std 620, *Design and Construction of Large, Welded, Low-Pressure Storage Tanks*, shall be applicable for LNG, except that the frequency of examination by radiography or ultrasonic methods in primary and secondary liquid containers shall be increased to 100 percent for all butt welds in the cylindrical shell (except for the shell-to-bottom welds associated with a flat bottom container) and all butt-welded annular plate radial joints.

8.4.12.3 Weld Procedure and Production Weld Testing for Membrane Containment Tank Systems. For membrane containment tank systems, weld procedure and production weld testing shall comply with EN 14620, *Design and manufacture of site built, vertical, cylindrical, flat-bottomed, steel tanks for the storage of refrigerated, liquefied gases with operating temperatures between 0°C and -165°C*, Part 2, and the requirements in 8.4.12.3.1 through 8.4.12.3.5.

8.4.12.3.1 Qualification of Welders. All personnel associated with the welding fabrication of the membrane system shall be qualified by the manufacturer per an agreed-upon schedule between the purchaser, the AHJ, and the fabricator, and all records shall be available for review.

8.4.12.3.2 Inspection. One hundred percent of all welds shall be visually examined for workmanship and conformance to the fabrication requirements by a qualified welding inspector.

8.4.12.3.2.1 Bead placement and consistency shall be, at a minimum, documented by digital means for review by supervisory personnel.

8.4.12.3.2.2 Upon cooldown of the welds to room temperature, provisions shall be made to perform a penetrant test (PT) of at least 5 percent of each weld type each day, subject to the following requirements:

- (1) Selection factors shall include orientation, welding direction, and the complexity of the welding being performed.
- (2) All profiles and configurations of welds shall be subjected to the 5 percent requirement, and the selection of this 5 percent sample shall be agreed upon by the fabricator, the customer's representative, and the AHJ.
- (3) The acceptance standard for this inspection technique shall be agreed upon by all parties.

- (4) Any indication of a leak shall require an additional 5 percent PT of the total distance welded by each welder.

8.4.12.3.2.3 Inspection after completion of the membrane shall include a leakage test in parallel with a mechanical stress test as follows:

- (1) The leakage test procedure shall be agreed upon by the manufacturer and the customer and approved.
- (2) Tracer gas for the leak test shall be in accordance with an approved procedure.
- (3) Mechanical stress testing of the welding joints shall be performed by applying three cycles from atmospheric pressure to +20 mbarg inside the insulation space, with the pressure maintained, for a minimum time of 30 minutes, and the data shall be recorded.
- (4) All areas where leakage occurs shall be repaired and inspected per 8.4.12.3.2 and the manufacturer's procedure.

8.4.12.3.3 Post-Repair Inspection.

8.4.12.3.3.1 Additional tracer gas testing shall be performed if more than four leaks per 1000 m² of membrane are identified.

8.4.12.3.3.2 All repaired areas shall be visually inspected (VT), vacuum box (VB) tested, and dye penetrant (PT) tested.

8.4.12.3.4 Final Global Test. The final acceptance testing of the completed membrane structure following completion of its installation in the structural outer shell/container shall be in agreement with the approved test procedure and witnessed by all relevant parties and performed as follows:

- (1) The overall tightness of the membrane shall be determined by establishing a pressure difference between the tank and the insulation space, which allows gas flow through the membrane representative of potential leaks on the membrane.
- (2) The potential leak(s) shall be characterized by measuring the oxygen content increase in the primary insulated space as the tank is pressurized with dry air.
- (3) The primary insulated space shall be regulated above the ambient pressure.
- (4) All test data, records, documentation, and witness records shall be submitted to all parties for review and final acceptance.

8.4.12.3.5 Control During Removal of Construction Equipment.

8.4.12.3.5.1 A daily tightness check and monitoring shall be performed during removal of construction equipment by pulling vacuum inside insulated spaces.

8.4.12.3.5.2 Any pressure rise, which is indicative of a leak, shall be reported and corrective action shall be taken.

8.4.13 Concrete Containers.

8.4.13.1 The design, construction, inspection, and testing of concrete containers shall comply with ACI 376, *Code Requirements for Design and Construction of Concrete Structures for the Containment of Refrigerated Liquefied Gases*.

8.4.13.2 A tank system with unlined concrete primary liquid containment shall include a means of detecting and eliminating liquid accumulation in the annular space.

8.4.13.3 Non-metallic coatings placed on a concrete container acting as a moisture and/or product vapor barrier shall meet

the criteria in ACI 376, *Code Requirements for Design and Construction of Concrete Structures for the Containment of Refrigerated Liquefied Gases*.

8.4.13.4 Metallic barriers incorporated in, and functioning compositely with, concrete containers shall be of a metal defined in Appendix Q of API Std 620, *Design and Construction of Large, Welded, Low-Pressure Storage Tanks*.

8.4.14 Seismic Design of Land-Based Field-Fabricated Tank Systems.

8.4.14.1 A site-specific investigation shall be performed for all installations except those provided for in 8.5.2 to determine the characteristics of seismic ground motion and associated response spectra.

▲ **8.4.14.1.1** The site-specific investigation performed in accordance with ASCE 7, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*, shall account for the regional seismicity and geology, the expected recurrence rates and maximum magnitudes of events on known faults and source zones, the location of the site with respect to these seismic sources, near source effects, if any, and the characteristics of subsurface conditions.

▲ **8.4.14.1.2** On the basis of the site-specific investigation, the ground motion of a maximum considered earthquake (MCE_R) shall be the motion having a 2 percent probability of exceedance within a 50-year period (mean recurrence interval of 2475 years), adjusted by the requirements of ASCE 7, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*.

N 8.4.14.1.3 Maximum Considered Tsunamis.

N 8.4.14.1.3.1 The maximum considered tsunamis (MCT_R) shall be based on a 2 percent probability of exceedance within a 50-year period (i.e., mean recurrence interval of 2,475 years), adjusted by the requirements of ASCE 7, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*.

N 8.4.14.1.3.2 The LNG outer container foundation shall be designed or otherwise protected from tsunami wave effects in accordance with the requirements of ASCE 7, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*.

8.4.14.1.4 For the MCE_R ground motion, vertical and horizontal acceleration response spectra shall be constructed covering the entire range of anticipated damping ratios and natural periods of vibration, including the fundamental period and damping ratio for the sloshing (convective) mode of vibration of the contained LNG.

▲ **8.4.14.1.5** The MCE_R response spectral acceleration for any period, T , shall correspond to a damping ratio that best represents the structure being investigated as specified in Appendix L of API Std 620, *Design and Construction of Large, Welded, Low-Pressure Storage Tanks*, and ACI 376, *Code Requirements for Design and Construction of Concrete Structures for the Containment of Refrigerated Liquefied Gases*.

8.4.14.1.6 Vertical Response Spectrum.

N 8.4.14.1.6.1 If information is not available to develop a vertical response spectrum, the ordinates of the vertical response spectrum shall not be less than two-thirds of those of the horizontal spectrum.

N 8.4.14.1.6.2 If information is available, the corresponding ratio shall not be less than one-half.

8.4.14.2 The LNG tank systems and their impounding systems shall be designed for the following three levels of seismic ground motion:

- (1) Safe shutdown earthquake (SSE) as defined in 8.4.14.3
- (2) Operating basis earthquake (OBE) as defined in 8.4.14.4
- (3) Aftershock level earthquake (ALE) as defined in 8.4.14.5

8.4.14.3 The SSE shall be represented by a ground motion response spectrum in which the spectral acceleration at any period, T , shall be equal to the spectral acceleration of the MCE_R ground motion defined in 8.4.14.1.

▲ **8.4.14.4*** The OBE ground motion shall be the motion represented by an acceleration response spectrum having a 10 percent probability of exceedance within a 50-year period (mean return interval of 475 years) that represents the maximum response in the horizontal plane. If a site-specific analysis is carried out, the site-specific OBE spectra shall represent the maximum response. The site-specific OBE spectra shall not be less than 80 percent of the USGS spectra, or equivalent, adjusted for local site conditions and scaled to the maximum response in accordance with Chapter 21.2 of ASCE 7, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*.

8.4.14.5 The ALE ground motion is defined as one-half SSE.

▲ **8.4.14.6** The three levels of ground motion defined in 8.4.14.3 through 8.4.14.5 shall be used for the earthquake-resistant design of the following structures and systems:

- (1) LNG tank systems and their impounding systems
- (2) System components required to isolate the LNG tank system and maintain it in a safe shutdown condition
- (3) Structures or systems, including fire protection systems, the failure of which could affect the integrity of 8.4.14.6(1) or 8.4.14.6(2)

8.4.14.6.1 The structures and systems shall be designed to remain operable during and after an OBE.

8.4.14.6.2 The OBE design shall be based on a response reduction factor equal to 1.0.

8.4.14.6.3 The SSE design shall provide for no loss of containment capability of the primary container of single, double, and full containment tank systems and of the metal liquid barrier of membrane tank systems, and it shall be possible to isolate and maintain the LNG tank systems during and after the SSE.

8.4.14.6.4 Response Reduction Factors.

N 8.4.14.6.4.1 Where used, response reduction factors applied in the SSE design shall be demonstrated not to reduce the performance criteria in 8.4.14.6.3.

N 8.4.14.6.4.2 The values in Appendix L of API Std 620, *Design and Construction of Large, Welded, Low-Pressure Storage Tanks*, shall be considered compliant for steel containers of the tank systems, and Section 8 of ACI 376, *Code Requirements for Design and Construction of Concrete Structures for the Containment of Refrigerated Liquefied Gases*, shall be considered compliant for concrete container(s) of the tank system.

8.4.14.7 The secondary liquid container or impounding system for single, double, or full containment tanks shall, as a minimum, be designed to withstand an SSE while empty and an ALE while holding a volume equivalent to the primary containment liquid at the maximum normal operating level as defined in API Std 625, *Tank Systems for Refrigerated Liquefied Gas Storage*.

8.4.14.8 Membrane Tank System.

N 8.4.14.8.1 For the membrane tank system, all components of the product-containing structure, including the liquid barrier, insulation system, thermal corner protection system (see 8.4.16.1) where required, and the outer concrete container, shall be designed to withstand without loss of function an SSE event with the tank filled to the maximum normal operating level.

N 8.4.14.8.2 The outer concrete container and the thermal corner protection shall be designed to withstand an ALE with a tank full to the maximum normal operating level assuming that the membrane has failed and that the outer concrete container wall and thermal corner protection system are exposed to LNG.

8.4.14.9 An LNG tank system shall be designed for the OBE, SSE, and ALE in accordance with API Std 620, *Design and Construction of Large, Welded, Low-Pressure Storage Tanks*, and ACI 376, *Code Requirements for Design and Construction of Concrete Structures for the Containment of Refrigerated Liquefied Gases*.

8.4.14.10 After an event exceeding OBE, the tank system shall be evaluated for safe continued operation. After an SSE event, the container shall be emptied and inspected prior to resumption of container-filling operations.

8.4.14.11 The design of the LNG tank systems and structural components shall be in accordance with API Std 620, *Design and Construction of Large, Welded, Low-Pressure Storage Tanks*, or ACI 376, *Code Requirements for Design and Construction of Concrete Structures for the Containment of Refrigerated Liquefied Gases*.

N 8.4.14.11.1 Soil-structure interaction (SSI) shall be included where the tank system is not founded on bedrock (Site Class A or B per ASCE 7, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*).

N 8.4.14.11.2 SSI shall be permitted to be performed in accordance with the requirements of ASCE 7, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*.

N 8.4.14.11.3 Reductions in seismic design loads due to SSI effects shall not exceed those permitted by ASCE 7, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*.

8.4.14.12 The outer concrete container analysis and design for the leak and leak plus ALE event shall take into account any damage that might have occurred to the outer concrete container due to prior events, including the SSE earthquake.

8.4.14.12.1 The outer concrete container shall be considered as undamaged during the prior SSE event if the following conditions are met:

- (1) Tensile stresses in the reinforcing steel do not exceed 90 percent of the reinforcing steel yield.
- (2) Maximum concrete compressive stresses do not exceed 85 percent of the concrete design compressive strength.

8.4.14.12.2 If the conditions in 8.4.14.12.1 are not met, the prior damage shall be taken into account in the spill analysis.

8.4.14.13 Instrumentation capable of measuring the ground motion to which tank systems are subjected shall be provided on the site.

8.4.15 Testing of LNG Containers.

Δ 8.4.15.1 The LNG primary container shall be hydrostatically tested and leak tested in accordance with the governing construction code or standard and all leaks shall be repaired.

8.4.15.2 The tank system designer shall provide a test procedure based on the applicable construction standard.

8.4.15.3* Membrane containment tank systems shall be tested in accordance with EN 14620, *Design and manufacture of site built, vertical, cylindrical, flat-bottomed, steel tanks for the storage of refrigerated, liquefied gases with operating temperatures between 0°C and -165°C*, Part 5, Table 1, as follows:

- (1) The leakage test, as defined in the Note under EN 14620, Part 5, paragraph 4.1.1, shall be performed.
- (2) Leakage through the membrane to the insulation space during service shall be controlled in order to maintain a gas concentration level below 30 percent of the lower explosive limit (LEL) by sweeping the insulated space with an inert gas.
- (3) If the gas concentration cannot be maintained below 30 percent of the LEL, the tank shall be decommissioned and retested.
- (4) For purposes of evaluating the 30 percent level, the flow of purge gas within the annular space shall not be increased above the normal operating rate.

8.4.15.4 Verification of all components of the membrane containment tank system design by experimental data from model tests shall be carried out.

• 8.4.16 Additional Requirements for Membrane Containment Tank Systems.

Δ 8.4.16.1 A thermal corner protection system functionally equivalent to the thermal corner protection system for concrete containers, as defined in Section 6 of API Std 625, *Tank Systems for Refrigerated Liquefied Gas Storage*, and if required by ACI 376, *Code Requirements for Design and Construction of Concrete Structures for the Containment of Refrigerated Liquefied Gases*, shall be provided for the outer concrete container of the membrane tank system where the concrete-to-base slab joint cannot maintain liquid tightness under the spill condition.

N 8.4.16.1.1 Thermal Corner Protection.

N 8.4.16.1.1.1 The thermal corner protection shall protect the entire bottom of the outer container and at least the lower 16.5 ft (5 m) of the wall necessary thermally isolate from the cold liquid and provide liquid tightness at the monolithic or pinned wall-to-slab junction.

N 8.4.16.1.1.2 The thermal corner protection shall be liquid-tight where in contact with LNG.

Δ 8.4.16.1.2 The thermal corner protection system shall be permitted to be either metallic or made from nonmetallic materials compatible with LNG and shall maintain structural integrity and liquid tightness under all applicable mechanical and thermal loads.

8.4.16.1.3 Tests.

N 8.4.16.1.3.1 The membrane containment tank system supplier shall provide tests independently witnessed and verified by a third-party agency clearly demonstrating the liquid leak-tightness of all the thermal corner protection system under spill conditions.

N 8.4.16.1.3.2 Historical tests shall be acceptable provided that construction processes and materials of construction are the same as those proposed.

8.4.16.1.4 Nondestructive examination (NDE) performed on the secondary barrier and NDE acceptance criteria shall ensure that the provided liquid tightness is equivalent to the liquid tightness provided by the metallic thermal corner protection system of the full containment tank system.

8.4.16.2 The outer concrete container of the membrane containment tank system shall meet all requirements of ACI 376, *Code Requirements for Design and Construction of Concrete Structures for the Containment of Refrigerated Liquefied Gases*, for the secondary concrete container, including materials, design, construction, inspection, and testing and the additional requirements specified in 8.4.16.2.1 through 8.4.16.2.5.

8.4.16.2.1 Liquid Product Pressure.

N 8.4.16.2.1.1 The pressure of the liquid product shall be a design load for the outer concrete container.

N 8.4.16.2.1.2 The liquid product pressure ultimate limit state (ULS) load factors for operating and abnormal loading conditions shall be in accordance with Table 7.2 of ACI 376, *Code Requirements for Design and Construction of Concrete Structures for the Containment of Refrigerated Liquefied Gases*.

8.4.16.2.2 Concrete Container Wall.

N 8.4.16.2.2.1 The outer concrete container wall and slab-to-wall junction shall be checked for fatigue assuming a minimum of four full load-unload cycles a week for the expected life of the tank system.

N 8.4.16.2.2.2 Performance criteria of Appendix C of ACI 376, *Code Requirements for Design and Construction of Concrete Structures for the Containment of Refrigerated Liquefied Gases*, shall apply.

8.4.16.2.3 The outer concrete container wall shall resist the specified impact load without perforation and scabbing.

Δ 8.4.16.2.3.1 The concrete wall thickness shall be at least 40 percent greater than the scabbing depth calculated per Section 4.1.2.2 of CEB 187, *Concrete Structures Under Impact and Impulsive Loading — Synthesis Report*.

Δ 8.4.16.2.3.2 The concrete wall thickness shall be at least 20 percent greater than the perforation thickness calculated per Section 4.1.1.1 of CEB 187, *Concrete Structures Under Impact and Impulsive Loading — Synthesis Report*.

Δ 8.4.16.2.3.3 The concrete wall shall be designed so that either one of the following conditions is satisfied:

- (1) The distance between the outer face of the concrete container and the centroid of the pre-stressing tendons is greater than the penetration depth calculated per Section 4.1.2.1 of CEB 187, *Concrete Structures Under Impact and Impulsive Loading — Synthesis Report*, with the following allowances for uncertainty:

- (a) 20 percent thicker than the penetration depth where $z > 0.75$
- (b) 50 percent thicker than the penetration depth where $z \leq 0.75$
- (2) The concrete wall is designed to be able to resist normal operating loads with any one horizontal tendon completely ineffective.

8.4.16.2.3.4 For concrete walls post-tensioned with a wire wrapping system, the wall shall be designed to resist normal operating loads with the wires affected by a specified impact load considered completely ineffective. No unwrapping of the post-tensioning wires shall be allowed.

8.4.16.2.4 At a minimum, the outer concrete container for the membrane tank system shall meet the construction tolerances specified in ACI 376, *Code Requirements for Design and Construction of Concrete Structures for the Containment of Refrigerated Liquefied Gases*. Where more stringent tolerances are required by the membrane and insulation systems, those more stringent tolerances shall be specified by the membrane tank engineer and met by the tank contractor.

8.4.16.2.5 The outer concrete container shall be hydrotested prior to membrane and insulation installation following the primary container hydrotest requirements of API Std 625, *Tank Systems for Refrigerated Liquefied Gas Storage*, Section 10.

8.5 ASME Containers.

8.5.1 General.

8.5.1.1 ASME containers used for the storage of LNG shall be either of the following:

- (1) Double-walled, with the inner container holding the LNG surrounded by insulation contained in the outer container as specified in 8.5.1.3 and 8.5.1.4
- (2) Single-walled, if designed and fabricated according to the criteria that is specified in 8.5.1.5

8.5.1.2 The insulation shall be evacuated or purged.

8.5.1.3 The inner container shall be of welded construction and in accordance with Section VIII of the ASME *Boiler and Pressure Vessel Code* and shall be ASME-stamped and registered with the National Board of Boiler and Pressure Vessel Inspectors or other agencies that register pressure vessels.

Δ 8.5.1.3.1 Where vacuum is utilized for insulation purposes, the design pressure of the inner container shall be the sum of the required working pressure (absolute) and the hydrostatic head of LNG.

8.5.1.3.2 Where vacuum is not utilized as part of the insulation, the design pressure shall be the sum of the required working gauge pressure and the hydrostatic head of LNG.

8.5.1.3.3 The inner container shall be designed for the most critical combination of loading resulting from internal pressure and liquid head, the static insulation pressure, the insulation pressure as the container expands after an in-service period, the purging and operating pressure of the space between the inner and outer containers, and seismic loads.

N 8.5.1.3.4 The inner vessel relief devices shall be sized in accordance with 8.4.10.5 or with CGA S-1.3, *Pressure Relief Device Standards — Part 3 — Stationary Storage Containers for Compressed Gases*.