

NFPA[®]

59A

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

2016



IMPORTANT NOTICES AND DISCLAIMERS CONCERNING NFPA® STANDARDS

NOTICE AND DISCLAIMER OF LIABILITY CONCERNING THE USE OF NFPA STANDARDS

NFPA® codes, standards, recommended practices, and guides (“NFPA Standards”), of which the document contained herein is one, are developed through a consensus standards development process approved by the American National Standards Institute. This process brings together volunteers representing varied viewpoints and interests to achieve consensus on fire and other safety issues. While the NFPA administers the process and establishes rules to promote fairness in the development of consensus, it does not independently test, evaluate, or verify the accuracy of any information or the soundness of any judgments contained in NFPA Standards.

The NFPA disclaims liability for any personal injury, property or other damages of any nature whatsoever, whether special, indirect, consequential or compensatory, directly or indirectly resulting from the publication, use of, or reliance on NFPA Standards. The NFPA also makes no guaranty or warranty as to the accuracy or completeness of any information published herein.

In issuing and making NFPA Standards available, the NFPA is not undertaking to render professional or other services for or on behalf of any person or entity. Nor is the NFPA undertaking to perform any duty owed by any person or entity to someone else. Anyone using this document should rely on his or her own independent judgment or, as appropriate, seek the advice of a competent professional in determining the exercise of reasonable care in any given circumstances.

The NFPA has no power, nor does it undertake, to police or enforce compliance with the contents of NFPA Standards. Nor does the NFPA list, certify, test, or inspect products, designs, or installations for compliance with this document. Any certification or other statement of compliance with the requirements of this document shall not be attributable to the NFPA and is solely the responsibility of the certifier or maker of the statement.



ALERT: THIS STANDARD HAS BEEN MODIFIED BY A TIA OR ERRATA

Users of NFPA codes, standards, recommended practices, and guides (“NFPA Standards”) should be aware that NFPA Standards may be amended from time to time through the issuance of Tentative Interim Amendments or corrected by Errata. An official NFPA Standard at any point in time consists of the current edition of the document together with any Tentative Interim Amendment and any Errata then in effect.

In order to determine whether an NFPA Standard has been amended through the issuance of Tentative Interim Amendments or corrected by Errata, visit the “Codes & Standards” section on NFPA’s website. There, the document information pages located at the “List of NFPA Codes & Standards” provide up-to-date, document-specific information including any issued Tentative Interim Amendments and Errata.

To view the document information page for a specific NFPA Standard, go to <http://www.nfpa.org/docinfo> to choose from the list of NFPA Standards or use the search feature to select the NFPA Standard number (e.g., NFPA 101). The document information page includes postings of all existing Tentative Interim Amendments and Errata. It also includes the option to register for an “Alert” feature to receive an automatic email notification when new updates and other information are posted regarding the document.

IMPORTANT NOTICES AND DISCLAIMERS CONCERNING NFPA® STANDARDS

ADDITIONAL NOTICES AND DISCLAIMERS

Updating of NFPA Standards

Users of NFPA codes, standards, recommended practices, and guides (“NFPA Standards”) should be aware that these documents may be superseded at any time by the issuance of new editions or may be amended from time to time through the issuance of Tentative Interim Amendments or corrected by Errata. An official NFPA Standard at any point in time consists of the current edition of the document together with any Tentative Interim Amendments and any Errata then in effect. In order to determine whether a given document is the current edition and whether it has been amended through the issuance of Tentative Interim Amendments or corrected through the issuance of Errata, consult appropriate NFPA publications such as the National Fire Codes® Subscription Service, visit the NFPA website at www.nfpa.org, or contact the NFPA at the address listed below.

Interpretations of NFPA Standards

A statement, written or oral, that is not processed in accordance with Section 6 of the Regulations Governing the Development of NFPA Standards shall not be considered the official position of NFPA or any of its Committees and shall not be considered to be, nor be relied upon as, a Formal Interpretation.

Patents

The NFPA does not take any position with respect to the validity of any patent rights referenced in, related to, or asserted in connection with an NFPA Standard. The users of NFPA Standards bear the sole responsibility for determining the validity of any such patent rights, as well as the risk of infringement of such rights, and the NFPA disclaims liability for the infringement of any patent resulting from the use of or reliance on NFPA Standards.

NFPA adheres to the policy of the American National Standards Institute (ANSI) regarding the inclusion of patents in American National Standards (“the ANSI Patent Policy”), and hereby gives the following notice pursuant to that policy:

NOTICE: The user’s attention is called to the possibility that compliance with an NFPA Standard may require use of an invention covered by patent rights. NFPA takes no position as to the validity of any such patent rights or as to whether such patent rights constitute or include essential patent claims under the ANSI Patent Policy. If, in connection with the ANSI Patent Policy, a patent holder has filed a statement of willingness to grant licenses under these rights on reasonable and nondiscriminatory terms and conditions to applicants desiring to obtain such a license, copies of such filed statements can be obtained, on request, from NFPA. For further information, contact the NFPA at the address listed below.

Law and Regulations

Users of NFPA Standards should consult applicable federal, state, and local laws and regulations. NFPA does not, by the publication of its codes, standards, recommended practices, and guides, intend to urge action that is not in compliance with applicable laws, and these documents may not be construed as doing so.

Copyrights

NFPA Standards are copyrighted. They are made available for a wide variety of both public and private uses. These include both use, by reference, in laws and regulations, and use in private self-regulation, standardization, and the promotion of safe practices and methods. By making these documents available for use and adoption by public authorities and private users, the NFPA does not waive any rights in copyright to these documents.

Use of NFPA Standards for regulatory purposes should be accomplished through adoption by reference. The term “adoption by reference” means the citing of title, edition, and publishing information only. Any deletions, additions, and changes desired by the adopting authority should be noted separately in the adopting instrument. In order to assist NFPA in following the uses made of its documents, adopting authorities are requested to notify the NFPA (Attention: Secretary, Standards Council) in writing of such use. For technical assistance and questions concerning adoption of NFPA Standards, contact NFPA at the address below.

For Further Information

All questions or other communications relating to NFPA Standards and all requests for information on NFPA procedures governing its codes and standards development process, including information on the procedures for requesting Formal Interpretations, for proposing Tentative Interim Amendments, and for proposing revisions to NFPA standards during regular revision cycles, should be sent to NFPA headquarters, addressed to the attention of the Secretary, Standards Council, NFPA, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101; email: stds_admin@nfpa.org

For more information about NFPA, visit the NFPA website at www.nfpa.org. All NFPA codes and standards can be viewed at no cost at www.nfpa.org/freeaccess.

Copyright © 2015 National Fire Protection Association®. All Rights Reserved.

NFPA® 59A

Standard for the

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

2016 Edition

This edition of NFPA 59A, *Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)*, was prepared by the Technical Committee on Liquefied Natural Gas. It was issued by the Standards Council on November 14, 2015, with an effective date of December 4, 2015, and supersedes all previous editions.

This document has been amended by one or more Tentative Interim Amendments (TIAs) and/or Errata. See “Codes & Standards” at www.nfpa.org for more information.

This edition of NFPA 59A was approved as an American National Standard on December 4, 2015.

Origin and Development of NFPA 59A

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

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

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

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

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

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

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

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

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

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

Technical Committee on Liquefied Natural Gas

Jay J. Jablonski, *Chair*
HSB PLC, CT [I]

Richard A. Hoffmann, *Secretary*
Hoffmann & Feige, NY [SE]

Donald Barber, Enmat International (UK), United Kingdom [SE]
Rep. Institute of Gas Engineers/Institute of Energy

Denise Beach, FM Global, MA [I]

Jeffrey P. Beale, CH-IV International, MD [SE]

John M. Blanchard, CB&I, IL [M]
Rep. Steel Tank Institute/Steel Plate Fabricators Association

Christopher Bourne, Massachusetts Department of Public Utilities,
MA [E]

Leon A. Bowdoin, Jr., Consultant, MA [SE]
Rep. NFPA Industrial Fire Protection Section

Jeffrey K. Brightwell, Lake Charles LNG, LA [U]
Rep. American Gas Association

David T. Butler, City of Everett Fire Department, MA [E]

Mark E. Fessenden, Tyco Fire Protection Products, WI [M]

James J. Gaughan, American Bureau of Shipping, NY [E]

Filippo Gavelli, GexCon U.S., MD [SE]

Constantyn Gieskes, Braemar Technical Services (Engineering)
Inc., TX [SE]

Charles A. Helm, U.S. Department of Transportation, OK [E]
Rep. U.S. Department of Transportation

Chris E. Humes, Kinder Morgan/Southern LNG & Gulf LNG, GA
[U]

Rep. Interstate Natural Gas Association of America

Francis J. Katulak, Distrigas of Massachusetts, LLC, MA [U]

Nicholas A. Legatos, Preload Incorporated, NY [M]
Rep. American Concrete Institute

Joel V. Madison, Ebara International Corporation, NV [M]

Peter A. Micciche, ConocoPhillips, AK [U]

Kenneth L. Paul, Chart Industries, Inc., NH [M]

Gilford W. Poe, ExxonMobil Upstream Research, TX [U]
Rep. American Petroleum Institute

Phani K. Raj, U.S. Department of Transportation Office of Safety,
DC [E]

Rep. U.S. Department of Transportation

James J. Regan, Starr Technical Risks Agency, Inc., IL [I]

Kevin L. Ritz, Baltimore Gas & Electric Company, MD [U]
Rep. American Gas Association

Thomas V. Rodante, Baker Engineering & Risk Consultants, Inc.,
TX [SE]

Jeffrey H. Sawchuk, BP Corporation, TX [U]

Terry L. Turpin, Federal Energy Regulatory Commission, DC [E]

Alternates

Jeffery J. Baker, CB&I, IL [M]
(Alt. to John M. Blanchard)

Leo Campos, American Bureau of Shipping, TX [E]
(Alt. to James J. Gaughan)

Allan M. Clarke, Duke Energy Corporation, TX [U]
(Alt. to Jeffrey K. Brightwell)

Pat Convery, Cornerstone Energy Services, MA [U]
(Alt. to Leon A. Bowdoin, Jr.)

Frank L. Del Nogal, BP America Inc., TX [U]
(Alt. to Jeffrey H. Sawchuk)

Alan D. Hatfield, Braemar Engineering, TX [SE]
(Alt. to Constantyn Gieskes)

Stanley T. Kastanas, U.S. Department of Transportation, MA [E]
(Alt. to Charles A. Helm)

Andrew Kohout, Federal Energy Regulatory Commission, DC [E]
(Alt. to Terry L. Turpin)

Bernard W. Leong, Chevron Energy Technology Company, TX [U]
(Alt. to Gilford W. Poe)

Matt Martineau, Chart Industries, Inc., MN [M]
(Alt. to Kenneth L. Paul)

Michael Jared Morrison, Starr Technical Risks Agency, Inc., TX [I]
(Alt. to James J. Regan)

Antonino Nicotra, Bechtel Oil Gas & Chemicals, TX [SE]
(Voting Alt.)

Davis R. Parsons, BWD Consulting, CA [U]
(Alt. to Peter A. Micciche)

Arthur Ransome, CH-IV International, MD [SE]
(Alt. to Jeffrey P. Beale)

Anthony J. Scaraggi, Distrigas of Massachusetts LLC, MA [U]
(Alt. to Francis J. Katulak)

Gregory J. Schneller, National Grid, NY [U]
(Alt. to Kevin L. Ritz)

Nonvoting

Swapan Kumar Hazra, GF Natural Gas LNG Ltd/CNG Technology
Ltd., India [U]

James P. Lewis, Jim Lewis LNG Expertise, TX [SE]
(Member Emeritus)

Daniel Gorham, NFPA Staff Liaison

This list represents the membership at the time the Committee was balloted on the final text of this edition. Since that time, changes in the membership may have occurred. A key to classifications is found at the back of the document.

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.

Contents

Chapter 1 Administration	59A- 7	Chapter 9 Piping Systems and Components	59A- 29
1.1 Scope.	59A- 7	9.1 Scope.	59A- 29
1.2 Purpose.	59A- 7	9.2 General.	59A- 29
1.3 Equivalency.	59A- 7	9.3 Materials of Construction.	59A- 29
1.4 Retroactivity.	59A- 7	9.4 Installation.	59A- 30
1.5 SI Units.	59A- 7	9.5 Pipe Supports.	59A- 31
1.6 Pressure Measurement.	59A- 7	9.6 Piping Identification.	59A- 32
1.7 Referenced Standards.	59A- 7	9.7 Inspection, Examination, and Testing of Piping.	59A- 32
Chapter 2 Referenced Publications	59A- 7	9.8 Purging of Piping Systems.	59A- 33
2.1 General.	59A- 7	9.9 Safety and Relief Valves.	59A- 33
2.2 NFPA Publications.	59A- 8	9.10 Corrosion Control.	59A- 33
2.3 Other Publications.	59A- 8	9.11 Cryogenic Pipe-in-Pipe Systems.	59A- 33
2.4 References for Extracts in Mandatory Sections.	59A- 9	Chapter 10 Instrumentation and Electrical Services	59A- 34
Chapter 3 Definitions	59A- 9	10.1 Scope.	59A- 34
3.1 General.	59A- 9	10.2 Liquid Level Gauging.	59A- 34
3.2 NFPA Official Definitions.	59A- 9	10.3 Pressure Gauging.	59A- 34
3.3 General Definitions.	59A- 9	10.4 Vacuum Gauging.	59A- 34
Chapter 4 General Requirements	59A- 11	10.5 Temperature Indicators.	59A- 34
4.1 Scope.	59A- 11	10.6 Emergency Shutdown.	59A- 34
4.2 Corrosion Control Overview.	59A- 11	10.7 Electrical Equipment.	59A- 34
4.3 Control Center.	59A- 11	10.8 Electrical Grounding and Bonding.	59A- 37
4.4 Sources of Power.	59A- 11	Chapter 11 Transfer Systems for LNG, Refrigerants, and Other Flammable Fluids	59A- 37
4.5 Records.	59A- 11	11.1 Scope.	59A- 37
4.6 Noncombustible Material.	59A- 11	11.2 General Requirements.	59A- 37
4.7 Ignition Source Control.	59A- 11	11.3 Piping System.	59A- 37
Chapter 5 Plant Siting and Layout	59A- 12	11.4 Pump and Compressor Control.	59A- 37
5.1 Scope.	59A- 12	11.5 Marine Shipping and Receiving.	59A- 38
5.2 Plant Site Provisions.	59A- 12	11.6 Tank Vehicle and Tank Car Loading and Unloading Facilities.	59A- 38
5.3 Site Provisions for Spill and Leak Control.	59A- 12	11.7 Pipeline Shipping and Receiving.	59A- 39
5.4 Buildings and Structures.	59A- 17	11.8 Hoses and Arms.	59A- 39
5.5 Designer and Fabricator Competence.	59A- 17	11.9 Communications and Lighting.	59A- 39
5.6 Soil Protection for Cryogenic Equipment.	59A- 18	Chapter 12 Fire Protection, Safety, and Security	59A- 39
5.7 Falling Ice and Snow.	59A- 18	12.1 Scope.	59A- 39
5.8 Concrete Design and Materials.	59A- 18	12.2 General.	59A- 39
5.9 Portable LNG Facility.	59A- 18	12.3 Emergency Shutdown (ESD) Systems.	59A- 40
Chapter 6 Process Equipment	59A- 19	12.4 Gas, Fire, and Leak Detection.	59A- 40
6.1 Scope.	59A- 19	12.5 Fire Protection Water Systems.	59A- 40
6.2 Installation of Process Equipment.	59A- 19	12.6 Fire Extinguishing and Other Fire Control Equipment.	59A- 40
6.3 Pumps and Compressors.	59A- 19	12.7 Maintenance of Fire Protection Equipment.	59A- 41
6.4 Flammable Refrigerant and Flammable Liquid Storage.	59A- 19	12.8 Personnel Safety.	59A- 41
6.5 Process Equipment.	59A- 19	12.9 Security.	59A- 41
Chapter 7 Stationary LNG Storage	59A- 20	Chapter 13 Requirements for Stationary Applications Using ASME Containers	59A- 41
7.1 Scope.	59A- 20	13.1 Scope.	59A- 41
7.2 General.	59A- 20	13.2 General Requirements.	59A- 41
7.3 Design Considerations.	59A- 20	13.3 Containers.	59A- 41
7.4 Tank Systems.	59A- 23	13.4 Container Filling.	59A- 42
7.5 ASME Containers Designed for Operation at More Than 15 psi (103 kPa).	59A- 26	13.5 Container Foundations and Supports.	59A- 42
Chapter 8 Vaporization Facilities	59A- 28	13.6 Container Installation.	59A- 43
8.1 Scope.	59A- 28	13.7 Automatic Product Retention Valves.	59A- 43
8.2 Classification of Vaporizers.	59A- 28	13.8 LNG Spill Containment.	59A- 44
8.3 Design and Materials of Construction.	59A- 28	13.9 Inspection.	59A- 44
8.4 Vaporizer Piping, Intermediate Fluid Piping, and Storage Valves.	59A- 28	13.10 Shop Testing of LNG Containers.	59A- 44
8.5 Relief Devices on Vaporizers.	59A- 29	13.11 Shipment of LNG Containers.	59A- 44
8.6 Combustion Air Supply.	59A- 29	13.12 Field Testing of LNG Containers.	59A- 44
8.7 Products of Combustion.	59A- 29	13.13 Welding on Containers.	59A- 44
		13.14 Piping.	59A- 44
		13.15 Container Instrumentation.	59A- 45

13.16	Fire Protection and Safety.	59A– 45	15.4	Risk Calculations and Basis of Assessment.	59A– 54
13.17	Gas Detection.	59A– 45	15.5	LNG and Other Hazardous Materials Release Scenarios.	59A– 55
13.18	Operations and Maintenance.	59A– 45	15.6	Release Probabilities and Conditional Probabilities.	59A– 55
Chapter 14	Operating, Maintenance, and Personnel Training	59A– 48	15.7	Environmental Conditions and Occurrence Probabilities.	59A– 55
14.1	Scope.	59A– 48	15.8	Hazard and Consequence Assessment.	59A– 56
14.2	General Requirements.	59A– 48	15.9	Risk Result Presentation.	59A– 57
14.3	Manual of Operating Procedures.	59A– 48	15.10	Risk Tolerability Criteria.	59A– 57
14.4	Emergency Procedures.	59A– 48	15.11	Risk Mitigation Approaches.	59A– 57
14.5	Monitoring Operations.	59A– 49	Annex A	Explanatory Material	59A– 58
14.6	Transfer of LNG and Flammables.	59A– 49	Annex B	Seismic Design of LNG Plants	59A– 66
14.7	Maintenance Manual.	59A– 51	Annex C	Security	59A– 67
14.8	Maintenance.	59A– 52	Annex D	Training	59A– 68
14.9	Personnel Training.	59A– 53	Annex E	Informational References	59A– 69
14.10	Records.	59A– 54	Index		59A– 72
Chapter 15	Performance (Risk Assessment) Based LNG Plant Siting	59A– 54			
15.1	Scope.	59A– 54			
15.2	General Requirements.	59A– 54			
15.3	Definitions.	59A– 54			

NFPA 59A

Standard for the

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

2016 Edition

IMPORTANT NOTE: This NFPA document is made available for use subject to important notices and legal disclaimers. These notices and disclaimers appear in all publications containing this document and may be found under the heading "Important Notices and Disclaimers Concerning NFPA Standards." They can also be viewed at www.nfpa.org/disclaimers or obtained on request from NFPA.

UPDATES, ALERTS, AND FUTURE EDITIONS: New editions of NFPA codes, standards, recommended practices, and guides (i.e., NFPA Standards) are released on scheduled revision cycles. This edition may be superseded by a later one, or it may be amended outside of its scheduled revision cycle through the issuance of Tentative Interim Amendments (TIAs). An official NFPA Standard at any point in time consists of the current edition of the document, together with all TIAs and Errata in effect. To verify that this document is the current edition or to determine if it has been amended by TIAs or Errata, please consult the National Fire Codes® Subscription Service or the "List of NFPA Codes & Standards" at www.nfpa.org/docinfo. In addition to TIAs and Errata, the document information pages also include the option to sign up for alerts for individual documents and to be involved in the development of the next edition.

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates that explanatory material on the paragraph can be found in Annex A.

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

Information on referenced publications can be found in Chapter 2 and Annex 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. The purpose of this standard is to provide minimum fire protection, safety, and related requirements for the location, design, construction, security, operation, and maintenance of LNG plants.

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

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

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

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

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

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

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

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

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

Chapter 2 Referenced Publications

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

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

NFPA 10, *Standard for Portable Fire Extinguishers*, 2013 edition.

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

NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*, 2015 edition.

NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems*, 2015 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 2016 edition.

NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, 2016 edition.

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*, 2016 edition.

NFPA 16, *Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems*, 2015 edition.

NFPA 17, *Standard for Dry Chemical Extinguishing Systems*, 2013 edition.

NFPA 20, *Standard for the Installation of Stationary Pumps for Fire Protection*, 2016 edition.

NFPA 22, *Standard for Water Tanks for Private Fire Protection*, 2013 edition.

NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*, 2016 edition.

NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*, 2014 edition.

NFPA 30, *Flammable and Combustible Liquids Code*, 2015 edition.

NFPA 37, *Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines*, 2015 edition.

NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work*, 2014 edition.

NFPA 54, *National Fuel Gas Code*, 2015 edition.

NFPA 58, *Liquefied Petroleum Gas Code*, 2014 edition.

NFPA 59, *Utility LP-Gas Plant Code*, 2015 edition.

NFPA 68, *Standard on Explosion Protection by Deflagration Venting*, 2013 edition.

NFPA 70®, *National Electrical Code®*, 2014 edition.

NFPA 72®, *National Fire Alarm and Signaling Code*, 2016 edition.

NFPA 101®, *Life Safety Code®*, 2015 edition.

NFPA 110, *Standard for Emergency and Standby Power Systems*, 2016 edition.

NFPA 274, *Standard Test Method to Evaluate Fire Performance Characteristics of Pipe Insulation*, 2013 edition.

NFPA 385, *Standard for Tank Vehicles for Flammable and Combustible Liquids*, 2012 edition.

NFPA 496, *Purged and Pressurized Enclosures for Electrical Equipment*, 2013 edition.

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

NFPA 750, *Standard on Water Mist Fire Protection Systems*, 2015 edition.

NFPA 1221, *Standard for the Installation, Maintenance, and Use of Emergency Services Communications Systems*, 2016 edition.

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

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

NFPA 1962, *Standard for the Care, Use, Inspection, Service Testing, and Replacement of Fire Hose, Couplings, Nozzles, and Fire Hose Appliances*, 2013 edition.

NFPA 1963, *Standard for Fire Hose Connections*, 2014 edition.

NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems*, 2015 edition.

NFPA 5000®, *Building Construction and Safety Code®*, 2015 edition.

Fire Protection Research Foundation, *"Evaluating Vapor Dispersion Models for Safety Analysis of LNG Facilities,"* 2007 edition.

2.3 Other Publications.

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

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

ACI 318, *Building Code Requirements for Structural Concrete and Commentary*, 2011.

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

ACI 376, *Code Requirements for Design and Construction of Concrete Structures for the Containment of Refrigerated Liquefied Gases*, 2010.

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

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

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

API 6D, *Specification for Pipeline Valves*, 2007 with errata 1-6 (2011) and addendums 1, 2 (2011), and 3 (2012).

API 620, *Design and Construction of Large, Welded, Low-Pressure Storage Tanks*, 2008, 11th edition, including 2009, 2010, and 2012 addendums.

API 625, *Tank Systems for Refrigerated Liquefied Gas Storage*, 2010, with addendum 1, July 1, 2013

API 2510, *Design and Construction of Liquefied Petroleum Gas (LPG) Installations*, 2001.

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

ASCE 7, *Minimum Design Loads for Buildings and Other Structures*, 2010.

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

Boiler and Pressure Vessel Code, 2013.

ASME B 31.3, *Process Piping*, 2012.

ASME B 31.5, *Refrigeration Piping*, 2013.

ASME B 31.8, *Gas Transmission and Distribution Piping Systems*, 2012.

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

ASTM E84, *Standard Test Method for Surface Burning Characteristics of Building Materials*, 2012.

ASTM E136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*, 2012.

ASTM E2652, *Standard Test Method for Behavior of Materials in a Tube Furnace with a Cone-shaped Airflow Stabilizer, at 750°C*, 2012.

2.3.7 CGA Publications. Compressed Gas Association, 14501 George Carter Way, Suite 103, Chantilly, VA 20151-2923.

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

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

2.3.8 CSA Publications. Canadian Standards Association, 5060 Spectrum Way, Mississauga, ON, L4W 5N6, Canada.

CSA B51, *Boiler, Pressure Vessel and Pressure Piping Code*, 2009.

CSA C22.1, *Canadian Electrical Code*, 2012.

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

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

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

NACE SP 0169, *Control of External Corrosion of Underground or Submerged Metallic Piping Systems*, 2007.

2.3.11 UL Publications. Underwriters Laboratories, Inc., 333 Pfingsten Road, Northbrook, IL 60062-2096.

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

2.3.12 Other Publications.

American Institute of Chemical Engineers (AIChE) Center for Chemical Process Safety (CCPS), “Guidelines for Chemical Process Quantitative Risk Analysis,” G-42, 2000 edition.

ASNT SNT-TC-IA, *Personnel Qualification and Certification in Nondestructive Testing*, 2011.

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

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

European Norm Standard, BSI EN 31010:2010, “Risk Management—Risk Assessment Techniques.”

Health and Safety Executive (HSE), “Risk Criteria for Land-use Planning in the Vicinity of Major Industrial Hazards,” HMSO, HSE 1989 and “Five Steps to Risk Assessment,” INDC 163, rev. 1, HSE 1998, United Kingdom.

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

TNO, “Guidelines for Quantitative Risk Assessment, RIVM, The Purple Book,” Netherlands, 2005.

2.4 References for Extracts in Mandatory Sections.

NFPA 52, *Vehicular Gaseous Fuel Systems Code*, 2016 edition.

NFPA 54, *National Fuel Gas Code*, 2015 edition.

NFPA 101®, *Life Safety Code®*, 2015 edition.

Chapter 3 Definitions

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

3.2 NFPA Official Definitions.

3.2.1* Approved. Acceptable to the authority having jurisdiction.

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

3.2.3 Shall. Indicates a mandatory requirement.

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

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

3.3 General Definitions.

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

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

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

3.3.4 Container.

3.3.4.1 Frozen Ground Container. A container in which the maximum liquid level is below the normal surrounding grade, that is constructed essentially of natural materials, such as earth and rock, that is dependent on the freezing of water-saturated earth materials, and that has appropriate

methods for maintaining its tightness or that is impervious by nature.

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

3.3.4.3 Tank System. Low pressure (less than 15 psi) equipment designed for the purpose of storing liquefied natural gas consisting of one or more containers, together with various accessories, appurtenances, and insulation.

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

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

3.3.4.3.3* Membrane Containment Tank System. A tank system consisting of a thin metal liquid barrier and load-bearing thermal insulation supported by a self-standing outer concrete container jointly forming an integrated composite tank structure designed to contain liquid and vapor during tank operation as well as LNG in the event of leakage from the liquid barrier, and where the vapor-containing roof of the outer container is either steel or concrete configured such that the excess vapor caused by a spill of LNG from the liquid barrier will discharge through the relief valves.

3.3.4.3.4* Single Containment Tank System. A single wall container or a double wall tank system in which only the self-supporting primary or inner container is designed to contain LNG.

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

3.3.6 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.

3.3.7 Dike. A structure used to establish an impounding area or containment. [52, 2016]

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

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

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

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

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

3.3.13 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, nitrogen, and other components normally found in natural gas.

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

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

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

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

3.3.20 Noncombustible Material. See Section 4.6. [101, 2015].

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

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

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

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

3.3.25 Sources of Ignition. Appliances or equipment that, because of their intended modes of use or operation, are capable of providing sufficient thermal energy to ignite flammable gas-air mixtures. [54, 2015]

3.3.26 Tank Vehicle. See 3.3.2, Cargo Tank Vehicle.

3.3.27* 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.

3.3.28 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.

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

3.3.30* Vaporizer.

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

3.3.30.2 Heated Vaporizer. A vaporizer that derives heat for vaporization from the combustion of fuel, electric power, or waste heat, such as from boilers or internal combustion engines. [52, 2016]

3.3.30.2.1 Integral Heated Vaporizer. A vaporizer, including submerged combustion vaporizers, in which the heat source is integral to the actual vaporizing exchanger. [52, 2013]

3.3.30.2.2 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.

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

3.3.31 Water Capacity. The amount of water at 60°F (16°C) required to fill a container. [52, 2016]

Chapter 4 General Requirements

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

4.2 Corrosion Control Overview.

4.2.1 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.

4.2.2 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

4.3 Control Center.

4.3.1 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 4.3.

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

- (1) It shall be located apart from or be protected from other components so that it is operational during a controllable emergency.
- (2) Each remotely actuated control system and each automatic shutdown control system required by this standard shall be operable from the control center.
- (3) It 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 is located at an LNG plant, each control center shall have more than one means of communication with every other center.
- (5) It shall have a means of communicating a warning of hazardous conditions to other locations within the plant frequented by personnel.

4.4 Sources of Power.

4.4.1 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.

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

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

4.5 Records.

4.5.1 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.

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

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

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

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

4.7 Ignition Source Control.

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

4.7.2 Welding, cutting, and hot work shall be conducted in accordance with the provisions of NFPA 51B.

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

4.7.4 Vehicles and other mobile equipment that constitute potential ignition sources shall be prohibited within diked areas or within 50 ft (15 m) of containers that contain LNG or other flammable fluids, except where authorized and at loading or unloading at facilities specifically designed for the purpose.

Chapter 5 Plant Siting and Layout

5.1 Scope. This chapter presents the criteria for plant and equipment siting.

5.2* Plant Site Provisions.

5.2.1 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

5.2.2 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.

5.2.3 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.

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

5.3 Site Provisions for Spill and Leak Control.

5.3.1 General.

5.3.1.1 Provisions shall be made to minimize the potential of accidental discharge of LNG at containers, pipelines containing LNG, and other equipment such that a discharge from any of these does not endanger adjoining property or important process equipment and structures or reach waterways. LNG containers shall be provided with one of the following methods to contain any release:

- (1) An impounding area surrounding the container(s) that is formed by a natural barrier, dike, impounding wall, or combination thereof complying with 5.3.2 and 5.3.3
- (2) An impounding area formed by a natural barrier, dike, excavation, impounding wall, or combination thereof complying with 5.3.2 and 5.3.3, plus a natural or man-made drainage system surrounding the container(s) that complies with 5.3.2 and 5.3.3
- (3) Where the container is constructed below or partially below the surrounding grade, an impounding area formed by excavation complying with 5.3.2 and 5.3.3
- (4) Secondary containment as required for double, full, or membrane containment tank systems complying with 5.3.2 and 5.3.3.

5.3.1.2 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

5.3.1.3 If impounding areas also are required in order to comply with 5.2.3, such areas shall be in accordance with 5.3.2 and 5.3.3.

5.3.1.4 The provisions of 5.2.3, 5.3.1.1, and 5.3.1.2 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.

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

5.3.2 Impounding Area and Drainage System Design and Capacity.

5.3.2.1 Impounding areas serving one LNG container shall have a minimum volumetric holding capacity, V , that is one of the following:

- (1) $V = 110$ percent of the maximum liquid capacity of the container
- (2) $V = 100$ percent where the impoundment is designed to withstand the dynamic surge in the event of catastrophic failure of the container
- (3) $V = 100$ percent where the height of the impoundment is equal to or greater than the container maximum liquid level

5.3.2.2 Impounding areas serving multiple LNG containers shall have a minimum volumetric holding capacity, V , in accordance with one of the following:

- (1) $V = 100$ percent of the maximum liquid capacity of all containers in the impoundment area
- (2) $V = 110$ percent of the maximum liquid capacity of the largest container in the impoundment area, where provisions are made to prevent leakage from any container due to exposure to a fire, low temperature, or both due to a leak from or fire on any other container in the shared impoundment

5.3.2.3 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.

5.3.2.4 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.

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

- (1) 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.
- (2) Where the outer shell of a tank system complies with the requirements of 5.3.1.1, the dike shall be either the outer shell or as specified in 5.3.1.1.

5.3.2.6 Double containment tank systems 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.

5.3.2.7 Double, full, and membrane containment tank systems shall be designed and constructed such that in the case of a fire in 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.

5.3.2.8 Double, full, and membrane containment tank systems shall have no pipe penetrations below the liquid level.

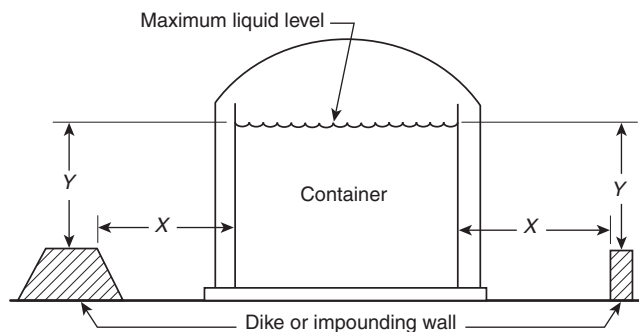
5.3.2.9 Dikes, impounding walls, and drainage channels for flammable liquid containment shall conform to NFPA 30.

5.3.2.10 Insulation systems used for impounding surfaces shall be, in the installed condition, noncombustible and suitable for the intended service, considering the anticipated thermal and mechanical stresses and loads. If flotation of the insulation can compromise its intended purpose, mitigating measures shall be provided.

5.3.2.11 The dike or impounding wall height and the distance from containers operating at 15 psi (103 kPa) or less shall be determined in accordance with Figure 5.3.2.11.

5.3.2.12 Water Removal.

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



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 equals or exceeds 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 has any value.

FIGURE 5.3.2.11 Dike or Impoundment Wall Proximity to Containers.

(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.

5.3.2.12.2 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.

5.3.2.12.3 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

5.3.3 Impounding Area Siting.

5.3.3.1 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.

5.3.3.2 The maximum radiant heat flux from a fire shall not exceed the limits listed in Table 5.3.3.2.

5.3.3.3* The use of passive fire mitigation techniques in the calculation of radiant heat distances shall be subject to the approval of the AHJ.

5.3.3.4* The distances to the radiant heat flux levels of Table 5.3.3.2 shall be calculated in accordance with a model that complies with all of the following:

- (1) Takes into account the physical phenomena observed in, and has been validated with the data obtained from, available LNG fire experimental data, published in peer-reviewed scientific literature applicable to the physical situation considered
- (2) Has been published in peer-reviewed scientific literature
- (3) Has a scientific assessment verifying the details of the physics, analysis, and execution process
- (4) Has been approved

5.3.3.5 Models employed in 5.3.3.4 shall incorporate the following:

- (1) 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.
- (2) 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.

5.3.3.6* The spacing of an LNG impoundment to the property line that can be built upon shall be such that, in the event of an LNG spill as specified in 5.3.3.7, a predicted 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 a model that is acceptable for use by the authority having jurisdiction that has been evaluated by an independent body using the Model Evaluation Protocol facilities published by the Fire Protection Research

Table 5.3.3.2 Radiant Heat Flux Limits to Property Lines and Occupancies

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

^aSee 5.3.3.7 for design spill.^bThe requirements for impounding areas are located in 5.3.2.^cSee NFPA 101 or NFPA 5000 for definitions of occupancies.

Foundation report "Evaluating Vapor Dispersion Models for Safety Analysis of LNG Facilities."

- (1) The computed distances shall include calculations based on one of the following:
 - (a) 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
 - (b) The Pasquill-Gifford atmospheric stability, Category F, with a 4.5 mph (2 m/sec) wind speed
- (2) 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).
- (3) 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.
- (4) 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.

5.3.3.7 The design spill shall be determined in accordance with Table 5.3.3.7.

5.3.3.8 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.

5.3.3.9 Containers with an aggregate storage of 70,000 gal (265 m³) or less on one site shall be installed either in accordance with 5.3.3 or in accordance with Table 5.3.4.1 where all connections are equipped with automatic fail-safe 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 fail-safe valve or with two backflow check valves.

(C) Automatic fail-safe 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.

5.3.3.10 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).

5.3.4 Container Spacing.

5.3.4.1 The minimum separation distance between any type of LNG container of 70,000 gal (265 m³) water capacity or less, single containment constructed LNG containers of greater than 70,000 gal (265 m³) water capacity, or tanks containing flammable refrigerants and exposures shall be in accordance with Table 5.3.4.1 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.

5.3.4.2 Double, full, and membrane containment tank systems of greater than 70,000 gal (265 m³) water capacity shall be separated from adjacent LNG storage containers such that a fire in an adjacent single or double containment impoundment or from a design spill will not cause loss of containment from adjacent containers. This shall be accomplished by ensuring that no part of the adjacent storage container roof, walls, or its impoundment structure reaches a temperature at which the strength of the material of the container roof, wall, or its impoundment is reduced to a level where the LNG tank, roof, or impoundment loses its structural integrity. The application of engineering analyses shall be used to determine this temperature by including the following conditions in the analyses:

- (1) The analyses shall be performed for a fire involving the complete loss of containment of the primary liquid container to an impoundment area that complies with the requirements of 5.3.2.1

Table 5.3.3.7 Design Spill

Design Spill Source	Design Spill Criteria	Design Spill Rate and Volume
<i>Containers with Penetrations Below the Liquid Level</i>		
Containers with penetrations below the liquid level without internal shutoff valves	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 If more than one container in the impounding area, use the container with the largest flow	Use the following formula: $q = \frac{4}{3} d^2 \sqrt{h}$ until the differential head acting on the opening is 0. For SI units, use the following formula: $q = \frac{1.06}{10,000} d^2 \sqrt{h}$ until the differential head acting on the opening is 0.
Containers with penetrations below the liquid level with internal shutoff valves in accordance with 9.4.2.5	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	Use the following formula: $q = \frac{4}{3} d^2 \sqrt{h}$ For SI units, use the following formula: $q = \frac{1.06}{10,000} d^2 \sqrt{h}$ for 10 minutes.
<i>Containers with Over-the-Top Fill, with No Penetrations Below the Liquid Level</i>		
Full or double containment containers with concrete secondary containers	No design spill	None
<i>LNG Process Facilities</i>		
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	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: (1) For 10 minutes if surveillance and shutdown is demonstrated and approved by the authority having jurisdiction (2) For the time needed to empty a full container where surveillance and shutdown is not approved
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

Note: q = flow rate [ft^3/min (m^3/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.

- (2) The analyses shall account for the following:
- (a) The duration of the fire, the radiant heat emission characteristics of the fire, and the physical attributes of the fire under the anticipated atmospheric conditions
 - (b) The atmospheric conditions producing the maximum separation distances shall be used except for conditions that occur less than 5 percent of the time based on recorded data for the area and using a LNG fire model in accordance with 5.3.3.4
 - (c) Active or passive systems to reduce thermal heat flux incident on the surface or to limit the surface temperature
 - (d) The materials, design, and methods of construction of the target LNG tank being analyzed

5.3.4.2.1 The outer concrete container shall be designed for the external fire in accordance with ACI 376, *Code Requirements for Design and Construction of Concrete Structures for the Containment of Refrigerated Liquefied Gases*, unless fire protection measures are provided. The outer tank thermal analysis shall be performed to determine temperature distribution for the heat flux and duration of exposure as specified in the fire risk assessment within API 625, *Tank Systems for Refrigerated Liquefied Gas Storage*.

Table 5.3.4.1 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 ³	ft	m	ft	m
<125*	<0.5	0	0	0	0
125–500	≥0.5–1.9	10	3	3	1
501–2,000	≥1.9–7.6	15	4.6	5	1.5
2,001–18,000	≥7.6–63	25	7.6	5	1.5
18,001–30,000	≥63–114	50	15	5	1.5
30,001–70,000	≥114–265	75	23		
>70,000	>265	0.7 times the container diameter but not less than 100 ft (30 m)		¼ of the sum of the diameters of adjacent containers [5 ft (1.5 m) minimum]	

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

(A) The applicable load components and the ultimate state load factors for the fire load combinations shall be in accordance with ACI 376, *Code Requirements for Design and Construction of Concrete Structures for the Containment of Refrigerated Liquefied Gases*, Table 7.3. For membrane tanks, an additional liquid pressure load in accordance with ACI 376, Table 7.2, shall be included.

(B) The design of the outer concrete container shall take into account the following factors:

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

(C) The concrete wall, including the wall concrete mix, shall be designed to avoid explosive spalling.

5.3.4.3 The minimum separation distance between LNG containers and containers containing flammable refrigerants or from property lines that can be built upon shall be in accordance with Table 5.3.4.1.

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

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

5.3.5 Vaporizer Spacing.

5.3.5.1 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 either is cooled down or is being cooled down.

5.3.5.2 Integral heated vaporizers shall be located at least 100 ft (30 m) from a property line that can be built upon (see 5.3.5.4) and at least 50 ft (15 m) from the following:

- (1) Any impounded LNG, flammable refrigerant, or flammable liquid (see 5.3.4) 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

5.3.5.3 Heaters or heat sources of remote heated vaporizers shall comply with 5.3.5.2.

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

5.3.5.5 Vaporizers used in conjunction with LNG containers having a capacity of 70,000 gal (265 m³) or less shall be located with respect to the property line in accordance with Table 5.3.4.1, assuming the vaporizer to be a container with a capacity equal to the largest container to which it is connected.

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

5.3.6 Process Equipment Spacing.

5.3.6.1 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.

5.3.6.2 Where control centers are located in a building housing flammable gas compressors, the building construction shall comply with 5.4.3.

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

5.3.7 Loading and Unloading Facility Spacing.

5.3.7.1 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.

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

5.3.7.3 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.

5.4 Buildings and Structures.

5.4.1 Buildings and Structures Design Classification. Buildings and structures shall be classified in accordance with the following:

- (1)* Classification A — Buildings and structures as defined in 7.4.4.6(3)
- (2) Classification B. — Buildings and structures supporting or enclosing equipment and piping that contain flammable or toxic materials
- (3) Classification C — All other buildings and structures

5.4.2 Buildings and Structures Design. Buildings and structures shall be designed for seismic, wind, ice and snow in accordance with 5.4.2.1 through 5.4.2.3.

5.4.2.1 Classification A. Seismic design shall use the operating basis earthquake (OBE), safe shutdown earthquake (SSE), and aftershock level earthquake (ALE) ground motions as defined in 7.4.4.3 through 7.4.4.5 for determination of loads to be used per ASCE 7, *Minimum Design Loads for Buildings and Other Structures*; wind, ice, and snow design shall use an occupancy category of IV per ASCE 7.

5.4.2.2 Classification B. Seismic, wind, ice, and snow design shall use a risk category of III per ASCE 7.

5.4.2.3 Classification C. Seismic, wind, ice, and snow design shall use a risk category of II per ASCE 7.

5.4.3 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.

5.4.4 Rooms containing LNG and flammable fluids, if located within or attached to buildings in which such fluids are not handled (e.g., control centers, shops), shall be designed for fire and explosion control in accordance with the following:

- (1) Deflagration venting shall be provided in accordance with NFPA 68.
- (2) Common walls shall have no doors or other communicating openings
- (3) Common walls shall have a fire-resistance rating of at least 1 hour.

5.4.5 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 5.4.5.1 through 5.4.5.4.

5.4.5.1 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

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

5.4.5.3 The ventilation rate shall be at least 1 cfm of air per ft² (5 L/sec of air per m²) of floor area.

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

5.4.6 Buildings or structural enclosures not covered by 5.4.3 through 5.4.5 shall be located, or provision otherwise shall be made, to minimize the possibility of entry of flammable gases or vapors.

5.4.7* Buildings or structural enclosures not covered by 5.4.3 through 5.4.5 shall be designed, constructed, and installed to protect occupants against explosion, fire, and toxic material releases.

5.5* Designer and Fabricator Competence.

5.5.1 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.

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

5.5.3 Designers, fabricators, and constructors of LNG facility systems and equipment shall be competent in their respective fields.

5.5.4 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.

5.6* Soil Protection for Cryogenic Equipment. LNG containers (*see* 7.3.7), 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.

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

5.8 Concrete Design and Materials.

5.8.1 Concrete used for construction of LNG containers shall be in accordance with 7.4.3.

5.8.2 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.

5.8.2.1 The design of the structures shall be in accordance with the provisions of 7.4.3.2.

5.8.2.2 The materials and construction shall be in accordance with the provisions of 7.4.3.2.

5.8.3 Structural concrete for pipe supports shall comply with Section 9.5.

5.8.4 Other Concrete Structures.

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

5.8.4.2 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 7.4.3.2.

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

5.8.6 Minimum Reinforcement.

5.8.6.1 Reinforcement for concrete structures designed for LNG containment or cold vapor containment, other than those in 5.8.1 and 5.8.2; or for concrete structures covered in 5.8.3 and 5.8.4 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*.

5.8.6.2 Minimum reinforcement for concrete for incidental nonstructural uses covered in 5.8.5 shall be in accordance with the shrinkage and temperature reinforcement provisions of ACI 318, *Building Code Requirements for Structural Concrete and Commentary*.

5.8.7 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.

5.9 Portable LNG Facility.

5.9.1 Where portable LNG 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) Temporary portable LNG equipment shall not remain in service more than 180 days at the portable equipment installation. Portable installations in service more than 180 days shall meet one of the following requirements:
 - (a) Approval by the AHJ to remain for a period exceeding 180 days
 - (b) Compliance with all the applicable requirements of Chapter 13 for stationary applications using ASME containers and with the security requirements in Section 12.9
- (2) LNG transport vehicles complying with U.S. Department of Transportation (DOT) requirements shall be used as the supply container.
- (3) All portable LNG equipment shall be operated by at least one person qualified by experience and training in the safe operation of these systems in accordance with requirements in 14.9.3 and 14.9.4, based on the written training plan requirements in 14.9.1 and 14.9.2.
- (4) All other operating personnel, at a minimum, shall be qualified by training in accordance with requirements in 14.9.3 and 14.9.4, based on the written training plan requirements in 14.9.1 and 14.9.2.
- (5) All personnel requiring training in 5.9.1(2) and 5.9.1(3) shall receive refresher training in accordance with requirements in 14.9.6.1.
- (6) All personnel training shall be documented in accordance with records requirements in 14.10.4.
- (7) Each operator shall provide and implement a written plan of initial training in accordance with requirements in 14.9.1 and 14.9.2 to instruct all designated operating and supervisory personnel.
- (8) 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.
- (9) Portable or temporary containment means shall be permitted to be used.
- (10) Vaporizers and controls shall comply with Section 8.3, 8.4.1, 8.4.2, 8.4.3.1, 8.4.6.1(1), 8.4.6.1(2), 8.4.7, and Section 8.5.
- (11) Each heated vaporizer shall be provided with a means to shut off the fuel source remotely and at the installed location.
- (12) Equipment and process design including piping, piping components, instrumentation and electrical systems, and transfer systems shall comply with Sections 4.5, 5.5; 6.3.1, 6.3.3, 6.3.4, 6.3.5, 6.5.1, 6.5.2, 6.5.4, 6.5.5, 9.2.1, 9.2.1.1, 9.2.1.2, 9.3.1.1, 9.3.1.2(3), 9.3.2.1 through 9.3.2.4, 9.3.3, 9.3.4; Sections 9.4 through 9.9; and if utilized, cryogenic pipe-in-pipe systems shall comply with Section 9.11, 10.7.1, 10.7.2, 10.7.6, 10.8.1, 11.4.1, 11.6.1, 11.6.2, 11.8.1, 11.8.2, 11.8.3, 11.8.6, 11.9.1, 11.9.2, 12.2.1, Section 12.3, and 12.3.3.

- (13) The LNG facility spacing specified in Table 5.3.4.1 shall be maintained except where necessary to provide temporary service on a public right-of-way or on property where clearances specified in Table 5.3.4.1 are not feasible and where 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 5.9.1(10), flag persons shall be continuously on duty to direct such traffic.
- (14) Provision shall be made to minimize the possibility of accidental ignition in the event of a leak.
- (15) Fire protection systems shall comply with 12.2.1, 12.3.1 through 12.3.6, 12.4.1, 12.4.2.2, 12.6.1, Section 12.7, 12.8.1, 12.9.1, and 12.9.2.
- (16) 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.
- (17) Operating and maintenance activities shall comply with Sections 13.17, 14.1 through 14.4, 14.6.1, 14.6.2, 14.6.4, 14.6.5, 14.6.6.5 through 14.6.6.8, 14.6.6.8.3, 14.6.6.8.4, 14.6.6.8.5, Section 14.7, 14.8.1, 14.8.2, 14.8.6, 14.8.8, 14.8.9, 14.8.10.1, 14.8.10.2, 14.8.10.3, 14.8.10.7, 14.8.13.1, 14.8.13.4, and 14.8.13.13.
- (18) The site shall be continuously attended, and provisions shall be made to restrict public access to the site whenever LNG is present.

5.9.2 If odorization is required of the temporary facility, the restrictions of 5.3.4.1 shall not apply to the location of odorizing equipment containing 20 gal (7.6 L) or less of flammable odorant within the retention system.

Chapter 6 Process Equipment

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

6.2 Installation of Process Equipment.

6.2.1 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 5.4.3 through 5.4.5

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

- (1) Welding and brazing of process equipment shall conform to the requirements of the standard to which the equipment is designed and constructed (*see 6.5.2 through 6.5.5*). Where equipment is not constructed to a specific standard, welding and brazing shall be in accordance with the requirements in 6.2.2(2).

- (2) All welding or brazing operations shall be performed with procedures qualified to Section IX of the ASME *Boiler and Pressure Vessel Code*.
- (3) All welding or brazing shall be performed by personnel qualified to the requirements of Section IX of the ASME *Boiler and Pressure Vessel Code*.

6.3* Pumps and Compressors.

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

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

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

6.3.4 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.

6.3.5 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.

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

6.4 Flammable Refrigerant and Flammable Liquid Storage. Installation of storage tanks for flammable refrigerants and liquids shall comply with NFPA 30, NFPA 58, NFPA 59, API 2510, *Design and Construction of Liquefied Petroleum Gas (LPG) Installations*, or Section 5.3 of this standard.

6.5 Process Equipment.

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

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

6.5.3 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, and shall be code-stamped.

6.5.4 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, where such components fall within the jurisdiction of the pressure vessel code.

6.5.5 Brazed aluminum plate fin heat exchangers shall be designed and fabricated in accordance with the ASME *Boiler and Pressure Vessel Code*, Section VIII, and ALPEMA *Standards of the Brazed Aluminum Plate-Fin Heat Exchanger Manufacturers Association*.

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

6.5.7 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.

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

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

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

Chapter 7 Stationary LNG Storage

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

7.2 General.

7.2.1 Storage Tank Systems.

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

7.2.1.2 Metal containers that are part of an LNG storage tank system shall comply with API 620, *Design and Construction of Large, Welded, Low-Pressure Tanks*, and the further requirements in Section 7.4 below.

7.2.1.3 Concrete containers that are part of an LNG storage tank system shall comply with ACI 376, *Code Requirements for Design and Construction of Concrete Structures for the Containment of Refrigerated Liquefied Gases*, and the requirements of Section 7.4.

7.2.1.4 The metallic membrane, load-bearing insulation, and the outer container moisture barrier specific to the membrane tank system shall comply with EN 14620, *Design and manufacture of site built, vertical, cylindrical, flat-bottomed, steel tanks for the storage of refrigerated, liquefied gases with operating temperatures between 0°C and -165°C*, Parts 1–5, for material selection, design, installation, examination, and testing and further requirements of Section 7.4. All other components of the membrane tank system shall comply with API 625, *Tank Systems for Refrigerated Liquefied Gas Storage*; API 620, *Design and Construction of Large, Welded, Low-Pressure Storage Tanks*; ACI 376, *Code Requirements for Design and Construction of Concrete Structures for the Containment of Refrigerated Liquefied Gases*; and additional requirements in Section 7.4.

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

7.2.1.6 Should any conflict exist among the requirements in 7.2.1.1 through 7.2.1.5, the most stringent requirement shall apply.

7.2.2 ASME Containers. ASME containers shall comply with the requirements of Section 7.5.

7.3 Design Considerations.

7.3.1 General.

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

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

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

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

(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 of piping which is part of the ASME container 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."

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

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

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

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

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

7.3.2 Wind, Flood, and Snow Loads.

7.3.2.1 The wind, flood, and snow loads for the design of LNG tank systems and storage containers in the United States shall be determined using the procedures outlined in ASCE 7, *Minimum Design Loads for Buildings and Other Structures*.

7.3.2.2 For flood and snow loads, where a probabilistic approach is used, a 100-year mean occurrence interval shall be used.

7.3.2.3 Basic design wind speed shall be based on ASCE 7 for risk category IV structures.

7.3.2.4 The wind, flood, and snow loads used for the design of LNG storage containers in other countries shall be determined using either ASCE 7, or the values in the national code of the country.

7.3.3 Container Insulation.

7.3.3.1 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 3.3.12.*)

7.3.3.2 The space between the inner container and the outer container shall contain insulation that is compatible with LNG and natural gas and that is noncombustible as installed for normal service and abnormal conditions.

(A) A fire external to the outer tank shall not cause a reduction to the internal containment system performance due to damage to any component of the insulation systems.

(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) For tank systems other than membrane containment tank system, 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.

(D) For membrane containment tank systems, the insulation system block shall include a non-foam cover (underneath the primary membrane) and shall include a welding thermal protection system in order to withstand all heat from welding during installation and during maintenance, if any.

7.3.3.3 Storage tank systems insulation shall meet the requirements of 625, Section 9.

7.3.4 Marking of LNG Storage Tank Systems and ASME Containers.

7.3.4.1 Each storage tank system shall be identified by the attachment in an accessible location of a corrosion-resistant nameplate as defined in API 625.

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

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

7.3.4.4 Penetration markings shall be visible if frosting occurs.

7.3.5 Container Drying, Purging, and Cooldown. Before an LNG tank system is put into service, it shall be dried, purged, and cooled in accordance with 14.3.5 and 14.5.5 and tank systems shall include the provisions within API 625 and/or ACI 376, as applicable to the type of tank construction.

7.3.6 Relief Devices.

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

7.3.6.2 Relief devices shall communicate directly with the atmosphere.

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

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

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

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

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

(D) No more than one stop valve shall be closed at one time.

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

7.3.6.5 Pressure Relief Device Sizing.

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

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

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

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

7.3.6.6 Vacuum Relief Sizing.

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

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

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

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

7.3.6.7 Fire Exposure.

7.3.6.7.1 The pressure-relieving capacity required for fire exposure shall be computed by the following formulas:
For U.S. customary units:

[7.3.6.7.1a]

$$H = 34,500 FA^{0.82} + H_n$$

For SI units:

[7.3.6.7.1b]

$$H = 71,000 FA^{0.82} + H_n$$

where:

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

F = environmental factor from Table 7.3.6.7.1

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

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

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

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

Table 7.3.6.7.1 Environmental Factors

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

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

7.3.6.7.4 Pressure Relief Valve Capacity.

(A) The relieving capacity shall be determined by the following formula:

[7.3.67.4(A)]

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

where:

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

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

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

(B) The equivalent airflow shall be calculated from the following formulas:

For U.S. customary units:

[7.3.6.7.4(B)a]

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

For SI units:

[7.3.6.7.4(B)b]

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

where:

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

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

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

Z = compressibility factor of product vapor at relieving condition

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