

# NFPA 59A

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

2006 Edition



NFPA, 1 Batterymarch Park, Quincy, MA 02169-7471  
An International Codes and Standards Organization

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## NFPA 59A

### Standard for the

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

### 2006 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 and acted on by NFPA at its June Association Technical Meeting held June 6–10, 2005, in Las Vegas, NV. It was issued by the Standards Council on July 29, 2005, with an effective date of August 18, 2005, and supersedes all previous editions.

This edition of NFPA 59A was approved as an American National Standard on August 18, 2005.

### 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 the 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, this 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 its standard 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 this purpose. The 1971 edition was the first edition developed under the broadened scope. Subsequent editions were adopted in 1972, 1975, 1979, 1985, 1990, 1994, 1996, and 2001.

The 2006 edition includes revisions in compliance with the *Manual of Style for NFPA Technical Committee Documents*, such as providing only administrative requirements in Chapter 1, referenced publications in Chapter 2, definitions in Chapter 3, and general requirements in Chapter 4. Former Chapters 2 through 11 have been renumbered as Chapters 5 through 14. In addition, editorial revisions were made to make the text more clear.

Chapter 5 has been revised to cover double and full containment LNG storage containers. Definitions of these types of containers have also been added to the standard. Seismic design criteria for LNG containers have been revised to correlate with the requirements of ASCE 7, *Minimum Design Loads for Buildings and Other Structures*. Chapter 11 has been revised to add requirements for a contingency plan for potential LNG marine transfer incidents.

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NOTE: Membership on a committee shall not in and of itself constitute an endorsement of the Association or any document developed by the committee on which the member serves.

**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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## Standard for the

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

## 2006 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 mandatory extracts are given in Chapter 2 and those for nonmandatory extracts are given in Annex E. Editorial changes to extracted material consist of revising references to an appropriate division in this document or the inclusion of the document number with the division number when the reference is to the original document. 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 E.

## Chapter 1 Administration

## 1.1\* Scope.

1.1.1 This standard shall apply to the following:

- (1) Facilities that liquefy natural gas
- (2) Facilities that store, vaporize, transfer, and handle liquefied natural gas (LNG)
- (3) The training of all personnel involved with LNG
- (4) The design, location, construction, maintenance, and operation of all LNG facilities

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. (Reserved)

**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.

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

**1.5.1** Where clearance distances are to be determined, the conversion from U.S. customary units to SI units shall be calculated to the nearest 0.5 m.

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

**1.6 Referenced Standards.** Reference shall be 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.

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

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

**1.6.3** 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 10, *Standard for Portable Fire Extinguishers*, 2002 edition.

NFPA 11, *Standard for Low-, Medium-, and High-Expansion Foam*, 2005 edition.

NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*, 2005 edition.

NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems*, 2004 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 2002 edition.

NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, 2003 edition.

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*, 2001 edition.

NFPA 16, *Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems*, 2003 edition.

NFPA 17, *Standard for Dry Chemical Extinguishing Systems*, 2002 edition.

NFPA 20, *Standard for the Installation of Stationary Pumps for Fire Protection*, 2003 edition.

NFPA 22, *Standard for Water Tanks for Private Fire Protection*, 2003 edition.

NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*, 2002 edition.

NFPA 30, *Flammable and Combustible Liquids Code*, 2003 edition.

NFPA 37, *Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines*, 2002 edition.

NFPA 54, *National Fuel Gas Code*, 2006 edition.

NFPA 58, *Liquefied Petroleum Gas Code*, 2004 edition.

NFPA 59, *Utility LP-Gas Plant Code*, 2004 edition.

NFPA 70, *National Electrical Code*<sup>®</sup>, 2005 edition.

NFPA 72<sup>®</sup>, *National Fire Alarm Code*<sup>®</sup>, 2002 edition.

NFPA 101<sup>®</sup>, *Life Safety Code*<sup>®</sup>, 2006 edition.

NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*, 2006 edition.

NFPA 385, *Standard for Tank Vehicles for Flammable and Combustible Liquids*, 2000 edition.

NFPA 600, *Standard on Industrial Fire Brigades*, 2005 edition.

NFPA 1221, *Standard for the Installation, Maintenance, and Use of Emergency Services Communications Systems*, 2002 edition.

NFPA 1901, *Standard for Automotive Fire Apparatus*, 2003 edition.

NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems*, 2004 edition.

NFPA 5000<sup>®</sup>, *Building Construction and Safety Code*<sup>®</sup>, 2006 edition.

## 2.3 Other Publications.

**2.3.1 ACI Publications.** American Concrete Institute, P.O. Box 9094, Farmington Hills, MI 48333.

ACI 301, *Specifications for Structural Concrete*, 1999.

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

ACI 311.4R, *Guide for Concrete Inspection*, 2000.

ACI 318, *Building Code Requirements for Reinforced Concrete*, 2005.

ACI 318R, *Building Code Requirements for Structural Concrete*, 2005.

ACI 350, *Code Requirements for Environmental Engineering Concrete Structures*, 2001.

ACI 372R, *Design and Construction of Circular Wire- and Strand-Wrapped Prestressed Concrete Structures*, 2003.

ACI 373R, *Design and Construction of Circular Prestressed Concrete Structures with Circumferential Tendons*, 1997.

ACI 506.2, *Specification for Materials, Proportioning, and Application of Shotcrete*, 1995.

**2.3.2 API Publications.** American Petroleum Institute, 1220 L Street, N.W., Washington, DC 20005-4070.

API 6D, *Specification for Pipeline Valves*, 1994.

API 620, *Design and Construction of Large, Welded, Low-Pressure Storage Tanks*, 1990.

API 2510, *Design and Construction of Liquefied Petroleum Gas (LPG) Installations*, 1989.

**2.3.3 ASCE Publication.** American Society of Civil Engineers, 1801 Alexander Bell Drive, Reston, VA 20191.

ASCE 7, *Minimum Design Loads for Buildings and Other Structures*, 2002.

**2.3.4 ASME Publications.** American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5990.

ASME Boiler and Pressure Vessel Code, 2004.

ASME B 31.3, *Process Piping*, 2004.

ASME B 31.5, *Refrigeration Piping*, 2001.

ASME B 31.8, *Gas Transmission and Distribution Piping Systems*, 2003.

**2.3.5 ASTM Publications.** American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM A 82, *Standard Specification for Steel Wire, Plain, for Concrete Reinforcement*, 2002.

ASTM A 416, *Standard Specification for Steel Strand, Uncoated Seven-Wire for Prestressed Concrete*, 2002.

ASTM A 421, *Standard Specification for Uncoated Stressed-Relieved Steel Wire for Prestressed Concrete*, 2002.

ASTM A 496, *Standard Specification for Steel Wire, Deformed, for Concrete Reinforcement*, 2002.

ASTM A 615, *Standard Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement*, 2004.

ASTM A 722, *Standard Specification for Uncoated High-Strength Steel Bar for Prestressing Concrete*, 2005.

ASTM A 821, *Standard Specification for Steel Wire, Hand Drawn for Prestressing Concrete Tanks*, 1999.

ASTM A 966, *Standard Specification for Rail-Steel and Axle-Steel Deformed Bars for Concrete Reinforcement*, 2004.

ASTM A 1008, *Standard Specification for Steel, Sheet, Cold-Rolled, Carbon, Structural, High-Strength Low-Alloy and High-Strength Low-Alloy with Improved Formability*, 2005.

ASTM C 33, *Standard Specification for Concrete Aggregates*, 2003.

**2.3.6 CGA Publications.** Compressed Gas Association, 4221 Walney Road, 5th Floor, Chantilly, VA 20151-2923.

CGA 341, *Standard for Insulated Cargo Tank Specification for Cryogenic Liquids*, 2002.

CGA S-1.3, *Pressure Relief Device Standards — Part 3 — Compressed Gas Storage Containers*, 2003.

**2.3.7 CSA Publications.** Canadian Standards Association, 5060 Spectrum Way, Mississauga, Ontario, L4W 5N6, Canada.

CSA A23.1, *Concrete Materials and Methods of Concrete Construction*, 2004.

CSA A23.3, *Design of Concrete Structures*, 2004.

CSA A23.4, *Precast Concrete — Materials and Construction/Qualification Code for Architectural and Structural Precast Concrete Products*, 2004.

CSA B51, *Boiler, Pressure Vessel and Pressure Piping Code*, 2003.

CSA C22.1, *Canadian Electrical Code*, 2002.

CSA G30.5, *Welded Steel Wire Fabric for Concrete Reinforcement*, 1998.

CSA G30.18, *Billet-Steel Bars for Concrete Reinforcement*, 2000.

G279, *Steel for Prestressed Concrete Tendons*, 1982.

**2.3.8 GRI Publications.** Gas Research Institute publications available from GTI, 1700 South Mount Prospect Road, Des Plaines, IL 60018.

GRI Report 0176, "LNGFIRE: A Thermal Radiation Model for LNG Fires," 1989.

GRI Report 0242, "LNG Vapor Dispersion Prediction with the DEGADIS Dense Gas Dispersion Model," 1989.

**2.3.9 IEEE Publication.** Institute of Electrical and Electronics Engineers, Three Park Avenue, 17th Floor, New York, NY 10016-5997.

IEEE/ASTM SI 10, *Standard for Use of the International System of Units (SI): The Modern Metric System*, 2002.

**2.3.10 NACE Publication.** NACE International, 1440 South Creek Drive, Houston, TX 77084-4906.

NACE RP 0169, *Control of External Corrosion of Underground or Submerged Metallic Piping Systems*, 2002.

**2.3.11 NRC Publication.** National Research Council of Canada, Ottawa, Ontario, K1A 0R6.

*National Building Code of Canada*, 1995.

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

## 2.4 References for Extracts in Mandatory Sections.

NFPA 52, *Vehicular Fuel Systems Code*, 2006 edition.

NFPA 220, *Standard on Types of Building Construction*, 2006 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.** A document, the main text of which contains only mandatory provisions using the word "shall" to indicate requirements and which is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions shall be located in an appendix or annex, footnote, or fine-print note and are not to be considered a part of the requirements of a standard.

### 3.3 General Definitions.

**3.3.1 Barrel.** A unit of volume. One barrel equals 42 U.S. gal, or 5.615 ft<sup>3</sup> (0.159 m<sup>3</sup>).

**3.3.2 Bunkering.** The loading of a ship's bunker or tank with fuel oil 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 Components.** A part, or a system of parts, that functions as a unit in an LNG plant 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 for storing liquefied natural gas.

**3.3.5.1 Double Containment Container.** A single containment container surrounded by and within 20 ft (6 m) of an opening to the atmosphere wall (secondary container) and designed to contain LNG in the event of a spill from the primary or inner container.

**3.3.5.2 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.

**3.3.5.3 Full Containment Container.** A container in which the inner (primary) container is surrounded by a secondary container designed to contain LNG in the event of a spill from the inner container and where 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.

**3.3.5.4 Membrane Container.** A container that has a non-self-supporting thin layer (membrane) inner tank that is supported through insulation by an outer tank.

**3.3.5.5 Prestressed Concrete Container.** A concrete container in which the stresses created by the different loads or loading combinations do not exceed the allowable stresses.

**3.3.5.6 Single Containment Container.** A single wall container or a double wall container where only the primary or inner container is 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, 2006]

**3.3.9 Failsafe.** 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.

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

**3.3.11 Flame Spread Index.** A number obtained according to NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*. [220, 2006]

**3.3.12\* G.** The normal or standard constant of gravity.

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

**3.3.14 Impounding Area.** An area defined through the use of dikes or the site topography for the purpose of containing any accidental spill of LNG or flammable refrigerants.

**3.3.15 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, or nitrogen. [52, 2006]

**3.3.16 LNG Plant.** A facility whose components can be used to store, condition, liquefy, or vaporize natural gas.

**3.3.17 Maximum Allowable Working Pressure.** The maximum gauge pressure permissible at the top of completed equipment, a container, or a vessel in its operating position for a design temperature.

**3.3.18 Model.** A mathematical characterization intended to predict a physical phenomenon.

**3.3.19 Noncombustible Material.** A material that, in the form in which it is used and under the conditions anticipated, will not ignite, burn, support combustion, or release flammable vapors when subjected to fire or heat. Materials that are reported as passing ASTM E 136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*, shall be considered noncombustible materials.

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

**3.3.21 Tank Vehicle.** See 3.3.3, Cargo Tank Vehicle.

**3.3.22\* Transfer Area.** The portion of a liquefied natural gas (LNG) plant containing a piping system where LNG, flammable liquids, or flammable refrigerants are introduced into or removed from the plant or where piping connections are connected or disconnected routinely.

**3.3.23 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.

#### 3.3.24 Vaporizer.

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

**3.3.24.2 Heated Vaporizer.** A vaporizer that derives its heat from the combustion of fuel, electric power, or waste heat, such as from boilers or internal combustion engines.

**3.3.24.2.1 Integral Heated Vaporizer.** A heated vaporizer in which the heat source is integral to the actual vaporizing exchanger (including submerged combustion vaporizers).

**3.3.24.2.2 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.

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

**3.3.25 Water Capacity** The amount of water at 60°F (16°C) required to fill a container. [52, 2006]

## Chapter 4 General Requirements

**4.1 Training of Personnel.** Persons engaged in the production, handling, and storage of LNG shall be trained in the hazards and properties of LNG.

### 4.2 Training Plan.

**4.2.1** Every operating plant shall have a written training plan to instruct all LNG plant personnel.

**4.2.1.1** The training plan shall include carrying out the emergency procedures that relate to their duties at the LNG plant as set out in the procedure manual referred to in 4.2.1 and providing first aid.

**4.2.1.2** The training plan shall include training of permanent maintenance, operating, and supervisory personnel with respect to the following:

- (1) The basic operations carried out at the LNG plant
- (2) The characteristics and potential hazards of LNG and other hazardous fluids involved in operating and maintaining the LNG plant, including the serious danger from frostbite that can result from contact with LNG or cold refrigerants
- (3) Methods of carrying out their duties of maintaining and operating the LNG plant as set out in the manual of operating and maintenance procedures referred to in 13.18.2 and 13.18.4
- (4) LNG transfer procedures
- (5) Fire prevention, including familiarization with the fire control plan of the LNG plant, fire fighting, the potential causes of fire in an LNG plant, and the types, sizes, and likely consequences of a fire at an LNG plant
- (6) Recognition of situations when it would be necessary to obtain assistance in order to maintain the security of the LNG plant

**4.2.2** Each LNG facility shall have a written plan to keep the personnel at its LNG plant up-to-date on the function of the systems, fire prevention, and security at the LNG plant, and refresher training shall be required at intervals that do not exceed 2 years.

**4.2.3** A record of all training shall be maintained for each employee of an LNG plant, and the records shall be maintained for at least 2 years after the date that the employee ceases to be employed at the LNG plant.

**4.2.4** All LNG plant personnel shall meet the following requirements:

- (1) LNG plant personnel shall receive the training referred to in Section 4.2.
- (2) LNG plant personnel shall have experience related to their assigned duties.

**4.2.5** Any person who has not completed the training or received experience set out in Section 4.2 shall be under the control of trained personnel.

#### **4.3 Corrosion Control Overview.**

**4.3.1** Components shall not be constructed, repaired, replaced, or significantly altered until a qualified person reviews the applicable design drawings and materials specifications from a corrosion control viewpoint and determines that the materials involved will not impair the safety or reliability of the component or any associated components.

**4.3.2** 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 materials specified
- (2) A failure caused by corrosion
- (3) An inspection that reveals a significant deterioration of the component due to corrosion

#### **4.4 Control Center.**

**4.4.1** Each LNG plant, other than those complying with Chapter 13, shall have a control center from which operations and warning devices are monitored as required by Section 4.4.

**4.4.2** A control center shall have the following capabilities and characteristics:

- (1) It shall be located apart from or be protected from other LNG facilities 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.
- (3) Each control center shall have personnel in attendance while any of the components under its control are in operation, unless either the control is being performed from another control center that has personnel in attendance or the facility has an automatic emergency shutdown system.
- (4) If more than one control center is located at an LNG plant, each control center shall have more than one means of communication with every other center.
- (5) Each control center must have a means of communicating a warning of hazardous conditions to other locations within the plant frequented by personnel.

#### **4.5 Sources of Power.**

**4.5.1** Electrical control systems, means of communication, emergency lighting, and fire-fighting systems 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.

**4.5.2** 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.

#### **4.6 Records.**

**4.6.1** Each plant shall have a record of materials of construction for components, buildings, foundations, and support systems used for containment of LNG and flammable fluids.

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

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

## **Chapter 5 Plant Siting and Layout**

### **5.1\* Plant Site Provisions.**

**5.1.1** A written site evaluation addressing the following factors shall be prepared and made available to the authority having jurisdiction upon request:

- (1) Potential incidents and mitigating measures
- (2) Adjacent activities
- (3) Severe weather patterns over a 100-year period
- (4) Other natural hazards
- (5) Security

**5.1.2** All-weather accessibility to the plant for personnel safety and fire protection shall be provided except where provisions for personnel safety and fire protection are provided on the site in accordance with Chapter 12.

**5.1.3** Site preparation shall include provisions for retention of spilled LNG, flammable refrigerants, and flammable liquids within the limits of plant property and for surface water drainage.

**5.1.4\*** Soil and general investigations of the site shall be made to determine the design basis for the facility.

### **5.2 Site Provisions for Spill and Leak Control.**

#### **5.2.1 General.**

**5.2.1.1** Provisions shall be made to minimize the possibility of the accidental discharge of LNG at containers endangering adjoining property or important process equipment and structures or reaching waterways, in accordance with one of the following methods:

- (1) An impounding area surrounding the container(s) that is formed by a natural barrier, dike, impounding wall, or combination thereof complying with Sections 5.2 and 5.3
- (2) An impounding area formed by a natural barrier, dike, excavation, impounding wall, or combination thereof complying with Sections 5.2 and 5.3 plus a natural or man-made drainage system surrounding the container(s) that complies with Sections 5.2 and 5.3
- (3) Where the container is constructed below or partially below the surrounding grade, an impounding area formed by excavation complying with Sections 5.2 and 5.3

**5.2.1.2** The following areas shall be graded, drained, or provided with impoundment in a manner that minimizes the possibility of accidental spills and leaks that could endanger important structures, equipment, or adjoining property or that could reach waterways:

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

**5.2.1.3** If impounding areas also are required in order to comply with 5.1.3, such areas shall be in accordance with Sections 5.2 and 5.3.

**5.2.1.4** The provisions of 5.1.3, 5.2.1.1, and 5.2.1.2 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.

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

## **5.2.2 Impounding Area and Drainage System Design and Capacity.**

**5.2.2.1** Impounding areas serving LNG containers shall have a minimum volumetric holding capacity,  $V$ , that is one of the following:

- (1) For an impoundment serving a single tank,  $V$  equals 110 percent of the LNG tank's maximum liquid capacity.
- (2) For an impoundment serving more than one tank,  $V$  equals 100 percent of all tanks or 110 percent of the largest tank's maximum liquid capacity, whichever is greater.
- (3) If the dike is designed to account for a surge in the event of catastrophic failure,  $V$  equals 100 percent.

**5.2.2.2** Impounding areas that serve only vaporization, process, or LNG transfer areas shall have a minimum volumetric capacity equal to the greatest volume of LNG, flammable refrigerant, or flammable liquid that can be discharged into the area during a 10-minute period from any single accidental leakage source or during a shorter time period based on demonstrable surveillance and shutdown provisions acceptable to the authority having jurisdiction.

**5.2.2.3** Enclosed drainage channels for LNG shall be prohibited except where they are used to rapidly conduct spilled LNG away from critical areas and they are sized for the anticipated liquid flow and vapor formation rates.

**5.2.2.4** Where enclosed container down comers are used to rapidly conduct spilled LNG away from critical areas, they shall be sized for the anticipated liquid flow and vapor formation rates.

**5.2.2.5** Dikes and impounding walls shall meet the following requirements:

- (1) Dikes and impounding walls shall be constructed of compacted earth, concrete, metal, or other materials.
- (2) Dikes shall be mounted integral to the container, installed against the container, or independent of the container.
- (3) Dikes, impounding walls, drainage systems, and any penetrations thereof shall be designed to withstand the full hydrostatic head of impounded LNG or flammable refrigerant, the effect of rapid cooling to the temperature of the liquid to be confined, any anticipated fire exposure, and natural forces, such as earthquakes, wind, and rain.
- (4) Where the outer shell of a double-wall tank complies with the requirements of 5.2.1.1, the dike shall be either the outer shell or as specified in 5.2.1.1.
- (5) Where the containment integrity of such an outer shell can be affected by an inner tank failure mode, an additional impounding area that otherwise satisfies the requirements of 5.2.1.1 shall be provided.

**5.2.2.6** Double and full containment containers shall be designed and constructed such that in the case of a spill and secondary container fire, the secondary container wall will contain the LNG for the duration of the fire.

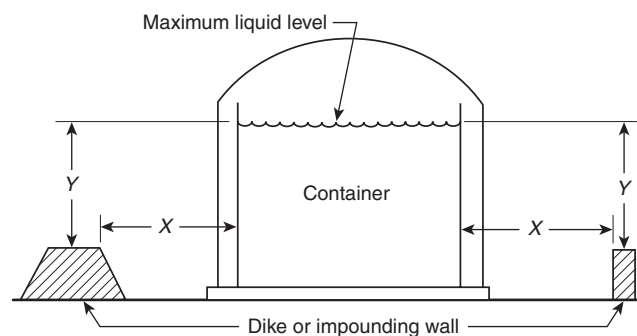
**(A)** In the case of a fire confined to the inner tank, the secondary container wall shall retain sufficient structural integrity to prevent collapse, which can cause damage to and leakage from the primary container.

**(B)** The tanks shall also be designed and constructed such that in the case of a fire in the primary or secondary container of an adjacent tank, the secondary container shall retain sufficient structural integrity to prevent collapse, which can cause damage to and leakage from the primary container.

**5.2.2.7** Double and full containment containers shall have no pipe penetrations below the liquid level.

**5.2.2.8** Dikes, impounding walls, and drainage channels for flammable liquid containment shall conform to NFPA 30, *Flammable and Combustible Liquids Code*.

**5.2.2.9** The dike or impounding wall height and the distance from containers operating at 15 psi (100 kPa) or less shall be determined in accordance with Figure 5.2.2.9.



### Notes:

- $X$  is the distance from the inner wall of the container to the closest face of the dike or impounding wall.
- $Y$  is the distance from the maximum liquid level in the container to the top of the dike or impounding wall.
- $X$  shall equal or exceed the sum of  $Y$  plus the equivalent head in LNG of the pressure in the vapor space above the liquid.

*Exception: When the height of the dike or impounding wall is equal to or greater than the maximum liquid level,  $X$  may have any value.*

**FIGURE 5.2.2.9 Dike or Impoundment Wall Proximity to Containers.**

## **5.2.2.10 Water Removal.**

**5.2.2.10.1** Impoundment areas shall be constructed such that all areas drain completely to prevent water collection.

**(A)** Drainage pumps and piping shall be provided to prevent water from collecting in the impoundment area.

**(B)** Impounding systems shall have sump pumps and piping running over the dike to remove water collecting in the sump basin.

**5.2.2.10.2** The water removal system shall have capacity to remove water at a minimum of 25 percent of the rate from a storm of a 10-year frequency and 1-hour duration, except if the design of the dike does not allow the entrance of rainfall.

**5.2.2.10.3** Sump pumps for water removal shall be as follows:

- (1) Operated as necessary to keep the impounding space as dry as practical

- (2) If sump pumps are designed for automatic operation, have redundant automatic shutdown controls to prevent operation when LNG is present

### 5.2.3 Impounding Area Siting.

**5.2.3.1** The provisions of Section 5.3 shall not apply to impounding areas that serve only transfer areas at the water's edge of marine terminals.

**5.2.3.2** Thermal radiation flux from a fire shall not exceed the limits listed in Table 5.2.3.2 when atmospheric conditions are 0 (zero) windspeed, 70°F (21°C) temperature, and 50 percent relative humidity.

**Table 5.2.3.2 Thermal Radiation Flux Limits to Property Lines and Occupancies**

| Thermal Radiation Flux |                  |                                                                                                                                                                                                                                                                                         |
|------------------------|------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Btu/hr/ft <sup>2</sup> | W/m <sup>2</sup> | Exposure                                                                                                                                                                                                                                                                                |
| 1,600                  | 5,000            | A property line that can be built upon for ignition of a design spill <sup>a</sup>                                                                                                                                                                                                      |
| 1,600                  | 5,000            | The nearest point located outside the owner's property line that, at the time of plant siting, is used for outdoor assembly by groups of 50 or more persons for a fire in an impounding area <sup>b</sup>                                                                               |
| 3,000                  | 9,000            | The nearest point of 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 fire in an impounding area <sup>b,c</sup> |
| 10,000                 | 30,000           | A property line that can be built upon for a fire over an impounding area <sup>b</sup>                                                                                                                                                                                                  |

<sup>a</sup>See 5.2.3.5 for design spill.

<sup>b</sup>The requirements for impounding areas are located in 5.2.2.1.

<sup>c</sup>See NFPA 101, *Life Safety Code*, or NFPA 5000, *Building Construction and Safety Code*, for definitions of occupancies.

**5.2.3.3** Thermal radiation distances shall be calculated in accordance with one of the following:

- (1) The Gas Research Institute's GRI Report 0176, "LNG-FIRE: A Thermal Radiation Model for LNG Fires," which is also available as the "LNGFIRE III" computer model produced by GRI, or alternative models that take into account the same physical factors and have been validated by experimental test data as follows:
  - (a) In calculating exclusion distances, the wind speed producing the maximum exclusion distances shall be used except for wind speeds that occur less than 5 percent of the time based on recorded data for the area.
  - (b) In calculating exclusion distances, the ambient temperature and relative humidity that produce the maximum exclusion distances shall be used except for values that occur less than 5 percent of the time based on recorded data for the area.

- (2) A model that incorporates the following:
  - (a) Impoundment configuration, wind speed and direction, humidity, and atmospheric temperature
  - (b) Validation by experimental test data appropriate for the size and conditions of the hazard to be evaluated
  - (c) Acceptance by the authority having jurisdiction
- (3) Where the ratio of the major and minor dimensions of the impoundment does not exceed 2, the following formula:

$$d = F\sqrt{A}$$

where:

$d$  = distance from the edge of impounded LNG [ft(m)]

$F$  = flux correlation factor equal to the following:

3.0 for 1600 Btu/(hr·ft<sup>2</sup>)

2.0 for 3000 Btu/(hr·ft<sup>2</sup>)

0.8 for 10,000 Btu/(hr·ft<sup>2</sup>)

$A$  = surface area of impounded LNG [ft<sup>2</sup>(m<sup>2</sup>)]

**5.2.3.4** The spacing of an LNG tank impoundment to the property line that can be built upon shall be such that, in the event of an LNG spill as specified in 5.2.3.5, an average concentration of methane in air of 50 percent of the lower flammability limit (LFL) does not extend beyond the property line that can be built upon, in accordance with calculations using one of the following:

- (1) The model described in GRI Report 0242, "LNG Vapor Dispersion Prediction with the DEGADIS Dense Gas Dispersion Model"
- (2) A model that incorporates the following:
  - (a) Physical factors influencing LNG vapor dispersion, including, but not limited to, gravity spreading, heat transfer, humidity, wind speed and direction, atmospheric stability, buoyancy, and surface roughness
  - (b) Validation by experimental test data appropriate for the size and conditions of the hazard to be evaluated
  - (c) Acceptance by the authority having jurisdiction

(A) The computed distances shall include calculations based on one of the following:

- (1) The combination of wind speed and atmospheric stability that can occur simultaneously and result in the longest predictable downwind dispersion distance that is exceeded less than 10 percent of the time
- (2) The Pasquill-Gifford atmospheric stability, Category F, with a 4.5 mph (2 m/sec) wind speed

(B) The computed distances shall be based on the actual liquid characteristics and the maximum vapor outflow rate from the vapor containment volume (the vapor generation rate plus the displacement due to liquid inflow).

(C) The effects of provisions for detaining vapor or otherwise mitigating flammable vapor hazards (e.g., impounding surface insulation, water curtains, or other methods) shall be permitted to be considered in the calculation where acceptable to the authority having jurisdiction.

(D) Where provisions for detaining vapor or mitigating flammable vapor hazards are used, such as impounding surface insulation, water curtains, or other methods, they shall be approved.

**5.2.3.5** The design spill shall be determined in accordance with Table 5.2.3.5.

Table 5.2.3.5 Design Spill

| Container Penetration                                                                                       | Design Spill                                                                                                                                                                                                                                                                  | Design Spill Duration                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|-------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Containers with penetrations below the liquid level without internal shutoff valves                         | <p>A 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</p> <p>If more than one container in the impounding area, use the container with the largest flow.</p> | <p>Use the following formula:</p> $q = \frac{4}{3} d^2 \sqrt{h}$ <p>until the differential head acting on the opening is 0.</p> <p>For SI units, use the following formula:</p> $q = \frac{1.06}{10,000} d^2 \sqrt{h}$ <p>until the differential head acting on the opening is 0.</p>                                                                                                                                                                          |
| Containers with over-the-top fill, with no penetrations below the liquid level                              | The largest flow from any single line that could be pumped into the impounding area with the container withdrawal pump(s) considered to be delivering the full-rated capacity                                                                                                 | <p>The largest flow from any single line that could be pumped into the impounding area with the container withdrawal pump(s) delivering the full rated capacity as follows:</p> <ol style="list-style-type: none"> <li>(1) For 10 minutes if surveillance and shutdown is demonstrated and approved by the authority having jurisdiction</li> <li>(2) For the time needed to empty a full container where surveillance and shutdown is not approved</li> </ol> |
| Containers with penetrations below the liquid level with internal shutoff valves in accordance with 9.3.2.5 | The flow 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                                                                                                  | <p>Use the following formula:</p> $q = \frac{4}{3} d^2 \sqrt{h}$ <p>For SI units, use the following formula:</p> $q = \frac{1.06}{10,000} d^2 \sqrt{h}$ <p>for 10 minutes.</p>                                                                                                                                                                                                                                                                                 |
| Impounding areas serving only vaporization, process, or LNG transfer areas                                  | The flow from any single accidental leakage source                                                                                                                                                                                                                            | For 10 minutes or for a shorter time based on demonstrable surveillance and shutdown provisions acceptable to the authority having jurisdiction                                                                                                                                                                                                                                                                                                                |
| Full or double containment containers with concrete secondary containers                                    | No design spill                                                                                                                                                                                                                                                               | None                                                                                                                                                                                                                                                                                                                                                                                                                                                           |

Note:  $q$  = flow rate [ft<sup>3</sup>/min (m<sup>3</sup>/min)] of liquid;  $d$  = diameter [in. (mm)] of tank penetration below the liquid level;  $h$  = height [ft (m)] of liquid above penetration in the container when the container is full.

**5.2.3.6** LNG container 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.

**5.2.3.7** Containers with an aggregate storage of 70,000 gal (265 m<sup>3</sup>) or less on one site shall be installed either in accordance with 5.2.3 or in accordance with Table 5.2.4.1 where all connections are equipped with automatic failsafe valves designed to close under any of the following conditions:

- (1) Fire detection
- (2) Excess flow of LNG from the container, as measured by loss of line pressure or other means

- (3) Gas detection
- (4) Manual operation from both a local and a remote location
  - (A) The appurtenances shall be installed as close to the container as practical and so that a break resulting from external strain occurs on the piping side of the appurtenance while retaining intact the valve and piping on the container side of the appurtenance.
  - (B) Connections used only for flow into the container shall be equipped with an automatic failsafe valve or with two back-flow check valves.
  - (C) Automatic failsafe valves shall not be required for connections for relief valves and instrument valves.

(D) The type, quantity, and location of the detection devices shall be in accordance with the requirements of Chapter 12.

**5.2.3.8** The distance from the nearest edge of impounded liquid to a property line that can be built upon or from the near edge of a navigable waterway as defined by federal regulations shall not be less than 50 ft (15 m).

#### 5.2.4 Container Spacing.

**5.2.4.1** The minimum separation distance between LNG containers or tanks containing flammable refrigerants and exposures shall be in accordance with Table 5.2.4.1 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.

**5.2.4.2** Double and full containment containers with concrete secondary containers shall have a separation distance to limit the incident thermal radiation flux from a fire within the primary or secondary container of an adjacent tank as follows:

- (1) Steel wall and roofs: 4,700 Btu/ft<sup>2</sup>/hr (15,000 W/m<sup>2</sup>)
- (2) Concrete walls: 9,500 Btu/ft<sup>2</sup>/hr (30,000 W/m<sup>2</sup>)

(A) The ambient conditions for thermal radiation flux shall be based on the conditions (temperature, wind speed, relative humidity) within the range expected for the site, calculated to produce the highest temperature in the secondary container structure.

(B) A water spray or deluge system shall be permitted to be used to limit the thermal radiation flux onto the structure, but in no event shall the separation distance be less than  $\frac{1}{2}$  the diameter of the largest tank.

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

**5.2.4.4** LNG containers of greater than 125 gal (0.5 m<sup>3</sup>) capacity shall not be located in buildings.

#### 5.2.5 Vaporizer Spacing.

**5.2.5.1** 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.

(A) 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.

(B) 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 is either cooled down or being cooled down.

**5.2.5.2** Integral heated vaporizers shall be located at least 100 ft (30 m) from a property line that can be built upon (see 5.2.5.4) and at least 50 ft (15 m) from the following:

- (1) Any impounded LNG, flammable refrigerant, or flammable liquid (see 5.2.4) or the paths of travel of such fluids between any other source of accidental discharge and the impounding area
- (2) 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) Control buildings, offices, shops, and other occupied or important plant structures

**5.2.5.3** Heaters or heat sources of remote heated vaporizers shall comply with 5.2.5.2.

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

**5.2.5.5** Vaporizers used in conjunction with LNG containers having a capacity of 70,000 gal (265 m<sup>3</sup>) or less shall be located

**Table 5.2.4.1 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 <sup>3</sup> | ft                                                                                                              | m   | ft                                                                          | m   |
| <125*                    | <0.5           | 0                                                                                                               | 0   | 0                                                                           | 0   |
| 125–500                  | ≥0.5–1.9       | 10                                                                                                              | 3   | 3                                                                           | 1   |
| 501–2000                 | ≥1.9–7.6       | 15                                                                                                              | 4.6 | 5                                                                           | 1.5 |
| 2001–18,000              | ≥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 m<sup>3</sup>) or greater, the minimum distance shall 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 shall 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.

with respect to the property line in accordance with Table 5.2.4.1, assuming the vaporizer to be a container with a capacity equal to the largest container to which it is connected.

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

### 5.2.6 Process Equipment Spacing.

**5.2.6.1** 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.

**5.2.6.2** Where control centers are located in a building housing flammable gas compressors, the building construction shall comply with 5.3.1.

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

### 5.2.7 Loading and Unloading Facility Spacing.

**5.2.7.1** 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.

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

**5.2.7.3** 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.

### 5.3 Buildings and Structures.

**5.3.1** Buildings or structural enclosures in which LNG, flammable refrigerants, and flammable gases are handled shall be of lightweight, noncombustible construction with non-load-bearing walls.

**5.3.2** If rooms containing LNG and flammable fluids are located within or attached to buildings in which such fluids are not handled (e.g., control centers, shops), the common walls shall be limited to no more than two, shall be designed to withstand a static pressure of at least 100 psf (4.8 kPa), shall have no doors or other communicating openings, and shall have a fire resistance rating of at least 1 hour.

**5.3.3** Buildings or structural enclosures in which LNG, flammable refrigerants, and flammable gases are handled shall be ventilated to minimize the possibility of hazardous accumulations of flammable gases or vapors, in accordance with 5.3.3.1 through 5.3.3.4.

**5.3.3.1** Ventilation shall be permitted to be by means of one of the following:

- (1) A continuously operating mechanical ventilation system
- (2) A combination gravity ventilation system and normally nonoperating mechanical ventilation system that is energized by combustible gas detectors in the event combustible gas is detected
- (3) A dual rate mechanical ventilation system with the high rate energized by gas detectors in the event flammable gas is detected

- (4) A gravity ventilation system composed of a combination of wall openings and roof ventilators
- (5) Other approved ventilation systems

**5.3.3.2** If there are basements or depressed floor levels, a supplemental mechanical ventilation system shall be provided.

**5.3.3.3** The ventilation rate shall be at least 1 cfm of air per ft<sup>2</sup> (5 L/sec of air per m<sup>2</sup>) of floor area.

**5.3.3.4** If vapors heavier than air can be present, a portion of the ventilation shall be from the lowest level exposed to such vapors.

**5.3.4** Buildings or structural enclosures not covered by Section 5.3 and 5.3.2 shall be located, or provision otherwise shall be made, to minimize the possibility of entry of flammable gases or vapors.

**5.3.5** Where LNG portable equipment is used for temporary use, for service maintenance during gas systems repair or alteration, or for other short-term applications, the following requirements shall be met:

- (1) LNG transport vehicles complying with U.S. Department of Transportation (DOT) requirements shall be used as the supply container.
- (2) All portable LNG equipment shall be operated by at least one person qualified by experience and training in the safe operation of these systems.
- (3) All other operating personnel, at a minimum, shall be qualified by training.
- (4) Each operator shall provide and implement a written plan of initial training to instruct all designated operating and supervisory personnel in the characteristics and hazards of LNG used or handled at the site, including low LNG temperature, flammability of mixtures with air, odorless vapor, boil-off characteristics, and reaction to water and water spray; the potential hazards involved in operating activities; and how to carry out the emergency procedures that relate to personnel functions and to provide detailed instructions on mobile LNG operations.
- (5) Provisions shall be made to minimize the possibility of accidental discharge of LNG at containers endangering adjoining property or important process equipment and structures or reaching surface water drainage.
- (6) Portable or temporary containment means shall be permitted to be used.
- (7) Vaporizer controls shall comply with 8.3.1, 8.3.2, and Section 8.4.
- (8) Each heated vaporizer shall be provided with a means to shut off the fuel source remotely and at the installed location.
- (9) Equipment and operations shall comply with 14.7.1, 14.7.2, Section 11.9, 11.10.1, 12.2.1, Section 12.3, 12.3.3, 12.3.4, 12.3.5, and 5.3.5(4), with the exception of the clearance distance provisions.
- (10) The LNG facility spacing specified in Table 5.2.4.1 shall be maintained, except where necessary to provide temporary service on a public right-of-way or on property where clearances specified in Table 5.2.4.1 are not feasible and the following additional requirements are met:
  - (a) Traffic barriers shall be erected on all sides of the facility subject to passing vehicular traffic.
  - (b) The operation shall be continuously attended to monitor the operation whenever LNG is present at the facility.

- (c) If the facility or the operation causes any restriction to the normal flow of vehicular traffic, in addition to the monitoring personnel required in 5.3.5(10), flag persons shall be continuously on duty to direct such traffic.
- (11) Provision shall be made to minimize the possibility of accidental ignition in the event of a leak.
- (12) Portable or wheeled fire extinguishers recommended by their manufacturer for gas fires shall be available at strategic locations and shall be provided and maintained in accordance with NFPA 10, *Standard for Portable Fire Extinguishers*.
- (13) The site shall be continuously attended, and provisions shall be made to restrict public access to the site whenever LNG is present.

**5.3.6** If odorization is required of the emergency facility, the restrictions of 5.2.4.1 shall not apply to the location of odorizing equipment containing 20 gal (7.6 L) of flammable odorant or less within the retention system.

#### **5.4\* Designer and Fabricator Competence.**

**5.4.1** Supervision shall be provided for the fabrication of and for the acceptance tests of facility components to the extent necessary to ensure that they are structurally sound and otherwise in compliance with this standard.

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

**5.4.3** Designers, fabricators, and constructors of LNG facility equipment shall be competent in the design, fabrication, and construction of LNG containers, cryogenic equipment, piping systems, fire protection equipment, and other components of the facility.

**5.4.4** 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.

**5.5\* Soil Protection for Cryogenic Equipment.** LNG containers (see 7.2.7), 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.

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

#### **5.7 Concrete Materials.**

**5.7.1** Concrete used for construction of LNG containers shall be in accordance with Section 7.4.

**5.7.2** 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.

**5.7.2.1** The design of the structures shall be in accordance with the provisions of 7.4.1.

**5.7.2.2** The materials and construction shall be in accordance with the provisions of 7.4.2.

**5.7.3** Pipe supports shall comply with Section 9.4.

#### **5.7.4 Other Concrete Structures.**

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

**5.7.4.2** 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 5.7.2.1 or 5.7.2.2.

**5.7.5\*** Concrete for incidental nonstructural uses, such as slope protection and impounding area paving, shall conform to ACI 304R, *Guide for Measuring, Mixing, Transportation and Placing of Concrete*.

**5.7.6** Reinforcement 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*.

**5.7.7** 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.

## **Chapter 6 Process Equipment**

**6.1 Installation of Process Equipment.** Process system equipment containing LNG, flammable refrigerants, or flammable gases 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 Section 5.3 and 5.3.2

#### **6.2 Pumps and Compressors.**

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

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

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

**6.2.4** 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.

**6.2.5** 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.

**6.3 Flammable Refrigerant and Flammable Liquid Storage.** Installation of storage tanks for flammable refrigerants and liquids shall comply with NFPA 30, *Flammable and Combustible Liquids Code*; NFPA 58, *Liquefied Petroleum Gas Code*; NFPA 59, *Utility LP-Gas Plant Code*; API 2510, *Design and Construction of Liquefied Petroleum Gas (LPG) Installations*; or Section 5.2 of this standard.

## 6.4 Process Equipment.

**6.4.1** 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*.

**6.4.2** Pressure vessels shall be 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*, and shall be code-stamped.

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

**6.4.4\*** Installation of internal combustion engines or gas turbines not exceeding 7500 horsepower per unit shall conform to NFPA 37, *Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines*.

**6.4.5** 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.

**6.4.5.1** Boil-off and flash gases shall discharge into the atmosphere so that it does not create a hazard to people, equipment, or adjacent properties, or into a closed system.

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

**6.4.6** 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.

**6.4.7** If gas is introduced, it shall not create a flammable mixture within the system.

## Chapter 7 Stationary LNG Storage Containers

### 7.1 Inspection.

**7.1.1** Prior to initial operation, containers other than ASME containers shall be inspected to ensure compliance with the engineering design and material, fabrication, assembly, and test provisions of this standard.

**7.1.2** 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.

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

### 7.2 Design Considerations.

#### 7.2.1 General.

**7.2.1.1** The following information shall be specified for each LNG container:

- (1) Maximum allowable working pressure, including a margin above the normal operating pressure
- (2) Maximum allowable vacuum

**7.2.1.2** 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  $-20^{\circ}\text{F}$  ( $-29^{\circ}\text{C}$ )] shall be physically and chemically compatible with LNG and intended for service at  $-270^{\circ}\text{F}$  ( $-168^{\circ}\text{C}$ ).

**7.2.1.3** All piping that is a part of an LNG container shall comply with Chapter 9.

(A) Container piping shall include all piping internal to the container, within insulation spaces and within void spaces, and external piping attached or connected to the container up to the first circumferential external joint of the piping.

(B) Inert gas purge systems wholly within the insulation spaces shall be exempt from compliance with Chapter 9.

(C) Piping that is a part of an ASME LNG container, including piping between the inner and outer containers, shall be in accordance with either the ASME *Boiler and Pressure Vessel Code*, Section VIII, or with ASME B 31.3, *Process Piping*.

(D) Compliance shall be stated on or appended to the ASME *Boiler and Pressure Vessel Code*, Appendix W, Form U-1, "Manufacturer's Data Report for Pressure Vessels."

**7.2.1.4\*** All LNG containers shall be designed for both top and bottom filling unless other means are provided to prevent stratification.

**7.2.1.5** Any portion of the outer surface area of an LNG container that accidentally could be exposed 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.

**7.2.1.6** Where two or more containers are sited in a common dike, the container foundations shall be capable of withstanding contact with LNG or shall be protected against contact with an accumulation of LNG that might endanger structural integrity.

**7.2.1.7** 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  $29.3 \text{ lb/ft}^3$  ( $470 \text{ kg/m}^3$ ).

**7.2.1.8** Provisions shall be made for removal of the container from service.

### 7.2.2 Seismic Design of Field-Fabricated Containers.

**7.2.2.1** A site-specific investigation shall be performed for all installations except those provided for in 7.2.3 to determine the characteristics of seismic ground motion and associated response spectra.

(A) The site-specific investigation 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.

(B) On the basis of the site-specific investigation, the ground motion of a probabilistic maximum considered earthquake (MCE) shall be the motion having a 2 percent probability of exceedance within a 50-year period (mean recurrence interval of 2475 years), subject to the exception in 7.2.2.1(G).

(C) Using the MCE 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.

(D) The MCE response spectral acceleration for any period,  $T$ , shall correspond to a damping ratio that best represents the structure being investigated.

(E) 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 those of the horizontal spectrum.

(F) If information is available, the corresponding ratio shall not be less than 1/2.

(G) Where the probabilistic spectral response ordinates for a 5 percent damped response spectrum having a 2 percent probability of exceedance within a 50-year period at  $T = 0.2$  second or 1 second exceed the corresponding ordinates of the deterministic limit of 7.2.2.1(I), the MCE ground motion shall be the lesser of the following:

- (1) The probabilistic MCE ground motion as defined in 7.2.2.1(B)
- (2) The deterministic ground motion of 7.2.2.1(H), but not less than the deterministic limit ground motion of 7.2.2.1(I)

(H) The deterministic MCE ground motion response spectrum shall be calculated at 150 percent of the median 5 percent damped spectral response acceleration at all periods resulting from a characteristic earthquake on a known active fault within the region.

(I) The deterministic limit on MCE ground motion shall be taken as the response spectrum determined in accordance with the provisions of ASCE 7, *Minimum Design Loads for Buildings and Other Structures*, with the value of  $S_s$  (mapped MCE spectral response acceleration at short periods) taken as 1.5 G, the value of  $S_1$  (mapped MCE spectral response acceleration at 1 second) taken as 0.6 G, and the values of  $F_a$  (short-period site coefficient at 0.2 second) and  $F_v$  (long-period site coefficient at 1 second) selected for the site class most representative of the subsurface conditions where the LNG facility is located.

**7.2.2.2** The LNG container and its impounding system shall be designed for the following two levels of seismic ground motion:

- (1) The safe shutdown earthquake (SSE) as defined in 7.2.2.3
- (2) The operating basis earthquake (OBE) as defined in 7.2.2.4

**7.2.2.3** 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 ground motion defined in 7.2.2.1.

**7.2.2.4\*** 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).

**7.2.2.5** The two levels of ground motion defined in 7.2.2.3 and 7.2.2.4 shall be used for the earthquake-resistant design of the following structures and systems:

- (1) An LNG container and its impounding system

- (2) System components required to isolate the LNG container 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 7.2.2.5(1) or 7.2.2.5(2)

(A) The structures and systems shall be designed to remain operable during and after an OBE.

(B) The OBE design shall be based on an elastic response spectrum.

(C) Where used, response reduction factors applied in the OBE design shall be demonstrated not to reduce the performance criteria in 7.2.2.5(A).

(D) The SSE design shall provide for no loss of containment capability of the primary container, and it shall be possible to isolate and maintain the LNG container during and after the SSE.

(E) Where used, response reduction factors applied in the SSE design shall be demonstrated not to reduce the performance criteria in 7.2.2.5(D).

**7.2.2.6** The impounding system shall, as a minimum, be designed to withstand an SSE while empty and an OBE while holding the volume,  $V$ , as specified in 2.2.2.1.

**7.2.2.7** After an OBE or an SSE, there shall be no loss of containment capability.

**7.2.2.8** An LNG container shall be designed for the OBE, and a stress-limit check shall be made for the SSE to ensure compliance with 7.2.2.5.

(A) OBE and SSE analyses shall include the effect of liquid pressure on buckling stability.

(B) Stresses for the OBE shall be in accordance with the document referenced in Section 7.3, 7.4, or 9.1, as applicable.

(C) Stresses for the SSE shall be subjected to the following limits:

- (1) Stresses in metal containers shall be allowed to reach the specified minimum yield for the tensile conditions and critical buckling for the compression condition.
- (2) Axial hoop stresses from unfactored loads in prestressed concrete containers shall not exceed the modulus of rupture for the tensile condition and shall not exceed 60 percent of the specified 28-day compressive strength for the compressive condition.
- (3) Extreme fiber stresses from combined axial and bending hoop forces from unfactored loads in prestressed concrete containers shall not exceed the modulus of rupture for the tensile condition and shall not exceed 69 percent of the specified 28-day compressive strength for the compressive condition.
- (4) Hoop tensile stresses in prestressed concrete containers shall not exceed the yield stress in non-prestressed reinforcement and shall not exceed 94 percent of the yield stress in prestressed reinforcement with the assumption of a cracked section.

**7.2.2.9** After an SSE event, the container shall be emptied and inspected prior to resumption of container-filling operations.

**7.2.2.10** The design of the LNG container and structural components shall incorporate a dynamic analysis that includes the effects of sloshing and restrained liquid.

(A) Container flexibility, including shear deformation, shall be included in the determination of the container response.

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

(C) Where the container is supported by pile caps, the flexibility of the pile system shall be considered in the analysis.

### 7.2.3 Shop-Built Containers.

**7.2.3.1** Shop-built containers designed and constructed in accordance with the ASME *Boiler and Pressure Vessel Code*, and their support system shall be designed for the dynamic forces associated with horizontal and vertical accelerations as follows:

For horizontal force,  $V$ :

$$V = Z_c \times W$$

For design vertical force,  $P$ :

$$P = 2/3 Z_c \times W$$

where:

$Z_c$  = seismic coefficient equal to 0.60  $S_{DS}$ , where  $S_{DS}$  is the maximum design spectral acceleration determined in accordance with the provisions of ASCE 7, *Minimum Design Loads for Buildings and Other Structures*, using an importance factor,  $I$ , of 1.0, for the site class most representative of the subsurface conditions where the LNG facility is located

$W$  = total weight of the container and its contents

(A) This method of design shall be used only when the natural period,  $T$ , of the shop-built container and its supporting system is less than 0.06 second.

(B) For periods of vibration greater than 0.06 second, the method of design in 7.2.2.1 through 7.2.2.6 shall be followed.

**7.2.3.2** The container and its supports shall be designed for the resultant seismic forces in combination with the operating loads, using the allowable stress increase shown in the code or standard used to design the container or its supports.

**7.2.3.3** The requirements of 7.2.3 shall apply to ASME containers built prior to July 1, 1996, when reinstalled.

**7.2.3.4** Instrumentation capable of measuring the ground motion to which containers are subjected shall be provided on the site.

### 7.2.4 Wind, Flood, and Snow Loads.

(A) The wind, flood, and snow loads for the design of LNG storage containers shall be determined using the procedures outlined in ASCE 7, *Minimum Design Loads for Buildings and Other Structures*.

(B) Where a probabilistic approach is used, a 100-year mean occurrence interval shall be used.

(C) In Canada, the wind and snow loads for the design of LNG storage containers shall be determined using the procedure outlined in the *National Building Code of Canada*.

(D) For wind, the value in the *National Building Code of Canada* for a 100-year mean recurrence interval shall be used.

### 7.2.5 Container Insulation.

**7.2.5.1** 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.

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

(B) Exposed weatherproofing shall have a flame spread index not greater than 25. (*See 3.3.11.*)

**7.2.5.2** The space between the inner tank and the outer tank shall contain insulation that is compatible with LNG and natural gas and that is noncombustible.

(A) A fire external to the outer tank shall not cause reduction of the insulation thermal conductivity due to melting or settling.

(B) 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.

(C) Only materials used between the inner and outer tank bottoms (floors) shall not be required to meet the combustibility requirements, where the material and the design of the installation comply with all of the following:

- (1) The flame spread index of the material shall not exceed 25, and the material shall not support continued progressive combustion in air.
- (2) The material shall be of such composition that surfaces that would be exposed by cutting through the material on any plane shall have a flame spread index not greater than 25 and shall not support continued progressive combustion.
- (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.
- (4) The materials in the installed condition shall be demonstrated to be capable of being purged of natural gas.
- (5) The natural gas remaining after purging shall not be significant and shall not increase the combustibility of the material.

**7.2.6 Filling Volume.** Containers designed to operate at a pressure in excess of 15 psi (100 kPa) shall be equipped with a device(s) that prevents the container from becoming liquid full or from covering the inlet of the relief device(s) with liquid when the pressure in the container reaches the set pressure of the relieving device(s) under all conditions.

### 7.2.7 Foundations.

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

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

**7.2.7.3** The bottom of the outer tank shall be above the groundwater table or protected from contact with groundwater at all times.

**7.2.7.4** The outer tank 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

**7.2.7.5** Where an outer tank is in contact with the soil, a heating system shall be provided to prevent the 32°F (0°C) isotherm from penetrating the soil.

(A) The heating system shall be designed to allow functional and performance monitoring,

(B) 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.

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

(D)\* Provisions shall be incorporated to prevent moisture accumulation in the conduit.

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

**7.2.7.7** A tank 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 tank foundation heating system (if provided) shall be installed.

**7.2.7.8** The system in 7.2.7.7 shall be used to conduct a tank bottom temperature survey 6 months after the tank has been placed in service and annually thereafter, after an OBE and after the indication of an abnormally cool area.

### 7.3 Metal Containers.

#### 7.3.1 Containers Designed for Operation at 15 psi (100 kPa) and Less.

**7.3.1.1** Welded containers designed for not more than 15 psi (100 kPa) shall comply with API 620, *Design and Construction of Large, Welded, Low-Pressure Storage Tanks*.

**7.3.1.2** API 620, Appendix Q, shall be applicable for LNG with the following changes:

- (1) In Q-7.6.5, "twenty-five percent" shall be changed to "all."
- (2)\*In Q-7.6.1 through Q-7.6.4, 100 percent examination of all vertical and horizontal butt welds associated with the container wall, except for the shell-to-bottom welds associated with a flat bottom container, shall be required.
- (3) API 620, Appendix C, C.11, shall be a mandatory requirement.

#### 7.3.2 Containers Designed for Operation at More Than 15 psi (100 kPa).

**7.3.2.1** Containers shall be double-walled, with the inner tank holding the LNG surrounded by insulation contained in the outer tank.

**7.3.2.2** The insulation shall be evacuated or purged.

**7.3.2.3** The inner tank 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.

(A) Where vacuum insulation is used, the design pressure shall be the sum of the required working pressure, 15 psi (100 kPa) for vacuum allowance, and the hydrostatic head of LNG.

(B) Where nonvacuum insulation is used, the design pressure shall be the sum of the required working pressure and the hydrostatic head of LNG.

(C) The inner tank 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 tank expands after an in-service period, the purging and operating pressure of the space between the inner and outer tanks, and seismic loads.

**7.3.2.4** The outer tank shall be of welded construction.

(A) The following materials shall be used:

- (1) Any of the carbon steels in Section VIII, Part UCS of the ASME *Boiler and Pressure Vessel Code* at temperatures at or above the minimum allowable use temperature in Table 1A of the ASME *Boiler and Pressure Vessel Code*, Section II, Part D
- (2) Materials with a melting point below 2000°F (1093°C) where the container is buried or mounded

(B) Where vacuum insulation is used, the outer tank shall be designed by either of the following:

- (1) The ASME *Boiler and Pressure Vessel Code*, Section VIII, Parts UG-28, UG-29, UG-30, and UG-33, using an external pressure of not less than 15 psi (100 kPa)
- (2) Paragraph 3.6.2 of CGA 341, *Standard for Insulated Cargo Tank Specification for Cryogenic Liquids*

(C) Heads and spherical outer tanks that are formed in segments and assembled by welding shall be designed in accordance with the ASME *Boiler and Pressure Vessel Code*, Section VIII, Parts UG-28, UG-29, UG-30, and UG-33, using an external pressure of 15 psi (100 kPa).

(D) The maximum allowable working pressure shall be specified for all components.

(E) The outer tank shall be equipped with a relief device or other device to release internal pressure, as follows:

- (1) The discharge area shall be at least 0.00024 in.<sup>2</sup>/lb (0.0034 cm<sup>2</sup>/kg) of the water capacity of the inner tank, but the area shall not exceed 300 in.<sup>2</sup> (2000 cm<sup>2</sup>).
- (2) The relief device shall function at a pressure not exceeding the internal design pressure of the outer tank, the external design pressure of the inner tank, or 25 psi (172 kPa), whichever is least.

(F) Thermal barriers shall be provided to prevent the outer tank from falling below its design temperature.

(G) Saddles and legs shall be designed to withstand loads anticipated during shipping and installation, and seismic, wind, and thermal loads.

(H) Foundations and supports shall be protected to have a fire resistance rating of not less than 2 hours.

(I) If insulation is used to achieve the fire resistance rating of not less than 2 hours, it shall be resistant to dislodgement by fire hose streams.

**7.3.2.5** Stress concentrations from the support system shall be minimized by the use of such items as pads and load rings.